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Original Article

Physiotherapy Section

The Influence of Yoga on HbA1c Levels in Patients with Type 2 Diabetes Mellitus: A Systematic Review

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ABSTRACT

Introduction: Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disease characterised by insulin resistance and hyperglycaemia due to insulin deficiency. Despite advances in traditional treatment approaches, achieving and maintaining optimal glycaemic control remains a clinical challenge.

Aim: To thoroughly evaluate and summarise the available evidence on the effects of yoga on HbA1c levels in patients with T2DM.

Materials and Methods: The present review was a systematic review in which five electronic databases were searched: PubMed/MedLine, SCOPUS, the Cochrane Library (including ICTRP and EMBASE), and the Physiotherapy Evidence Database (PEDro). The keywords used were "yoga", "HbA1c", "diabetes" and "T2DM". Google Scholar was also searched for supplementary information and manually reviewed references from identified publications. After removing duplicates and making the full text available, 24 articles were included in the systematic review.

Results: This systematic review demonstrates the benefits of various yoga techniques for patients with T2DM. The review primarily focused on fasting blood glucose, postprandial blood glucose, hormone levels, lipid profiles, blood pressure, cardiac function, vitamin C and E levels, anthropometric measurements, quality of life and psychological factors. This review aids in predicting the benefits of various yoga techniques as an integrated approach and assesses the cumulative benefits of medication among patients with diabetes. Out of the 24 included studies, numerous yogic practices were employed; seven studies used *Suryanamaskar*, eight studies used *Trikonasana* and the remainder utilised *Padmasana*, *Paschimottasana*, *Tadasana*, *Mandukasana*, *Ardh Matsyendrasana*, *Sukhasana* and others. The studies also incorporated various Pranayamas, including *Sudarshan Kriya*, *Bhastrika*, *Bhramari*, *Kapalbhati*, *Nadi Shuddhi*, *Viparitakarani*, *Sitkari*, *Anuloma-Viloma*, and Om chanting.

Conclusion: This review highlights the benefits of various yoga techniques as an integrated approach and underlines the cumulative benefits of pharmacological treatment in patients with diabetes.

Keywords: Glycaemic control, Insulin, Metabolic diseases

INTRODUCTION

The T2DM is a chronic metabolic disease characterised by insulin resistance and hyperglycaemia due to insufficient insulin secretion. Despite advances in traditional treatment approaches, achieving and maintaining optimal glycaemic control remains a clinical challenge. Its escalating prevalence and associated complications pose substantial challenges to global public health systems [1]. In response to this problem, there is growing interest in exploring complementary and alternative interventions that can be combined with standard pharmacotherapy to improve glycaemic control and overall wellbeing in patients with T2DM. Among these modalities, yoga—a multifaceted mind-body practice with roots in ancient Indian traditions—has emerged as a promising complementary therapy within holistic approaches to health promotion [2]. Yoga encompasses a variety of practices, including physical postures (asanas), breathing exercises (pranayama), meditation (dhyana), and ethical precepts (yamas and niyamas), all aimed at promoting physical, mental and spiritual wellbeing [3]. It addresses not only the physiological aspects of diabetes, but also the psychosocial factors that often accompany the disease, such as stress, anxiety and depression [4,5].

The treatment of T2DM is based on the necessity of achieving glycaemic control, as reflected by haemoglobin A1c (HbA1c) levels [6]. HbA1c serves as an important indicator of long-term blood glucose levels, providing insight into overall glycaemic control and associated risks. Lowering HbA1c levels is a major therapeutic goal in the treatment of T2DM [7], as it is associated with a reduced risk of microvascular and macrovascular complications [7,8].

Anecdotal studies suggest a potential benefit of yoga in improving glycaemic control and lowering HbA1c levels in people with T2DM; however, establishing the consistency, magnitude and clinical significance of these effects requires a comprehensive synthesis of the existing literature. Therefore, this systematic review aims to thoroughly evaluate and summarise the available evidence on the effect of yoga on HbA1c levels in patients with T2DM [9-11]. By systematically analysing a diverse range of studies, this review seeks to provide clinicians, researchers and patients with a clearer understanding of the therapeutic potential of yoga in glycaemic management and its broader implications for the treatment of T2DM. Additionally, by identifying methodological limitations and research gaps in the existing literature, this review aims to uncover the mechanisms underlying the effects of yoga on glycaemic control and guide future research efforts to optimise the integration of yoga into comprehensive models of diabetes care.

MATERIALS AND METHODS

Search strategy and source of information: Five electronic databases were searched for this review: PubMed/MedLine (88 articles), SCOPUS (155 articles), the Cochrane Library (including ICTRP and EMBASE) (4 articles), and the Physiotherapy Evidence Database (PEDro) (21 articles) [Table/Fig-1]. Additionally, Google Scholar was explored to gather supplementary information and a manual search was conducted, which included reviewing references in identified publications. We also sought input from colleagues in the field. The search strategy for this review involved the amalgamation of key terms and their synonyms. For inclusion in the review, each

study's title or abstract had to include at least one term from the search strategy.

Database	Search terms	Articles extracted
Medline/PubMed	"yoga" AND "HbA1c" AND ("diabetes" OR "type 2 diabetes mellitus" OR "T2DM")	54
	"yoga" AND "HbA1c" AND ("diabetes" OR "type 2 diabetes mellitus" OR "T2DM") AND (observational study OR cross sectional study)	00
	"yoga" AND "HbA1c" AND "diabetes" AND "randomised controlled trial" AND "clinical trial"	13
	"yoga" AND "HbA1c" AND "diabetes" AND "randomised controlled trial" AND "clinical trial"	13
	"yoga" AND "HbA1c" AND "diabetes" AND "randomised controlled trial" AND "clinical trial"	08
SCOPUS	"yoga" AND "HbA1c" AND "diabetes"	53
	"yoga" AND "HbA1c" AND "diabetes" AND Articles	40
	"yoga" AND "HbA1c" AND "diabetes" AND Articles	39
	"yoga" AND "HbA1c" AND "diabetes"	23
Cochrane library	"yoga" AND "HbA1c" AND "diabetes"	04
PEDro	yoga and HbA1c and diabetes	21
Hand picked articles		4

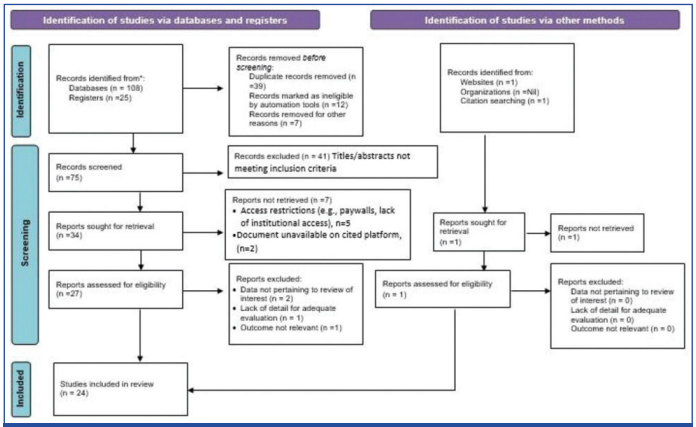
[Table/Fig-1]: Search strategy.

Medical Subject Headings (MeSH) terms and keywords related to yoga, HbA1c and T2DM were utilised. These terms were selected in line with the research questions and were identified during the initial literature review of studies focusing on HbA1c levels. The types of studies included were observational studies, cross-sectional studies, and Randomised Controlled Trials (RCTs) or clinical trials. The search was conducted using Boolean operators 'AND', 'OR', and 'NOT'.

Study selection: During the initial screening stage, studies were considered based on their titles and abstracts. In the second stage, approval was based on a full-text review. Articles discovered through manual searches were also included in the full-text screening stage. At each stage of the selection process, two independent reviewers screened and selected articles, resolving differences through discussion until consensus was reached.

Inclusion criteria: Studies evaluating the impact of yoga interventions on HbA1c levels in adult patients with T2DM, employing experimental or observational designs, reporting pre- and postintervention HbA1c levels and being available in English were included in the study.

Exclusion criteria: Reviews or conference abstracts without full-text availability were excluded from the study. Agreement between the two reviewers before consensus discussions ranged from 94% at the abstract level to 92% at the full-text level. [Table/Fig-2] demonstrates the PRISMA flowchart for the inclusion and exclusion of the articles.



[Table/Fig-2]: Prisma flowchart.

Data extraction: Two reviewers independently extracted data using a standardised form, capturing study characteristics (e.g., design, sample size, intervention duration), participant demographics (e.g., age, gender, diabetes duration), details of the yoga intervention (e.g., type, frequency, duration) and changes in HbA1c levels pre- and postintervention. Discrepancies were resolved through consensus or consultation with a third reviewer.

Quality assessment: Methodological quality assessment was conducted using two established tools: the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach and the Physiotherapy Evidence Database (PEDro) scale [Table/Fig-3] [12-31].

Author/Year	1	2	3	4	5	6	7	8	9	10	11
Sharma A et al., 2015 [23]	√	√	×	√	×	×	×	√	√	√	×
Bock BC et al., 2019 [12]	√	√	√	√	√	×	×	√	√	√	√
Jyotsna VP et al., 2012 [21]	√	√	×	√	×	×	×	√	√	√	×
Jyotsna VP et al., 2013 [22]	√	√	×	√	×	×	×	√	√	√	×
Kanaya AM et al., 2014 [13]	√	√	×	√	×	×	×	√	√	√	√
Innes KE et al., 2011 [28]	√	×	×	√	×	×	×	√	√	×	×
Mangala Gowri M et al., 2022 [14]	√	√	×	√	×	×	×	√	√	√	√
Hirosaki M et al., 2023 [15]	√	√	×	√	×	×	√	√	√	√	√
Kumar P and Bhardwaj I, 2019 [16]	√	×	×	√	×	×	×	√	√	√	√
Misra P et al., 2021 [17]	√	√	×	√	×	×	×	√	√	√	×
Raghuram N et al., 2021 [18]	√	√	√	√	√	×	×	√	√	√	√
Sarika KS et al., 2021 [24]	√	√	×	√	×	×	×	√	√	√	×
Dash S and Thakur AK, 2014 [29]	√	×	×	√	×	×	×	√	√	√	×
Hegde SV et al., 2011 [30]	√	×	×	×	×	×	×	√	√	√	×
Hegde SV et al., 2013 [25]	√	√	×	√	×	×	×	√	√	√	×
Skoro-Kondza L et al., 2009 [31]	√	√	×	√	×	×	×	√	√	√	×
Sreedevi A et al., 2017 [19]	√	√	√	√	×	×	×	√	√	√	√
Ranga SA et al., 2021 [26]	√	√	×	√	×	×	×	√	√	√	√
Vijayashankar U et al., 2022 [27]	√	√	×	√	×	×	×	√	√	√	×
Singh VP and Khandelwal B, 2020 [20]	√	√	√	√	√	√	×	√	√	√	√

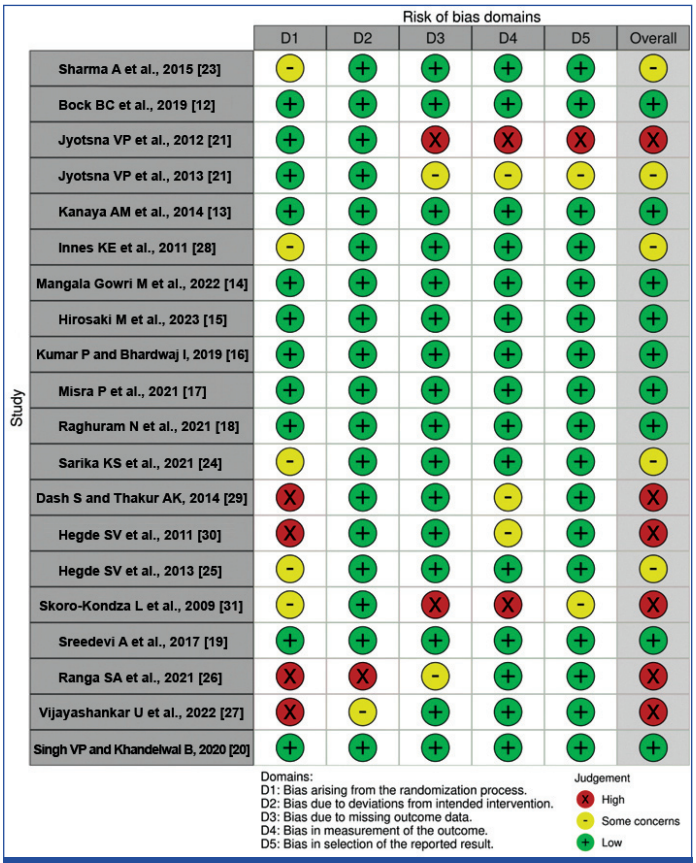
[Table/Fig-3]: PEDro scale* analysis of the studies included in the systematic review [12-31].
*https://pedro.org.au/english/resources/pedro-scale/(1: eligibility criteria were specified; 2: subjects were randomly allocated to groups; 3: allocation was concealed; 4: the groups were similar at baseline regarding the most important prognostic indicators; 5: there was blinding of all subjects: 6: there was blinding of all therapists who administered the therapy; 7: there was blinding of all assessors who measured at least one key outcome; 8: measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9: all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"; 10: the results of between-group statistical comparisons are reported for at least one key outcome; 11: the study provides both point measures and measures of variability for at least one key outcome)

GRADE approach: The GRADE approach assesses the quality of evidence based on study design, risk of bias, inconsistency, indirectness, imprecision and publication bias. Each included study was evaluated and rated as being of high, moderate, low, or very low quality based on these domains. This assessment indicates how confident we are in the study findings.

Level of evidence: After the GRADE assessment, the level of evidence for each outcome was assigned, ranging from high to very low based on the overall quality of the studies. High-quality evidence implies a high level of confidence in the effect estimate, while very low-quality evidence suggests considerable uncertainty [32].

PEDro scale: The PEDro Scale assesses the methodological quality of RCTs of physiotherapy interventions. It consists of 11 items, including randomisation-related criteria, blinding, eligibility criteria, outcome measures and statistical analysis. Each criterion met is worth one point, with a maximum score of 10. Out of the 24 included studies, 20 articles (four studies were not RCTs) were assessed based on the PEDro score, with a higher score indicating better methodological quality [33].

Risk of bias assessment: The lead researcher assessed the internal validity of the included studies by examining their susceptibility to bias. This assessment employed the Cochrane Risk of Bias Tool for Randomised Trials (RoB 2), version 2, which is specifically designed for reviews focusing on the effectiveness and management of care. RoB 2 defines specific areas of bias related to trial planning, implementation and documentation [34]. Each area includes a "signal question" designed to elicit trial properties relevant to susceptibility to bias. The algorithm then evaluates the answers to these questions, providing a judgement of susceptibility to bias for each area, with options such as "low" or "high" risk, "some concern", and "no information". A visual representation of these results is provided using a traffic light diagram available on a dedicated website at https://www.riskofbias.info/welcome/robvis-visualisation-tool [Table/Fig-4,5] [12-31].



[Table/Fig-4]: Risk of bias according traffic light plots and summary plots according to cochrane criteria [12-31].

[Table/Fig-5]: Overall risk of bias.

Data synthesis: The data synthesis of the included studies demonstrates promising trends in the effect of yoga on HbA1c in patients with T2DM. The review encompassed a diverse set of studies with varying designs and intervention characteristics. Although the specifics of the yoga interventions varied across studies, most indicated improvements in HbA1c levels following the intervention. However, heterogeneity across studies—including differences in participant demographics, intervention protocols and outcome measures—precludes making firm conclusions about the overall effectiveness of yoga in controlling HbA1c levels in T2DM. Nevertheless, this synthesis highlights the potential of yoga as an adjunctive therapy for glycaemic control in the treatment of T2DM.

RESULTS

Characteristics of Included Studies

A total of 133 articles were retrieved from various databases and manual searches. Using a combination of keywords, 53 articles were extracted from PubMed, 54 articles from SCOPUS, 4 studies from the Cochrane Library, and 21 articles from PEDro. Additionally, four articles were hand-picked from the cross-references of various articles. After removing duplicates and ensuring the availability of full-text articles, 24 articles were included for the systematic review . Among the 24 articles included in this systematic review, 20 were RCTs, two were case reports, one was a retrospective case-control study, and one was a prospective cohort study.

Risk of Bias

[Table/Fig-2] represents the summary of the risk of bias for the included RCTs. Overall, the risk of bias was low in nine out of the 24 studies included in the systematic review [12-17,32-34]. Eleven of the 24 studies exhibited adequate randomisation [12-19,32-34], while 18 of the 24 studies demonstrated low bias in the measurement of the outcomes [12-17,23-28,32-37]. Additionally, 20 out of 24 studies had low bias in the selection of reported results [12-20,23-30,35-37]. Deviation from the intended intervention was reported as having high bias in one study [26] and moderate bias in another [27]. Only two studies reported high bias regarding missing outcome data and measurement of outcomes [21,31]. High bias in the selection of reported results was noted in one study [21], with moderate concern raised in the reported results of three studies [22,31,38]. The details of the characteristics of the included articles are provided in [Table/Fig-6] [12,31,35-38].

Intervention

Details of interventions: The types of interventions, their duration, and outcomes are summarised in [Table/Fig-2]. Various Yogasanas and Pranayama techniques have been employed to assess their effects on HbA1c levels.

Out of the 24 included studies, a variety of Yogasanas were used. Seven studies [16,19,20,23,29,36,37] utilised *Suryanamaskar*, while eight studies [14,17,20,23,25,30,36,37] implemented Trikonasana. Other commonly used Yogasanas included *Padmasana* [20,23], *Paschimottasana* [16,20,23,25,30], *Tadasana* [14,20,23,25,30], *Mandukasana* [16,23,29], *Ardh Matsyendrasana* [14,16,17,19,20,23,29,36], *Sukhasana* [23], *Pawanmuktasana* [14,19,23,25,29,30,36], *Bhujangasana* [16,19,20,23,25,30,36], *Vajrasana* [20,23,25,29,30], *Dhanurasana* [20,23,25,26,30], *Vakrasana* [14,17,25,36,37,30], *Chakrasana* [17,36,37], *Shavasana* [14,16,23,25,29,30], *Shalabhasana* [19,25,30], *Veerasana* [14], *Parsvakonasana* [14,25,30], *Navasana* [14,20,37], *Ushtrasana* [16], *Padahastasana* [25,30,37], *Gomukhasana*, *Uttanapadasana*, and *Vrikasana* [25-30,36,37], as well as *Ardh Machendrasana* [37].

Pranayama techniques [14,16-23,37] were also included in the studies, such as *Sudarshan Kriya* [14,16,21,22], *Bhastrika* [14,16-23], *Bhramari* [17,20,25,29,30,36], *Kapalbhati* [14,16,18,20,29,36,37], *Nadi Shuddhi* [14,17,36], *Viparitakarani*, *Sitkari* [25,30], *Anuloma-Viloma* [20,25,29,30,37], and *Om chanting* [14,17,21,22,29,36].

Additionally, Iyengar Yoga was implemented in two studies [12,13], demonstrating improvements in fasting blood glucose and HbA1c levels. Another study employed Laughter Yoga [15] to determine its effects. Seven studies did not specify the types of Yogasanas used. The authors of these studies included yoga as part of an integrated approach to reduce blood glucose levels and glycaemic index [24,26-28,31,35,38]. Some studies also included relaxation and breathing techniques [17-19,31,37].

The control groups primarily included standard therapy or pharmacotherapy [12,14,15,18,19,21,22,24,30,35,37], stretching exercises [13,17,20,31], a waitlist control group [17,25,31], or a

Author/Year [Ref No] GRADE	Study design	Population	Sample size (n)	Age (years) (mean±SD	Aim	Intervention	Outcomes	Main findings
Skoro-Kondza L et al., 2009 [31] **GRADE – Low quality**	Exploratory Randomised Controlled Trial (RCT)	13 men and 36 women	59	60±10	To explore the feasibility of researching community based yoga classes in Type 2 diabetes with a view to informing the design of a definitive, multicentre trial.	Intervention group: 12 weeks of a twice-weekly 90-minute yoga class; the control group: waiting list for the yoga classes. Both groups received advice and leaflets on healthy lifestyle and were encouraged to exercise.	The primary outcome measure was HbA1c. Secondary outcome measures were The UK Prospective Diabetes Study (UKPDS) cardiovascular risk score (a composite of blood pressure, smoking status, lipid ratio, presence of atrial fibrillation, and HbA1c which has high predictive value in diabetes)	This exploratory trial, which failed to demonstrate a significant impact of yoga in Type 2 diabetes.
Innes KE et al., 2011 [28] **GRADE – Low quality**	Randomised-controlled trial	Older adults with type 2 diabetes	38	48-78 (Mean age: 60.6±7.8)	To evaluate the association of serum fructosamine values to lipid profiles and to other indices of glycaemia both at baseline and over time in adults with Type 2 Diabetes (T2DM).	Intervention group: yoga program and usual care on glycaemia; control group: usual care on glycaemia.	Glycaemic parameters and lipid profiles	The results indicated that fructosamine was significantly correlated with measures of dyslipidaemia and glycaemia both at baseline and over time, and may represent a relatively sensitive and low cost index of short to medium term change in both glycaemia and certain lipid profiles.
Hegde SV et al., 2011 [30] **GRADE – Moderate quality**	Randomised-controlled trial	Type-II diabetic patients	123	40-75 (Mean age: 59.8±9.9 and 57.5±8.9: yoga and control group respectively)	To assess the effect of yoga on anthropometry, blood pressure, glycaemic control and oxidative stress in T2DM patients on standard care in comparison with standard care alone.	Intervention group: yoga and standard care; Control group: standard care.	Body Mass Index (BMI), glycaemic and biochemical variables, waist circumference, waist-to-hip ratio, blood pressure	The study demonstrated that yoga can be used as an effective therapy in reducing oxidative stress in T2DM. Yoga in addition to standard care helps reduce BMI and improve glycaemic control in type 2 diabetic patients.
Jyotsna VP et al., 2012 [21] **GRADE – Low quality**	Randomised-controlled trial	Patients with T2DM on treatment with lifestyle modification	49	Mean age: 50.59±10.11 (Sudarshan Kriya Yoga (SKY)); 45.27±10.31 (non-SKY)	To assess the effect of a comprehensive yogic breathing program on glycaemic control and Quality of Life (QoL) in patients with diabetes.	Group-I: standard treatment of diabetes; Group-II: standard treatment of diabetes and taught and told to regularly practice the comprehensive yogic breathing program.	QoL; glycaemic parameters: Fasting Blood Glucose (FBS), Postprandial Blood Sugar (PPBS), Glycosylated Haemoglobin (HbA1c)	The results of the study concluded the significant improvement in the QoL and a non significant trend towards improvement in glycaemic control in the group practicing the comprehensive yogic breathing program compared with the group that was following standard treatment alone.
Hegde SV et al., 2013 [25] **GRADE – Moderate quality**	Randomised-controlled trial	Prediabetes subjects	29	30-75 (Mean age: 46.50±13.03 and 44.67±9.57: yoga and control group respectively)	To study the effectiveness of yoga intervention on oxidative stress, glycaemic status, blood pressure and anthropometry in prediabetes.	Participants were randomised to either 3-month yoga (for at least 3 days/week); wait-list control groups.	Main outcome measures: Malondialdehyde, glutathione, vitamin C, vitamin E, superoxide dismutase, plasma glucose, glycated haemoglobin, BMI, waist circumference, waist-to-hip ratio and blood pressure	The study demonstrated that yoga intervention may be helpful in control of oxidative stress in prediabetes subjects.
Jyotsna VP et al., 2013 [22] **GRADE – Low quality**	Prospective randomised controlled intervention trial	Patients with diabetes	64 (28 patients in standard group and 36 patients in SKY group)	35-72 (Mean age: 48±2.2)	To observe the effect comprehensive yogic breathing (SKY and Pranayam) had on cardiac autonomic functions in patients with diabetes.	Group-I: standard treatment of diabetes; Group-II: standard treatment of diabetes and comprehensive yogic breathing program.	Cardiac autonomic functions; glycaemic parameters: FBS, PPBS, HbA1c	Cardiac autonomic functions improved in patients with diabetes on standard treatment who followed the comprehensive yogic breathing program compared to patients who were on standard therapy alone.

Kanaya AM et al., 2014 [13] **GRADE – Low quality**	Randomised clinical trial	Participants from 21 to 65 years old with metabolic syndrome	135 (yoga: n=72; stretching: n=63)	21-65 (mean age 55±7)	To compare restorative yoga compared and active stretching for the Metabolic Syndrome.	Group I: yoga Group II: stretching.	Metabolic outcomes included: changes in fasting and 2-hour glucose, HbA1c, triglycerides, High Density Lipoprotein (HDL)-cholesterol, fasting insulin, systolic blood pressure and visceral fat area and quality of life	The study concluded that restorative yoga was marginally better than stretching for improving fasting glucose but not other metabolic factors.
Dash S and Thakur AK, 2014 [29] **GRADE – Moderate quality**	Randomised-controlled trial	Type-II diabetic patients	60	40-60 (40-49 year constitute the 63.33% of total subjects and 50-59 years constitute the 36.37%)	To find out the effect of yogic asana and pranayama on various biochemical parameters of T2DM patients over a period of 40 days in the western Odisha.	Group I: yoga asna for 40 days along with diet plus diabetic medicines; Group II: diet plus normal medical therapy.	Biochemical investigations: FBG, PPBG, HbA1C and lipid profile	The study concluded that yoga asana and pranayama may be used as an adjunct to medical therapy to optimise the biochemical parameters. Yoga therapy also improves the status of diabetics in terms of reduction of drug doses, physical and mental alertness and prevention of complications.
Sharma A et al., 2015 [23] **GRADE – Low quality**	Randomised-controlled interventional study	Type-II diabetic patients	80	35-55 (Mean age: 47.8 and 48.65: yoga and control group respectively)	To assess and compare the effect of yogasanas on FBG, PPBG, HbA1c before and after intervention (Yogasans) in patients of T2DM.	Experimental group: 13 types of yoga-asans in the sequence for three continuous months. Subjects were made to practice yogic exercises by yoga instructor for 40-45 minutes, 5 days in a week in the morning Control group:	FBG, PPBG, HbA1C and dose variation in treatment if any	These findings suggested that yogasans have a beneficial effect on glycaemia control in T2DM and decrease the dosage of oral hypoglycaemic drugs.
Bairy S et al., 2016 [38] **GRADE – Low quality**	Prospective cohort study	The known cases of T2DM who were on antidiabetes medications (for at-least 1 year)	101	49-62 with mean age of 55	To assess the short-term effect of Integrated Naturopathy and Yoga (INY) as an adjunct to pharmacotherapy on glycaemic control among T2DM patients.	Integrated Naturopathy and Yoga.	Glycaemic control parameter: HbA1C, FBG, PPBS	This study demonstrated that INY, adjunctive to pharmacotherapy, was associated with a significant beneficial effect on glycaemic control and reduced the overall need for antidiabetes medications.
Sreedevi A et al., 2017 [19] **GRADE – High quality**	Randomised-controlled trial	Women with T2DM	99 (n=32 (yoga), n=32 (peer), n=35 (control)	30-65 (mean age 51.9±7.3)	To examine the feasibility and effect of two low cost interventions; yoga and peer support on glycaemic and other outcomes among women with T2DM.	Yoga Intervention: Instructor driven yoga sessions; Peer support intervention: control: standard treatment.	Primary outcomes: fasting plasma glucose, HbA1c, quality of life and pharmacological adherence; secondary outcomes: BMI and Waist Hip Ratio (WHR), blood pressure and total cholesterol	The results of the study concluded that the effect of yoga and peer support on glycaemic outcomes was incremental.
Gowda S et al., 2017 [37] ***GRADE– Low quality**	Case report	Male participant with sedentary lifestyle	1	50	To study the effective possibility of integrating yoga and naturopathy in the management of Metabolic syndrome (MetS).	Integrated Yoga Naturopathy (IYN) for 6 week.	Blood glucose, Blood pressure, Lipid profile, Thyroid profile, VAS for pain	The case report showed remarkable changes in MetS status that improved the quality of life following a 6 week Integrated Yoga Naturopathy (IYN) intervention. The change was sustainable for 12 weeks through simple lifestyle modifications.

Bock BC et al., 2019 [12] **GRADE – Low quality**	Two-arm randomised clinical trial	Individuals over 18 years with type-II diabetes for at least 6 months	48 30 women and 18 men (Yoga (n=24) or SE (n=24)	32-74 (mean age 55.7±8.8)	To examine the feasibility and acceptability of yoga as a complementary therapy for adults with T2DM.	Standard Exercise (SE) consisted of a 60-minute session twice weekly for 12 weeks; Yoga intervention: Iyengar yoga, consisted of two 60-minute sessions weekly for 12 weeks.	Primary outcomes: Feasibility and Acceptability, adverse events; Secondary outcomes: HbA1C, FBG, quality of life, diabetes self care, BMI, mindfulness, diabetes related emotional distress, physical activity	This study concluded yoga intervention was highly feasible and acceptable, and produced improvements in blood glucose and psychosocial measures of diabetes management.
Kumar P and Bhardwaj I, 2019 [16] **GRADE – Moderate quality**	Experimental study	Type-II diabetic patients	40	35-55	To examine the effect of Yogic Practices on HbA1c level of T2DM in Urban Adults.	Experiment group: Yoga and dietary advice for 12 week. Control group: Dietary advice only for 12 week.	HbA1C	The study revealed that the effect of Yogic Practices have significant effect on HbA1c level of T2DM in Urban Adults.
Singh VP and Khandelwal B, 2020 [20] **GRADE – Low quality**	Randomised-controlled trial	Type-II diabetic patients	200	23-73 (Mean age: 50.3±9.1 and 49.4±8.7: yoga and control group respectively	To evaluate the effect of yoga and exercise over glycaemic control, anxiety, depression, Exercise Self-efficacy (ESE), and QOL after 3-month program.	Yoga group: practiced yoga for 2 weeks under supervision and then carried out practice at home for 3 months. The exercise group: practiced 30 min of brisk walking for 5 days a week for 3 months.	HbA1C, Spielberger's State Anxiety Inventory, Spielberger's Trait Anxiety Inventory, Beck Depression Inventory, Exercise Self-Efficacy Scale, Diabetes quality of life	Yoga shows better improvement in glycaemic control measured by HbA1c, anxiety, depression, QOL, and ESE as compared to exercise alone.
Misra P et al., 2021 [17] **GRADE – Moderate quality**	Randomised-controlled interventional study	Type-II diabetic patients with HbA1C ≥6.5%	321	Mean age: 52.8±10.1 and 54.2±11.2: intervention and control group respectively	To assess the effect of structured yoga programs on diabetes.	For intervention group: yoga of 50 min daily, 2 consecutive weeks in a nearby park and health centre followed by twice a week home practice up to the 3rd month. Wait-listed Control Group: medication as prescribed by their physicians.	HbA1C, FBG, Lipid profile	The study concluded that structured yoga program improved glycaemic outcome and lipid profile of individuals in a community-based setting. Yoga can be a feasible strategy to control hyperglycaemia, lipid levels, and can help better control T2DM.
Ranga SA et al., 2021 [26] **GRADE – Moderate quality**	Randomised-controlled interventional study	Type-II diabetic patients	100	30-50 (Mean age: 47.8 and 48.65: yoga and control group respectively)	To assess and compare the effect of yoga on BP, FBG, HbA1c level before and after the intervention (Yoga) in patients of T2DM.	Group-1/Yoga group: patients were taking medicine with practicing yoga. Group 2/Control group: patients were only taking medicine without practicing yoga.	Weight, height, BMI, FBG, PPBG, HbA1C, Blood pressure and Dose variation in treatment if any	Yogic practices play a role in both primary and secondary prevention of DM. Yoga therapy can also be considered to be a beneficial adjuvant in the treatment of T2DM.
Raghuram R et al., 2021 [18] **GRADE – High quality**	Multicentre cluster randomised controlled clinical trial	Individuals with Indian Diabetes Risk Score (IDRS) more than 60%	4450 individuals in 80 clusters	Adults between 20-70	The primary aim of the Niyantrita Madhumeha Bharat Abhiyan trial (NMB-trial) was to provide a piece of preliminary evidence on the efficacy of YLP in harnessing the progression of diabetes and using a rapid study design in community settings of India, the second diabetes capital across the globe.	Intervention group: yoga based lifestyle modification protocol (YLP) for 3 months; control group: standard of care advice for diabetes prevention.	HbA1C, Blood pressure, BMI	The NMB-trial provides strong evidence towards the effectiveness of Yoga-Based Lifestyle Protocol (YLP) in reducing the incidence of type 2 diabetes in high-risk individuals (RRR=63.81%) compared to the control group.

Goyal Mehra C et al., 2022 [35] **GRADE – Moderate quality**	Retrospective case-control study	17% were in the age group of 20-35 years (yr), 49% were between 36 and 50 yr, 26% were between 51 and 65 yr, and 8% were between 66 and 80 yr. The average age of the participants was 50 years.	150	20-80	To evaluate the effectiveness of a comprehensive and multi-interventional diabetes care program called Sugar. Fit Diabetes Reversal Programme (SDRP) on HbA1c, FBG and body weight for T2D reversal.	Sugar.fit Diabetes Reversal Programme (SDRP) includes: SDRP is a personalised intervention program that uses technology-enabled medical management, dedicated coach-led diabetes, and nutrition experts to provide customised nutrition, progressive fitness (brisk walking, yoga, resistance exercise), and behavioural modification for the holistic management of T2DM.	HbA1c, FBS, Body weight	The SDRP demonstrated that the reversal of T2DM is possible using a multi-interventional approach involving diabetic expert physicians and health coaches emphasising personalised nutrition, physical activity, and behavioural modifications.
Kumari S et al., 2022 [36] **GRADE – Low quality**	Case report	Female patient with sedentary lifestyle (housewife)	1	52	To find out the effectiveness of the Ayurvedic approach of Panchakarma, Ayurvedic medications, Yoga, Pathyahara and lifestyle counseling for diagnosed case of T2DM.	Integration of Ayurvedic treatment and diet, Panchakarma therapies and Yoga for 1 year.	Blood glucose: FBS; PPBS; HbA1C	This case report revealed the protocol based integrated Ayurveda and Yoga practices for diagnosed case of T2DM without causing any untoward effect along with reversal of the diabetes.
Vijayashankar U et al., 2022 [27] **GRADE – Low quality**	Experimental study	Sedentary adults with T2DM	200	30-60	To assess the effectiveness of metabolic control with life style intervention (yoga) for 6 months among Type II diabetics.	Group-1: yogasanas alone; Group 2: only diet modifications; Group 3: yoga sessions and followed diet modifications. Added all three groups attended educational sessions conducted every fortnight; Group 4: controls.	Weight, BMI, blood glucose, insulin, HbA1C, lipid profile	The study concluded that short-term interventions produced positive modest changes in metabolic control. Further the study documented that lifestyle modifications with the intervention of yoga and diet counseling was effective in the management of weight loss, glycaemic control, plasma Insulin and lipid profile levels which on longer duration may yield a better effective result along with constant motivation.
Mangala Gowri M et al., 2022 [14] **GRADE – Low quality**	Experimental study	Individuals with T2DM	70 (yoga intervention: females n=21, males n=14; control: females, n=12, males, n=23)	30-70	To explore the possible beneficial effects of integrated yoga therapy with reference to glycaemic control and Insulin Resistance (IR) in individuals with diabetes maintained on standard oral medical care with yoga therapy, compared to those on standard oral medical care alone.	Group I: Yoga therapy twice weekly and oral hypoglycaemic agents; Group II: oral hypoglycaemic agents.	FBG, PPBG, HbA1c, insulin, and lipid profile	Administration of integrated yoga therapy to individuals with diabetes leads to a significant improvement in glycaemic control, insulin resistance, and key biochemical parameters.
Sarika KS et al., 2021 [24] **GRADE – Moderate quality**	Experimental study	Adults with male: female ratio 40:60 and 54.3:45.7 in the interventional and control group respectively	70	30-65 (52.83±7.45 and 49.91±8.67 in IAM® and control group, respectively)	To determine the psychological, physiological, and biochemical modulations brought about by stress reduction in T2DM.	Group-1/Integrated Amrita Meditation (IAM): Diabetic patients receiving standard medical care and undergoing IAM intervention. Group 2/Control: Diabetic patients receiving standard medical care alone and not undergoing meditation.	Physiologial and psychological variables: Heart Rate (HR), Respiratory Rate (RR), BMI, perceived stress scale and biochemical variables: FBG, HbA1C, lipid profile, CRP (C reactive protein), IL6 (interleukin 6), GABA (gamma amino butyric acid).	The study indicated the therapies that help people deal with stress can have a substantial positive impact on the quality of life and glycaemic regulation.

Hirosaki M et al., 2023 [15] **GRADE – Moderate quality**	Randomised controlled clinical trial	Individuals with type-II diabetes	42	71.8±6.4 (Laughter yoga group); 70.6±8.2 (control group)	To investigate whether laughter yoga can improve glycaemic control among individuals with T2DM.	Control group: standard therapy; Intervention group: standard therapy and the laughter yoga program.	HbA1c, body weight, waist circumference, psychological factors, and sleep duration	The study concluded that 12-week laughter yoga program is feasible for individuals with T2DM and improves glycaemic control.

[Table/Fig-6]: Study characteristics and quality appraisal.

pure control group without any intervention [16,19,23,27,28]. Two studies, which were case reports [26,36,37], had no control group; one study did not include any control group either [38].

The durations of the interventions varied across the studies: five studies had interventions lasting less than two months [17,18,29,36,37], one study lasted for two months [28] and 15 studies provided interventions for three months [12,15,17,19-21,26,30,31,38]. One study had a four-month intervention [14], while two studies offered interventions for six months [13-27,36,37] to observe the effects on glycaemic index levels. Follow-up assessments were conducted at three months [17,18], six months [12,21,22,24], or nine months [21], and some studies had follow-ups at 12 months [13,36].

Outcome Measures

Glycosylated Haemoglobin (HbA1c) was the outcome measure used in each study. Additionally, the most common outcome measures included fasting blood glucose, which was assessed by 18 studies [12-14,17,21-30,36-38]. Twelve studies evaluated postprandial blood glucose [13,14,21-23,25,27,29,30,36,37], while nine studies assessed lipid profiles [13,14,17,19,27-29,31,37]. Anthropometric measurements were evaluated by 11 articles [12 ,14,15,19,25,27,30,31,35,37]. Quality of life was assessed by six articles [12,13,19-21,31], and four studies evaluated psychological factors [12,15,20,24]. Hormonal levels were assessed in seven studies [13,14,24,25,27,28,30], while two studies examined cardiac function tests [21,31]. Blood pressure was monitored in seven articles [13,19,24-26,30,31], and the levels of Vitamins C and E were assessed by two studies [25,30].

DISCUSSION

This systematic review demonstrates the benefits of various yoga techniques for patients with T2DM. The review primarily included fasting blood glucose, postprandial blood glucose, hormone levels, lipid profile, blood pressure, cardiac function, vitamin C and E levels, anthropometric measurements, quality of life, and psychological factors. This review aids in predicting the benefits of various yoga techniques as an integrated approach, as well as the cumulative benefits of medication among patients with diabetes. The analysis of this study is closely supported by a systematic review and meta-analysis by Kumar V et al., published in 2016 [39].

The beneficial effects of yoga on diabetes may be attributed to improvements in the mental and psychological health of patients, which lead to reduced stress levels. Most importantly, the improvement in HbA1c levels through yoga, as mentioned in our systematic review, may be associated with reduced stress levels in patients with diabetes. Stress has been documented to worsen the risk and severity of diabetes by inducing Hypothalamic-Pituitary-Adrenal (HPA) axis and sympathetic and parasympathetic withdrawal [40]. This is accompanied by increased levels of cortisol, epinephrine, norepinephrine, growth hormone, glucagon, catecholamines, prolactin, leptin and neuropeptide Y [40].

Researchers have hypothesised that yoga addresses the root of the disease, rather than just the symptoms. Yoga has been found to be a precursor to improvements in blood sugar levels, stress management and overall quality of life [2,20,41]. These improvements are mediated by a variety of mechanisms postulated in previous studies, which support the findings of this systematic review. Studies have shown that the effects of yoga attenuate the HPA axis, which is accelerated by physical inactivity and psychological stress. Yoga also stimulates vagal tone and activates the parasympathetic nervous system [42].

Yoga has been shown to be effective in lowering HbA1c by improving the number of insulin receptors and increasing receptor binding in diabetes. Improvements in insulin dynamics were associated with adjustments in the insulin-glucose ratio, reductions in fasting insulin levels, and a leftward shift in peak insulin levels [43]. Additionally, Body Mass Index (BMI) adjustments reported in eight studies were strongly associated with weight loss and glycaemic control. Numerous studies have identified stress as a key characteristic of hunger, which is related to dense, glucose-rich foods and fats. Furthermore, emotional stress can increase overeating and lead to a lack of control over the pattern, quality and quantity of food intake [44,45].

Previous studies have shown that stress activates the HPA axis, ultimately leading to excess circulating cortisol, which may contribute to abdominal obesity [40,46]. Present review findings are supported by studies conducted in diverse populations that have documented a strong correlation between meditation and improved eating habits [47,48]. This may provide a basis for the observed changes in BMI.

Yoga has been shown to have beneficial effects on HbA1c, stress and blood glucose levels, in addition to improving quality of life for people with diabetes. The observed differences were significant, suggesting that yoga could be implemented as a supportive intervention for individuals with diabetes, with minimal or no negative impact on their overall health.

Limitation(s)

One limitation of this review is that only five studies included in this systematic review were of international origin, while the remaining studies were sourced from trials conducted in India. Additionally, most of the supplementary studies did not include a diabetic population, and the largest study examined the effects for a duration of only three months. Future studies with larger sample sizes and standardised yoga intervention protocols over the long term could provide more information on the superior effectiveness of yoga as an intervention for diabetes treatment.

CONCLUSION(S)

This review demonstrates that yoga significantly benefits the management of T2DM by improving blood glucose levels, HbA1c and stress reduction, which in turn enhances overall quality of life. Yoga's positive effects are linked to improved insulin sensitivity and reduced stress, addressing both the physiological and psychological aspects of diabetes. The findings suggest that incorporating yoga into diabetes care can be a valuable and low-risk complementary therapy.

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