REVIEW ARTICLE

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Effect of Yoga and Walking on Glycemic Control for the Management of Type 2 Diabetes: A Systematic Review and Meta-analysis

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Abstract

Background. A daily habit of yogic practice or walking, along with an oral hypoglycemic agent (OHA) could be beneficial for better control of type 2 diabetes mellitus (T2DM). We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) to find out the efficiency of yoga or walking on glycemic control in T2DM.

Methodology. The present systematic review and meta-analysis were completed according to the PRISMA guidelines. The risk of bias in included studies was evaluated, by using the revised Cochrane risk-of-bias tool for randomized trials. Meta-analysis was implemented using RevMan software. Forest plots were used to illustrate the study findings and meta-analysis results.

Results. Sixteen studies were included in this systematic review, where 1820 participants were allocated to one of the following interventions: yoga, walking, and without any regular exercise (control group). Participants were between 17–75 years of age. Compared to the control group, the yoga group had a significant reduction in fasting blood glucose (FBG) by 31.98 mg/dL (95% CI = –47.93 to –16.03), postprandial blood glucose (PPBG) by 25.59 mg/dL (95% CI = –44.00 to –7.18], glycosylated hemoglobin (HbAlc) by 0.73% (95% CI = –1.24 to -0.22), fasting insulin by 7.19 µIU/mL (95% CI = –12.10 to –2.28), and homeostatic model assessment for insulin resistance (HOMA-IR) by 3.87 (95% CI = –8.40 to -0.66). Compared to the control group, the walking group had a significant reduction in FBG by 12.37 mg/dL (95% CI = –20.06 to –4.68) and HbA1c by 0.35% (95% CI = –0.70 to –0.01). Compared to the walking group, the yoga group had a significant reduction in FBG by 12.07 mg/dL (95% CI = –24.34 to – 0.20), HbA1c by 0.20% (95% CI = –0.37 to –0.04), fasting insulin by 10.06 µIU/mL (95% CI = –23.84 to 3.71) and HOMA-IR by 5.97 (95% CI = –16.92 to 4.99).

Conclusions. Yoga or walking with OHA has positive effects on glycemic control. For the management of T2DM, yoga has relatively more significant effects on glycemic control than walking.

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Key words: yoga, walking, type 2 diabetes, glycemic control, insulin resistance

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a common metabolic disorder characterized by chronic hyperglycemia.[1] It is affected by a combination of two primary factors: defective insulin secretion of pancreatic β-cells and the inability of insulin-sensitive tissues to respond appropriately to insulin.[2] Poor glycemic control among T2DM patients is a major community health problem and is a significant risk factor for the advancement of diabetic complications. Glycemic control is the key healing objective for the prevention of organ damage and other health-related problems from diabetes. A rapid change in people's lifestyle in terms of physical inactivity collectively increases metabolic complications and gives rise to the problems related to T2DM.[3]

Yoga is an ancient pre-Vedic science and a way of life. Yoga originated in ancient India over 5000 years ago. It mainly aims to develop the psychophysiological health of an individual. The practice of yoga embraces moral observances *(Yama)*, self-disciplines *(Niyama)*, physical postures *(Asana)*, voluntarily controlled breathing *(Pranayama)*, Sensory withdrawal *(Pratyahara)*, Concentration *(Dharana)*, Meditation *(Dhyana)*, and self-realization *(Samadhi)* and certain philosophical principles.[4] Regular yogic practice

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with proper scientific dose is beneficial for controlling numerous lifestyle diseases, including type 2 diabetes.[5] Walking is a natural and primitive exercise pattern that an individual follows from childhood. It is the fundamental base of locomotion and good exercise for the whole body.[6]

A daily habit of yogic practice reduces mental and oxidative stress and is beneficial to attain glycemic control.[5,7] A growing body of evidence reports that regular physical activity like walking or yoga has a beneficial effect on metabolic activity by helping to promote better glycemic control.[7,8] Scientific research on walking suggests that walking is one of the safest cardiovascular activities that improves glycemic control and insulin sensitivity.[6,8]

Walking and yoga have an impact on glycemic control and insulin resistance for type 2 diabetes patients. The aim of this systematic review and meta-analysis was to pool all experimental results of randomized control trials (RCTs) to update and consolidate the evidence on the effect of yoga and walking on glycemic control in patients with T2DM.

METHODOLOGY

The present systematic review and meta-analysis was completed following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[9]

Search strategies

Data were collected by searching the online databases PubMed, Scopus, Web of Science, BioMed Central, ClinicalTrials.gov, and International Clinical Trials Registry Platform (ICTRP) to find out appropriate RCTs. The following keywords were used: 'type 2 diabetes,' 'T2DM,' 'yoga,' 'walking,' 'yoga and Type 2 diabetes,' and 'walking and Type 2 diabetes,' which is illustrated in Table 1. Appropriate trials were limited to human subjects and only trials published with the full text in the last 10 years (2012 to 2022) and written in English were included in this study. The related studies acquired from the above databases were assembled and duplicates were removed; some inappropriate studies were further screened and excluded by reading the title, abstract, and selected manuscripts. After the final assessment, eligible articles were included in the systematic review and meta-analysis. The total selection process is illustrated in Figure 1.

Eligibility criteria

Inclusion criteria

The existing studies followed the PICOS criteria,[10] including:

1. (P) Participants: patients with type 2 diabetes mellitus with standard medication (OHA).
2. (I) Intervention: walking and yoga.
3. (C) Control: without any regular exercise.
4. (O) Outcomes: fasting blood glucose (FBG), postprandial blood glucose (PPBG) and glycosylated 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 T2DM (under 17 years of age) and geriatric age groups (above 75 years of age); those with severe diseases or any severe illness; pregnancy; those who were participating in another physical exercise program at the same time.
2. Study design: articles that were not RCTs were not included in the study;
3. Review studies, duplicate studies, only abstracts, conference proceedings, editorials, book chapters, and commentaries were excluded.
4. Studies published before the year 2012 were excluded.

Risk of bias assessment

The risk of bias in included studies was evaluated by using the revised Cochrane risk-of-bias tool for randomized controlled trials (RoB-2)[11] which is illustrated in Table 5. According to this tool, the risk of bias in the study was assessed through five Domains. 1. Risk of bias arising from the randomization procedure; 2. Risk of bias due to deviances from the intended interventions (effect of assignment to intervention and adhering to intervention); 3. Risk of bias due to missing results data; 4. Risk of bias in the measurement of the outcome; and 5. Risk of bias in the selection of the reported outcome. The risk of bias is classified as "Low risk," "Some concerns," and "High risk".

Statistical analysis

Quantitative outcomes were collected from the included studies[3,6,12-25] for the statistical meta-analysis was performed by using RevMan statistical software (version 5.4.1). In order to pool the measures of treatment effect, a random effects model based on the inverse variance method was

Table 1. Articles identified according to search sequence and database used for the systematic review

Bibliographic databases↓	Search strategies			
	Yoga vs control on T2DM	Walking vs control on T2DM	Yoga vs walking on T2DM	Other exercises on T2DM
PubMed = 154	64	52	16	22
Scopus = 113	40	38	17	18
Web of Science = 99	28	29	18	24
BioMed Central = 79	28	29	13	9
ClinicalTrials.gov (United States National Library of Medicine) = 27	12	8	4	3
International Clinical Trials Registry Platform (ICTRP) = 26	6	8	0	12

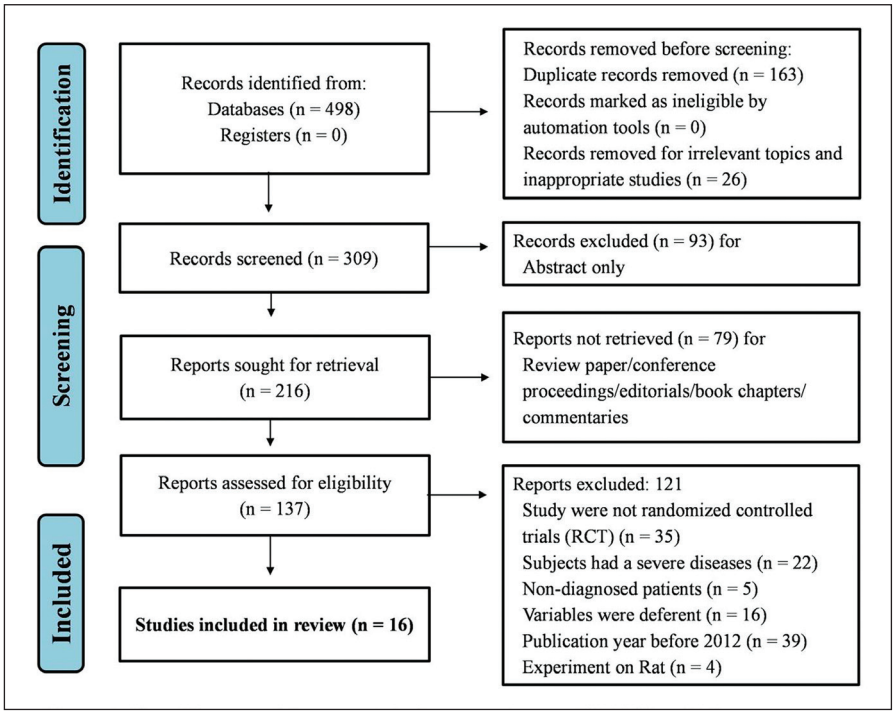

Figure 1. Flow diagram of the present study prepared as per PRISMA guidelines.

used. The effect size was calculated by taking the difference from mean and standard deviation (SD) of FBG, PPBG, HbA1c levels, fasting insulin, and HOMA-IR in the subjects before and after the 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:[26,27]

$$\text{Mean difference} = \text{BaselineMean} - \text{FinalMean},$$

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

where r=0.7. Gowri et al., 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 was calculated by using this formula $x = \frac{q_1 + m + q_3}{3}$ and $SD = \frac{q_3 - q_1}{1.35}$.[28]

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 effect size among studies included in the meta-analysis. Forest plots were used to illustrate the study findings and meta-analysis results. FBG and PPBG are stated as mg/dL. HbA1c is stated as a percentage (%). Fasting insulin is stated as μIU/mL.

RESULTS

Study characteristics

After the removal of duplicates, screening of studies, and excluding some studies, 16 RCTs were finally included in this systematic review. Nine studies were included as a comparison of the yoga intervention group with the control group. They are summarized in Table 2. Seven studies were included as a comparison of the walking intervention group with the control group. They are summarized in Table 3. Six studies were included as a comparison of the yoga intervention group with the walking group. They are summarized in Table 4. Three studies were included as a comparison of yoga and walking with the control group.[6,12,13] These three studies were analyzed in three sub-groups (yoga vs control, walking vs control, and yoga vs walking). A total of 1820 participants (1054 males, 766 females) were included, and the age range of participants was 17–75 years.

In this review study, included articles used yoga interventions like Trikonasana, Paschimottanasana, Ardha-Matsyendrasana, Dhanurasana, Pawanmuktasana, Vakrasana, Bhujangasana, Anulom-vilom and Bhamri Pranayama, and relaxation techniques such as meditation, prayer, and Savasana. In the majority of the included studies, yoga interventions involved 30-60 minutes per day and five days per week (5 d/w) for twelve weeks (12 w). Subjects of every included study joined the yoga practice in the morning; these practices were facilitated by a yoga expert from the day of recruitment. Included studies had selected similar kinds of OHA: metformin and glimepiride.

This review study included articles that used walking interventions for 30-60 minutes, three days per week (3 d/w) for 8-12 weeks with moderate intensity (brisk walking) on a plane ground surface.

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 5, eleven studies showed 'low risk of bias' because

these eleven studies were judged to be at low risk of bias for all domains. Four studies showed 'some concerns' as these studies were judged to raise some concerns in at least one domain for this effect, but not to be at high risk of bias for any domain. Two studies failed to maintain the criteria of RoB-2 for low risk of bias due to deviances from the intended interventions (intervention assignment).[12,14] One study failed to maintain the criteria of low risk of bias due to deviations from the intended interventions (adhering to intervention),[15] and one study failed to maintain the criteria of low risk of bias due to missing result data.[6] One study showed a 'high risk of bias'; this study was judged to be at high risk of bias in at least one domain for this outcome or the study is judged to have some concerns for multiple domains in a way that substantially lowers confidence in the result. This study was judged to be at 'high risk of bias' due to deviances from the intended interventions (intervention assignment), measurement of the outcome, and selection of the reported result.[24]

Effect of yoga on glycemic control

Glycemic control was determined by measuring FBG, PPBG, and HbA1c along with fasting insulin level and HOMA-IR. The effect on FBG was studied in nine studies (9 interventions, n = 1199)[3,6,12,13,16,17] included in the meta-analysis. Forest plots for FBG in Figure 2(I) show that there was a significant reduction in FBG in the yoga group in comparison to the control group. The pooled mean difference for FBG between the yoga group and control groups from random effects analysis was 31.98 mg/dL (95% CI = –47.93 to–16.03), and the statistical heterogeneity of the data as indicated by I^2 = 96% was statistically significant (p <0.00001). There were five studies (5 interventions, n = 899)[3,16-19] in which the effect of yoga on PPBG was studied. The pooled mean difference for PPBG between the yoga group and control groups from random effects analysis was 25.59 mg/dL (95% CI = –44.00 to –7.18; I^2 = 87%, p <0.00001) in Figure 2(II). HbA1c was assessed in four of the studies[3,16-18] included in the meta-analysis (4 interventions, n = 795). The pooled mean difference from

Table 2. Characteristics of included studies on yoga intervention and control group

Sl. No.	Authors and year	Participants (Recruited, age and sex)	Intervention (Type, intensity and duration)	Comparison condition	Outcomes	Study design
1	Gowri et al., 2022	Yoga – M/F 14/21, Age 54 ± 13 Control – M/F 23/12, Age 52.5 ± 11.2	Yoga 60 min/day, 2 days/week for 16 weeks	Control group with standard medication	FBG, PPBG, HbA1c, BMI, HOMA-IR, Lipids	RCT
2	Kaur et al., 2021	Yoga – M/F 19/72, Age 47.77 ± 9.59 Control – M/F 30/63, Age 49.24 ± 10.53	Yoga 60 min/day, 5 days/week for 12 weeks	Control group with standard medication	FBG, PPBG, HbA1c, BMI, WC, Lipids	RCT
3	Danasegaran et al., 2021	Yoga – M/F 40/0, Age 51.95 ± 6.17 Control – M/F 40/0, Age 51.48 ± 8.47	Yoga 40 min/day, 5 days/week for 12 weeks with medication	Control group with standard medication	FPG, BP, Insulin, BMI, Lipids	RCT
4	Viswanathan et al., 2021	Yoga – M/F 93/57, Age 50.8 ± 8.3 Control – M/F 103/47, Age 52.8 ± 7.0	Yoga 50 min/day, 5 days/week for 12 weeks	Control group with standard medication	FPG, PPPG, HbA1c, Lipids	RCT
5	Yuniartika et al., 2021	Yoga – M/F 7/11, Age 51.66 Control – M/F 8/10, Age 51.11	Yoga 60 min/day, 3 days/week for 12 weeks	Control group with standard medication	FBG, Lipids	RCT
6	Saberipour et al., 2020	Yoga – M/F 32/0, Age 48.25 ± 7.14 Control – M/F 33/0, Age 51.66 ± 11.06	Yoga 60 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, Lipids, BP, BMI	RCT
7	Sharma et al., 2020	Yoga – M/F 32/20, Age 50.8 ± 8.3 Control – M/F 25/27, Age 52.8 ± 7.0	Yoga 40 min/day, 5 days/week for 24 weeks	Control group with standard medication	FBG, PPBG, HbA1c, Lipids, WHR	RCT
8	Keerthi et al., 2017	Yoga – M/F 31/29, Age 37.28 ± 6.21 Control – M/F 32/27, Age 36.72 ± 6.12	Yoga 38-45 min/day, 3 days/week for 12 weeks	Control group with standard medication	FPG, Fasting Insulin, HOMA-IR, QoL, IDRS	RCT
9	Kumpatla et al., 2015	Yoga – M/F 87/44, Age 41.0 ± 8.7 Control – M/F 71/39, Age 44.2 ± 7.4	Yoga 30 min/day, 7 days/week for 12 Weeks	Control group with standard medication	FPG, PPPG, HbA1c, BP, Lipids, BMI	RCT

FPG – Fasting Plasma Glucose; PPBG – Post-prandial Blood Glucose; HbA1c – Glycosylated hemoglobin; BMI – Body Mass Index; HOMA-IR – Homeostatic Model Assessment for Insulin Resistance; BMI – Body Mass Index; WC – Waist Circumference; PPPG – Post-prandial Plasma Glucose; FBG – Fasting Blood Glucose; RCT – Randomized Controlled Trial; WHR – Waist Hip Ratio, QoL – Quality of Life

Table 3. Characteristics of included studies of walking intervention and control group

Sl. No.	Authors and year	Participants (Recruited, age and sex)	Intervention (Type, intensity and duration)	Comparison condition	Outcomes	Study design
1	Leischik 2021	Waking – M/F 17/0, Age 60.4 ± 5.9 Control – M/F 16/0, Age 59.1 ± 8.5	Walking 40 min/day, 3 days/week for 12 weeks	Control group with standard medication	FPG, HbA1c, Lipids	RCT
2	Yuniartika et al., 2021	Walking – M/F 5/13, Age 61.33 Control – M/F 8/10, Age 51.11	Walking 30 min/day, 3 days/week for 12 weeks	Control group with standard medication	FBG, Lipids	RCT
3	Saberipour et al., 2020	Walking – M/F 33/0, Age 49.83 ± 9.58 Control – M/F 33/0, Age 51.66 ± 11.06	Walking 60 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, Lipids, BP, BMI	RCT
4	Rafii et al., 2018	Waking – M/F 15/18, Age 53.18 ± 4.99 Control – M/F 14/20, Age 51.85 ± 7.83	Walking 30 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, BMI	RCT
5	Akbarina et al., 2018	Waking – M/F 0/12, Age 61.92 ± 3.63 Control – M/F 0/12, Age 61.92 ± 3.63	Walking 45-60 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, BMI, HbA1c, Lipids	RCT
6	Keerthi et al., 2017	Walking – M/F 30/28, Age 37.28 ± 6.21 Control – M/F 32/27, Age 36.72 ± 6.12	Walking 45 min/day, 3 days/week for 12 weeks	Control group with standard medication	FPG, Fasting Insulin, HOMA-IR, QoL, IDRS	RCT
7	Karstoft et al., 2013	Waking – M/F 4/8, Age 60.8 ± 2.2 Control – M/F 3/5, Age 57 ± 3.0	Walking 60 min/day, 5 days/week for 16 weeks	Control group with standard medication	FBG, Fasting Insulin, HbA1c, BP, Lipids.	RCT

FPG – Fasting Plasma Glucose; FBG – Fasting Blood Glucose; BP – Blood Pressure; BMI – Body Mass Index; HbA1c – Glycosylated hemoglobin; HOMA-IR – Homeostatic Model Assessment for Insulin Resistance; IDRS – Indian Diabetes Risk Score; RCT – Randomized Controlled Trial

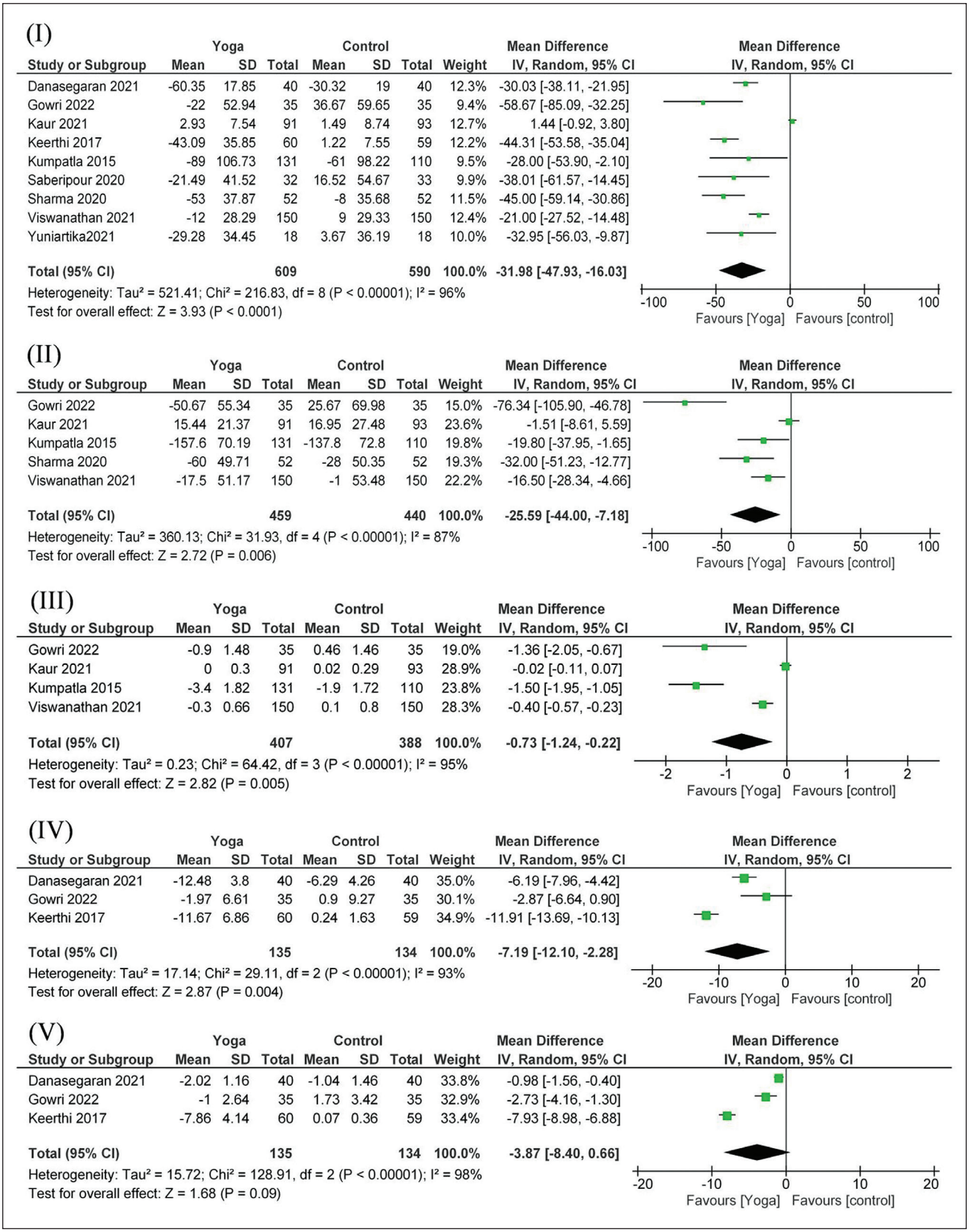

Figure 2. Forest plots presenting the effect of Yoga compared to Control group on **(I)** Fasting Blood Glucose, **(II)** Postprandial Blood Glucose, **(III)** Glycosylated Hemoglobin, **(IV)** Fasting Insulin and **(V)** Insulin Resistance.

Table 4. Characteristics of included studies on yoga intervention and walking intervention

Sl. No.	Authors and year	Participants (Recruited, age and sex)	Yoga (Type, intensity and duration)	Walking (Type, intensity and duration)	Outcomes	Study design
1	Yuniartika et al., 2021	Yoga – M/F 7/11, Age 51.66 Walking – M/F 5/13, Age 61.33	Yoga 60 min/day, 3 days/week for 12 weeks	Walking 30 min/day, 3 days/week for 12 weeks	FBG, Lipids	RCT
2	Gupta et al., 2020	Yoga – M/F 21/19, Age 51.1 ± 8.6 Walking – M/F 24/17, Age 50.2 ± 8.6	Yoga 45 min/day, 5 days/week for 16 weeks	Walking 30 min/day, 5 days/week for 16 weeks	FPG, SBP, DBP, HbA1c, Lipids, BMI, WC	RCT
3	Saberipour et al., 2020	Yoga – M/F 32/0, Age 48.25 ± 7.14 Walking – M/F 33/0, Age 49.83 ± 9.58	Yoga 60 min/day, 3 days/week for 8 weeks	Walking 60 min/day, 3 days/week for 8 weeks	FBG, SBP, DBP, Lipids, BMI	RCT
4	Singh et al., 2020	Yoga – M/F 41/60, Age 50.3 ± 9.1 Walking – M/F 49/50, Age 49.4 ± 8.7	Yoga 38-115 min/day, 5 days/week for 12 weeks	Walking 30 min/day, 5 days/week for 12 weeks	HbA1c, SSAI, STAI, BDI, ESE	RCT
5	Keerthi et al., 2017	Yoga – M/F 31/29, Age 37.28 ± 6.21 Walking – M/F 30/28, Age 37.28 ± 6.21	Yoga 38-45 min/day, 3 days/week for 12 weeks	Walking 45 min/day, 3 days/week for 12 weeks	FPG, Fasting Insulin, HOMA-IR, QoL, IDRS	RCT
6	McDermott et al., 2014	Yoga – M/F 9/12, Age 47.0 ± 9.7 Control – M/F 7/13, Age 47.2 ± 9.1	Yoga 75 min/day, 3-6 days/week for 8 weeks	Walking 30 min/day, 3-6 days/week for 8 weeks	FBG, PPBG, HbA1c, HOMA-IR, BP, Lipids	RCT

FBG – Fasting Blood Glucose; FPG – Fasting Plasma Glucose; SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure; HbA1c – Glycosylated hemoglobin; BMI – Body Mass Index; WC – Waist Circumference; SSAI – Spielberger's State Anxiety Inventory; STAI – Spielberger's Trait Anxiety Inventory; BDI – Beck Depression Inventory; ESE – Exercise Self-Efficacy; HOMA-IR – Homeostatic Model Assessment for Insulin Resistance; BP – Blood Pressure

Table 5. Risk of bias assessment of the included studies

Sl. No	Authors 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 (selection of the 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	Kaur et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
3	Danasegaran et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
4	Viswanathan et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
5	Sharma et al., 2020	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
6	Kumpatla et al., 2015	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
7	Leischik 2021	Low risk	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns
8	Rafii et al., 2018	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
9	Akbarina et al., 2018	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
10	Karstoft et al., 2013	Low risk	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
11	Yuniartikaet et al., 2021	Low risk	Low risk	Low risk	Some concerns	Low risk	Low risk	Some concerns
12	Gupta et al., 2020	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
13	Saberipour et al., 2020	Low risk	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
14	Singh et al., 2020	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
15	Keerthi et al., 2017	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
16	McDermott et al., 2014	Low risk	High risk	Low risk	Some concerns	High risk	High risk	High risk

random effects analysis was 0.73% (95% CI = –1.24 to -0.22; I^2 = 95%, p <0.00001) in Figure 2(III). There were three studies (3 interventions, n = 269)[3,13,20] for fasting insulin between the yoga group and control groups. The pooled mean difference from random effects analysis was 7.19 μIU/mL (95% CI = –12.10 to –2.28; I^2 = 93%, p <0.00001) in Figure 2(IV). HOMA-IR was assessed in 3 of the studies included in the meta-analysis (3 interventions, n = 269).[3,13,20] The pooled mean difference for HOMA-IR between the yoga group and control groups from random effects analysis was 3.87 (95% CI = –8.40 to -0.66) in Figure 2(V), and the statistical heterogeneity of the data as indicated by I^2 = 98% was significant (p <0.00001).

Effect of walking on glycemic control

Glycemic control was determined in the same way by measuring FBG, PPBG, and HbA1c along with fasting insulin and HOMA-IR. The effect on FBG was studied in 7 studies (7 interventions, n = 363)[6,12-15,21,22] included in the meta-analysis. There was a statistically significant reduction in FBG in the walking group in comparison to the control group. Forest plots for FBG Figure 3(I) show that there was a significant reduction in FBG in the walking group. The pooled mean difference for FBG between the walking group and control groups from random effects analysis was 12.37 mg/dL (95% CI = –20.06 to –4.68), and the statistical heterogeneity of the data as indicated by I^2 = 52% was statistically significant (p = 0.05). There were three studies (3 interventions, n = 77)[14,15,22] in which the effect of walking on HbA1c was studied. The pooled mean difference for HbA1c from random effects analysis was 0.35% (95% CI = –0.70 to –0.01; I^2 = 69%, p = 0.04) Figure 3(II). The change of HbA1c by 0.35% and FBG of 12.37 mg/dL in the walking group in comparison to the control group is statistically significant but may not be clinically significant.

Comparative effect of yoga and walking on glycemic control

The effect on FBG was studied in five studies (5 interventions, n = 335)[6,12,13,23,24] included in the meta-analysis. There was a statistically significant reduction in FBG in the yoga group in comparison to the walking group.

Forest plots for FBG in Figure 4(I) showed that there was a significant reduction in FBG in the yoga group. The pooled mean difference from random effects analysis was 12.07 mg/dL (95% CI = –24.34 to – 0.20; p = 0.03, I^2 = 62%). There were two studies (2 interventions, n = 278)[23,25] in which the effect of yoga and walking on HbA1c was studied. The pooled mean difference for HbA1c between the yoga group and walking group from random effects analysis was 0.20% (95% CI = –0.37 to –0.04; I^2 = 0%, p <0.90) in Figure 4(II). The effect on fasting insulin was studied in two studies (n = 156)[13,24] included in the meta-analysis. The pooled mean difference for fasting insulin between the yoga group and walking group from random effects analysis was 10.06 μIU/mL (95% CI = –23.84 to 3.71; I^2 = 98%, p <0.00001) in Figure 4(III). There were two studies (2 interventions, n = 159)[13,24] in which the effect of yoga and walking on HOMA-IR was studied. The pooled mean difference for HOMA-IR between the yoga group and walking group from random effects analysis was 5.97 (95% CI = –16.92 to 4.99; I^2 = 99%, p <0.00001) in Figure 4 (IV).

DISCUSSION

This meta-analysis observed either the effects of yoga or walking on glycemic control among patients with T2DM. Nine studies with 1197 adults (719 males, 478 females) comparing the yoga intervention to a control group were evaluated. Yoga interventions improved glycemic control by reducing HbA1c, FBG, PPBG, fasting insulin, and HOMA-IR compared to the control group. Seven studies with 365 adults (211 males, 154 females) comparing the walking intervention to a control group were evaluated. Walking interventions improved glycemic control by reducing HbA1c and FBG compared to the control group. Six studies with 541 adults (289 males, 252 females) comparing the yoga intervention to a walking intervention were evaluated. Yoga interventions improved glycemic control by reducing HbA1c, FBG, fasting insulin, and HOMA-IR compared to the walking intervention. Three studies were included comparing yoga and walking with control groups; these were analyzed in three sub-groups (yoga vs control, walking vs control, and yoga vs walking).[6,12,13]

Our results demonstrate a significant reduction in FBG (31.98 mg/dL), PPBG (25.59 mg/dL), HbA1c (0.73%), fasting insulin (7.19 μIU/mL), and HOMA-IR (3.87) in the yoga intervention compared to the control group (no exercise) in the pooled analysis. In the case of walking intervention compared to the control group (no exercise), the significant reduction of FBG was 12.37 mg/dL and HbA1c was 0.35% in the pooled analysis, but they did not evaluate the PPBG. Only Keerthi et al., evaluated fasting insulin and insulin resistance.[13] Similarly our results show a significant reduction in FBG (12.07 mg/dL), HbA1c (0.20%), fasting insulin (10.06 μIU/mL) and HOMA-IR (5.97) in the yoga intervention compared to the walking group in the pooled analysis. Kour et al., showed that after yoga intervention, the mean difference of glycemic control (FBG, PPBG, and HbA1c) decreased in a smaller amount than the control group in patients with type 2 diabetes mellitus.[16] McDermott showed that walking has more significant effects on FBG in comparison to yoga in type 2 diabetes mellitus patients.[24]

Viswanathan et al., revealed that there was a significant reduction in blood glucose levels and HbA1c in the yoga group as compared to the non-yoga group.[18] Kumpatla

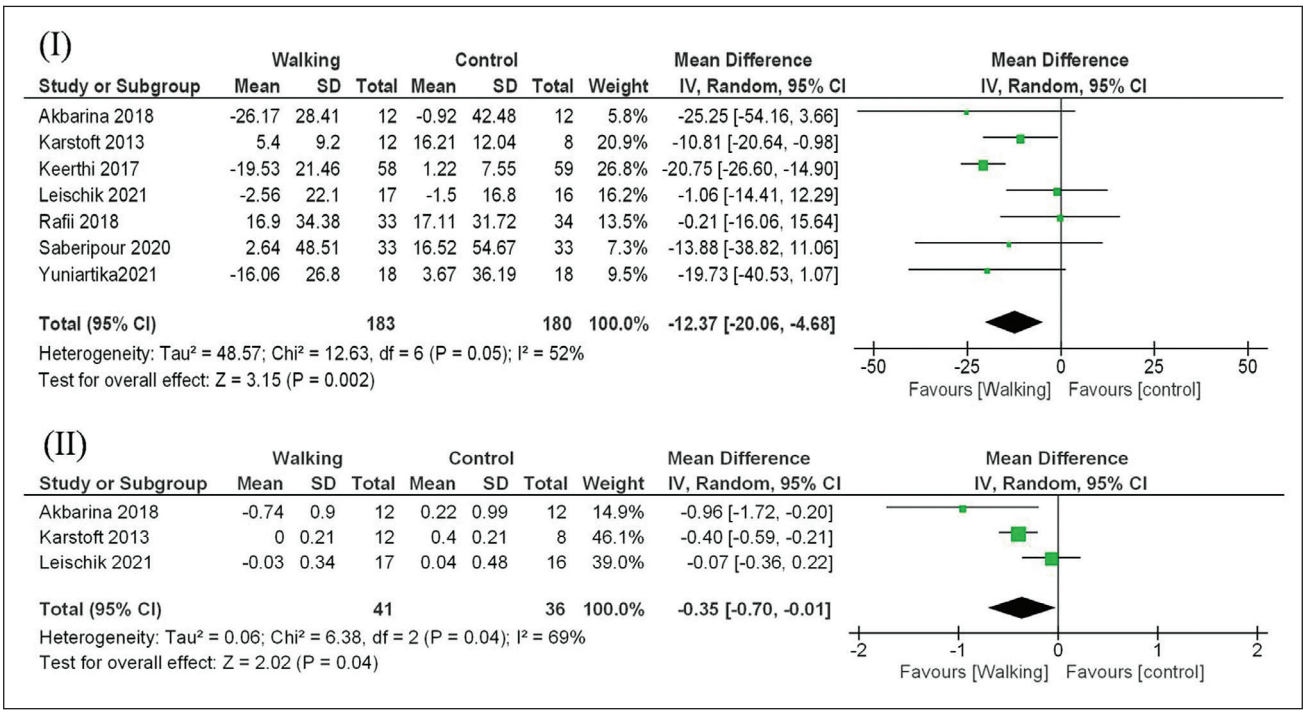

Figure 3. Forest plots presenting the effect of Walking compared to Control group on **(I)** Fasting Blood Glucose and **(II)** Glycosylated Hemoglobin.

et al., showed that the regular practice of yoga along with conventional medicines could be beneficial for better control of diabetes.[17] Saberipour et al., showed that yoga and walking had a positive effect on improving the laboratory indicators in men with type 2 diabetes, but yoga had more significant effects in diabetic patients as compared to walking.[12] Some studies exhibited a reduction in FBG, PPBG and HbA1c in the control group compared to the baseline and post-intervention due to the taking of oral hypoglycemic drugs (OHD),[15,17-20,22] but this change was not statistically significant. Diabetes is a psychosomatic disease related to both mind and body so psychoneuroendocrine and immune mechanisms are involved in the benefits of yoga on diabetes.[5]

Diabetes is a growing epidemic among lifestyle-associated cardiometabolic risk syndromes. It is accompanied by insulin resistance.[29] The idea of positive health was first introduced by Charaka, the father of the ancient Indian medical system called Ayurveda. He is the composer of the Ayurvedic foundational text, "Charaka Samhita." According to Charaka, body, mind, and soul are like a tripod.[30] In the Vasistha Samhita, we find two types of disease. One is mental (Adhija Vyadhi) and the other is physical (Anadhija Vyadhi).[31,32] Disease can germinate in either body or mind. Psychosomatic diseases are those that manifest in the mind and creep into the body, while in somatopsychic it is reversed. Yoga is a therapy that is a mind–body medicine.[33] Yoga as a part of Vedic philosophy that regards the human body as a combination of the mind, body, and soul.[34]

From this study, it may be recommended that Trikonasana, Paschimattanasana, Pawanmuktasana, Vakrasana,

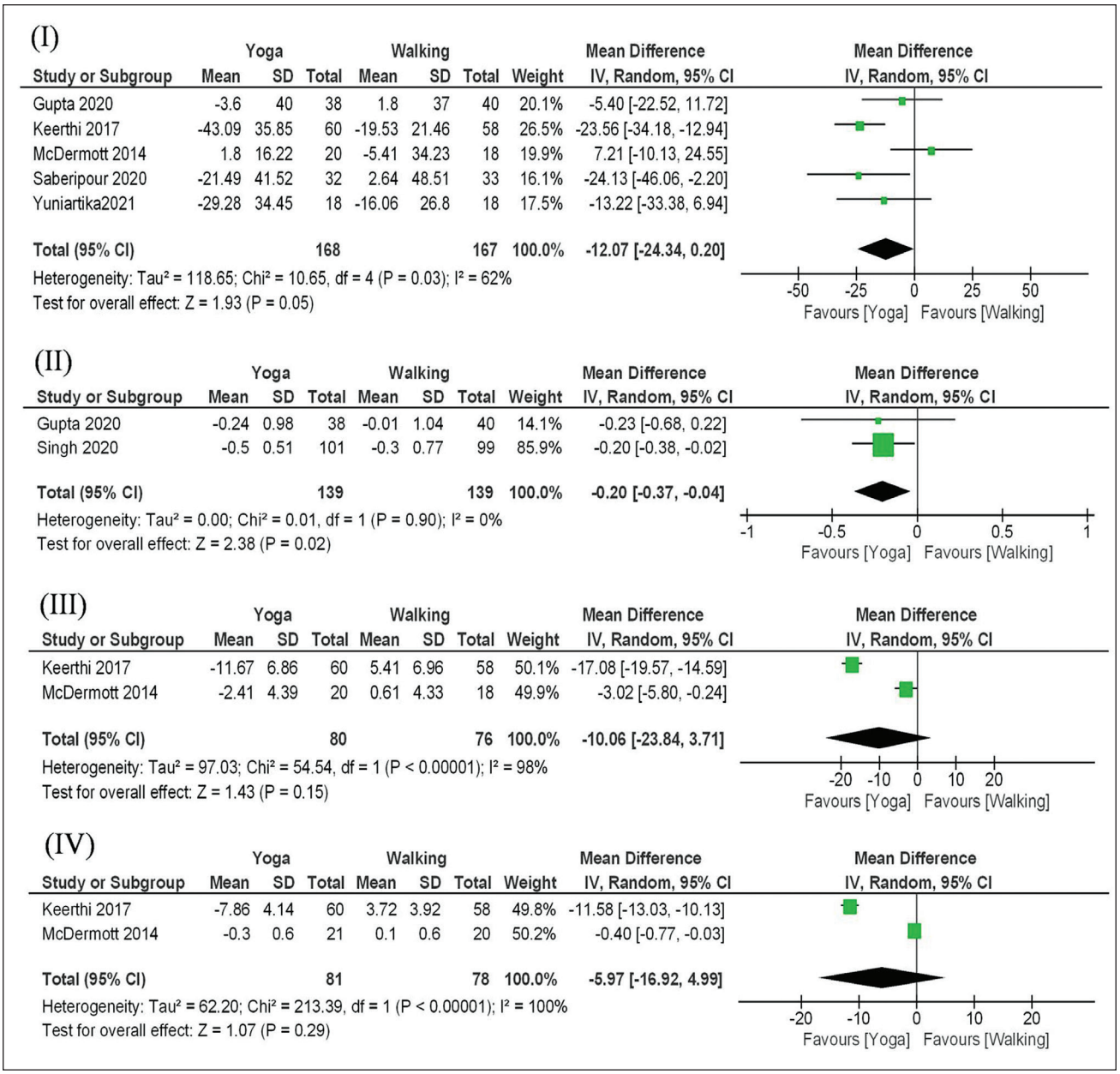

Figure 4. Forest plots presenting the effect of Yoga compared to Walking intervention on **(I)** Fasting Blood Glucose, **(II)** Glycosylated Hemoglobin, **(III)** Fasting Insulin and **(IV)** Insulin Resistance.

Bhujangasana, Ardha-Matseyendrasana, Dhanurasana, Sabasana, Kapalbhati, Anulom-Vilom and meditation for at least 45-60 minutes for five days per week can be beneficial for patients with diabetes. Walking five days per week and at least 45 minutes daily for people with diabetes can realize benefits to improve glycemic control. Additionally, concentration towards walking (Buddhist walking meditation) has a more favorable effect than the traditional walking program in patients with type 2 diabetes.[35] Future studies should emphasize the effects of different parameters of walking exercise on glycemic control of diabetes patients, such as walking frequency, walking time, and intensity.

CONCLUSIONS

In conclusion, this systematic review and meta-analysis provides evidence that either yoga or walking has positive effects on glycemic control and insulin resistance in comparison to the control group (no regular exercise) in patients with type 2 diabetes taking oral hypoglycemic agents. The change of HbA1c and FBG in the walking group compared to the control group is statistically significant but may not be clinically significant. Comparatively, yoga has more significant effects on glycemic control and insulin resistance in comparison to walking for the management of type 2 diabetes.

Statement of Authorship
The authors certified fulfillment of ICMJE authorship criteria.

CRediT Author Statement
BD: Methodology, Software, Validation, Formal analysis, Investigation, resources, Data Curation, Writing – original draft preparation, Writing – review and editing, Visualization, Project administration; **SC:** Conceptualization, Methodology, Validation, Investigation, Resources, Data Curation, Writing – original draft preparation, Writing – review and editing, Visualization, Supervision, Project administration; **SSD:** Validation, Writing – review and editing, Supervision, Project administration; **MC:** Validation, Writing – review and editing, Supervision.

Author Disclosure
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