VIA MEDICA
REVIEW ARTICLE
ISSN 2450–7458
e-ISSN 2450–8187

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Effect of Yoga on Insulin Resistance in Type 2 Diabetes: A Systematic Review and Meta-Analysis

ABSTRACT

Objective: We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) to observe the efficacy of yoga on insulin resistance in type 2 diabetes (T2D).

Materials and methods: The present systematic review and meta-analysis were done following the PRISMA guidelines. Data were collected through specific keyword searches from eminent databases. The risk of bias in included studies was assessed, using the revised Cochrane risk-of-bias tool. Meta-analysis was performed using RevMan software. Forest plots were used to illustrate the study findings and meta-analysis results.

Results: A total of six studies were finally included in this systematic review, where 375 participants were allocated to a yoga intervention with the control group, and the age range of participants was 15–75 years. In the yoga group compared to the control, there was a significant reduction in fasting blood glucose (FBG) by 33.02 mg/dL, post-prandial blood glucose (PPBG) by 62.54 mg/dL, fasting insulin by 4.95 μIU/mL and insulin resistance (HOMA-IR) by 2.81 in the meta-analysis.

Conclusions: Regular yogic practice with oral hypoglycemic agents (OHA) have positive effects on insulin resistance compared to the control group (no regular exercise with OHA) in patients with type 2 diabetes. (Clin Diabetol 2023; 12; 3: 201–208)

Keywords: meta-analysis, yoga, type 2 diabetes, insulin resistance

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Clinical Diabetology 2023, 12; 3: 201–208
DOI: 10.5603/DK.a2023.0022
Received: 9.03.2023 Accepted: 13.04.2023
Early publication date: 28.06.2023

Introduction

Yoga originated in ancient India more than 5000 years ago and is a means of balancing and harmonizing the body, mind, and emotions. The yogic practice embraces moral observances (Yama), self-disciplines (Niyama), physical postures (asana), voluntarily controlled breathing (Pranayama), sensory withdrawal (Pratyahara), concentration (Dharana), meditation (Dhyana), self-realization (Samadhi), and certain philosophical principles [1]. Yoga, as part of Vedic philosophy, emphasizes the unity of mind, body, and soul in the human body [2].

Yoga practice is useful in controlling numerous lifestyle diseases, including type 2 diabetes (T2D). Psycho-neuro-endocrine and immune mechanisms are convoluted in the beneficial effects of yoga on diabetes. Regular yogic practice with proper guidance is beneficial for controlling numerous lifestyle diseases, including type 2 diabetes. The various postures during yoga practice help to improve the sensitivity of ß-cells to glucose, thereby refining insulin secretion, and surging the blood supply to the muscle, thereby promoting glucose uptake [3].

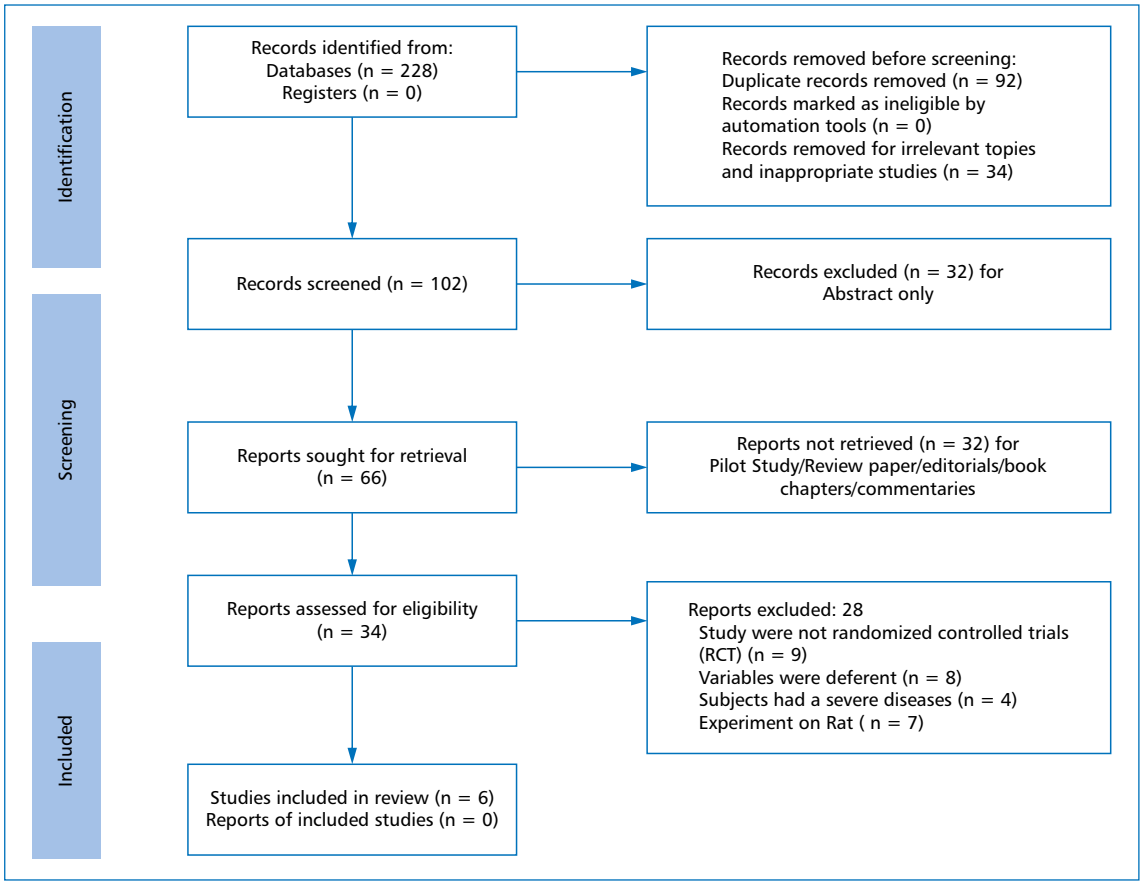

Figure 1. Flow Diagram of the Present Study Prepared as per PRISMA Guidelines

There are several systematic reviews and meta-analyses examining the benefits of yoga for diabetes management, but there is no study directly conducted to observe the effect of yoga on insulin resistance in type 2 diabetes. Hence, the present study aims to systematically evaluate the literature and conduct meta-analyses of randomized controlled trials (RCTs) to evaluate the effectiveness of yoga on insulin resistance in type 2 diabetes.

Materials and Methods

This systematic review and meta-analysis was conducted in accordance with PRISMA guidelines [4].

Search strategies

The data were gathered by searching the online databases Scopus, Web of Science, PubMed, Science Direct, MDPI, BioMed Central, and Medline to find appropriate articles using the keywords "type 2 diabetes", "T2D", "yoga", "yoga and type 2 diabetes", "insulin resistance", "yoga and insulin resistance". Proper articles, restricted to human subjects and written in English were included in this study. After obtaining related articles from the above databases, duplicates and some unsatisfactory studies were screened and excluded through the process of identification, screening, and inclusion as followed by the PRISMA guidelines. After the final assessment, appropriate studies were included in this systematic review and meta-analysis. Figure 1 illustrates the complete selection process.

Eligibility criteria

Inclusion criteria

The existing studies followed the PICOS criteria [5], including:

1. (P) Participants: type 2 diabetes mellitus patients;
2. (I) Intervention: Yogic exercise;
3. (C) Control: without any regular exercise;
4. (O) Outcomes: fasting blood glucose (FBG), post-prandial blood glucose (PPBG), glycated hemoglobin (HbAlc), fasting insulin level and homeostatic model assessment for insulin resistance (HOMA-IR);
5. (S) Study design: randomized controlled trials (RCT).

Exclusion criteria

1. Participants: adolescents with T2D (under 15 years of age) and geriatric age groups (above 75 years of age); those who had any severe diseases; those who were pregnant; and those who were participating in another regular physical exercise program at the same time;
2. Non-randomized controlled trials (NRCT) were excluded;
3. Pilot studies, review studies, duplicate studies, only abstracts, conference proceedings, editorials, book chapters and commentaries were excluded.

Data extraction

Data were withdrawn from the included articles [6–11] by the first reviewer (BD) using a structured form on MS Excel and it was cross-checked for precision by the second reviewer (SC). The data were extracted from every study based on six categories: (a) Study Details (first author and publication year), (b) Participants (sample size along with male/female and age), (c) Details of Intervention: (type of yoga: frequency, duration, time and intensity) (d) Details of the Control Group (no exercise with or without standardised care (medication), (e) Outcomes (FBG, PPBG, HbA1c, fasting insulin and HOMA-IR) and (f) Study Design (randomized controlled trials) that is summarized in Table 1, some differences in the extracted data were determined by discussion, with a contribution of the second, third and fourth reviewer (SC, SSD and MD) when necessary.

Risk of bias assessment

The risk of bias in the involved articles was assessed by the revised Cochrane risk-of-bias tool for randomized controlled trials (RoB-2) [12]. Using this tool, the risk of bias in this study was evaluated through the 5 domain. 1) Risk of bias arising from the randomization procedure; 2) Risk of bias due to deviances from the suggested interventions (effect of assignment to intervention and adhering to intervention); 3) Risk of bias caused by missing outcomes; 4) Risk of bias in quantity of the outcomes and 5) Risk of bias in the collection of the stated result. The risk of bias is classified as "Low risk", "Some concerns" and "High risk".

Statistical analysis

Numerical results were accumulated from the included studies for the statistical meta-analysis using RevMan statistical software (version 5.4.1). The effect size was measured by taking the difference in mean and standard deviation of FBG, PPBG, fasting insulin and HOMA-IR in the subjects of pre- and post-intervention in both the experimental group and the control group. If the study failed to report this data, the effect size of the mean difference and SD difference was calculated by the following formula [13, 14] *Mean difference* = = Baseline Mean – Final Mean

$$SD\ difference = \sqrt{SD^2\ baseline + SD^2\ final - (2 \times r \times \times\ baseline\ SD \times final\ SD)}$$

where r equals 0.7. Gowri et al. [6] reported only the median and interquartile range (upper and lower value) in their study so in that case from median (m), first quartile (q1), and third quartile (q3) sample mean ($\bar{x}$) and SD were calculated using this formula [15] $\bar{x} = \frac{q_1 + m + q_3}{3}$ and $SD = \frac{q_3 - q_1}{1.35}$. Mean difference and 95% confidence intervals were used as the summary statistic for the overall effect sizes. The I^2 statistic was used to test for heterogeneity of the effect size among studies included in the meta-analysis. Forest plots were used to express the outcomes of the study and meta-analysis results (Fig. 2). FBG and PPBG were stated as mg/dL, and for studies which stated these parameters as mmol/L, a numerical conversion to mg/dL was done. Fasting insulin was specified as μIU/mL, and for studies specified this parameter as pmol/L or ug/dL, a numerical conversion to μIU/mL was done. Funnel plots were used to illustrate the publication bias in the meta-analysis of the efficacy of yoga and the control group (no exercise) on FBG, PPBG, HbA1c, fasting insulin and HOMA-IR (Fig.3). In order to measure insulin resistance, HOMA-IR formula was employed. This formula is HOMA-IR = fasting insulin (μIU/mL) × fasting glucose (mmol/L)/22.5 [8, 16].

Results

Literature search

Literature search was shown according to the searching criterion that is illustrated in Figure 1. There were a total of 228 articles identified through keyword searches from across the seven databases. Every single article was individually screened by title resulting in 92 duplicate records removed and 34 records removed for irrelevant topics and inappropriate studies before screening. After screening the 102 studies 36 studies were excluded for Abstract only. Following this, 32 studies were excluded because they fell into one of the following categories: pilot study, review article, conference proceedings, editorial, book chapter, and commentary. The remaining 28 studies were not eligible for our meta-analysis because they were non-randomized controlled trials, and due to different variables, severe diseases of subjects and experiments conducted on rats.

Study characteristics

After the removal of duplicates, screening of studies and excluding some studies, six studies (randomized

Table 1. Characteristics of Included Studies of Yoga Intervention and Control Group

Sl. No.	Authors and year	Participants (recruited, sex and age)	Intervention (type, intensity and duration)	Comparison condition	Outcomes	Study design
	Gowri et al., 2022	Yoga: M/F 14/21 54 ± 13 years Control: M/F 23/12 52.5 ± 11.2 years	Yoga 60 min/day, 2 days/week for 16 weeks	Control group with standard medication	BMI, FBG, PPBG, HbA1c, insulin, HOMA-IR	RCT
2	Danasegaran et al., 2021	Yoga: M/F 40/0 51.95 ± 6.17 years Control: M/F 40/0 51.48 ± 8.47 years	Yoga 40 min/day, 5 days/week for 12 weeks with medication	Control group with standard medication	BMI, SBP, DBP, FPG, Insulin, HOMA-IR, lipids.	RCT
3	Pahlevaninejad,, 2019	Yoga: M/F 0/8 47.37 ± 3.62 years Control: M/F 0/8 44.62 ± 3.24 years	Yoga 75 min/day, 3 days/week for 8 weeks	Control group	BMI, WHR, FBG, insulin, HOMA-IR, creatinine	RCT
4	Keerthi et al. 2017	Yoga: M/F 31/29 37.28 ± 6.21 years Control: M/F 32/27 36.72 ± 6.12 years	Yoga 38–45 min/day, 3 days/week for 12 weeks	Control group	WHR, FPG, insulin, HOMA-IR,	RCT
5	Chen et al. 2016	Yoga: M/F 0/15 18–25 years Control: M/F 0/15 18–25 years	Yoga 60 min/day, 2 days/week for 8 weeks	Control group	Insulin, FPG, HOMA-IR, lipids, SBP, DBP, BMI	RCT
6	Singh et al. 2008	Yoga: M/F 30/0 35–60 years Control: M/F 30/0 35-60 years	Yoga 45 min/day, 7 days/week for 6 weeks	Control group with standard medication	BMI, FBG, PPBG, lipids, insulin	RCT

BMI — body mass index; DBP — diastolic blood pressure; FBG — fasting blood glucose; FPG — fasting plasma glucose; HbA1c — glycated hemoglobin; HOMA-IR — Homeostatic Model Assessment for Insulin Resistance; IR — insulin resistance; PPBG — postprandial blood glucose; RCT — randomized controlled trial; SBP — systolic blood pressure; WHR — waist–hip ratio

controlled trials) were finally included in this systematic review as yoga intervention group with control group that is summarized in Table 1. In total, 375 participants (male — 240 and female — 135) were assigned to yoga with control group and the age range of subjects was 15–75 years.

In this study, yoga intervention involved loosening exercises, breathing exercises, asanas, pranayama, kriya and relaxation techniques also included meditation, prayer and Savasana. Maximum articles used yoga interventions like Tadasana, Trikonasana, Ardha-Matsyendrasana, Pawanmuktasana, Paschimottanasana, Savasana; Anulom-Vilom pranayama, Bhamri pranayama; Kapalbhati kriya; OM mantra. The majority of the studies used 40–60 minutes per day; 2–3 days per week and 8–12 weeks yoga intervention.

Risk of bias analysis

According to the criteria of the revised Cochrane risk-of-bias tool for randomized controlled trials that is illustrated in Table 2, five studies showed 'low risk of biases, because these five studies were considered to be at low risk of bias for all domains for these outcomes. One study showed 'some concerns' as this study was judged to raise some concerns in a minimum of one domain for this result, but not to be at high risk of bias in any domain.

Fasting blood glucose

The effect of fasting blood glucose was considered in six studies (6 interventions, n = 375) [6–11] involved in the meta-analysis. Forest plots for FBG in Figure 2A show that there was a significant decrease in FBG in the yoga group compared to the control group. The collective mean difference for FBG of the yoga group and the control groups from random effects analysis was 33.02 mg/dL (95% CI: –54.91, –11.13) and the statistical heterogeneity as stated by I^2 = 97% was statistically significant ($p < 0.00001$).

Post-prandial blood glucose

There were two studies (2 interventions, n = 130) [6, 11] where the effect of yoga on post-prandial blood glucose (PPBG) was considered. Forest plots for PPBG in Figure 2B showed a significant reduction in PPBG in the yoga group compared to the control group. The pooled mean-difference of PPBG between the yoga group and the control groups of the random effects analysis was 62.54 mg/dL (95% CI: –86.67, –38.42 and the statistical heterogeneity was indicated by I^2 = 37%, p = 0.21).

Fasting insulin

Fasting insulin level was assessed in six studies (6 interventions, n = 375) [6–11]. Forest plots for fasting

Table 2. Risk of Bias Assessment of the Included Studies

Sl. No	Author and year	Domain 1 (Randomization process)	Domain 2 (Assignment to intervention)	Domain 2 (Adhering to intervention)	Domain 3 (Missing outcome data)	Domain 4 (Measurement of the outcome)	Domain 5 (Reported result)	Overall risk of bias
1	Gowri et al., 2022	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
2	Danasegaran et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
3	Pahlevaninejad, 2019	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
4	Keerthi et al., 2017	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
5	Chen et al., 2016	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
6	Singh et al., 2008	Low risk	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns

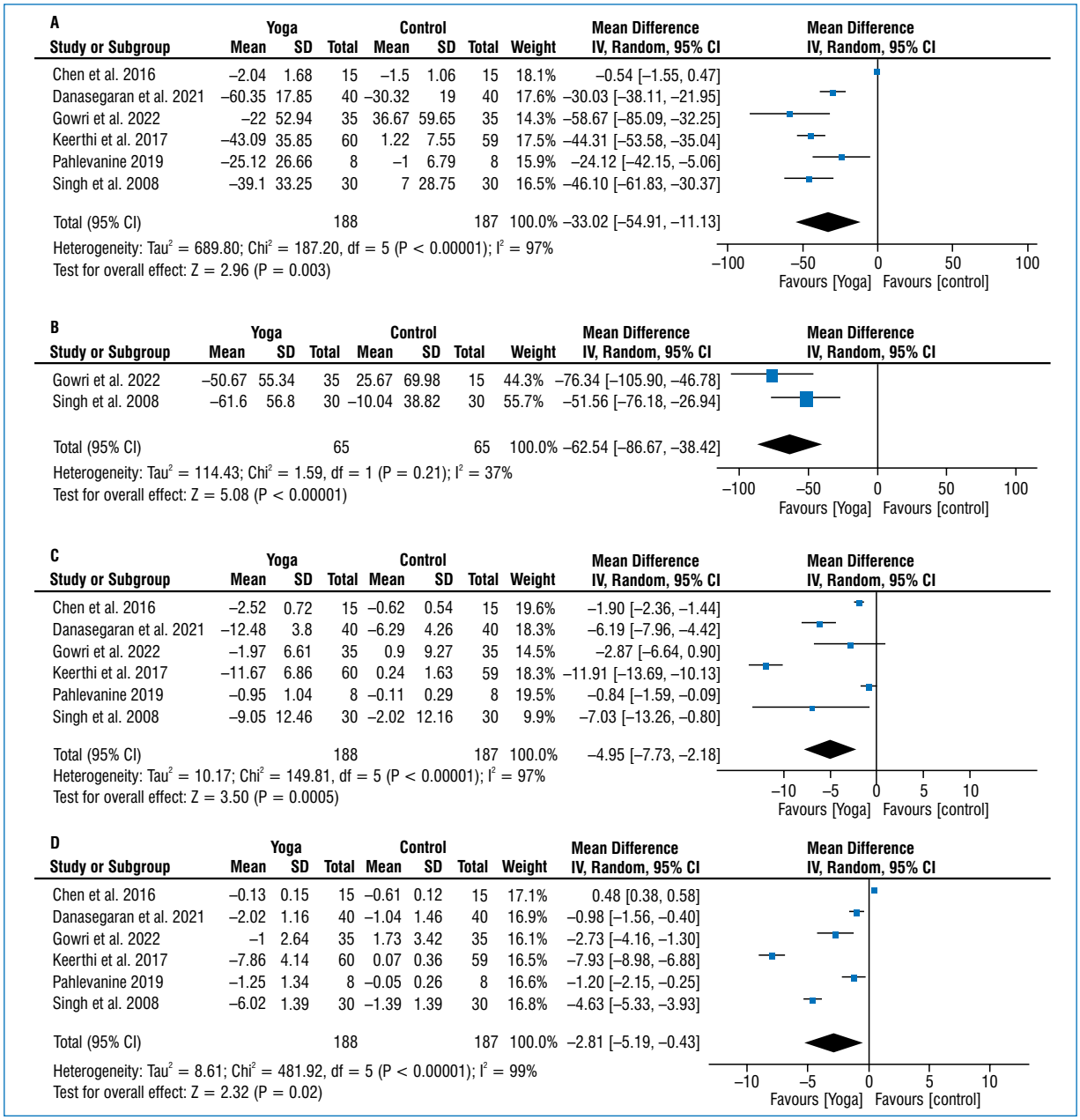

Figure 2. Forest Plots Presenting the Effect of Yoga Compared to Control Group on (**A.**) Fasting Blood Glucose (**B.**) Postprandial Blood Glucose, (**C.**) Fasting Insulin and (**D.**) Insulin Resistance
CI — confidence interval; df — degrees of freedom, I — indicates the level of heterogeneity, SD — standard deviation

insulin in Figure 2C showed the pooled mean difference in fasting insulin level between the yoga group and the control group of the random effects analysis was 4.95 μIU/mL (95% CI: –7.73, –2.18 and the statistical heterogeneity was indicated by $I^2 = 97\%$, $p < 0.00001$).

Homeostatic Model Assessment for Insulin Resistance (HOMA-IR)

HOMA-IR was assessed in six studies included in the meta-analysis (6 interventions, n = 375) [6–11]. Forest plots for HOMA-IR in Figure 2D showed the pooled mean-difference in HOMA-IR between the yoga group and the control groups of the random effects analysis was 2.81 (95% CI: –5.19, -3.93) and the statistical heterogeneity of the data as indicated by $I^2 = 99\%$ was significant ($p < 0.00001$).

Discussion

Yoga and insulin resistance in patients with type 2 diabetes were investigated in this meta-analysis. Six studies with 375 adults (male — 240 and female — 135) comparing the yoga intervention to a control

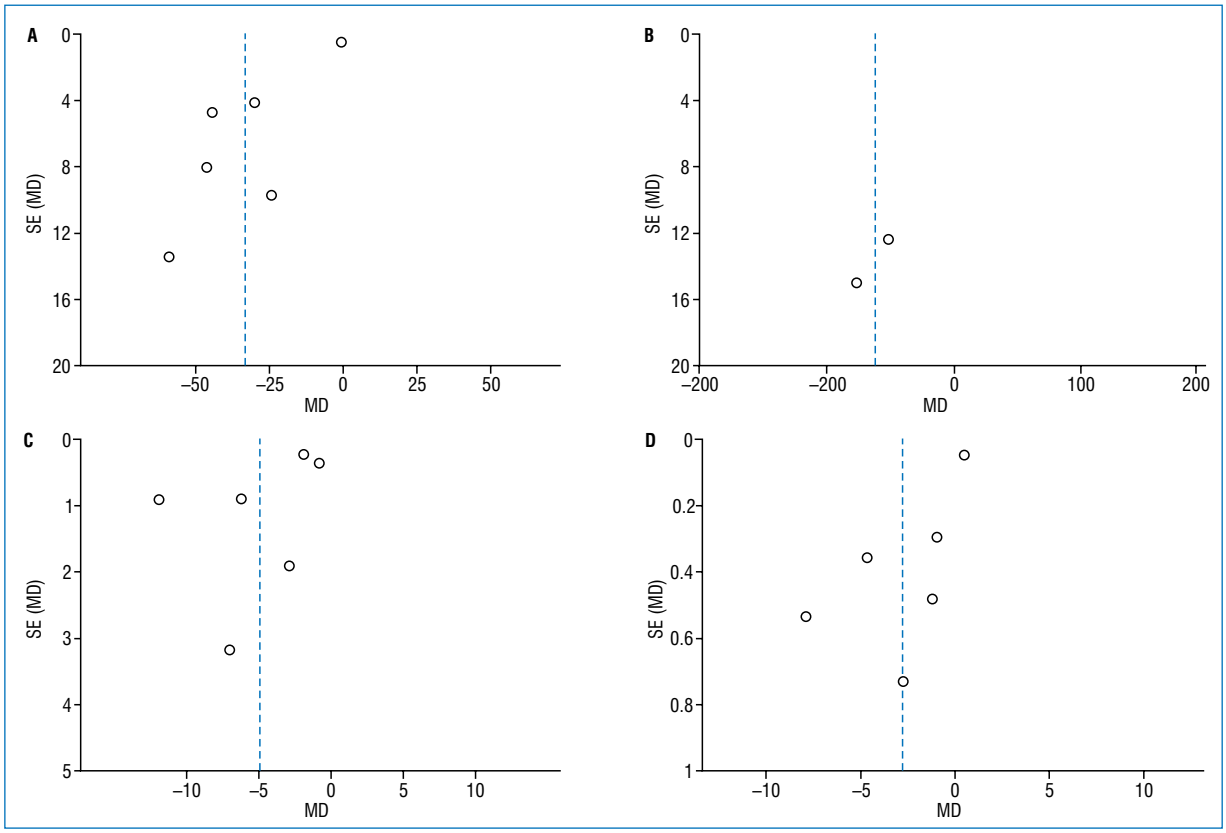

Figure 3. Funnel plots of estimate of publication bias in meta-analysis of the efficacy of Yoga compared to Control group (no exercise) on (**A.**) Fasing Blood Glucose, (**B.**) Postprandial Blood Glucose, (**C.**) Fasting Insulin and (**D.**) Insulin Resistance

group were evaluated. Yoga interventions improved FBG, PPBG, fasting insulin and HOMA-IR compared to the control group. Our results showed a significant reduction in FBG (33.02 mg/dL), PPBG (62.54 mg/dL), fasting insulin (4.95 μIU/mL) and HOMA-IR (2.81) in the yoga intervention compared to the control group (no exercise) in the meta-analysis. Only one study by Gowri et al. [6] evaluated the HbA1c and there was a significant fall in HbA1c level in the yoga group compared to the control group.

Keerthi et al. [9] showed that 12 weeks of yoga given along with standard treatment improved quality of life and reduced diabetes risk scores in patients with diabetes. Gowri et al. [6] showed that the management of combined yoga therapy for individuals with diabetes leads to a significant improvement in glycemic control, insulin resistance, and key biochemical parameters. Yoga helps improve glucose tolerance and insulin sensitivity, anthropometric characteristics, lipid profiles, and blood pressure in diabetes [17]. Some studies showed a reduction in FBG, PPBG, and HbA1c in the control group when comparing the pre- and post-intervention data, which was due to taking of OHA and was not statistically significant [18]. Diabetes is a psychosomatic disease that involves both mind and body, so psycho-neuro-endocrine and immune mechanisms are involved in the beneficial effects of yoga on diabetes [19].

According to the results of this study, the following yoga poses may be recommended: asanas such as Tadasana, Trikonasana, Ardha-Matsyendrasana, Pawanmuktasana, Paschimottanasana, Savasana; Kapalbhati kriya; Anulom-Vilom pranayama and OM mantra meditation for 45–60 minutes per day, five days per week, were more beneficial for type 2 diabetes patients by improving insulin resistance. Asanas, pranayama, kriya, and meditation should be the focus of future studies, with an emphasis on the effects of different intensities of yoga interventions.

Conclusions

In conclusion, this systematic review and meta-analysis delivers a strong indication to conclude whether yoga with oral hypoglycemic agent (OHA) has positive effects on insulin resistance and glycemic control compared to the control group (no regular exercise) with taking OHA in patients with T2D.

Funding

None.

Conflict of interest

None declared.

Acknowledgments

Not applicable.

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