Effectiveness of yoga for patients with diabetes mellitus

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Diabetes mellitus is a multifactorial metabolic disorder which requires lifestyle interventions for its management. A number of controlled yoga trials in last few years have observed lifestyle interventions especially yoga to be efficacious in the management of diabetes. The aim of this study is to systematically review the research conducted in the field to understand the effectiveness of yoga on diabetes mellitus. A systematic search was done using search engines such as PubMed, Google Scholar, Cochrane Library, MEDLINE, CAMbase, PsycINFO and IndMED. A total of 212 articles were selected, of which 166 were excluded and 46 controlled trials (CTs) were included in the review. Among the 46 CTs, 31 studies were categorized based on the primary outcome variables, 10 were based on the secondary outcome variables and 5 studies were control studies. Risk of bias assessment was conducted on all the studies. The review demonstrates significant improvement due to yoga practice in the primary outcome measures such as blood glucose levels along with secondary outcome measures such as cardiac autonomic variables, lipid profile, liver enzymes, respiratory variables, quality of life, anxiety and depression. Thus yoga has not only been found to be beneficial for improved glycaemic control, but also for the wide variety of symptoms associated with the diabetes. Despite this evidence, it is worth mentioning that further gold standard randomized controlled trials are warranted with more specific sets of practice, to prescribe yoga especially as an alternative treatment for the management of diabetes.

Keywords: Controlled trials, diabetes mellitus, primary and secondary outcome variables, yoga.

Introduction

DIABETES MELLITUS (DM) is a metabolic disorder of multiple aetiology characterized by chronic hyperglycaemia with disturbances of carbohydrate, fat and protein metabolism resulting from deficits in insulin secretion, insulin action, or both[1]. DM may present with characteristic symptoms such as polyphagia (excessive hunger), polydipsia (excessive thirst), polyuria (frequent micturition), blurring of vision and weight loss[1].

The incidence of DM is increasing worldwide; the prevalence of diabetes for all age-groups worldwide is estimated to be 2.8% in 2000 and 4.4% by 2030. The total number of people with diabetes is projected to rise from 171 million in 2000 to 366 million in 2030 (ref. 2). DM is increasingly common due to increase in the prevalence of non-genetic determinants of the disease such as sedentary lifestyle and obesity. It can be prevented by changes in lifestyle[3], diet modification and activity. There is enough scientific evidence of the effectiveness of complementary and alternative treatments in the management of chronic diseases like DM[4].

Yoga as one of the complementary and alternative treatment methods has been advocated for controlling the symptoms, pre-existing complications associated with DM[5–7] and in management of blood sugar levels. A meta-analysis study conducted by Kumar *et al.*[8] showed that most randomized controlled trials (RCTs) had a small sample size where the duration of intervention and follow-up was short. However, as more than three months duration of intervention and follow-up of up to 12 months is considered as a long-term indicator of good glycaemic status, in this review we have included all such controlled trials (CTs). Pandey *et al.*[9] have discussed the effectiveness of alternative therapies for the management of DM. In this review, we have focused only on yoga as an intervention in the management of diabetes. In another review by Yang[10], the focus was on effect of yoga on improved risk factors of chronic disease; however, the adherence rate to yoga in this study was low. To address this lacunae, here we have included studies that look at the effect of yoga and its long-term follow-up (12 months) on primary and secondary outcome variables on all types of diabetes (type 1 DM (T1DM), type 2 DM (T2DM) and gestational DM).

A critical review of the studies conducted on yoga for diabetes brings out the fact that they have either excluded meditation and or have focused on specific practices such

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as mindfulness for management of diabetes. Further, most studies have not focused on all types of diabetes, for example, most studies have been done on persons with T2DM. In this context, we felt the need for a systematic review of all studies conducted in the field of yoga for diabetes inclusive of those across all types of diabetes, and also look at studies that cover meditation/ mindfulness component which is traditionally considered a part of yoga. All studies thus reviewed here are CTs (inclusive of RCTs, self as control, quasi-experimental studies and comparative studies) which focus on understanding the effect of yoga on DM.

Methods

The PRISMA (preferred reporting items for systemic reviews and meta-analysis)[11] guidelines and Cochrane collaboration[12] recommendations provided the basis for this review study. A comprehensive search was done by two independent researchers (P.M. and V.K.) on major biomedical and specialist databases and websites. Reference list of relevant review articles was also checked. Databases such as Google Scholar, PubMed, Cochrane Library, MEDLINE, CAMbase, PsycINFO and IndMed were searched till 31 July 2016. The following terms were used for the search of relevant material in the above databases: yoga, diabetes mellitus, mindfulness, meditation, asana, pranayama, mudra, bandha, kriya, vaman, kunjal, sankhaprakshalan, yama, niyama, yogic practices, breathing practices, suryanamaskara and yoga-based practices. All clinical trials, controlled or uncontrolled, were identified and included in the review. It was mandatory for the studies selected to have patients with DM as sample, though any variant of the disease was also considered as a part of the review. It also included studies from any type/style/school of yoga, different components of yoga- and yoga-related practices. Studies with different yoga components such as asana, pranayama, meditation, yama, niyama, kriyas, suryanamaskara, pratyahara, mudras and bandhas were included. Research articles focusing on the role of yoga or yoga-related practices on blood sugar levels in healthy individuals were not considered. Trials with yoga or its components as part of multimodal intervention were also not included in this review. Further, only the published literature in English formed a part of the review due to inability of the authors to decipher other languages and lack of availability of experts in other languages.

Data were extracted using a data extraction form preplanned for the study. Data included details about selection criteria for subjects, type of participants, intervention, design of the study, outcome measures and results. Data extraction was done by two researchers (P.M. and V.K.) independently and any discrepancies were resolved with discussion. In situations of difficulty in establishing consensus, the opinion of a senior researcher (A.J.) was taken.

Assessment of risk of bias

Screening for risk of bias (ROB) was done by two researchers (P.M. and V.K.) independently with Cochrane ROB tool[12]. This tool rules out ROB at seven levels – random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and other sources of bias. Other sources of bias were assessed based on: (1) sampling procedure used in the study (random or non-random), and (2) baseline matching of data between groups. For all these criteria, ROB was assessed as low, unclear or high. Discrepancies between the above two researchers on assignment of level ROB for each study was sorted out with discussions between them in consultation with a senior researcher.

Results

Literature review

The literature search revealed 212 articles after sorting out for duplication. The number of studies reviewed further reduced to 46 after removal of 166 articles – review articles (38), adherence and acceptance-related articles (3), comments to published articles (3), conceptual articles (11), conference proceedings (1), healthy/mixed subjects/subjects at risk (14), irrelevant articles (19), irrelevant outcome measures (1), considered in earlier meta-analysis review published by the authors (18), multimodal intervention articles (11), non-interventional articles (9), Qigong and DM (1), qualitative articles (1), single group pre–post studies (19), unavailable full text (2). Forty-six CTs were included in this review, of which 31 focused on the primary outcome measures, 10 depicted secondary outcome measures and 5 studies were self as control. Figure 1 depicts the process of data extraction and flow of study.

Study characteristics

Table 1 elaborates the characteristics of the 41 CTs included in this study. The sample size of the participants in all the 41 studies put together ranged between 10 and 277. Age range of the participants in all the 41 CTs was 30–70 years, with only sampling participants between the age group of 18 and 70 years.

The intervention group underwent different therapies such as yoga nidra, mindfulness-based cognitive therapy (MBCT), simplified kundalini yoga along with kayakalpa yoga, laghusankhaprakshalana (yogic kriya) along with

dietary restrictions, laughter yoga, supervised yoga therapy sessions, hatha yoga, mindfulness-based intervention, sudarshanakriya yoga and pranayama comprehensive training, yoga-based lifestyle modification with home practices, pranava pranayama, comprehensive yoga breathing programme, mindfulness eating, mindfulness-based stress reduction (MBSR) and relaxation therapy in the form of raja yoga.

The control group in most studies underwent standard care with moderate physical activity, oral hypoglycaemic agents/conventional medicines, physical exercise, walking, ayurvedic treatment, dietary restrictions, education and lectures, lifestyle modification, brisk walking, sham relaxation and aerobic exercise. In some studies the control group was provided no intervention or was considered for intervention after a wait-listed period. The average duration of intervention in the studies ranged between 10 min (immediate effect) and 120 min (MBSR programme) with the frequency of classes being 1–6 per week for 1–12 weeks. One of the studies provided a 10 min diabetes and stress management education after the intervention.

The follow-up period in these studies was any where between 1 and 12 months. The assessments were mainly done at baseline, after the intervention and at regular follow-up intervals based on the duration of the study period. A 2 h booster session was provided in one of the studies with MBCT as intervention, 3 months after intervention.

In majority of the studies, the intervention provided to the experimental group was a mix of asana, pranayama, relaxation and meditation techniques with minor variations in the duration of practice.

The 41 CTs included in this review were divided into Indian (22) and non-Indian (19) studies. The outcome measures were again divided into primary (31 CTs) and secondary (10 CTs) where in blood sugar levels (fasting blood sugar (FBS), post prandial blood sugar (PPBS), glycosylated haemoglobin (HBA1C) were considered as primary outcome measures and cardiac autonomic variables, lipid profile, liver enzymes, respiratory variables, quality of life and other DM-related questionnaires, etc. were considered as the secondary outcome variables. In the primary outcome variables, 12 Indian studies and 12 non-Indian studies were listed. In secondary outcome variables six Indian and four non-Indian CTs were included.

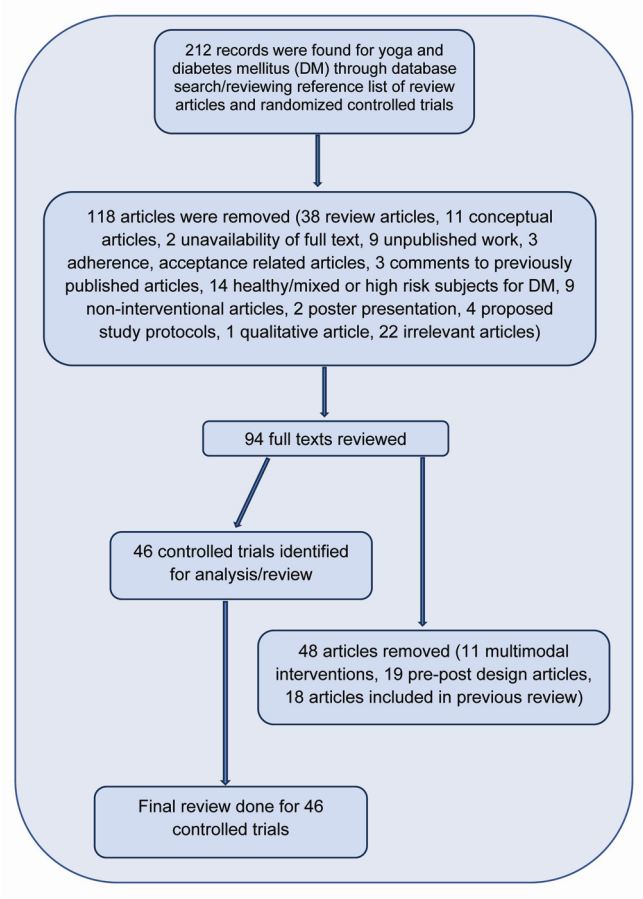

Figure 1. Schematic presentation of the review process.

Results

On an average the results showed significant improvement post yoga on primary outcome measures (FBS/PPBS/HBA1C/percentage of insulin-binding receptor, serum insulin) and positive effects on secondary outcome measures such as lipid profile, body mass index (BMI), weight, waist circumference (WC), anxiety, depression, diastolic blood pressure, health status, domains of World Health Organization Quality of Life (WHOQOL) brief and quality of life, cognitive measures such as memory, attention regulation, sympathetic functioning, nutrition and eating-related self-efficacy, respiratory rate, vital capacity, respiratory rate interval, heart rate and time domain parameters of Heart Rate Variability (HRV). Tables 1 and 2 enumerate the results of the studies.

Discussion

In this review of 46 CTs, evidence in favour of yoga as an effective add-on complementary treatment for patients with DM is fairly well established. Among the 31 studies which looked at the effectiveness of yoga on primary outcome variables, 19 studies showed significant improvement in some or either of the outcome variables[13–31]. Maximum duration of the intervention in any study was 12 months[17]. One study has focused on the immediate effects of laughter yoga practice[18]. In other studies[32–42] positive trends were observed which were not significant, however, significant worsening of HBA1C was observed

Table 1. Characteristics of the study with primary outcome variables

Reference	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
Abirami and Raj[13]	212 (104 + 108)	30–40 min/day for 12 weeks (24–36th week)	Standard care	FBS, PPBS; assessments: 24th, 28th, 32nd and 36th week	Significant improvement in FBS, PPBS in yoga group in comparison to control	Gestational diabetes mellitus (DM)
Amita *et al.*[14]	41 (20i + 21c)	Yoga nidra + OHA; 30 min yoga nidra/day for 90 days	Oral hypoglycaemic agents	FBS, PPBS, symptoms; assessments: 0, 30, 60 and 90 days	Significant improvement in FBS, PPBS and symptoms in intervention group in comparison to control group (Student's *t*-test)	DM on OHA
Arab-Sheibani *et al.*[59]	14i + 14c; 40–50 years	Eight group sessions of MBCT, one session per week, 1 h/ session; assessments at baseline, second and third months	No intervention for control group	HBA1C, problem areas in diabetes questionnaire (PAID), audit of diabetes-dependent quality of life (ADDQOL19)	Significant improvement between groups in PAID and ADDQOL19 at baseline and third month; significant improvement in HBA1C in both groups	Only women, random sampling; methodology not clear about the total sample of 80 patients and finally dividing into five groups; no clear explanation about other groups
Arjunan and Guide[15]	30; 40–60 years	12 weeks (6 days/week) of simplified kundalini yoga + kayakalpa yoga; clear details about standard care not mentioned for any of the groups	Clear details about standard care not mentioned for any of the groups	HBA1C	Authors claim improvement; detailed results missing in article	Sample selection, randomization details are missing
Beenarani and Sreekumaran[16]	143 (73i + 70c); 60–70 years	Yoga session 90 min/day, 6 days a week for 3 months	Advised to continue routine physical exercise, walking, etc.	Glucose, HBA1C, aspartate aminotransferase, alanine aminotransferase, glutamyltranspeptidase; assessments: 0 and 90 days	Significant improvement in glucose, HBA1C and liver enzymes (independent *t*-test)	Type-2 DM (T2DM), otherwise healthy, all non-vegetarians with similar food habits
Bhardwaj *et al.*[17]	30 (15 + 15); 40–70 years	Yoga (45 min twice daily) + laghu sankhaprakshalana twice monthly + dietary restrictions + walking 1–3 km daily	Ayurveda treatment + dietary restrictions + walking 1–3 km daily	FBS, PPBS, HBA1C, urine sugar; assessments: 0 and 1 year	Significant improvement in FBS, PPBS, HBA1C urine sugar in both groups; no significant differences between groups	Yoga and ayurveda comparative study; T2DM

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Table 1. (*Contd*)

Reference	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
Cokolic *et al.*[18]	211 (110i + 101c)	Brunch 250 kcal, 90 min lecture and then laughter yoga for 30 min (clapping, laughing, walking, stretching, breathing exercises)	Brunch 250 kcal, 90 min lecture + 30 min lecture	PPBS; assessments: pre and post	Significant inhibitory effect of laughter yoga on increase in PPBS	T2DM and not on insulin; immediate effect; RCT; procedure of randomization not elaborated
Dash and Thakur *et al.*[19]	60 (30i + 30c); 30i (20m + 10f); 30 (18m + 12f); 40–60 years	Yoga for 30 min/day for 40 days + diet + medicines	Diet + medicines	FBS, PPBS, HBA1C, lipid profile	Significant improvement in mean FBS, PPBS, HBA1C, TC, TG, HDL, LDL in yoga group in comparison to control	T2DM
Deshmukh and Bedekar[20]	30 (15i + 15c); 40–70 years	Yoga therapy 1 h session for 6 days a week for 4 weeks; total 24 supervized sessions	Oral medication	FBS, PPBS	Significant improvement in PPBS in experimental group; no significance achieved for FBS; no significance change in control group; no significant between groups for FBS/PPBS	Random allocation to groups with chit method
Giri and Artanayasa[33]	36 (18i + 18c); 40–50 years	Yoga 60 min/day for 2 days/week for 10 weeks	Walking 30 min; 2–3 days/week	BP, waist circumference, BMI, hospital anxiety scale (HADS), FBS, PPBS	No between group difference for FBS, PPBS; significant improvement in BMI, weight, anxiety score and waist circumference in comparison to walking control	T2DM
Gordon *et al.*[21]	231 (77y + 77pt+77c) (15m + 61f); 40–70 years	Hatha yoga, 6 months, 24 classes, one class per week, each class 2 h, and at home 3–4 days/week; training in diabetes education, and instruction, exercise, diet and medication	Treatment plan as recommended by physician and no active exercise of any type	FBS, serum insulin, percentage insulin-binding receptor, internalization of insulin receptor complex, TSH, T3, T4, cortisol; assessments: 0, 3 and 6 months	FBS significant improvement in interventional groups in comparison to control; percentage of insulin-binding receptor significantly improved at 6 months in comparison to baseline in interventional groups and in PT group, it is significant in comparison to control group as well; no significant changes in other parameters	Matched control

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Table 1. (*Contd*)

Reference	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
Hartmann *et al.*[34]	110 (53i + 57c)	Mindfulness-based intervention: 8 weeks programme, once weekly and booster session at 6 months	Treatment as usual	Albuminuria using 24 h urine for consecutively 3 days; patient health questionnaire (PHQ); short form health survey (SF-12)	No significant effect immediately after intervention; significant reduction in levels of depression and improved health status; significant reduction in diastolic blood pressure; no significance observed for HBA1C, albuminuria and systolic blood pressure	T2DM with microalbuminuria
Jyotsna *et al.*[35]	49 (27i + 22c)	Sudarshan kriya yoga and pranayama comprehensive training for 3 days and then home practice of 25–35 min/day; once weekly session at centre for ensuring home practice	Lifestyle modification, exercise and diet	FBS, PPBS, HBA1C, WHOQOL Bref	Significant improvement in physical, psychological and social domains of WHOQOL Bref; trend towards improvement for glycaemic control	Prospective randomized controlled trial
Karthikeyan[22]	60(20A + 20B + 20C); 35–45 years; Group A: hatha yoga; Group B: aerobic exercise; Group C: no intervention	12 weeks training	No training for control group	Blood glucose, oral glucose tolerance	Significant improvement in both intervention groups with aerobic training resulting in better results	
Kerr *et al.*[36]	37 patients (14 with type 1 DM), four dropped out in control group and did not contribute to data	32 hatha yoga sessions, 90 min each, biweekly for 16 weeks	Education and advise simple exercise	HBA1C, lipid profile, blood pressure, pulse rate QOL, daily insulin requirement	No improvement in glycaemic control, though insulin requirements stabilized in yoga group	Mixed type 1 (T1) and T2DM patients

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Table 1. (*Contd.*)

Reference	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
McDermott *et al.*[37]	41 (21i + 20c); drop out (1i + 2c); 21i (9m + 12f); 20c (7m + 13f)	Yoga 3–6 days/week for 8 weeks; 75 min per session with 10 min reserved for diabetes and stress management education	Monitored walking 3–6 days/week for 8 weeks; 75 min walking per day with breaks for rest in between	BMI, waist circumference, FBG, PPBG, insulin, insulin resistance, blood pressure and cholesterol	No between group differences in FBG, PPBG, insulin resistance, psychological well-being; significant improvement in weight, waist circumference and BMI in comparison to control; significant improvement in BP, cholesterol, anxiety, depression, negative affect, perceived stress in both groups	A pilot RCT; randomization with computer-generated random numbers and group allocation through opaque sealed envelopes; participants at risk of DM; FBG >5.6 mmol/l
Mondal and Kundu[23]	20 (10i + 10c); 50–70 years	12 weeks; 3 sessions/ week; 45 min/ session + conventional medicine	Conventional medicine	FBS, PPBS, lipid profile	Significant improvement for all dependent variable in intervention group; no significant changes observed in control group	Female subjects
Nagarathna *et al.*[60]	277 (141i + 136c); >28 years; 141i (91m + 50f); 136c (99m + 37f)	Yoga-based lifestyle modification (1 h/day, 5 days/week, for 12 weeks, advised for home practice, one weekly 2 h session till end of study)	Exercise-based life-style modification (1 h/day, 5 days/week, for 12 weeks, advised for home practice, one weekly 2 h session till end of study)	Medication score, blood glucose, HBA1C, lipid profile; assessment: 0 and 9 months	Significant improvement in FBG, oral hypoglycaemic medication. LDL. HDL in yoga group in comparison to control; within group significant improvement in all parameters in all groups	Prospective two-armed interventional randomized controlled study
Popli *et al.*[25]	80i + 50c; 80i (44m + 36f); 50c (25m + 25f); 30–60 years	1 h yoga session, 5 days a week for 1 month, home practice after one month; patients were followed up to 12 months	No intervention	FBS, PPBS, HBA1C: assessments: monthly for FBS, PPBS and HBA1C were tested three times monthly	Between group analyses not presented; significant improvement in the intervention group in FBS, PPBS, HBA1C at 6 months; no significant changes observed in control group	T2DM, baseline significant difference in FBS levels (higher for intervention group); OHA and/or insulin treatment was in exclusion criteria
Bharatha Priya and Gopinath[26]	45 (15 + 15 + 15); 35–40 years	Group 1: Yoga Group 2: Physical exercise 5 days/week for 8 weeks	Group 3: control	Blood sugar, HDL	Significant improvement in blood sugar and HDL in both interventional groups in comparison to control	Women

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Table 1. (*Contd*)

Reference	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
Rast *et al.*[27]	30 (15 + 15)	8 weeks of yoga therapy (3 sessions/week, 60 min/session	No exercise training	Blood glucose and lipid profile; assessments: baseline and after 8 weeks	Significant improvement in blood sugar levels, TC, TG, LDL, HDL; no significant changes in control group	Women; quasi-experimental studies
Rajani *et al.*[28]	20 (10i + 10c); 35–55 years	Yoga + OHA 6 months of practice of yoga	OHA	HBA1C, Addenbrooke's cognition examination – revised battery, cardiac autonomic functions tests; assessments: one time	Significantly better results for yoga practitioners for HBA1C and mean cognitive scores; No significant difference in cardiac autonomic functions	T2DM; a case-control study
Santhakumari *et al.*[43]	10 (5i + 5c); 35–55 years	Yoga + OHAs 6 months of yoga practice	OHA	HBA1C, proton magnetic resonance spectroscopy (H-MRS), PGI battery of brain dysfunction (PGIBBD); assessments: one time	Yoga intervention achieved comparative significance in memory; all other measures were insignificant and HBA1C worsened significantly	Type 2 DM; a case control study
Skoro-Kondza *et al.*[38]	59 (29i + 30c); (13m + 36f) people	12 weeks of twice weekly 90 min yoga class; both groups leaflet advice and encouraged for lifestyle change and exercise	Wait-list control; both groups leaflet advice and encouraged for lifestyle change and exercise	HBA1C, ADDQoL, UKPDS, weight, waist circumference, lipid profile, measure yourself medical outcome profile (MYMOP), self-efficacy	No difference in any outcome measures	Patients with T2DM and not on insulin; more emphasis on pranayama and relaxation, but also asanas
Singh *et al.*[29]	60 (30i + 30c); 35–60 years; 1–10 years of diabetes	Yoga + conventional medicine; 45 days of yoga, 5 group sessions on first 5 days and then once weekly group session; advised to practice at home; 45 min/session	Conventional medicine	FBS, PPBS, lipid profile and serum insulin; assessments: baseline and after 45 days	Significant improvement in FBS, PPBS, lipid profile and serum insulin in intervention group (ANOVA)	No details about randomization, sampling mentioned

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Table 1. (*Contd*)

Reference	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
Singh *et al.*[30]	112i + 110i + 115c; Drop out 16i + 18i + 25c; 96y (36m + 60f); 92m (51m + 41f); 90 (49m + 41f)	6 months, Two intervention groups with yoga and music + standard care; training for two weeks for yoga and music groups; Music groups: 10 types of Indian non-lyric classical music (3 min in morning and evening)	Standard care involving physical activity of moderate intensity (150 min/week)	HBA1C, FBS, PPBS, lipid profile, state and train anxiety (STAI), beck depression inventory (BDI), diabetes quality of life (D-QOL), weight, BMI, QOL; assessments: baseline and after 3 and 6 months	Significant improvement in glycaemic control, anxiety, depression, weight, BMI and QOL in yoga group; significant improvement I anxiety and depression in music group	An RCT; T2DM not on insulin; block randomization with 35 opaque sequentially numbered blocks with 10 chits in each block for random allocation
Thangapandiyan *et al.*[31]	20 (10i + 10c)	Yoga for 1 h/day for 15 days	Brisk walking for 1 h/day for 15 days	Blood glucose level; assessments: 0 and 15 days	Significant improvement in intervention group (paired *t*-test)	Male with T2DM
Tovote *et al.*[39]	94 (31i MBCT + 32i CBT + 31xc); 18 to 70 years	8 weekly individual sessions of 45–60 min each; daily homework for 30 min (MBCT – meditation, yoga exercises and mindfulness)	Wait-list control	Beck depression inventory-II (BDI-II); Toronto Hamilton depression rating scale (HAM-D7); generalized anxiety disorder 7 (GAD-7); well-being index (WHO-5); problem areas in diabetes (PAID); HBA1C; baseline and 3rd month	Significant improvement in depression, anxiety, well-being and diabetes-related stress in MBCT and CBT groups in comparison to control; no significant effect on HBA1C	T1D or T2DM; computer randomization stratified by sex and antidepressants
Tovote *et al.*[40]	91 (45 MBCT + 46 CBT)	8 weekly sessions of 60 min each for every intervention; assessments at baseline, after 2nd, 3rd and 9th months	8 weekly sessions of 60 min each for every intervention; assessments at baseline, after 2nd, 3rd and 9th months	Severity of depressive symptoms (BDI-II); WHO-5 well-being index; generalized anxiety disorder 7 questionnaire (GAD-7); problem areas in diabetes questionnaire (PAID); HBA1C	Significant improvement in depressive symptoms (time effect) for both groups, which was not sustained at 3rd and 9th months; significant improvement in well-being, anxiety and diabetes related stress (time effect) and sustained up to 9th month; HBA1C showed improvement, trend but not significant; time and group effect was insignificant	

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Table 1. (*Contd*)

Reference	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
van Son *et al.*[41]	139 (70 MBCT + 69c)	8 weekly 2 h sessions of MBCT; advice for home practice 30 min/day for 5 days/week; 2 h booster session added 3 months after end of intervention	Wait-list control (MBCT provided after 6 months)	Perceived stress scale (PSS); hospital anxiety and depression scale (HADS); profile of mood states (POMS); problem areas in diabetes (PAID); short form health survey (SF12); HBA1C; at baseline, 4 and 8 weeks	Significant improvement in stress, depressive symptoms, anxiety and quality of life in comparison to control group; no significance observed for diabetes-related stress and HBA1C	T1DM and T2DM, an RCT
van Son *et al.*[42]	139 (70i + 69c)	8 weekly 2 h group sessions; 3 months after end of intervention one booster session	Wait-list control	Perceived stress scale (PSS); hospital anxiety and depression scale (HADS); profile of mood states (POMS); problem areas in diabetes survey (PAID); short form health survey (SF-12); five facet mindfulness questionnaire (FFMQ); acceptance and action diabetes questionnaire (AADQ); Rosenberg self-esteem scale (RSES); HBA1C; assessments at pre and post intervention and then after 6 months post intervention	Significant effect on perceived stress, depressive symptoms, anxiety symptoms; no significant changes in HBA1C and diabetes stress	T1DM and T2DM

FBS (FBG), Fasting blood sugar (glucose); PPBS (PPBG) Post prandial blood sugar (Glucose); OHA, Oral hypoglycaemic agent; HBA1C, Glycosylated haemoglobin; RCT, Randomized controlled trial; TC, Total cholesterol; TG, Triglyceride; LDL, Low density lipoproteins; HDL, High density lipoproteins; T2DM, Type 2 diabetes mellitus; HADS, Hospital anxiety and depression scale; BP, Blood pressure; TSH, Thyroid stimulating hormone; T3, Triiodothyronine; T4, Thyroxine; QOL, Quality of life; CBT, Cognitive behaviour therapy; T1DM, Type 1 diabetes mellitus; W/H ratio, Waist hip ratio; FEV1, Forced expiratory volume in one second; FVC, Forced vital capacity; PEFR, Peak expiratory flow rate; MVV, Maximum voluntary ventilation; DBP, Diastolic blood pressure; SBP, Systolic blood pressure; HR, Heart rate.

Table 2. Characteristics of study with secondary outcome variables

Study	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
Bhavanani *et al.*[44]	29 (15i + 14c) (15m + 14f); 15i (8m + 7f); 14c (7m + 7f)	Pranava pranayama (10 min) with simple supine rest in first and last 2 min and pranava pranayama in rest 6 min + standard medical care	Sham relaxation (10 min) with instructions for relaxation of different body parts in the first and last 2 min + standard medical care	Heart rate, blood pressure; assessments: before and after 10 min of intervention	Systolic blood pressure, pulse pressure, mean pressure improved significantly in intervention group (interaction effect)	Patients with hypertension as well as diabetes; study focuses on immediate effects nada-anusandhana (AUM and OM chanting); patients were on regular yoga therapy for the last one month
Jayanti *et al.*[45]	60 females (20y + 20e + 20ye); 30–60 years; Age range: Group A (yoga) – 30–40 years; Group B (exercise) – 41–50 years; Group C (yoga and exercise) – 51–60 years	75 days intervention; yoga and exercises were done twice weekly	Comparative study	BMI	22.22% improvement in yoga and exercise group; 7.66% improvement in yoga group; no details mentioned about exercise only group	Three-arms study involving yoga and diet-based lifestyle modification programme; exercise and diet-based lifestyle modification program; and yoga, exercise and diet-based lifestyle modification programme; random sampling
Jyotsna *et al.*[46]	64 (36i + 28c);	Comprehensive yoga breathing programme + standard therapy; 12 h course spread over 3 days; advised to practice daily at home and once in a week at nearby centre	Standard therapy; included dietary advice, brisk walking for 45 min/day and OHA	Cardiac autonomic functions test; assessments: at baseline and 6 months	Significant improvement in sympathetic functions in intervention group (using ANOVA)	Prospective randomized controlled trial
Miller *et al.*[47]	27 + 25 +; 35–65 years	3 month mindful eating intervention	3 month smart choices intervention	Block 2005 food frequency questionnaire; diabetes-specific nutrition self-efficacy questionnaire; eating self-efficacy scale; three-factor eating questionnaire; beck anxiety inventory, five facets mindfulness questionnaire; Assessment: done at baseline (0), on 3rd month and on 6th month	Significant improvement in depressive symptoms, outcome expectations, nutrition and eating-related self-efficacy and cognitive control for both groups; significant improvement in mindfulness in mindful eating intervention group and nutrition knowledge and use of fruit and vegetables; no change in weight in either group	T2DM

(*Contd*)

Table 2. (*Contd*)

Study	Subjects	Intervention group	Control group	Outcome measures	Results (primary outcome measures)	Additional information
Rahmani *et al.*[48]	24 (12i + 12c); 20–55 years	MBSR and conscious yoga for 8 weekly sessions; each session 120 min	Wait-list control	Quality of life (SF-36); assessments – pre and post intervention and 2 months after intervention	Significant improvement in QOL (between group difference)	Quasi-experimental design; convenient sampling
Schroevers *et al.*[49]	24 (12i + 12c); 12i (7m + 5f); 12c (7m + 5f) 2 drop out in intervention group; 18–70 years	Individualized mindfulness-based cognitive therapy (I-MBCT) for 8 weeks (one 60 min session per week), with yoga component +; advise of home practice 30 min/day	Wait-list control	Center for Epidemiological Studies depression scale (CES-D); problem areas in diabetes questionnaire (PAID); five-factor Mindfulness questionnaire (FFMQ); the self-regulation scale	Between group; significant improvement in depression and diabetes-related stress, mindfulness and attention regulation	A pilot RCT, consecutive sampling; assessment 2–3 weeks prior to 8 weeks intervention and 2 weeks after intervention
Shantakumari *et al.*[50]	100 (50y + 50c); 50y (24m + 26f); 50c (27m + 23f);	OHA + yoga for 3 months, 2 weeks of supervised training followed by practice at home; no changes in treatment and dietary habits for either group	OHAs; no changes in treatment and dietary habits for either group	Weight, BMI, W/H ratio and lipid profile	Significant change in weight, W/H ratio, TC, TG and LDL	Pre-post significance observed in yoga groups; between groups comparison not shown
Teixeira *et al.*[61]	20 (10i + 10c) (5m + 15f); 50–92 years; one drop out from each group	4 weeks training and then advise of home practice (single one-time session)	Attention-placebo control group (single lecture on nutrition)	Neuropathic pain scale (NPS), NeuroQol; Pittsburgh sleep quality index (PSQI); assessments: baseline and at week 4	No significant difference observed	T2DM; 7 patients on insulin
Tiwari *et al.*[51]	83 (51i + 32c); 51i(28m + 21f); 32c(16m + 16f) (44m + 39f); 35–65 years	Pranayama 15 min/day for 3 months	Control	Respiratory rate, spirometry; assessments: 0, 1 and 3 months	Significant improvement in respiratory rate; slow vital capacity (SVC) in intervention group in comparison to control; no significant improvement in forceful vital capacity (FVC)	Confusing information about assessment timing; no information about medication
Verma *et al.*[52]	120 (60i + 60c); 30–70 years	Relaxation therapy in the form of rajayoga meditation + drug therapy	Drug therapy	Heart rate variability (HRV)	Significant increase in RR interval and decrease in HR in intervention group; time domain parameters of HRV showed significant increase and frequency domain parameter LF/HF ratio decreased significantly	T2DM with autonomic neuropathy; randomization with sealed envelopes

Table 3. Characteristics of self as control studies

Reference	Subjects	Intervention group	Control group	Outcome measures	Results	Additional information
Malhotra *et al.*[5]	40 (20i + 20c); 30–60 years	Yoga for 30–40 min/day for 40 days + medicine + diet	Medication + light physical exercise like walking	Basal blood glucose, nerve conduction velocity of median nerve (right and left); assessments: 0, 40 days	Paired *t*-test shows significant improvement in intervention group; nerve conduction deteriorated in control group	Contradictory information in article about control group
Malhotra *et al.*[62]	24; 30–60 years	Yoga training for 30–40 min/day for 40 days	Self as control	FBS, PPBS, HBA1C, pulmonary function tests	Significant improvement in FBS, FEV1, FVC, PEFR, MVV; improvement trend observed for rest of the parameters	NIDDM self as control
Malhotra *et al.*[63]	(56i + 50c); 30–60 years	Yoga asanas 30–40 min/day for 40 days + diet + medication	Medication + light physical exercise like walking	Blood glucose, serum insulin, lipid profile, BMI, monoaldehyde (MDA), cardiac function, p300, median nerve velocity	Significant improvement in waist to hip ratio, FBS, TC, TG, MDA, DBP, SBP, HR	Contradictory information about group division
Maras *et al.*[64]	8; 21–65 years	Meditation of their choice for 20 min/twice daily for one month with their own chosen mantra	Self as control	FBS, PPBS, HBA1C, 24 h urinary glucose, perception of well-being; assessments: 0, 1, 2 and 3 months	Significant improvement in perception of well-being; improvement not maintained in post-meditation phase	Self as control; insulin-dependent diabetes mellitus (T1DM); control, meditation and post-meditation phase in study
Singh *et al.*[65]	19; 30–60 years	Yoga + diet + medicine; yoga 30–40 min/day, 40 days	Self as control	FBS, PPBS, MDA, HBA1C,	Significant improvement in FBS, PPBS, MDA, HBA1C	Self as control

Table 4. Risk of bias for primary outcome variable studies in individual studies

Reference	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other sources of bias
Abirami *et al.*[13]	Unclear	Unclear	High	Low	Low	Low	High
Amita *et al.*[14]	Unclear	Unclear	High	Unclear	Low	Low	Unclear
Arab-Sheibani *et al.*[32]	Unclear	Unclear	High	Unclear	Low	Low	Unclear
Arjunan *et al.*[15]	Unclear	Unclear	High	Low	Unclear	High	Unclear
Beenarani *et al.*[16]	Unclear	High	High	Low	Low	Low	Unclear
Bhardwaj *et al.*[17]	Unclear	Unclear	High	Low	Unclear	Low	High
Cokolic *et al.*[18]	Unclear	Unclear	High	Unclear	Low	Low	Unclear
Dash *et al.*[19]	Unclear	Unclear	High	Low	Unclear	Low	Unclear
Deshmukh *et al.*[20]	High	Low	High	Low	Unclear	Low	Unclear
Giri *et al.*[33]	Low	Low	High	Low	Low	Low	Low
Gordon *et al.*[21]	High	Unclear	High	Low	Low	Low	Unclear
Hartmann *et al.*[34]	Unclear	Unclear	High	Unclear	Low	Low	Unclear
Jyotsna *et al.*[35]	Low	Unclear	High	Unclear	Unclear	Low	Low
Karthikeyan[22]	Unclear	Unclear	High	Low	Unclear	Low	Unclear
Kerr *et al.*[36]	Unclear	Low	High	Unclear	Unclear	Low	Unclear
McDermott *et al.* [37]	Low	Low	High	Unclear	Low	Low	Low
Mondal *et al.*[23]	Unclear	Unclear	High	Low	Unclear	Low	Unclear
Nagarathna *et al.*[60]	Low	Low	High	Low	Low	Low	Low
Popli *et al.*[25]	Unclear	Unclear	High	Low	Unclear	Low	High
Priya *et al.*[26]	Unclear	Unclear	High	Low	Unclear	Low	Unclear
Rast *et al.*[27]	Unclear	Unclear	High	Unclear	Unclear	Low	Unclear
Santhakumari *et al.*[28]	Unclear	Unclear	High	Low	Low	Low	Unclear
Santhakumari *et al.*[43]	Unclear	Unclear	High	Low	Low	Low	Unclear
Skoro-Kondza *et al.*[61]	Unclear	Low	High	Unclear	Unclear	Low	Unclear
Singh *et al.*[29]	Unclear	Unclear	High	Low	Unclear	Low	Unclear
Singh *et al.*[30]	Low	Low	High	Unclear	Low	Low	Unclear
Thangapandiyan *et al.*[31]	High	Unclear	High	Low	Low	Low	Unclear
Tovote *et al.*[39]	Low	Low	High	Unclear	Low	Low	Unclear
Tovote *et al.*[40]	Low	Low	High	Unclear	Low	Low	Unclear
van Son *et al.*[41]	Low	Low	High	Unclear	Low	Low	Low
van Son *et al.*[42]	Low	Low	High	Unclear	Low	Low	Low

positive trends were observed which were not significant, however, significant worsening of HBA1C was observed in one study[43]. The duration of intervention in these studies was between 8 weeks and 9 months. Among the ten studies that looked at the effects of yoga on secondary outcome variables, nine showed improvement over a period ranging between 8 weeks and 6 months in either some or all the outcome variables they assessed[44–52]. Though majority of the studies showed significant improvement in the primary and secondary outcome variables, the reasons for non-significant difference in outcomes in yoga group compared to control group could be attributed to the variance in sample size, duration and type of intervention, and possible variations in the quality of training provided and performance/adherence levels of the participants. It is interesting to note that except for one study which showed a worsening in an outcome variable[43], the remaining showed either improvement or no difference in them. A look at the type of intervention provided, quality of training and performance/adherence levels of participants in this one study could help understand the reasons for this negative result. Overall the results show that there are no ill-effects of practicing yoga for the management of diabetes; however, whether it provides an impetus or not, and the degree of impetus it provides to standard treatments can be concluded only after analysing the results of studies with similar standard methodology/intervention.

A related interesting observation is that majority of the studies showed improvement in the primary outcome variables with yoga interventions ranging immediate effect, 15 days to 12 months. In this context, if effectiveness of yoga intervention can be observed in 15 days of intensive supervised practice, the rationale for providing 12 months of supervised practice needs to be explained. Brief supervised interventions and advocating for continued home-based practice could be a more feasible option to improve yoga practice adherence in participants, especially in todays' fast-paced life.

It is interesting to note the wide variety of ways in which yoga interventions have been provided in the studies. Yoga practices which were included in different trials ranged from asanas, paranayama[29], meditative techniques[53], kriyas (cleansing practices)[17], chanting, relaxation and laughter yoga[18], independently as well as in combination. Role of yoga was observed not only for better

Table 5. Risk of bias for secondary outcome variable studies

Reference	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other sources of bias
Bhavanani *et al.*[44]	Unclear	Unclear	High	Unclear	Low	Low	Unclear
Jayanti *et al.*[45]	Unclear	Unclear	High	Unclear	Unclear	Low	Unclear
Jyotsna *et al.*[46]	Low	Low	High	Low	Unclear	Low	Unclear
Miller *et al.*[47]	Unclear	Low	High	Unclear	Low	Low	High
Rahmani *et al.*[48]	Unclear	Unclear	High	Unclear	Unclear	Low	High
Schroevers *et al.*[49]	Low	Unclear	High	Unclear	Low	Low	High
Shantakumari *et al.*[50]	Unclear	Unclear	High	Unclear	Low	Low	Unclear
Teixeira[61]	Unclear	Unclear	High	Unclear	Low	Low	High
Tiwari *et al.*[51]	Unclear	Unclear	High	Unclear	Unclear	Low	Unclear
Verma *et al.*[52]	Unclear	Low	High	Low	Low	Low	Unclear

glycaemic control, but also in various other areas like anthropometric measures, daily insulin requirement, blood pressure, anxiety symptoms[54], depression symptoms[54], specific problem areas for diabetics, quality of life, lipid profile[27], cardiac autonomic functions[46], pulmonary functions[51], cognitive decline[55], liver functions[16], nerve conduction[5] and oxidative stress[56]. This improvement was not specific to the set practices proposed in the interventions. Improvement in symptoms of anxiety, depression[57], quality of life[58] and health status was observed with interventions based on asanas, pranayama as well as with meditational intervention. Underlying similarity in the interventions may be the reason for this improvement. The similar component in all the practices is stability of the posture, specific pattern of breathing and awareness. Further, the extent to which these practices were correctly taught and implemented by the participants could have also played a role in the degree of effectiveness of yoga as pronounced in the outcome variables.

Reported evidence is unable to conclude at what stage of the disorder yoga can provide the best results. For now, different studies have shown that it seems to be appropriate at all stages of the disorder, especially due to the absence of any reported side-effects or complications. To posit yoga as a better intervention than exercise for management of diabetes at any stage, the aspect of meditative awareness along with regular update of dose and frequency of yoga practice needs to tailored to the patient's requirements.

Some studies have reported the benefits of yoga as a stand-alone intervention for the management of diabetes and reported improvement in glycaemic control[17]. Though there is limited evidence to support this statement, trials adopting this design need to be cognisant of the ethical issues involved in withholding standard medical treatment, unless voluntarily chosen by the participant.

The studies in this review have depicted the effect of yoga interventions across all the three types of DM. As limited studies are available for patients with T1DM and gestational DM, with the available evidence it may be difficult to have specific guidelines for yoga interventions for each type of DM. This may, however, be necessary especially in participants with gestational DM as the practices need to be tailored based on the trimester of pregnancy. However, for T1DM and T2DM, a common protocol of yoga practices could be attempted due to the similarity in intervention targets and outcomes assessed. Further, clinical understanding of a patient's health issues and requirements can help provide need-based individualized yoga interventions.

There have been limitations in research in measuring the effectiveness of certain yoga interventions such as meditation and mindfulness. Most of the outcome measures that are used in studies have used diabetes-related primary and secondary outcome variables as a measure to understand the effectiveness of yoga. Outcome measures to assess yoga training, yoga performance, level of meditation and mindfulness achieved, etc. could further add to the understanding of the degree of effectiveness of the yoga intervention provided. As currently there are no objective outcome measures available to assess these aspects, this could be an area of future research in the field of yoga, to help determine the correlation between the level of practice and benefits expected.

The available evidence establishes that yoga targets the human being as a whole and expected benefits are pronounced in all domains. Yoga is, thus, holistic in its approach to treatment as against the medical model, which is reductionist in its approach. In this context, it may be more appropriate to mention that yoga interventions are to be adopted as a whole instead of focusing on specific components. Thus, inclusions of kriyas (yogic cleansing practices) and chanting could make the yoga intervention look more complete and holistic; however, most of the studies in this review have (for reasons not mentioned), not included these practices as part of their intervention, in spite of no conclusive evidence against these specific practices being contraindicative for diabetes. As following a reductionist model of treatment is against the very philosophy of yoga, we emphasize that further research on comparisons between the effects of holistic yoga interventions and specific yoga interventions for

diabetes need to be conducted. Inclusion of many components of yoga as a single intervention may seem inappropriate from the point of view of a reductionist approach of treatment, where effort is made to identify the single possible independent variable which can be altered to obtain the desired results (as in the medical model). This, however, in most situations places the participant in an artificial situation, the results of which may be difficult to achieve in view of various confounders present in the practical settings. A holistic yoga intervention on the other hand, works on the personality and hence could have the ability to alter unknown confounders in its favour.

The possibility of the yoga fraternity to showcase any categorical results on its effectiveness of diabetes would depend on the steps they take to tackle the concern of poor quality of methodology and/or reporting of the trials conducted. Apart from ROB, salami publication may also be an important factor which needs to be addressed. Quality of trials and their reporting could be improved by stipulating compulsory trial registrations and following the CONSORT guidelines for reporting study results.

Conclusion

Yoga as a complementary intervention is effective in improving glycaemic control and a wide variety of symptoms associated with diabetes. Further gold standard RCTs are warranted, especially if the yoga fraternity wants to propagate it as an alternative treatment/adjuvant therapy to pharmacology intervention for the management of DM.

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