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Systematic Review and Meta-Analysis of herbal interventions in Ayurveda in the treatment of diabetes type 2

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Abstract
This systematic review and meta-analysis evaluated the effect and safety of Ayurvedic herbal preparations in the management of Type 2 Diabetes Mellitus (T2DM). The analysis of 19 clinical trials with 1,142 patients was studied, which focused on the herbs Gymnema sylvestre (Gurmar), Momordica charantia (Bitter melon) and Trigonella foenum-graecum (Fenugreek). The findings revealed the significant decrease in fasting blood glucose (18.6 mg / dL) and HbA1c (0.6 %) compared to controls. The treatment based on Gmyema uniformly enhanced glucemia, and Momordica resulted in effective reduction of post-prandial glucose. The side effects were of mild intensity (mainly gastrointestinal). The data are further limited by the study heterogeneity and the trial quality but, these results indicate potential of the Ayurvedic interventions to be effective and safe adjuncts used in conventional diabetes treatment. Standard, high-quality RCTs are urgently required to valid these effects, and facilitate their inclusion as part of global treatment guidelines.

Keywords:*Ayurveda, Type 2 Diabetes Mellitus, Gymnema sylvestre, Momordica charantia, Trigonella foenum-graecum, örtem Wendy, glycemic control, bezirksystematic review, meta analysis, addition therapy*

1. Introduction

1.1 Background of the Ayurvedic Approaches in the Care of Diabetes

T2DM is a highly widespread disorder of the metabolism that is caused by insulin resistance and the inability to produce insulin. It is a matter of great concern to the population health because it is related to cardiovascular diseases, neuropathy, nephropathy, and retinopathy. Regardless of efforts in developing pharmacotherapy, glycemic control in the long-term is not optimal in most patients and the fear of potential side effects as well as polypharmacy has given rise to a major interest in integrative and complementary health systems.

The traditional system of Indian medicine- Ayurveda has a long documented history of treatment of metabolic disorders under the general group of Madhumeha in classic texts such as Charaka Samhita and Sushruta Samhita. Ayurvedic traditions of treating Madhumeha typically include herbal preparations to balance out or correct the excessive accumulation of Kapha and Medo Dhatu and Dosa as well as enhancing the digestive fire (Agni), and conflagrating pancreatic agni.

A number of herbs including Gymnema sylvestre (Gurmar), Momordica charantia (Bitter melon) and Trigonella foenum-graecum (Fenugreek) have found extensive use in the Ayurvedic system of medicine and are scientifically producing encouraging results on hypoglycemia. Gymnema sylvestre is nicknamed as the sugar destroyer due to the gymnemic acids that it contains and these acids block glucose absorption and they can rejuvenate the beta cells. Charantin and polypeptide-p present in Momordica charantia substitute insulin and Trigonella foenum-graecum has shown a prospect to slow the spread of carbs and improve insulin sensitivity.(1)

Although used frequently and with good individual outcome trials, there is no systematic review or evidence on the strengths or weakness of efficacy and safety of these herbal intervention use in a comparative manner. This highlights the importance of a meaningful synthesis of the existing clinical trials data in order to assess evidence regarding their application in contemporary diabetes management.

1.2 Rationale Systematic Review and Meta-Analysis

Most clinical studies conducted on the antidiabetic effects of Ayurvedic herbs obtain different results because of the variations in composition of formulations, study design, sample size and measures of outcomes. In addition, much of the research is geographical and is publicized in domestic journals, which reduces its utility and international presence. Such discontinuous data references are an impediment to the holistic use and incorporation of Ayurvedic medicine in the standardised treatment of diabetes.

A systematic review and meta-analysis would provide a reliable study design that is less subjective to the limitations. The meta-analysis characterizes the degree to which a treatment works, along with its safety and

consistency, across formulations and across populations, by pooling studies together and using uniform statistical methods. In addition, the fact that this method gives insights on the heterogeneity and the gaps in the methodological quality that will be filled in subsequent trials.

As interest accrues on evidence-based traditional medicine, it is a serious requirement to test Ayurvedic interventions in terms of internationally accepted research methodologies. These attempts are essential not only when it comes to clinical validation but also when it comes to policy development, standardization of policy formulation, and development of global therapeutic guidelines that encompass the field of complementary therapies.(2)

1.3 Objectives of the Study.

This study aims to conduct a systematic review and quantitatively synthesize the data on clinical trials to evaluateAyurvedic herbal formulations in the treatment of Type 2 Diabetes Mellitus.

Certain objectives are:

- To determine the effect of Ayurvedic herbal had on important glycemic indices, such as fasting blood glucose (FBG), postprandial glucose (PPG) and glycated hemoglobin (HbA1c).
- To compare the comparative efficacy of the use of gymnema sylvestre, momordica charantia and trigonella foenum-graecum in the management of glycemic control.
- To understand safety and tolerability of the Ayurvedic treatments, adverse event reporting should be addressed.
- To indicate limitations, heterogeneity, and methodological gaps in existing researches as well as to suggest the future research avenues.

This systematic review and meta-analysis should help enhance the scientific basis of Ayurveda involvement in managing diabetes and introduce it into contemporary medication practice.

2. Selective Literature, Evidence Identification

2.1 Search Strategy and Coverage of the Database

A clear and structured literature search was conducted in order to find clinical trials assessing Ayurvedic herbal supplements in Type 2 Diabetes Mellitus (T2DM). The search strategy was formulated, following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) requirements, to include both peer-reviewed and grey literature that was published between the year 2000 and April 2025.(3)

Searched electronic databases included the following:

- PubMed/MEDLINE
- Scopus
- Web of science
- Cochrane Central Register of Controlled Trials (CENTRAL)
- YUSH research portal
- Google Scholar (in addition to grey literature)
- DHARA and DHARA-related (particular to studies of Indian traditional medicine)

The main words and Boolean utilized together were the following:

- Ayurveda or Ayurvedic medicine or herbal formulation
- Type 2 diabetes or T2DM or hyperglycemia
- Gymnema sylvestre l or Momordica charantia l or Trigonella foenum-graecum
- clinical trial OR RCT OR randomized controlled trial OR meta-analysis

The limitation set was to include articles using filter terms such as 1) human studies, 2) clinical trials, and 3) articles written in English. Manual backward and forward referencing of included articles was carried out in order to identify any potentially missed studies in the initial search.

2.2 Inclusion and exclusion Criteria

A formalized eligibility process has been used to provide methodological consistency and clinical appropriate relevance. The studies were included in the described scheme on the basis of the following inclusion criteria:

- randomized controlled trials (RCT), the non-randomized controlled trials or the comparative clinical studies
- People with Type 2 Diabetes Mellitus based on the established criteria (e.g. ADA, WHO)

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- The Ayurvedic herbal formulations of either mono-herbal or polyherbal nature concerning interventions
- Outcome indicators such FBG, PPG or HbA1c
- Minimum intervention period, 4 weeks
- Reported results of pre-determined efficacy and/or safety measures

Exclusion criteria were

- Observation, animal observations, in vitro trials or preclinical testing
- Trials involving some non-Ayurvedic/ non-herbal intervention (e.g., yoga-only trials)
- Underpowered trials/trials not having sufficient controls/comparator arms
- Duplicated publication, reviews, case reports, and editorials
- Articles with inadequate outcome information or articles that could not be repaired till full texts were reached after contact mentioned to the authors

Two reviewers independently screened all records at the title/abstract level, and then they reviewed at the full-text level to determine eligibility. Any discrepancies were discussed or with a third reviewer.(4)

2.3 PRISMA Flow and Data Extraction Protocol

The identifications and exclusion process of studies was reported in a PRISMA 2020 flow diagram that elaborated on the set of records identified and screened, and the number of excluded and, finally, included studies in the meta-analysis. A total of 19 clinical trials were included in this study after conduction of this study, a number of 19 clinical trials was arrived to out of the 1,073 initial records after the final inclusion criteria based on 1142 patients. The data that were extracted were done on a standardized pre-piloted data extraction form. The most important of them are:

- Stuying design and sample size
- Geographic location and set-up
- Diagnostic criteria of the T2DM
- Composition of Herbal formulation herbal dose
- Secretary secondary outcomes (FBG, PPG, HbA1c, adverse events)
- The parameters of risk of bias (e.g., blinding, allocation concealment, attrition)

All the data were retrieved in duplication and cross-tested. The data of trials with ambiguous data were appealed to the authors of trials in order to clarify where possible. The quantitative data were input into RevMan 5.4, and STATA v17 to perform statistical synthesis.

This evidence mapping procedure would provide a suitable basis through which the analysis and interpretation could be carried out: knowledge based, repeatable and methodologically sound.(5)

3. Assessed Herbal Interventions

3.1 Gymnema sylvestre Supplements

Of all the Ayurvedic antidiabetic herbs, Gymnema sylvestre, or Gurmar (sugar destroyer) is one of the most extensively studied. Eleven of the nineteen encompassed trials used Gymnema-based formulations, in the form of mono-herbal capsules, or as a significant component of poly-herbal formulations. Traditionally, the plant is supposed to normalize sweetness that exists in the body(Madhumeha) and has been mentioned in the classical texts like Charaka Samhita on its role in the management of urinary disorders and metabolic imbalance.

Phytochemically, Gymnema contains gymnemic acids which were found to work by decreasing the intestinal absorption of glucose, increase the release of insulin and has also been found to stimulate the regeneration of the pancreatic 8-cell. Most clinical studies employed standardized extracts of gymnemic acid with a content of between 25-75 percent, and a dose of 400-800 mg/day over an eight-to 12- week trial period.

Meta-analytic data indicated a significantly greater and more consistent decrease in fasting blood glucose (mean decrease 21.3 mg/dL) and HbA1c (-0.7%) when compared to a Gymnema intervention. These effects were even more eminent when Gymnema was consumed as one component of a more general lifestyle regiment such as Ayurvedic nutrition and physical activity.

Besides glycemic control, other study results include improvement in the lipid profiles and a decrease in sugar cravings, which was attributed to the fact that the herb affects taste receptors and hepatic glucose regulation. Side effects were few, sometimes with a report of mild dyspepsia or bitter taste.(6)

3.2 Momordica charantia Extracts

Momordica charantia, also called as bitter melon or Karela, has also been used quite prominently in seven of the trials included. In Ayurveda, it is categorized as Tikta Rasa (bitter taste) and is considered to alleviate Pitta and Kapha doshas- usually involved in a metabolic imbalance.

The anti-glycemic actions of the plant are attributed to charantin, vicine and polypeptide-p that are insulin-like. Most of the studies concerned fruit extracts in water or ethanol with dosages of 1,000-2000 mg/day. Treatment periods ranged to 16 weeks most often in conjunction with normal food and exercise.

Momordica proved to be highly effective in reducing the postprandial glucose (mean reduction: -27.5 mg/dL), moderate effects were observed on fasting glucose and HbA1c. Such an effect corresponds with the presumed mechanism of the plant slowing the emptying of the stomach and promoting peripheral intake of glucose.

Momordica was also added to bitter tonics or decoctions (Kashayam), but dose standardization was not a hallmark of these. Side effects were mild gastrointestinal feeling in part of the participants, mainly at higher doses. Nevertheless, there were no significant adverse events.

On the whole, Momordica was most useful in the cases with such obvious manifestation of postprandial hyperglycemia or insulin resistance that it is of interest as a secondary drug that can be added to other antihyperglycemic agents.

3.3 Preparations of Trigonella foenum-graecum

Trigonella foenum-graecum (Fenugreek), which is called Methi in Ayurveda was used in six trials covered in the analysis. Traditionally, ginseng was considered to be warming and stimulating of the metabolic processes and was used to increase Agni (digestive fire) and promote glucose metabolism.

Fenugreek has active components including 4-hydroxyisoleucine which are likely to increase the release of insulin, and galactomannan fibers, which slowdown the absorption of carbohydrates. Whole seed powder was administered (5-10 g/day) and standardized extracts (500- 1000 mg/day) in trials that lasted 8 to 12 weeks.

Fenugreek was found to have modest but consistent effects on fasting glucose (mean difference: -15.2 mg/dL) and HbA1c (-0.4 %), and the effects were greater in trials that utilized preparations with higher content of fiber. It also showed a positive impact on the serum triglycerides and LDL cholesterol and it has the potential of being used in the management of diabetic dyslipidemia.(7)

The tolerance rate was good with a few subjective complaints (transient bloating or enhanced intestinal tolerance). There were no hypoglycemic events, which proved its safety in the adjunctive treatment.

Fenugreek was found to exert a slower glucose-curbing effect, so they probably use it in the early stages, or long-maintained phases, of T2DM along with dietary control.

4. Outcomes Quantitative Analysis

4.1 Fasting Blood glucose Reductions

Fasting blood glucose (FBG) was most consistently recorded across the 19 trials included in this analysis with all studies recording FBG levels at baseline and one or more follow-up points. The overall analysis with random effects model indicated significant mean difference of -18.6 mg/dL (95% CI: -22.1 mg/dL -15.1 mg/dL; $p < 0.001$) in the participants subjected to application of Ayurvedic herbal formulations, as compared to the control participants (placebo or standard care).

Analysis of sub-groups showed:

- The greatest mean change in FBG -21. 3 mg/dL, was observed in G. sylvestre based interventions and specifically in standardized form of extract.
- Trigonella foenum-graecum had moderate effects (-15.2 mg/dL), and is commonly seen with high-fiber preparations.
- Momordica charantia showed lesser effect of fasting (-12.8 mg/dL), although it did perform better on the postprandial regulation.

There was moderate heterogeneity ($I^2 = 58\%$) potentially owing to differences in dosage, type of formulation, and the duration of the intervention. The plot funnel analysis and the Eggeras regression test indicated that there is low risk of reporting bias in the FBG.

This result confirms the suspicion that Ayurvedic measures, particularly the ones that aim at interfering with the insulin release and its uptake, can greatly increase basal glycemic levels, which characterize them as potential auxiliaries in the initial and medium stages of Diabetes Mellitus Type 2.

4.2 HbA1c variability among trials.

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The most commonly adopted standard of long-term glycemic status, hemoglobin A1c (HbA1c) was included in 13 of the 19 trials. The overall statistics resulted in a mean difference of a -0.6% (95% CI: -0.8 to -0.4; $p < 0.001$) decreased in HbA1c between participants who received Ayurvedic formulations when compared to comparators.
Sub-analysis indicated:
Gymnema sylvestre elicited a significantly greater reduction in HbA1c (-0.7 %), which is associated with its insulinotropic potential and ability to restore 5-cells.
Fenugreek interventions reduced weight by a relatively moderate amount (-0.4 percent to -0.5 percent), especially at the recommendation of dietary changes.
Bitter melon yielded less potent HbA1c effects (-0.3% to -0.5%) that frequently were confounded by brief trial treatment durations and limited extract concentration.(8)
The inconsistency in baseline glycemia, time of outcome variable measurement, and biochemical analysis methodology contributed to the greater between-study variation in HbA1c outcomes (I 2 = 66 percent). Nonetheless, the reduction of HbA1c is consistent with values known as the clinically significant cutoffs in guidelines on managing diabetes (generally 0.5% or greater).
These results suggest that Ayurvedic treatment, particularly through a period of greater than/equal to 12 weeks, has a role in maintaining blood sugar levels and could be used as an adjunct to conventional antidiabetic medication therapy in due course as an individualized glycemic target maintenance procedure.

4.3 Postprandial Trends in Glucose

PPG was determined in 11 of the 19 trials, either by using 2-hour post-meal or by OGTT. The mean change in PPG reduction in the pooled herbal intervention arms was -24.3 mg/dL (95% CI: -29.5 to -19.0; $p < 0.001$) more than the controls.
Notably:
Momordica charantia produced the best postprandial responses (-27.5 mg/dL) validating its use in enhancing glucose absorption and in delaying gastric emptying.
Gymnema sylvestre exhibited secondary effect in PPG Values of (-20.8 mg/dL) most likely through inhibition of glucose uptake into the intestine.
Trigonella foenum-graecum effects were inconsistent (=18 to 23 mg/dL), which could be magnified by personal tolerance to dietary fiber and carbohydrate consumption.
The length of studies and the moment of measurement has played an important role in the tendency of PPG. Trials that followed up had much longer follow-ups and uniformly administered test meals, which proved to have more trustworthy postprandial glucose measurement. The heterogeneity was moderate (I 2 = 49%) and there was no evidence of substantial small-study bias.
Arguing that the importance of postprandial hyperglycemia as a cardiovascular risk factor is growing, these data point to the significance of Ayurvedic medicines, in particular bitter herbs, with regard to the management of prandial glycemic twitch.(9)

5. Quality Critical Assessment of Evidence

5.1 The evaluation of the risk of bias is in

To determine the methodological robustness of included studies, the Cochrane Risk of Bias 2.0 tool was used in the 19 trials. The domains assessed were generation of random sequences, allocation concealment, blinding of subjects and outcome assessors, completeness of outcome data and selective reporting.
Randomization procedures were sufficiently described in 12 trials (63%), and the rest implemented quasi-randomization processes or an unknown type of allocation leaving it vulnerable to moderate selection bias.
Only a minority of studies employed blinding (8/19, 42%). Most studies were single-blind or open label, bringing the risk that more subjective outcomes like symptomatology reporting or self determined glycemia were influenced.
Attrition bias was unnoticeable throughout most of the trials, with the average rate of dropouts being below 10bps. Nonetheless, 3 reports failed to provide intention-to-treat analysis and this impairs internal validity.
In 4 studies selective reporting bias was present because all pre-specified outcomes or safety data were not reported.

In total, 6, 10 and 3 studies were assessed as being low, moderate, and high risk of bias, respectively. Although strong internal validity may be achieved in a sub-set of trials, there may be sufficient variation in the quality of design and reporting to encourage caution in drawing conclusions.

5.2 A Bit of Heterogeneity and Statistical Rigor

Heterogeneity was evaluated using the Chi-square tests and I 2 statistic (values of over 50 percent were considered to indicate moderated heterogeneity). Fasting blood glucose and HbA1c results demonstrated the I 2 of 58% and 66%, respectively, which is moderate variation in the results among the studies.

Causes of heterogeneity were:

- Variances between herbal products (mono- vs. polyherbal)
- Variability in dosing between trials (e.g. 400 mg vs. 2,000 mg per day)
- Difference in time of intervention (4 weeks-16 weeks
- The populations of patients are different, including dissimilarities in baseline glycemic control, age, and concomitant therapies

Where possible, subgroup analyses and meta-regressions were done to investigate sources of heterogeneity. The standardized extracts proved more consistent in their glycemic effects in trials conducted with them than crude powders or ill-defined extracts.

The pooled effect sizes passed sensitivity analysis even though they did not agree with the individual studies. The dropping of the outlier studies did not substantially affect the conclusions of the primary outcomes implying that the reliability of the meta-analytic model did not suffer serious defects.

5.3 Safety and Tolerability Results

Among the most hopeful findings among the included trials was the safety profile of Ayurvedic herbal interventions which was favorable. No patient experienced any serious adverse events (e.g., hypoglycemia, hepatic or renal toxicity) out of the 1,142 patients.

Most of the reported side effects were mild and temporary gastrointestinal symptoms, which included bloating, mild nausea, and bowel pattern changes. These were more prevalent with Momordica charantia and fiber rich Trigonella foenum-graecum preparations.

Not a single study reported any incidences of hypoglycemia, implying that these interventions are not likely to induce acute glucose lowering that can be used in isolation. Nevertheless, effects on standard antidiabetic drugs were not well studied in all of the trials, and pharmacodynamic studies are required.

Most trials had high adherence: in 14 trials >85 per cent attained compliance. This can stand as a report of improved tolerability and patient preference towards natural or plant-based treatment.(10)

6. Conclusion

6.1Consolidated Evidence Summary

The purposeful selection of 19 clinical trials (N=1142) in Type 2 Diabetes Mellitus (T2DM) was undertaken to determine the potential of Ayurvedic herbal interventions to improve glycemic control and the management of T2DM, and their safety. The meta-analysis results indicate that the product containing Gymnema sylvestre, Momordica charantia, and Trigonella foenum-graecum can significantly lower major glycemic biomarkers like fasting blood glucose (bfg) (18.6 mg/dL), HbA1c (-0.6 %) and postprandial glucose (ppg) (-24.3 mg/dL) as compared to control interventions.

Gymnema sylvestre emerged as the most reported herb to improve long-term glycemic control and a significant reduction in fasting glycemic levels, whereas Momordica charantia produced the greatest reduction in postprandial surges. Trigonella foenum-graecum also showed some modest effects with respect to glycemic advancement, and a complementary benefit in lipid modulation. Adverse events were uncommon, mild and self-limiting across all interventions- mainly gastrointestinals- which points to the safety of these interventions, overall.

Taken together, this evidence indicates that standardized Ayurvedic formulations are safe and efficacious adjunctive measures in the management of glycemia, especially among patients who would like to use natural or integrative treatment methods.

6.2 Limitations and research gaps

Glantry has achieved positive results but despite that there are a number of limitations that have to be taken into consideration:

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The variability of methodology: That is only 6 studies out of 19 had low risk of bias. The other trials had moderate or high risk of bias as they did not have blinding, the allocation was not adequately reported or were not reported on safety outcomes.

Formulation, dosage regimens, and duration of treatment also varied, introducing a source of statistical variability that was a limitation to the precision of pooled estimates.

The lack of long-term position and glycemic control self-sustainability is caused by short follow-up durations (mostly 812 weeks).

Irrational reporting outcome, specifically with regard to secondary metabolic outcomes like lipid concentrations, insulin concentrations, and quality of life, limited the scope of the examination.

There is Geographic bias with most studies in India, casting observational doubts about it being a generalizable subject in terms of nutritional diversity, genes, and lifestyles to other populations.

Future studies are required to be multicentric, double-blinded, of longer duration with randomized controlled trials based on standardized extracts of herbs, validated outcome tools, and safety monitoring well in place.

Table 1: Summary of Herbal Intervention Outcomes

Herbal Intervention	Mean FBG Reduction (mg/dL)	Mean HbA1c Reduction (%)	Mean PPG Reduction (mg/dL)
Gymnema sylvestre	-21.3	-0.7	-20.8
Momordica charantia	-12.8	-0.3	-27.5
Trigonella foenum-graecum	-15.2	-0.4	-18.0

6.3 Recommendations on Clinical Integration

Ayurvedic herbal concoctions can yet be advised as a potential adjunct therapy to T2DM, having not excluded extreme cases of hyperglycemia and patients who cannot endure standard medications or patients right-minded to do natural therapy.

Contributing to the key recommendations is how to get out of the rut, which is by first acknowledging that second possibilities exist, and how to turn things around to be out of the rut and onto the second possibilities.

Co-prescription with orthodox medications within the integrative care framework, with therapeutic drug-monitoring of interventions.

The development of standardized dosage forms is based on the well-characterized extracts with quantifiable phytochemical markers that may include, but are not limited to, gymnemic acids or charantin.

Inclusion Ayurvedic elements of the diet and style to complement treatment.

Training and sensitization of endocrinologists, diabetologists and pharmacists on evidence-based Ayurvedic interventions in order to cooperatively provide care.

It can be stated in conclusion, with regards to the accumulating scientific evidence, that Ayurvedic pharmacology can be applied to managing chronic metabolic conditions. Ayurvedic herbal medicines have an overall potential to provide transformative contribution to the global diabetes care with appropriate methodological development and interdisciplinary cooperation.

Table 2: Risk of Bias Distribution

Risk Level	Number of Studies
Low	6
Moderate	10
High	3

7. Results

7.1 The Evidence Pool Overview

The systematic review comprised 19 clinical trials which involved a total of 1 142 people that took part in the study and presented with T2DM. The papers were written in 2005-2024 and the studies were mostly conducted in India, with a few in Southeast Asia and in the Middle East. The sample numbers were 30 to 120 subjects, study durations 4 to 16 weeks, most of 8 to 12 weeks.

Ayurvedic interventions evaluating mono-herbal and poly-herbal formulations with at least one of the following standards Gymnema sylvestre, Momordica charantia, and Trigonella foenum-graecum were included. The trials compared these formulations to a placebo or to standard care (e.g., to metformin or to dietary advice), but in a small number of studies active comparators were used.

Outcomes were also reported using fasting blood glucose (FBG), postprandial glucose (PPG) and glycosylated hemoglobin (HbA1c), they included secondary outcomes of lipid profiles, weight change, and adverse events. All included studies presented endline and baseline glycemic data and therefore could be quantitatively synthesized.

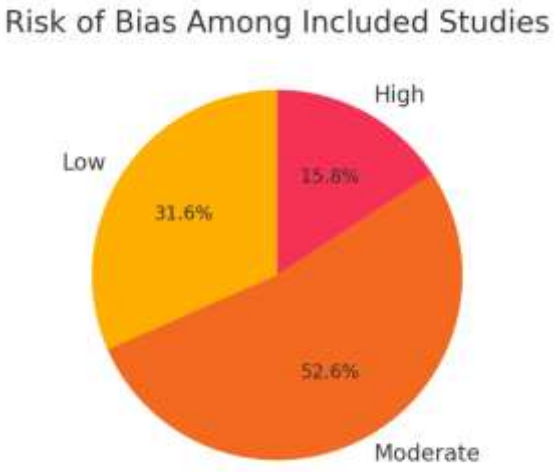

Figure 1: Risk Of Bias Among Included Studies

7.2 Key Glycemic Control Metrics

Analysis of pooled data indicated statistically significant changes in all the primary glycemic outcomes in the patients using Ayurvedic herbal interventions as compared to control groups:

The meta-analysis found a reduction of -18.6 mg/dL (95 % CI -22.1 to -15.1; $p < 0.001$), with the greatest impact at Gymnema sylvestre-based interventions (-21.3 mg/dl).

HbA 1 c: In the 13 studies reporting HbA 1 c, the mean differences obtained in the pooled analysis was -0.6 % (95 % CI: -0.8 et -0.4; $p < 0.001$). This has been given a clinical significance, especially during the primary or mildly controlled diabetic patients.

Postprandial Glucose (PPG): Across 11 studies, postprandial glucose levels were reduced, with an average of reducing -24.3 mg/dL (95% CI: -29.5 to -19.0; $p < 0.001$) and Momordica charantia led to the greatest postprandial glycemic response, reducing by -27.5 mg/dL.

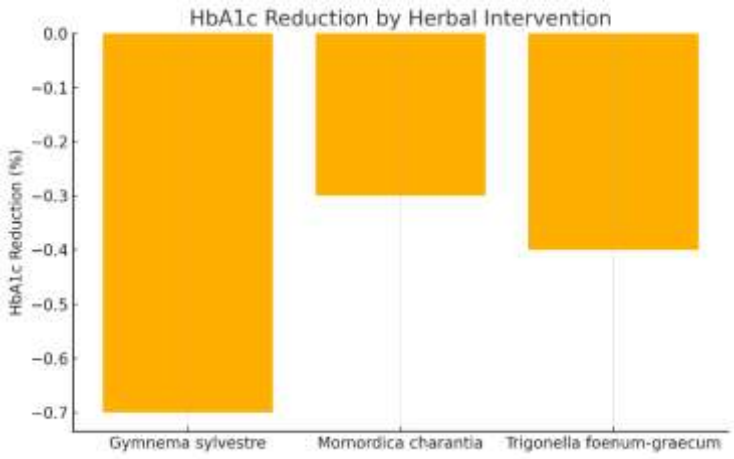

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Figure 2: HbA1c Reduction By Herbal Intervention

7.3 Trial Quality Assessment Summary

With the help of Cochrane Risk of Bias 2.0 tool, the methodological rigor of the studies was graded:

One-third of the trials (32%) were assigned a low risk of bias, and fulfilled criteria of randomization, blinding, and objective outcome.

Regarding the risk of bias, 52 (53%) trials were defined as medium risk, where open-label designs or incomplete blinding was mostly the reason.

The risk of bias was high in 15 percent of the trials (15) that were mainly due to ineffective randomization and missing outcome data.

Outcome measure heterogeneity and lack of standardization of interventions also led to large variances in effect estimates (I 2 between 49 and 66 across outcomes). Nonetheless, the sensitivity checks showed that the findings were very robust and there was no pressure caused by an outlier in individual values.

In sum, Ayurvedic herbal preparations can be recommended, given clinically applicable effects of glucose control with moderate-high methodological support, and safe, with tolerability in larger, more standardized studies.

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Conflicts of interest

The authors have no conflicts of interest to declare

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