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Mind- and Body-Based Interventions Improve Glycemic Control in Patients with Type 2 Diabetes: A Systematic Review and Meta-Analysis

Fatimata Sanogo, MS,[1,2] Keren Xu, PhD,[1] Victoria K. Cortessis, PhD,[1,3]
Marc J. Weigensberg, MD,[2,4] and Richard M. Watanabe, PhD[1,2,5]

Abstract

Aims/Hypothesis: Only 51% of patients with type 2 diabetes achieve the hemoglobin A1c (HbA1c) <7% target. Mind and body practices have been increasingly used to improve glycemic control among patients with type 2 diabetes, but studies show inconsistent efficacy. The authors conducted a systematic review and meta-analysis to assess the association between mind and body practices, and mean change in HbA1c and fasting blood glucose (FBG) in patients with type 2 diabetes.

Methods: The authors conducted a literature search of Ovid MEDLINE, Embase, and ClinicalTrials.gov seeking through June 10, 2022, published articles on mind and body practices and type 2 diabetes. Two reviewers independently appraised full text of articles. Only intervention studies were included. Reviewers extracted data for meta-analysis. Restricted maximum likelihood random-effects modeling was used to calculate the mean differences and summary effect sizes. The authors assessed heterogeneity using Cochran's Q and I^2 statistics. Funnel plots were generated for each outcome to gauge publication bias. Weighted linear models were used to conduct study-level meta-regression analyses of practice frequency.

Results: The authors identified 587 articles with 28 meeting the inclusion criteria. A statistically significant and clinically relevant mean reduction in HbA1c of –0.84% (95% confidence interval [CI]: −1.10% to –0.58%; $p<0.0001$) was estimated. Reduction was observed in all intervention subgroups: mindfulness-based stress reduction: –0.48% (95% CI: –0.72% to –0.23%; $p=0.03$), *qigong*: –0.66% (95% CI: −1.18% to –0.14%; $p=0.01$), and yoga: −1.00% (95% CI: −1.38% to –0.63%; $p<0.0001$). Meta-regression revealed that for every additional day of yoga practice per week, the raw mean HbA1c differed by –0.22% (95% CI: –0.44% to –0.003%; $p=0.046$) over the study period. FBG significantly improved following mind and body practices, with overall mean difference of −22.81 mg/dL (95% CI: –33.07 to −12.55 mg/dL; $p<0.0001$). However, no significant association was found between the frequency of weekly yoga practice and change in FBG over the study period.

Conclusions/Interpretation: Mind and body practices are strongly associated with improvement in glycemic control in patients with type 2 diabetes. The overall mean reduction in HbA1c and FBG was clinically significant, suggesting that mind and body practices may be an effective, complementary nonpharmacological intervention for type 2 diabetes. Additional analyses revealed that the mean decrease in HbA1c was greater in studies requiring larger number of yoga practice sessions each week.

[1]Department of Population and Public Health Sciences, Keck School of Medicine of USC, Los Angeles, CA, USA.
[2]USC Diabetes and Obesity Research Institute, Keck School of Medicine of USC, Los Angeles, CA, USA.
Departments of [3]Obstetrics and Gynecology, [4]Pediatrics, and [5]Physiology and Neuroscience, Keck School of Medicine of USC, Los Angeles, CA, USA.

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Introduction

Despite the availability of a range of therapies[1,2] to address the management of hyperglycemia, it is estimated that only 51% of patients with type 2 diabetes achieve the therapeutic target of hemoglobin A1c (HbA1c) <7%.[3] A variety of factors, including clinical inertia, polypharmacy, overly complex medication regimens, socioeconomic status, health disparities, and psychiatric disorders, are thought to reduce treatment compliance and efficacy, thus contributing to inadequate glycemic control.[4] In addition, the prevalence of diabetes distress, the emotional distress resulting from living with diabetes and the anxiety associated with daily self-management, in people with type 2 diabetes is reported to be 36%[5] and has been shown to be significantly linked to poor glycemic control[6] and treatment compliance.

More than half of U.S. adults use some form of complementary and alternative medicine (CAM)[7] for health reasons. Studies have shown that CAM helps a variety of conditions including relieving stress, improving sleep, decreasing chronic pain, and improving mental and emotional health.[8] According to the National Center for Complementary and Integrative Health, mind and body practices are a large and diverse subset of CAM procedures and techniques.[8] The most common mind and body modalities used in the United States are mindfulness-based stress reduction (MBSR) and other forms of meditation, yoga, guided imagery, and *qigong*.[7] In the United States, it is estimated that 66% of patients with type 2 diabetes use mind and body practices,[9] of whom 6%–20% are using it specifically to treat their diabetes.[10]

Studies have shown inconsistent results regarding the association between mind and body practices and improvements in glycemic control, measured by HbA1c or fasting blood glucose (FBG), in patients with type 2 diabetes.[11,12] In addition, the biological mechanism(s) by which mind and body practices improve glycemic control has largely been unexplored. A recent meta-analysis on the effects of yoga interventions on glycemic control reported overall improvement reflected by improved HbA1c and FBG.[13] However, the study also reported high heterogeneity in the findings with no exploration of factors that could explain the heterogeneity. This earlier meta-analysis did not include several experimental studies of yoga that are now available, and information about the efficacy of other common modes of mind and body practices on glycemic control has not, to the best of the authors' knowledge, been systematically explored.

The objective of this study was to conduct a systematic review and meta-analysis to assess whether mind and body practices (including yoga, *qigong*, guided imagery, MBSR, and other forms of meditation) improve glycemic control in patients with type 2 diabetes.

Materials and Methods

The authors adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines, and a detailed protocol is available on Prospero.[14] The authors applied the population, intervention, comparison, outcome (PICO) method, defining population as patients with type 2 diabetes only and intervention as mind and body interventions that include yoga, *qigong*, meditation, MBSR, or guided imagery. The authors distinguish other forms of meditation from MBSR, the standardized evidence-based mindfulness training developed by Dr. Jon Kabat Zin and used in clinical practice.[15] The comparator depended on study design. In randomized control trials (RCTs), it was glycemic control in individuals who did not receive the intervention during the study period, and in matched pre–post studies, it was glycemic control before the intervention. The primary outcome of interest was glycemic control as measured by the mean change in HbA1c, with the mean change in FBG serving as a secondary outcome of interest.

Data sources and searches

The authors conducted literature search of Ovid MEDLINE, Embase, and ClinicalTrials.gov seeking all published articles on common mind and body practices in patients with type 2 diabetes through June 10, 2022. The authors conducted separate searches using both controlled vocabulary (MeSH terms) and keywords, clinically and commonly used terms as well as definite and possible terms for each of type 2 diabetes, mind and body practices, and glycemic outcome (FBG and HbA1c). Results of each search were then intersected using the Boolean operator ''AND'' to capture articles relevant to this systematic review. Additional details, including specific search terms, can be found in the Supplementary Data.

Inclusion criteria

The authors included only human intervention studies meeting the PICO criteria, identifying a mind and body practice intervention, and reporting measures of glycemic control needed to estimate the raw mean difference for intervention versus comparator groups. Studies were excluded if they provided incomplete data, reported only median values of the outcome, included participants with type 1 diabetes or other conditions, or were not available as English language full-text reports.

Study selection

All citations identified in the search were imported into Covidence[16] and screened for duplicate entries, which were removed in accordance with PRISMA guidelines. The remaining abstracts were independently reviewed by two members of the research team to identify those with the potential to meet the criteria for inclusion. These articles were reviewed in full by independent reviewers, with critical appraisal of study quality and to identify those that met the study inclusion criteria. Disagreements between reviewers were resolved by consensus. Publication authors were contacted to request missing information for studies that met the inclusion criteria but did not report data needed for the meta-analysis.

Data extraction and quality assessment

Two independent reviewers extracted the data for the meta-analysis from qualifying reports. Redundant data from repeated publications were eliminated. Data were extracted for study design, subject recruitment, sample size for intervention and control groups, intervention type, outcome assessment, demographic variables, potential confounders, and mean baseline and follow-up measures of glycemic control and corresponding standard deviation for each study group. Data were managed using Research Electronic Data Capture (REDCap) hosted at the University of Southern California (Los Angeles, CA).[17]

Data synthesis and analysis

The authors performed meta-analysis of the raw mean differences assuming equal variance as there was no evidence to assume variances are unequal. The primary advantage of the raw mean difference is that it is inherently meaningful since the results are reported on a known scale. Means and standard deviations for the treatment and control groups were used for RCTs, and the baseline and follow-up means were used for matched pre–post studies. The standard correlation of $r = 0.5$ was used to account for the within-subject correlation between pre- and post-scores for matched studies.[18] Negative effect sizes indicate participants who received the intervention improved on measures of glycemia (i.e., showed reduction in glycemic measures).

The restricted maximum likelihood random-effect model was used to calculate the weighted means and corresponding 95% confidence intervals (CIs). Estimates for individual studies and summary estimates were displayed as forest plots stratified according to specific intervention type. Heterogeneity was assessed using Cochran's Q and I^2 statistics.[19] Funnel plots were generated for each outcome to gauge publication bias.

The authors observed high heterogeneity for the yoga intervention and subsequently explored the influence of duration of intervention and frequency of yoga practice (days/week) on effect size by conducting univariate meta-regression using data from all included studies, as well as from the subset of studies that reported on both HbA1c and FBG. The authors additionally conducted cumulative meta-analyses ordered on relative study weight (large to small) to explore the robustness of available data addressing each outcome by determining the minimum number of studies needed to achieve statistical significance. Finally, the authors performed a separate meta-analysis of the mean change in HbA1c stratifying by intervention type (pre–post studies vs. RCTs) to assess the effect of study design in the observed heterogeneity. All analyses were conducted using Stata 16 (College Station, TX).

Results

Figure 1 illustrates the flow of data through the study. The authors initially identified 587 citations, from which 159 duplicates were detected and removed. Independent review of titles and abstracts of the remaining 428 reports identified 164 candidates, which potentially met the inclusion criteria. Critical review of these reports revealed that 71 were not intervention studies, 17 did not use an intervention of interest, 16 included participants with conditions other than type 2 diabetes (type 1 diabetes or prediabetes as defined by the individual study), 14 did not report an outcome measure of interest, 2 were not available in English, 1 was missing full text, 1 used combined interventions, 4 lacked relevant information on participants' recruitment process and baseline characteristics, 4 did not provide data needed for meta-analysis, and 6 reused the same set of data reanalyzed from studies already included in the meta-analysis.[20–25]

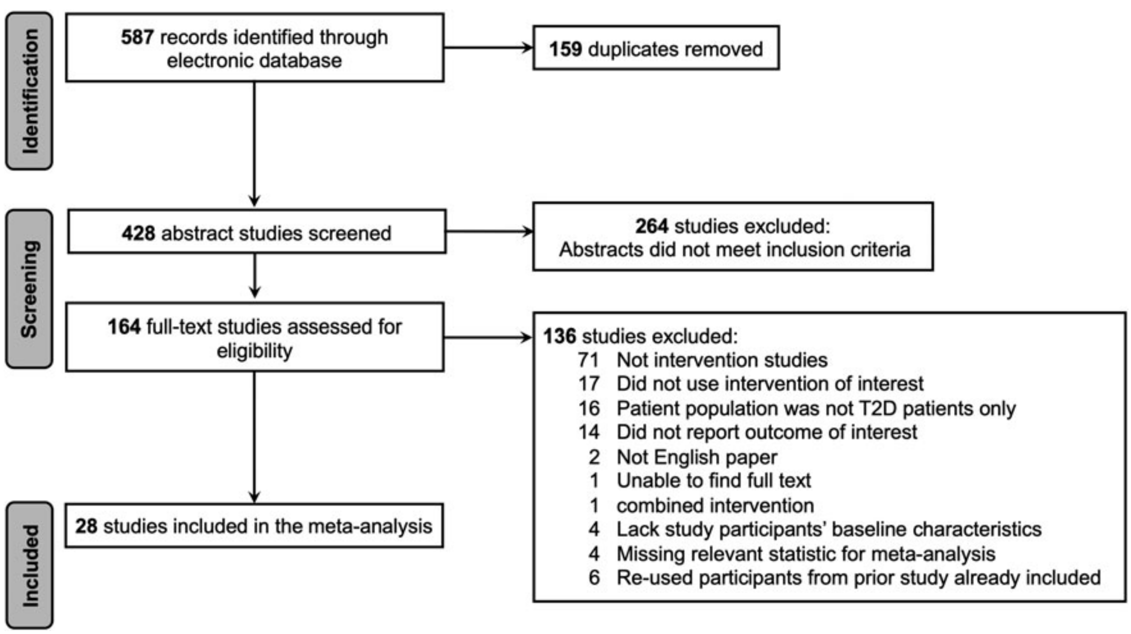

FIG. 1. Meta-analysis flow diagram. The meta-analysis flow diagram outlines how the final publications were selected. Literature search identified 587 studies, and 159 duplicates were detected through Covidence and removed. Two-hundred and sixty-four studies that did not meet the study inclusion criteria were excluded. The remaining 164 studies were submitted to a full-text critical appraisal, and a final 28 studies were included in the meta-analysis.

Authors of three of the four publications with missing data who were contacted did not respond to our queries, and authors of the fourth were unable to provide the measurements of interest. Thus, 28 studies were included in the final meta-analysis. Studies included used guided imagery ($n=1$), MBSR ($n=5$), meditation ($n=1$), *qigong* ($n=3$), or yoga ($n=18$) as the intervention. The single meditation intervention study used Buddhist Walking meditation, which distinguishes it from MBSR, the standard evidence-based mindfulness training used in clinical practice.

Included studies, published from 1993 to 2022, are summarized in Table 1. Eighteen studies were RCTs, and 10 were matched pre–post studies in which values of glycemic measures were compared for individual participants at time points before and after the intervention. Seven studies reported on both the primary (HbA1c) and secondary outcomes (FBG), 8 studies reported on HbA1c alone, and 13 studies reported on FBG alone. Two studies[26,27] reported results for three independent subpopulations, and data for these subpopulations were analyzed separately and distinguished in this report with suffixes A, B, and C.

Studies included in the meta-analysis are diverse in several ways. Population samples represented a variety of countries, including Australia, India, the United States, Germany, South Korea, Cuba, Thailand, China, and Japan, reflecting a range of race/ethnicity. The duration of intervention ranged from 1 week to 3 years of follow-up, while the weekly frequency ranged from once per week to daily. The reported mean age across studies ranged from 42 to 68 years and represented both sexes, except for the study by Sreedevi et al. that enrolled only females.[28] Participants were mostly recruited from clinical settings, although a few studies extended recruitment into the community. Ascertainment schemes varied across studies.

The studies also shared several important features. All excluded type 2 diabetes patients treated with insulin and those with medical complications (e.g., coronary artery disease, renal complications), thereby controlling by restriction for diabetes complication and duration. Participants in all studies were kept on their standard medical care, controls in most RCTs received standard of care only. However, in one study,[29] participants were randomly assigned to either intervention or a waitlist

Table 1. Characteristics of Studies Included in the Meta-Analysis

Study	Location	Sample	Study type	Intervention details		
				Type	*Duration*	*Frequency sessions*
Jablon et al.[50]	USA	10 c, 10 tx	RCT	GI	4 weeks	Daily
Rosenzweig et al.[51]	USA	11	Pre–post	MBSR	8 weeks	1 day/week
Kopf et al.[12]	Germany	57 c, 53 tx	RCT	MBSR	3 years	1 day/week[a]
Jung et al.[32]	South Korea	28 c, 28 tx	RCT	MBSR	8 weeks	2 days/week
Whitebird et al.[11]	USA	31	Pre-post	MBSR	8 weeks	1 day/week
Guo et al.[38]	China	50 c, 50 tx	RCT	MBSR	12 weeks	Daily
Gainey et al.[35]	Thailand	11c, 12 tx	RCT	Meditation	12 weeks	3 days/week
Tsujiuchi et al.[52]	Japan	10 c, 16 tx	RCT	*qigong*	4 months	1 day/week
Wang et al.[53]	China	20 c, 20 tx	Pre–post	*qigong*	4 months	Daily
Lam et al.[41]	Australia	25 c, 28 tx	RCT	*qigong*	6 months	2 times/week[b]
Jain et al. (A)[26]	India	45	Pre–post	Yoga	40 days	2 times/week
Jain et al. (B)[26]	India	28	Pre–post	Yoga	40 days	2 times/week
Jain et al. (C)[26]	India	76	Pre–post	yoga	40 days	2 times/week
Gordon et al.[23]	Cuba	77 c, 77 tx	RCT	Yoga	24 weeks	1 day/week
Singh et al.[55]	India	30 c, 30 tx	RCT	Yoga	45 days	Daily
Amita et al.[54]	India	21 c, 20 tx	RCT	Yoga	3 months	Daily
Hegde et al.[29]	India	63 c, 60 tx	RCT	Yoga	3 months	3 days/week
Beena and Sreekumaran (A)[27]	India	37 c, 33 tx	RCT	Yoga	3 months	6 days/week
Beena and Sreekumaran (B)[27]	India	21 c, 26 tx	RCT	Yoga	3 months	6 days/week
Beena and Sreekumaran (C)[27]	India	12 c, 14 tx	RCT	Yoga	3 months	6 days/week
Vizcaino[42]	USA	10	Pre–post	Yoga	6 weeks	3 times/week
Popli et al.[43]	India	80	Pre–post	Yoga	6 months	5 days/week
Rajani et al.[44]	India	34c, 34 tx	RCT	Yoga	6 months	6 days/week
Vinutha et al.[45]	India	15	Pre–post	Yoga	1 week	Daily[c]
Mullur and Ames[46]	USA	5c, 5 tx	RCT	Yoga	3 months	Daily
Angadi et al.[47]	India	52	Pre–post	Yoga	6 months	Daily
Sreedevi et al.[28]	India	38 c, 35 tx	RCT	Yoga	3 months	2 days/week
Mondal et al.[48]	India	10 c, 10 tx	RCT	Yoga	12 weeks	3 days/week
Vijayakumar et al.[49]	India	189	Pre–post	Yoga	10 days	Daily
Vijayakumar and Kannan[25]	India	9	Pre–post	Yoga	14 days	Daily
Nair et al.[39]	India	23 c, 22 tx	RCT	Yoga	10 weeks	4 days/week
Viswanathan et al.[40]	India	150 c, 150 tx	RCT	Yoga	3 months	5 days/week

Each of these publications are cited in the references.
[a]Intervention frequency was 1 day/week for 8 weeks, followed by booster session every 6 months.
[b]Intervention was 2 times/week for 3 months, followed by 1 time/week for 3 months.
[c]Daily from 5:30 AM to 9 PM.
C, control group; GI, guided imagery; MBSR, mindfulness-based stress reduction; pre–post, matched study; RCT, randomized control trial; tx, treatment group.

group, and the waitlist group served as controls during the study but received the intervention at completion of the study.

Meta-analysis results for change in HbA1c are shown in Figure 2a. The overall mean reduction in HbA1c across all intervention types was –0.84% (95% CI: –1.10% to –0.58%; $p < 0.0001$). The largest mean reduction in HbA1c was observed in studies in which the intervention was yoga (–1.00% [95% CI: –1.38% to –0.63%]; $p < 0.0001$), although reductions in the mean HbA1c were also observed in studies of MBSR (–0.48% [95% CI: –0.72% to –0.23%]; $p = 0.03$), *qigong* (–0.66% [95% CI: –1.18% to –0.14%]; $p = 0.01$), and meditation (–0.50% [95% CI: –2.54% to 1.54%]; $p = 0.64$). The funnel plot (Fig. 2b) of studies that reported on change in the mean HbA1c appeared symmetric and provided no indication that results reflect publication bias.

Meta-analysis results for the mean change in FBG were consistent with the mean change in HbA1c (–22.81 mg/dL [95% CI: –33.07 to –12.55 mg/dL]; $p < 0.0001$; Fig. 3a). The funnel plot (Fig. 3b) again provided no indication of publication bias.

The authors observed significant heterogeneity of effect size for HbA1c as reflected in both Cochran's Q and I^2. I^2 was estimated to be 87% for HbA1c. This heterogeneity appeared to arise from differences among the yoga studies and was not apparent for the other interventions. A similar heterogeneity pattern was observed for the mean change in FBG. The authors attempted to identify the source of this heterogeneity by exploring the influence of duration of intervention and frequency of yoga practice (days/week) on effect size. There was no statistically significant association between duration of intervention and either the mean change in HbA1c or FBG. A statistically significant inverse association between the number of yoga sessions per week and the effect size was observed for HbA1c, but not for FBG (Fig. 4a, b). For every additional day of yoga practice per week, the raw mean HbA1c differed by –0.22% (95% CI: –0.44% to –0.003%; $p = 0.046$) over the study period.

Very similar results were found by limiting meta-regression to the seven studies that reported on both HbA1c and FBG. This sensitivity analysis also identified statistically significant inverse association between the number of yoga sessions per week and the mean reduction in HbA1c ($p = 0.02$), but not in FBG ($p = 0.75$). In this subset of studies, the raw mean difference in HbA1c was estimated to decrease by –0.27% (95% CI: –0.50% to –0.04%; $p = 0.02$) for every additional day of practice per week (Supplementary Fig. S1). Finally, the authors performed a separate meta-analysis of the mean change in HbA1c stratifying studies by intervention type (pre–post studies vs. RCTs) and found moderate heterogeneity in pre–post studies (60.12%), but high heterogeneity in RCTs (89.71%). Despite variation in heterogeneity between study types, the mean change in HbA1c was nearly identical between study types (–0.84% in RTCs vs. –0.85% in pre–post studies).

Finally, cumulative meta-analyses reveal summary estimates of effects of yoga to be very robust because results for both HbA1c and FBG require data from only 1 of 9 studies and 1 of 18 studies, respectively, to achieve statistical significance (Fig. 5a, b).

Limitations

There are several limitations of this study. Participants in the studies included in the meta-analysis were not blinded to the intervention. However, while lack of blinding may readily increase the risk of bias in the reporting of subjective outcomes such as behavior, outcome measures used in this analysis are objective in nature, making this a minor concern. The authors had to exclude data from four reports that may have qualified for inclusion despite the efforts to contact the investigators to obtain the required information. In addition, the authors did not include studies identified in the gray literature because available information did not allow them to adequately assess quality of the methodology employed. It is unlikely these exclusions could have spuriously created the inverse associations reported here, in light of the robust nature of the contributing data, reasonably symmetrical shape of the funnel plots, and lack of *a priori* rationale for excluded studies to differ from those included.

Discussion

The authors identified and synthesized experimental evidence regarding the effects of mind and body practices on glycemic control among patients with type 2 diabetes. The 28 studies included in this analysis show that taken together, a range of different mind and body practices significantly reduced both HbA1c and FBG compared with standard of care in patients with type 2 diabetes. The overall absolute estimated decrease of 0.84% in the mean HbA1c is statistically and clinically significant.[30] Hirst et al. estimated a 1.12% decrease in HbA1c in a meta-analysis of 35 trials of metformin monotherapy of at least 12 weeks duration.[31] By comparison, the overall effect of mind and body practices on reduction in the mean HbA1c estimated in this meta-analysis is 75% that reported for metformin.

Because participants in the studies included in this meta-analysis received standard of care before and throughout the studies, and, for the most part were actively treated with metformin, the observed effect of mind and body practices appears to represent an additional decrease in the mean HbA1c beyond the monotherapeutic effect of metformin. This raises the question of whether mind and body practices could be useful if initiated early in the course of diabetes therapy along with conventional lifestyle treatments. It further suggests that mind and body practices may also be an effective preventive measure in people at risk for type 2 diabetes.

The results of this study evoke the question by what mechanism may mind and body interventions improve glycemic control. Prior studies have shown significant associations between diabetes distress and poor glycemic control in patients with type 2 diabetes.[6] Four studies included in this meta-analysis reported on various measures of patient stress obtained using the Patient's Health Questionnaire,[12] Diabetes Distress Scale,[11,32] or Perceived Stress Scale.[33] The two studies reporting specifically on diabetes distress showed a decrease in both diabetes distress and HbA1c in the intervention group, which is consistent with the prior literature. One possible theory is that a decrease in psychological distress followed by increased treatment and regimen compliance may mediate the effect of mind and body practices on glycemia.

Prior studies have also shown significant associations between elevated serum cortisol and poor glycemic control in patients with type 2 diabetes.[34] Two studies included in the meta-analysis[32,35] reported a significant decrease in serum cortisol and glycemia following intervention. Cortisol

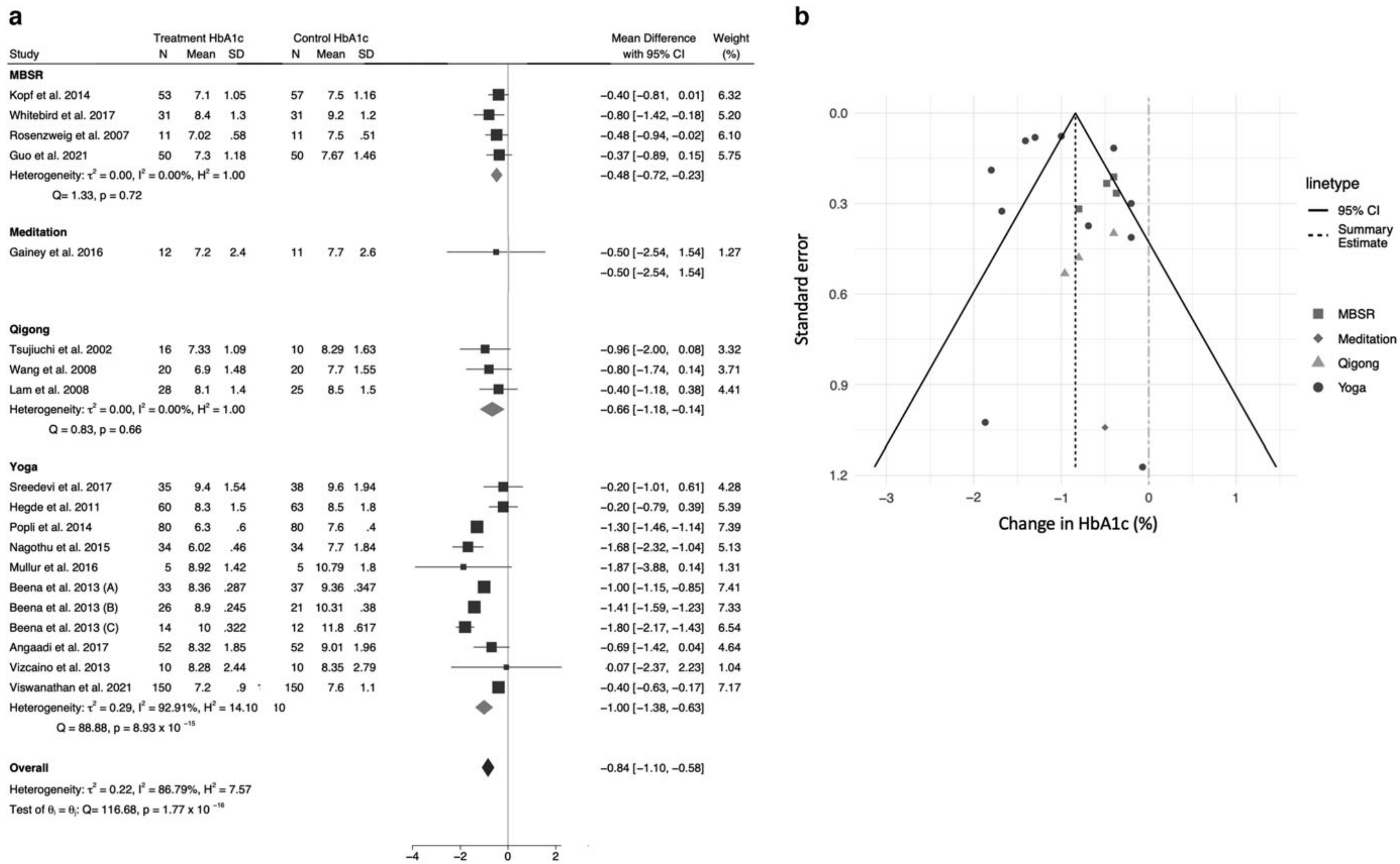

FIG. 2. Results of the mean change in HbA1c. **(a)** The forest plot of change in HbA1c stratified by intervention type. The mean difference in HbA1c was computed as treatment minus control. The combined result together with heterogeneity statistics was computed for each intervention type and overall across all interventions (overall $p<0.0001$). **(b)** Funnel plot of studies reporting on change in HbA1c. The funnel plot appears symmetrical and shows no significant evidence of publication bias.

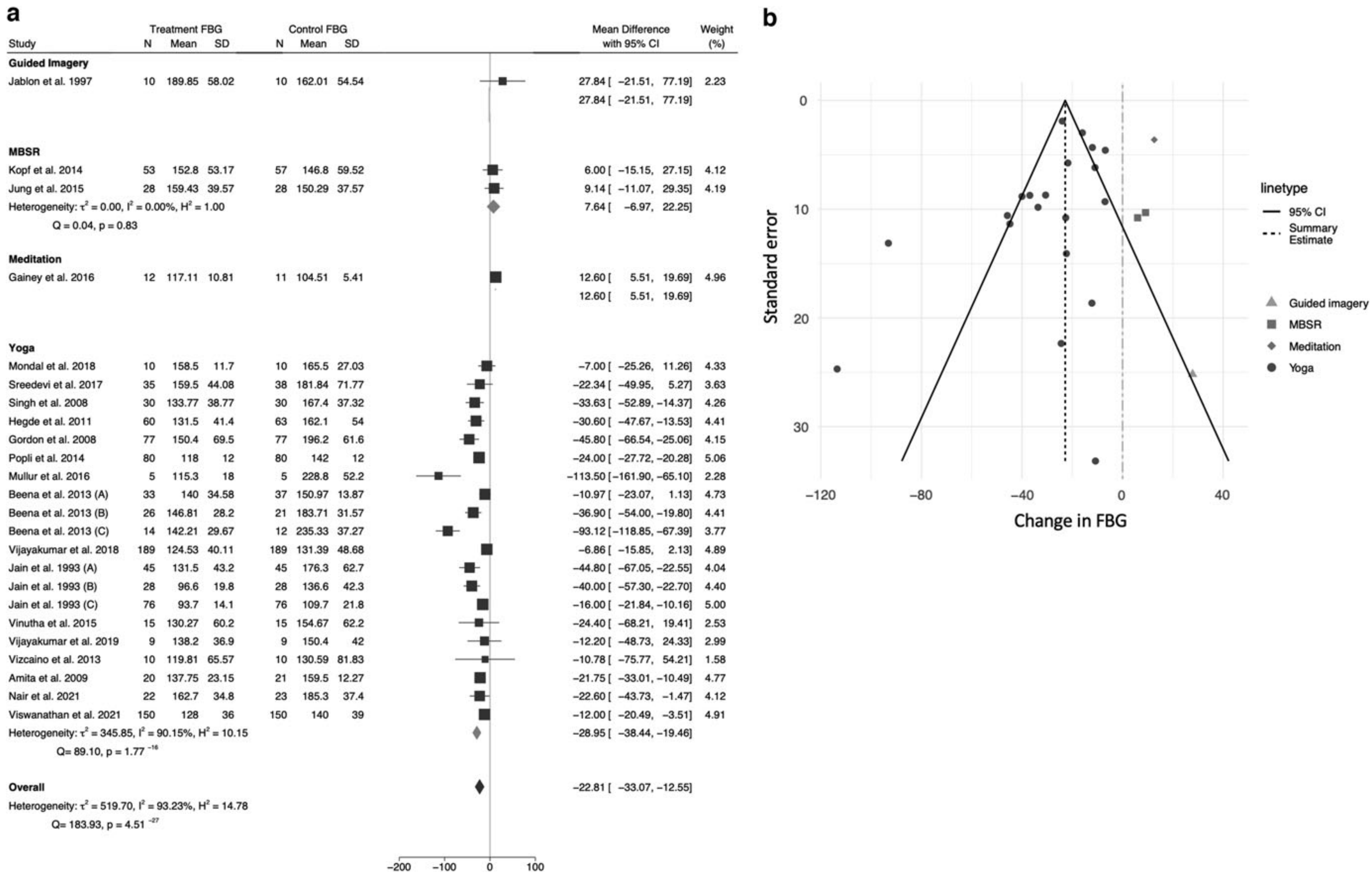

FIG. 3. Results of the mean change in FBG. (**a**) The forest plot summarizes the meta-analysis for the change in the mean FBG stratified by intervention type. The mean difference in FBG was computed as treatment minus control. The combined result together with heterogeneity statistics was computed for each intervention type and overall across all interventions (overall $p < 0.0001$). (**b**) Funnel plot appears symmetrical and shows no significant evidence of publication bias. FBG, fasting blood glucose.

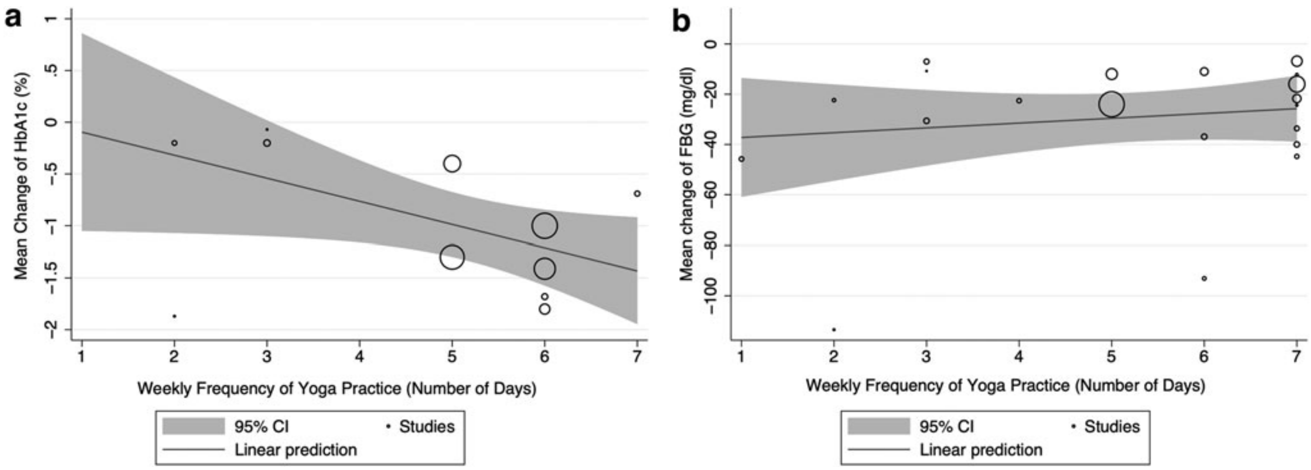

FIG. 4. **(a)** Bubble plot of change in HbA1c. The bubble plot shows that the mean change in HbA1c decreases as the number of weekly yoga practice increases. For every additional day of yoga practice per week, the mean difference in HbA1c decreases –0.22% (95% CI: –0.44% to –0.003%; $p = 0.046$) over the study period. **(b)** The bubble plot shows no relationship between the raw mean change in FBG and the number of weekly yoga practice. For every additional day of yoga practice per week, the raw mean difference in FBG increases 1.9 mg/dL (95% CI: –3.14 to 6.96 mg/dL; $p = 0.46$) over the study period.

could plausibly mediate the benefit of mind and body practices on glucose control through reduced inflammation and a cascade of homeostatic mechanisms that improve lipid profiles, insulin sensitivity, and glycemia.[36,37] This hypothesis will require additional study.

The primary objective of this study was to identify and synthesize experimental data on efficacy of common forms of mind and body practices on glycemic control in patients with type 2 diabetes, which to the best of the authors' knowledge has not previously been performed. The results of this study accord with the findings of a previous meta-analysis[13] that reported improvement in HbA1c and FBG to be associated with yoga. However, these investigators did not consider other forms of mind and body practice, and they included data from only four of the experimental studies that contributed to this meta-analysis. In addition, the previous meta-analysis was based largely on studies conducted in India, in contrast to the far broader geographic distribution of source populations contributing to this report.

This is, therefore, the first report providing summary estimates of efficacy of mind and body practices on glycemic control in type 2 diabetes to extend synthesis of human data beyond yoga. While the summary estimates for other common types of mind and body practices are similar to those for yoga, this systematic review established that data for MBSR, meditation, guided imagery, and *qigong* are very limited. These other forms of mind and body practices warrant further investigation in people with type 2 diabetes because they may be similarly beneficial in reducing both diabetes distress and physiological distress and may be more accessible than yoga to some patients with type 2 diabetes.

In all studies, point estimates of effect of yoga on the mean change in HbA1c and FBG were consistently negative, although a degree of heterogeneity was apparent. Heterogeneity could reflect differing degrees of systematic error and thus bias between studies or true differences in effect size. Most studies controlled for *a priori* potential confounders through randomization, matching, and/or restriction to patients without complications and those treated without insulin. These measures also make greatly varying degrees of participation bias unlikely. Nonetheless, differing degrees of measurement error, and thus information bias, may have been present in contributing studies. FBG has high day-to-day variability and is a more variable indicator of control, compared with HbA1c. The clear inverse association between number of yoga sessions per week and effect size observed for HbA1c, but not for FBG, may reflect true differences in effect size that were obscured by error inherent in measuring glycemic control by FBG.

In this scenario, while heterogeneity in FBG data may be due largely to bias, heterogeneity in HbA1c data may in part reflect greater efficacy of more intensive yoga practice. This interpretation is supported by results of the sensitivity analysis of the subset of studies that reported on both measures of glycemic control. These studies revealed a pattern of inverse association between number of yoga sessions per week and HbA1c, but not FBG, that is remarkably similar to results from all studies. This agreement strongly implicates differences in accuracy of the outcome measure because all study elements and other data—participants, interventions, and covariate data—would have been identical in these seven studies.

Other factors that could create true differences in effect size include the types of yoga practiced. Although some studies reported the type of yoga used in the protocol, others did not, so the authors could not address this as a study-level variable. Finally, differences in ascertainment schemes for recruitment in clinical settings may have produced study populations with differing propensity to benefit from yoga. It is worth noting, for example, that some reports did not provide a diagram illustrating the process of recruitment and randomization of participants and therefore do not comply to current methodological standards of reporting intervention studies. Additionally, some studies did not report important details on patient demographics or loss to follow-up.

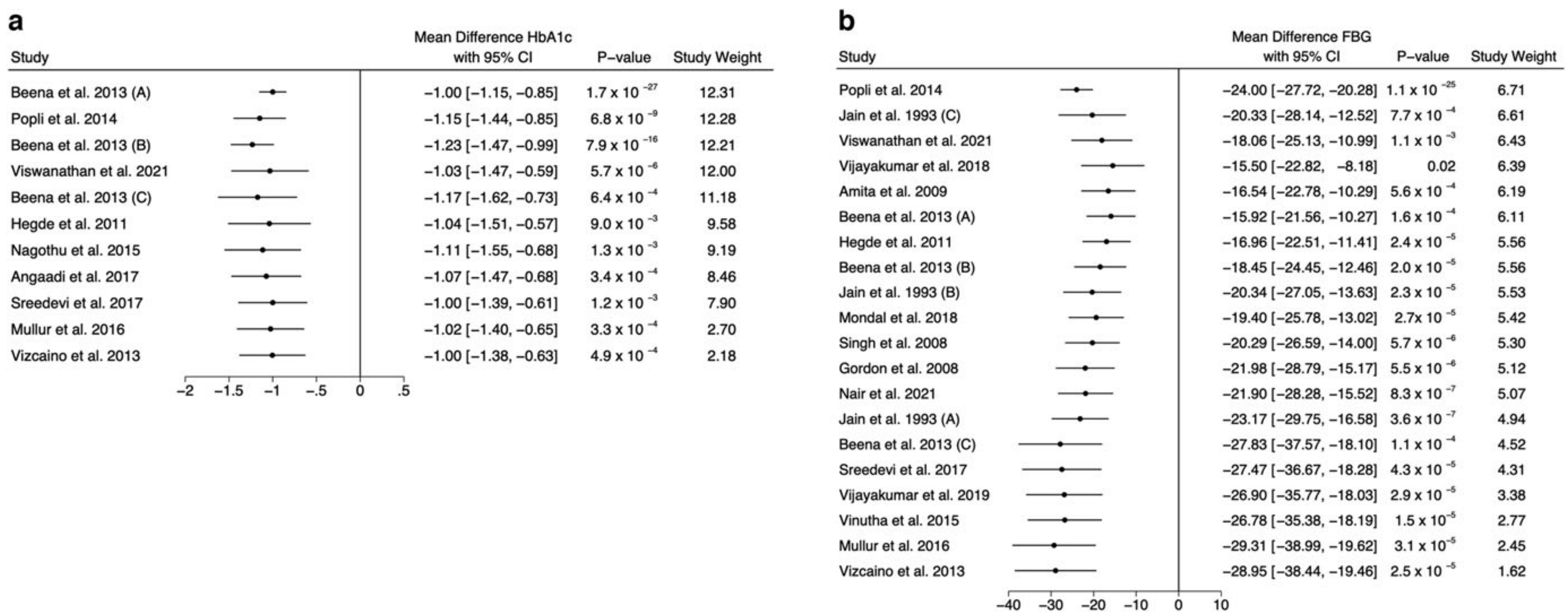

FIG. 5. Cumulative meta-analyses by study weight (large to small) for yoga intervention studies. (**a**) Results for change in HbA1c, and (**b**) results for change in FBG. In both cases, only one study is required to achieve statistical significance.

Conclusions

In conclusion, the authors showed by systematic review followed by critical appraisal and meta-analysis that mind and body practices reduce HbA1c and FBG in patients with type 2 diabetes. The overall estimated effect is clinically significant and suggests that these practices may be an effective, complementary nonpharmacological intervention for type 2 diabetes. The results further suggest that early initiation of mind and body practices along with conventional lifestyle intervention could be useful in mitigating hyperglycemia or an effective preventive measure in those at risk for type 2 diabetes.

Authors' Contributions

F.S.: study concept and design, collected the data and performed the meta-analysis, and drafted the article. V.K.C.: study concept and design, critically reviewed the analysis and draft of the article. M.J.W.: study concept and design, critically reviewed the analysis and draft of the article. K.X.: collected the data and performed the meta-analysis, critically reviewed the analysis and draft of the article. R.M.W.: study concept and design, critically reviewed the analysis and draft of the article, is the guarantor of this work, has full access to the data, and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Author Disclosure Statement

No competing financial interests exist.

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Supplementary Material

Supplementary Data
Supplementary Figure S1

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Address correspondence to:
Richard M. Watanabe, PhD
Department of Population and Public Health Sciences
Keck School of Medicine of USC
2250 Alcazar Street, CSC-204
Los Angeles, CA 90033
USA

E-mail: rwatanab@usc.edu