Effects of yogic exercise on glycemic control and lipid profiles in Type 2 diabetes: A meta-analysis of randomized controlled trials

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This study was to evaluate the effectiveness of yogic exercise on glycemic control and lipid profiles in type 2 diabetes. PubMed, Embase, Scopus, and the Cochrane library were searched to identify randomized controlled trials (RCTs) reported effects of yogic exercise on glycemic control and lipid profiles in type 2 diabetes published in English language between January 1966 and December 2013. Statistical analyses were carried out using Comprehensive Meta-Analysis 2 software. The effect sizes of yogic exercise on type 2 diabetes generally had a moderate to high level on fasting blood sugar, glycosylated hemoglobin, total cholesterol, triglycerides, high density lipoprotein, low density lipoprotein, and very low density lipoprotein levels with standardized mean difference effect sizes (95 % confidence interval) of -0.70 (-1.03 to -0.36), -0.57 (-0.94 to -0.19), -0.86 (-1.43 to -0.29), -0.63 (-0.99 to -0.27), 0.62 (0.23 to 1.01), -0.78 (-1.16 to -0.39), and -0.52 (-0.73 to -0.31), respectively ($p < 0.05$). Our meta-analysis indicates that yoga exercise improves glycemic control and lipid profiles in type 2 diabetes. Further high-quality RCTs are needed to confirm and further comprehend the effects of standardized yoga programs in people with type 2 diabetes.

Keywords: Glycemic control, Lipid profiles, Meta-analysis, Yogic exercise

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The growing incidence of type 2 diabetes on a global scale is widely recognized as one of the most challenging contemporary threats to public health. Diabetes is a syndrome characterized by a perturbation of glucose homeostasis. It is necessary for people with diabetes type 2 to control blood glucose and HbA1c level to prevent any complications due to type 2 diabetes. Dyslipidemia also causes morbidity and mortality due to elevated total cholesterol (TC), triglycerides (TG), low density lipoprotein (LDL), and very low density lipoprotein (VLDL) levels and decreased high density lipoprotein (HDL) level in type 2 diabetes. Therefore, management of lipid profiles for type 2 diabetes is also very important. The major factors in controlling diabetes are medication, diet, and exercise, etc. Of these, yogic exercise is easily accessible because of low cost and simplicity of implementation. One important regimen for people with type 2 diabetes is participation in appropriate yogic exercise. The beneficial effects of yogic exercise typically include a reduction in glucose level, glycosylated hemoglobin (HbA1c) level, and other glycemic control indexes in diabetes. Yoga also has a beneficial effect on the lipid profiles such as TC, TG, HDL, LDL, and VLDL in diabetes. Yogic exercise generally includes various physical postures, breathing exercises, relaxation, and meditation, etc. Most of these yogic exercises have been selected on the basis of the following mechanisms. Researchers reported that “Yogic exercise has a direct influence on pancreatic secretion by rejuvenation of the pancreatic cells through alternate abdominal contractions and relaxation.” They also stated that yogic exercise reduces blood glucose levels due to muscular exercise and relaxation. Additionally, other investigators pointed out that the improvement in lipid profiles with yogic practice could be due to increased hepatic lipase and lipoprotein lipase. They also stressed that this would increase the uptake of triglycerides by adipose tissue and affect the lipoprotein metabolism. As stated, yogic exercise has been shown to benefit...
individuals who have type 2 diabetes. However, in spite of its growing acceptability and known positive effects on physical and physiological variables, yoga has not been widely adopted as part of a regimen to prevent type 2 diabetes. This means that evidence-based studies are needed to identify the effectiveness of yogic exercise on glycemic control and lipid profiles in type 2 diabetes through analytic methods. That is to say, an adequately powered, well-designed RCTs are needed to remedy the methodological deficiencies of previous studies. Therefore, we have performed a meta-analysis to evaluate the effectiveness of yogic exercise on glycemic control and lipid profiles as assessed by fasting blood sugar (FBS), HbA1c, TC, TG, HDL, LDL, and VLDL levels in type 2 diabetes.

Methodology

Research design
This study is a descriptive study using meta-analysis methodology to evaluate the effects of yogic exercise on glycemic control and lipid profiles in type 2 diabetes.

Study selection
We searched PubMed, Embase, Scopus, and the Cochrane Central Register of Controlled Trials to identify RCTs published in English between January 1966 and December 2013. Our search terms were "yoga", “type 2 diabetes” and “blood glucose” or “yoga”, “type 2 diabetes” and “lipid profiles”. We manually searched the reference lists by ‘footnote chasing’ to identify any additional studies relevant to our analysis. Two independent investigators reviewed all the articles from the previous search based on the following selection criteria. These researchers were trained on meta-analytic operation by statistical practitioners. All potentially eligible studies were retrieved and the full-text articles were reviewed to determine whether they met the inclusion criteria. To be eligible, studies had to meet the following conditions:

Types of studies: RCTs were eligible. Studies were eligible only if they were published as a full paper in the English language.

Types of participants: Only studies of adults having diagnosed type 2 diabetes were eligible.

Type of interventions: Studies that compared yoga intervention with no treatment to any active treatment were eligible.

Types of outcome measures: Studies were eligible if they assessed levels of FBS, HbA1c, TC, TG, HDL, LDL, and VLDL. Included studies must have been prospective RCTs comparing yoga exercise with non-yoga programs for type 2 diabetes. Nonrandomized studies, case reports, letters and comments were excluded from our analysis. Disagreements were resolved by discussion.

Assessment of study quality
Scoring the quality of the included reports was accomplished by using the Jadad composite scale, which assesses descriptions of randomization, blinding and dropouts. The evaluation method of the scale was 2 points for randomization, 2 points for blinding and 1 point for dropouts. The quality scale ranges from 0 to 5 points, with a low-quality report receiving a score of 2 points or less and a high-quality report receiving a score of at least 3 points.

Statistical analysis
We performed all statistical analyses with Comprehensive Meta-Analysis 2 software (Biostat, Englewood, NJ, USA). All available trials with reporting data were summarized. The heterogeneity assessment among the trials was calculated by using the Cochrane’s Q test and I² test. If there was significant homogeneity, we used a fixed-effects model, and if significant heterogeneity, a random-effects model was used to confirm the trial results. Results for the outcomes are reported as ES with 95 % confidence intervals. The strength of the effect sizes was categorized based on Cohen’s criteria: trivial (0.1–1.0), a low effects (0.2-0.5), a moderate effects (0.5-0.8), a high effects (≥ 0.8). The results of the study were considered to be significant at $p < 0.05$.

Publication bias
We estimated publication bias using the funnel plot and Fail-Safe N (FSN). Rosenthal suggested that we actually compute how many missing studies we would need to retrieve and incorporate in the analysis before the p-value became non-significant. He referred to this as a 'File-drawer' analysis which means file drawers being the presumed location of the missing studies. Cooper proposed the term 'Fail-Safe N', a reference to the number of missing studies that would nullify the effect. If the fail-safe N is 146, this means that we would need to locate and include 146 'null' studies in order for the combined 2-tailed p-value to
exceed 0.05. Rosenthal suggested that one would regard as resistant to the file drawer problem any combined results for which the tolerance level reached \( 5k + 10 \), where \( k \) is the number of studies included in the meta-analysis\(^{20}\). The FSN was calculated using Comprehensive Meta-Analysis 2 software.

**Results**

**Included studies**

Fig. 1 shows the selection process from initial review to decision to include in our meta-analysis. The initial search identified 102 publications, of which 96 were excluded, leaving 6 publications and adding 5 publications by footnote chasing for analysis. Thirty five studies were a duplicate of another journal, 59 studies did not use RCTs and 2 studies did not include the data regarding blood glucose level. The remaining total of 11 RCTs (2,3,4,5, 6,7,8,9, 10, 11, and 13) were finally selected to perform our meta-analysis.

**Characteristics of the studies**

The characteristics and quality of each selected study are defined in Table 1. Six RCTs originated from India, 2 from the US, 1 from England, 1 from the UAE and 1 from Cuba. Yoga group was combined conventional medication therapies and yoga programs. Yoga traditions were heterogeneous between studies; 1 \( \text{kyria yoga} \), 1 \( \text{hatha yoga} \), 1 restorative \( \text{yoga} \), 1 \( \text{vinyasa yoga} \) and in 7 of the studies the specific style of \( \text{yoga} \) was not reported. Nine RCTs compared \( \text{yoga} \) to medication treatment intervention; 1 RCTs compared \( \text{yoga} \) to medication and stretching intervention; 1 RCT compared \( \text{yoga} \) to medication and education intervention. Program duration, frequency, and length varied, ranging from weekly sessions over 6 weeks to daily sessions over 45 days.

The quality of included trials scored 3.2 average points of the total 5 points of the \( \text{Jadad} \) composite scale\(^{18}\). Seven trials were classified as high quality (\( \text{Jadad score} \geq 3 \)), and the remaining 4 trials were classified as low quality (\( \text{Jadad score} < 3 \)). Five studies did not report blinding. One study did not report descriptions of blinding and dropouts.

**Publication bias**

The fail-safe \( N \) for FBS was 146, HbA1c was 44, TC was 80, TG was 99, HDL was 112, LDL was 84, and VLDL was 14 (Table 2). The funnel plots of the outcomes of the included studies are shown in Fig. 2. These results indicate that publication bias was unlikely in this meta-analysis.

**Effect sizes of \( \text{yoga} \) on glycemic control and lipid profiles**

The effect sizes of \( \text{yoga} \) on glycemic control and lipid profiles are demonstrated in Table 2, and forest plots of the outcomes of the included studies in Fig. 3.

**Glycemic control**

Nine studies reported FBS levels. There was statistical heterogeneity among studies (\( Q = 32.93, p < 0.001 \)); random-effects models were in the analysis. The effect size (95 % CI) among studies was -0.70 (-1.03 to -0.36, \( p < 0.001 \)).

Six studies reported HbA1c levels. There was statistical heterogeneity among studies (\( Q = 21.93, p = 0.001 \)); random-effects models were in the analysis. The effect size (95 % CI) among studies was -0.57 (-0.94 to -0.19, \( p = 0.003 \)).

**Lipid profiles**

Five studies reported TC levels. There was statistical heterogeneity among studies (\( Q = 27.68, p = 0.001 \)); random-effects models were in the analysis. The effect size (95 % CI) among studies was -0.86 (-1.43 to -0.29, \( p = 0.003 \)).

Seven studies reported TG levels. There was statistical heterogeneity among studies (\( Q = 32.66, p = 0.001 \)); random-effects models were in the analysis. The effect size (95 % CI) among studies was -0.63 (-0.99 to -0.27, \( p = 0.001 \)).
## Table 1 — Study characteristics

<table>
<thead>
<tr>
<th>Author et al. (year)</th>
<th>Blinding</th>
<th>Randomization</th>
<th>Dropouts</th>
<th>Total</th>
<th>Country</th>
<th>Sample Size &quot;[n]&quot; (Exp./Cont.)</th>
<th>Sex “[n]” M/F</th>
<th>Age, [range] (mean)</th>
<th>DM Duration Years</th>
<th>Yoga group (Drug + Yoga)</th>
<th>Control group:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrawal et al. (2003)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>India</td>
<td><a href="82/72">154</a></td>
<td>108/46</td>
<td>NR</td>
<td>51.45</td>
<td>NR</td>
<td>Drug</td>
</tr>
<tr>
<td>Agte et al. (2004)</td>
<td>NR</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>India</td>
<td><a href="57/30">87</a></td>
<td>41/46</td>
<td>45-65</td>
<td>55.1</td>
<td>NR</td>
<td>Drug</td>
</tr>
<tr>
<td>Gordon et al. (2008)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>Cuba</td>
<td><a href="77/77">154</a></td>
<td>30/124</td>
<td>40-70</td>
<td>63.7</td>
<td>NR</td>
<td>Drug</td>
</tr>
<tr>
<td>Hegde et al. (2011)</td>
<td>NR</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>India</td>
<td><a href="60/63">123</a></td>
<td>NR</td>
<td>40-75</td>
<td>NR</td>
<td>Yoga</td>
<td>Drug</td>
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<tr>
<td>Kanaya et al. (2013)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
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<td><a href="88/83">171</a></td>
<td>47/124</td>
<td>21-65</td>
<td>NR</td>
<td>Restorative yoga</td>
<td>Drug</td>
</tr>
<tr>
<td>Izom et al. (2010)</td>
<td>NR</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>India</td>
<td><a href="30/30">60</a></td>
<td>35/30</td>
<td>35-60</td>
<td>52.9</td>
<td>Yoga</td>
<td>Drug</td>
</tr>
<tr>
<td>Mahapure et al. (2008)</td>
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<td>2</td>
<td>1</td>
<td>3</td>
<td>India</td>
<td><a href="30/10">40</a></td>
<td>27/13</td>
<td>40-55</td>
<td>NR</td>
<td>Yoga</td>
<td>Drug</td>
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<tr>
<td>Monroe et al. (1992)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>England</td>
<td><a href="10/11">21</a></td>
<td>10/11</td>
<td>45-67</td>
<td>55.0</td>
<td>Yoga</td>
<td>Drug</td>
</tr>
<tr>
<td>Shantakumari et al. (2013)</td>
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<td>2</td>
<td>1</td>
<td>4</td>
<td>UAE</td>
<td><a href="50/50">100</a></td>
<td>48/52</td>
<td>NR</td>
<td>45</td>
<td>Yoga</td>
<td>Drug</td>
</tr>
<tr>
<td>Singh et al. (2008)</td>
<td>NR</td>
<td>1</td>
<td>NR</td>
<td>1</td>
<td>India</td>
<td><a href="30/30">60</a></td>
<td>NR</td>
<td>35-60</td>
<td>NR</td>
<td>Yoga</td>
<td>Drug</td>
</tr>
<tr>
<td>Yang et al. (2011)</td>
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<td>2</td>
<td>1</td>
<td>4</td>
<td>U.S.</td>
<td><a href="12/11">23</a></td>
<td>2/21</td>
<td>45-65</td>
<td>51.7</td>
<td>Vinyasa</td>
<td>Drug</td>
</tr>
</tbody>
</table>

NR, not reported; Exp., experimental group; Cont., control group; M, male; F, female; DM, diabetic mellitus

## Table 2 — Effect size of glycemic control and lipid profile

<table>
<thead>
<tr>
<th>Variables</th>
<th>K</th>
<th>Sample size (n)</th>
<th>ES</th>
<th>95 % CI</th>
<th>Z(p)</th>
<th>Q(p)</th>
<th>I²</th>
<th>FSN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycemic control</td>
<td></td>
<td>Exp</td>
<td>Cont</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FBG</td>
<td>9</td>
<td>319</td>
<td>276</td>
<td>-0.700</td>
<td>-1.03--0.36</td>
<td>-4.15 (&lt;.001)</td>
<td>32.93 (&lt;.001)</td>
<td>75.7</td>
</tr>
<tr>
<td>HbA1c</td>
<td>6</td>
<td>268</td>
<td>216</td>
<td>-0.570</td>
<td>-0.94--0.19</td>
<td>-2.95 (.003)</td>
<td>21.52 (.001)</td>
<td>76.7</td>
</tr>
<tr>
<td>Lipid profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>5</td>
<td>231</td>
<td>193</td>
<td>-0.865</td>
<td>-1.43--0.29</td>
<td>-2.98 (.003)</td>
<td>27.68 (&lt;.001)</td>
<td>85.5</td>
</tr>
<tr>
<td>TG</td>
<td>7</td>
<td>396</td>
<td>353</td>
<td>-0.636</td>
<td>-0.99--0.27</td>
<td>-3.43 (.001)</td>
<td>32.66 (&lt;.001)</td>
<td>81.6</td>
</tr>
<tr>
<td>HDL</td>
<td>7</td>
<td>396</td>
<td>353</td>
<td>0.623</td>
<td>0.23--1.01</td>
<td>3.15 (.002)</td>
<td>36.95 (&lt;.001)</td>
<td>83.7</td>
</tr>
<tr>
<td>LDL</td>
<td>5</td>
<td>251</td>
<td>240</td>
<td>-0.781</td>
<td>-1.16--0.39</td>
<td>-3.94 (&lt;.001)</td>
<td>15.31 (.004)</td>
<td>73.8</td>
</tr>
<tr>
<td>VLDL</td>
<td>3</td>
<td>189</td>
<td>179</td>
<td>-0.527</td>
<td>-0.73--0.31</td>
<td>-4.96 (&lt;.001)</td>
<td>1.73 (.420)</td>
<td>0.0</td>
</tr>
</tbody>
</table>

K=Number of studies combined, Q=Heterogeneity, ES=Effect size, FSN=Fail-Safe
Seven studies reported HDL levels. There was statistical heterogeneity among studies ($Q = 33.95, p < 0.001$); random-effects models were in the analysis. The effect size (95% CI) among studies was $0.62 (-0.23 \text{ to } 1.01, p = 0.002)$.

Five studies reported LDL levels. There was statistical heterogeneity among studies ($Q = 15.31, p = 0.004$); random-effects models were in the analysis. The effect size (95% CI) among studies was $-0.78 (-1.16 \text{ to } -0.39, p < 0.001)$.

Three studies reported VDRL levels. There was statistical homogeneity among studies ($Q = 1.73, p = 0.420$); fixed-effects model were in the analysis. The effect size (95% CI) among studies was $-0.52 (-0.73 \text{ to } -0.31, p < 0.001)$. 

Fig. 2 — Funnel plot of the effects of yogic exercise on glycemic control and lipid profiles in type 2 diabetes. Panels are adjusted for (A) FBS, (B) HbA1c, (C) TC, (D) TG, (E) HDL, (F) LDL, and (G) VLDL.
Fig. 3 — Forest plot of the effects of yogic exercise on glycemic control and lipid profiles in type 2 diabetes. Panels are adjusted for 
(A) FBS, (B) HbA1c, (C) TC, (D) TG, (E) HDL, (F) LDL, and (G) VLDL. The effects of yogic exercise on type 2 diabetes generally had 
a moderate to high level on FBS, HbA1c, TC, TG, HDL, LDL, and VLDL levels with standardized mean difference effect sizes(95% CI) 
of -0.70(-1.03 to -0.36), -0.57(-0.94 to -0.19), -0.86(-1.43 to -0.29), -0.63(-0.99 to -0.27), 0.62(0.23 to 1.01), -0.78(-1.16 to -0.39), and 
-0.52(-0.73 to -0.31), respectively (p<0.05).
Discussion

The findings from this meta-analysis by Cohen’s criteria, based on 993 study participants of type 2 diabetes, demonstrate a moderate effect size between yoga exercise and glycemic control, a moderate to high effect size between yoga exercise and lipid profiles in type 2 diabetes. To our knowledge, there have been no previous studies such as a meta-analysis to investigate effects of yoga exercise on type 2 diabetes. Therefore, the researchers compared our findings with similar studies that reported effects of yoga practice on type 2 diabetes. These findings are similar to that of study reporting that a general effect of yoga on diabetic patients was most prominent in fasting plasma glucose (FPG) levels and lipid profiles. Using Ovid, it reviewed yoga practice systematically for the management of type 2 diabetes in adults to the end of May 2007. From the review of four type 2 diabetes studies, the researchers reported that between the yoga intervention and control group, yoga intervention provided favorable results in significantly lowering FPG. Compared to non-yoga, they also suggested that yoga intervention lowered HbA1c levels. Similarly, they also pointed out that yoga intervention had a positive effect on lowering lipid profile values such as TC, LDL and in increasing the level of HDL. Our findings also support that of another study which systematically reviewed original studies published from 1970 to 2006 on the influence of yoga-based programs on risk profiles in adults with type 2 diabetes. The researchers indicated that compared with patients who had non-yoga, those who had yoga had significantly lower levels of FBS and HbA1c. They also suggested that yogic practice and yoga-based programs demonstrated significant improvement in lipid profiles such as TC, TG, HDL, LDL, and VLDL. That is, observed improvements in blood lipid fractions included reductions in TC, TG, LDL, and VLDL, and an increase in HDL. Additionally, these findings support that a study was appropriate to provide evidence to elucidate the effects of yoga programs in type 2 diabetes. However, additional studies, including subgroup parameters taking into consideration participants and yoga intervention characteristics are needed to confirm the effects of standardized yoga programs in type 2 diabetes. The quality of these included studies showed slightly higher levels using the Jadad scale. Generally the low quality of included studies for a meta-analysis could result from methodological deficiencies such as randomization, allocation concealment, blinding, reasonable dropout or withdrawal rates, non-selective reporting of outcomes, selection bias, statistical analysis, or usage of multiple interventions and adjustment for confounders. These were noticed with varying degrees among the included studies. Five studies of the included studies did not report blinding. And one study did not report descriptions of blinding and dropouts. Therefore additional studies are needed using rigorous study methodologies including the specific use of randomization, dropouts and blinding of researchers. Publication bias assessed for the different outcomes was reported by the trials to assess if there was any evidence suggesting a bias that would lead to publication of specific trials and not others. The bias coefficient from weighted regression was not significant for all of the included studies and the numbers of the studies with negative results that could cause the effect of yoga practice on the outcome variables, FBS, HbA1c, TC, TG, HDL and LDL to the null were 146, 44, 80, 99, 112 and 84. The results indicate that publication bias was unlikely to occur in this meta-analysis. But FSN of VLDL was 14. There is a possibility that VLDL has publication bias. This meta-analysis also has several strengths that should be considered. Only RCTs were included in our investigation, which enhances the quality of our results. Furthermore, the present study is, to our knowledge, the first meta-analysis study of RCTs to examine the effects of yogic exercise on type 2 diabetes using publications from 1966 to 2013.

Our study also has limitations. First, we reviewed studies published only in the English language and publication bias or language bias may be possible. However, results of the fail-safe N for outcome variables by Rosenthal’s method, indicated that publication bias of these included studies was not observed. Second, the heterogeneity of our findings due to small size studies may interfere with actual effects sizes, nevertheless these findings used a random effects model to remedy this limitation.
Conclusion

In summary, yoga exercise among patients with type 2 diabetes showed favorable outcomes. These improvements were mainly physiological parameters such as FBS, HbA1c, TC, TG, HDL, LDL, and VLDL in type 2 diabetes. Factors like blinding of the study qualities and intervention characteristics should be taken into consideration. And additional high quality RCTs are needed to confirm and further elucidate the effects of standardized yoga programs in populations with type 2 diabetes.

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