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Review

The effectiveness of regular leisure-time physical activities on long-term glycemic control in people with type 2 diabetes: A systematic review and meta-analysis

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ABSTRACT

The objective of this study was to systematically review the effectiveness of different types of regular leisure-time physical activities and pooled the effect sizes of those activities on long-term glycemic control in people with type 2 diabetes compared with routine care. This review included randomized controlled trials from 1960 to May 2014. A total of 10 Chinese and English databases were searched, following selection and critical appraisal, 18 randomized controlled trials with 915 participants were included. The standardized mean difference was reported as the summary statistic for the overall effect size in a random effects model. The results indicated yoga was the most effective in lowering glycated haemoglobin A1c (HbA1c) levels. Meta-analysis also revealed that the decrease in HbA1c levels of the subjects who took part in regular leisure-time physical activities was 0.60% more than that of control group participants. A higher frequency of regular leisure-time physical activities was found to be more effective in reducing HbA1c levels. The results of this review provide evidence of the benefits associated with regular leisure-time physical activities compared with routine care for lowering HbA1c levels in people with type 2 diabetes.

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1. Introduction

Diabetes is one of the leading causes of mortality throughout the world [1]. Type 2 diabetes is a chronic disease characterized by a lack of insulin or the ineffective use of insulin by the human body, often associated with lifestyle factors such as a lack of physical activity and obesity. The consequences of long-term hyperglycemia include neurological or vascular complications, which may result in amputation, retinopathy, kidney failure, or other severe complications [3,4].

Effective strategies for glycemic control in patients with type 2 diabetes include strict compliance to medications, a suitable diet, and regular physical activity [2]. Randomized controlled studies have shown that regular physical activity effectively lowers blood sugar levels in people with type 2 diabetes in the short term and lowers glycated haemoglobin A1c (HbA1c) levels in the long term. Among these physical activities, aerobic physical activities and resistance training are more beneficial [5–7]. Therefore, the World Health Organization and American College of Sports Medicine (ACSM) suggests that type 2 diabetes patients should maintain at least 150 min of moderate intensity exercise or 90 min of vigorous intensity exercise every week as part of glycemic control [2,8]. The types of physical activities can be further classified into housework, leisure-time physical activities, and physical activities at work. Leisure-time physical activity is defined as physical activity practiced during leisure time [35]. If patients with diabetes increase the amount of leisure-time physical activities in addition to housework and physical activities at work, it would provide additional benefit for glycemic control [9]. In addition, regular leisure based physical activity has been associated with better self-rated health among people with diabetes [10]. Kaizu et al. [11] investigated the effect of leisure-time physical activities on glycemic control and cardiovascular risk factors in 4870 patients with type 2 diabetes. The study found that a high participation rate in leisure-time physical activities correlated with good control of HbA1c levels [11].

Appropriate leisure-time physical activities in type 2 diabetes patients included hula hoop, jogging, walking, gardening, yoga, tai chi, qigong, swimming, dancing, cycling [12]. Previous systematic reviews or meta-analyses have demonstrated a beneficial effect of leisure-time physical activities on glycemic control in type 2 diabetes patients. For example, the meta-analysis by Qiu et al. found a positive association between regular walking exercises, lower HbA1c levels, body mass index, and diastolic blood pressure [13]. However, meta-analyses to date have only focused on single leisure-time physical activities [14], or included control groups that did not receive routine care [15]. No systematic reviews have been published to date that systemically explore the effectiveness of different types of regular leisure-time physical activities and pooled the effect sizes of those activities on glycemic control compared with routine care.

The objective of this study was to conduct a thorough and comprehensive systemic review of randomized controlled studies, using meta-analysis to provide a pooled estimate of the beneficial effects of different types and overall regular leisure-time physical activities on long-term glycemic control in patients with type 2 diabetes. This study also compared the effect of different frequency of leisure-time physical activities on long-term glycemic control.

2. Methods

2.1. Search strategy

The date range of the included databases was from 1960 to May 2014 and included English language and Chinese language papers. The databases searched were CINAHL Plus with Full Text, PubMed, Academic Search Complete, The Cochrane Central Register of Controlled Trials, Medline, SPORTDiscus with Full Text, Embase, Web of Science, Science Direct, and Airiti Library. The initial key words were identified in the Medical Subject Headings (MESH) database. The keywords included ‘‘diabetes’’, ‘‘exercise’’, ‘‘yoga’’, ‘‘tai chi’’, "walking", "swimming", "gardening", "qigong", "jogging", "riding a bicycle", "cycling", "dancing", "glycemic control", and "haemoglobin A1c (HbA1c)". Then, the authors used the key words to construct database specific search strings and run those in the databases to identify potential papers.

2.2. Inclusion and exclusion criteria

The intervention of interest was (1) quantitative leisure-time physical activities intervention for patients with type 2 diabetes. (2) The participants of interest were adults over 18 years of age diagnosed with type 2 diabetes mellitus, being treated with either oral medicine, or insulin injection treatment. (3) The preferred study design sought was randomized controlled studies. (4) The leisure-time physical activities included "yoga", "tai chi", "walking", "swimming", "gardening", "qigong", "jogging", "riding a bicycle", "cycling", and "dancing", (5) the interventions had to have a duration of at least 8 weeks and could not be in combination with any other regular educational interventions; be implemented at least 2 to 3 times per week, with a duration at least 30 min per episode. (6) The primary outcome of interest was the HbA1c levels (%). HbA1c levels reflect the long-term average glycemic control level in a subject over the previous 2 to 3 months [16]. The control group must have received routine care as advised by clinical professionals, which included medications, dietary control and general physical activities.

Studies were excluded from this review if participants had recently undergone serious operations, had a myocardial infarction, stroke, severe liver or kidney diseases, or any illness limiting participation in a physical activity program; or who were participating in an alternate physical exercise program at the same time.

2.3. Assessment of methodological quality and data extraction

This systematic review used a critical appraisal instrument developed by the Joanna Briggs Institute [44]. The appraisal instrument included the following criteria: whether (1) subjects were randomly assigned in the intervention group; (2) subjects in the intervention group were aware of which group they were in; (3) subject assigners were aware of which subject received intervention; (4) there were descriptions of subjects who exited the study midway and whether these cases were included in the analyses; (5) the reviewers were aware of who was in the intervention group; (6) the subjects in the control and intervention groups were homogenous before entering the study; (7) other conditions were consistent across the two groups besides the intervention; (8) the methods measuring effectiveness were the same in the two groups; (9) effectiveness was conducted in a reliable manner; (10) appropriate follow up >80%; and (11) appropriate statistical methods were used. Each criterion was assessed and classified into one of the three options: "Yes", "No", or "unclear". Study quality was scored on a scale of 0–11. Two authors who had received training used the appraisal instrument independently to evaluate the quality of each study. No disagreements between raters required arbitration by a third author.

2.4. Statistical methods

Quantitative results were pooled in a statistical meta-analysis using Review Manager (5.2) software. The effect size was calculated by taking the difference in mean and standard deviation of HbA1c levels 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 was calculated using the mean and standard deviation of HbA1c levels after the treatment in both groups. The standardized mean difference (SMD) (and 95% Confidence Intervals) was 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 meta-analysis. Subgroup analysis was used to evaluate the effect of different types of leisure-time physical activities on HbA1c levels.

3. Results

3.1. Searching

Fig. 1 illustrates the keywords and searching process used to conduct the literature search. There were a total of 2192 articles identified through keyword searches from across the 10 databases. Each of the 2192 articles were individually screened by title resulting in 2113 articles not being selected for full paper retrieval. The abstracts of 79 potentially relevant articles was then independently screened by two reviewers. Subsequently 42 studies were excluded because they did not meet the inclusion criteria outlined in Section 2.2. The full text of 37 articles was reviewed and following critical appraisal, 18 were included in this systematic review. On critical appraisal, the included studies scored between 9 and 11, indicating a low risk of bias.

3.2. Description of study characteristics

The characteristics of the included studies are reported in Table 1 [17–34]. Eleven of the included randomized controlled trials compared before and after HbA1c levels within the experimental and control groups. The remaining seven compared the before-and-after difference in HbA1c levels between the two groups. The intervention period lasted from 8 weeks to 24 weeks, and intervention durations lasted between 90 and 720 min. Participants across the included studies were between the ages of 35 and 71, with slightly more females (65%) than male participants (35%). The majority of the subjects were recruited through hospital outpatient clinics (67%) followed by community centres (22%) and advertising (11%). The study locations included the United States, the United Kingdom, India, Denmark, Italy, Korea, Mainland China and Taiwan. The types of intervention reported in the study included walking (8), tai chi (2), qigong (3), yoga (5).

3.3. Meta-analysis

3.3.1. Subgroup analysis and combined effect of regular leisure-time physical activities on HbA1c levels

The funnel plot suggested symmetry indicating low risk of publication bias (Fig. 2). Fig. 3 illustrates the effect of different

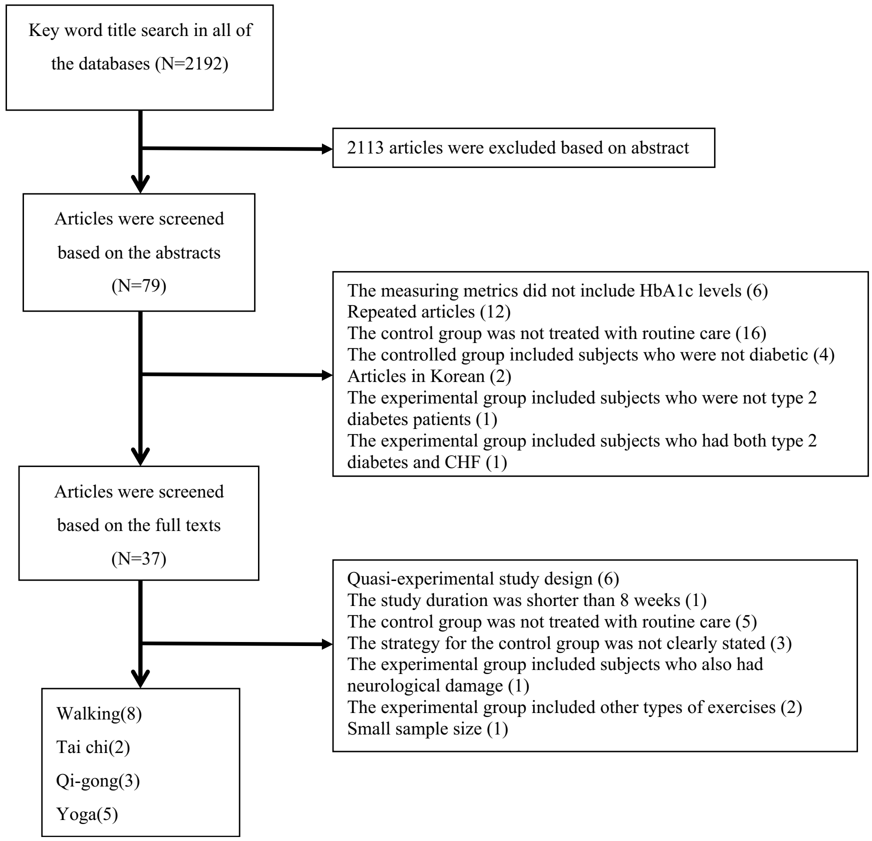

Fig. 1 – Search process.

types of regular leisure-time physical activities on HbA1c levels based on subgroups. The I^2 statistic for walking and yoga groups was greater than 50%, indicating heterogeneity. However, since the direction of the effects was the same, a random effects model was used. The results indicated that yoga was the most effective in lowering HbA1c levels (SMD–0.81, 95% CI: −1.22 to −0.39), followed by tai chi (SMD −0.75, 95% CI: −1.15 to −0.35) and walking (SMD −0.56, 95% CI: −0.92 to −0.20). Of the included interventions, qigong SMD −0.04, 95% CI: −0.49 to 0.41) showed no statistical benefit. As the walking and yoga group results demonstrated heterogeneity, subgroup analyses were performed to analyze frequency per week of each physical activity. These subgroup analyses showed that heterogeneity decreased when the frequency per week of each physical activity was taken into account. Further to this, the higher the frequency of these activities the more effective they were in reducing HbA1c levels (Table 2).

The sum of the I^2 statistic for the combination of all regular leisure-time physical activities was also greater than 50%, indicating heterogeneity. Using a random effects model to explore the data, showed that the effect on HbA1c levels was 0.60% higher in the experimental group than the control group (SMD −0.60, 95% CI: −0.83 to −0.37, $I^2 = 93\%$). Subgroup analysis on those studies which compared differences in the before-and-after HbA1c levels between the two groups showed the effect on HbA1c levels was 0.41% (SMD −0.41, 95% CI: −0.63 to −0.20, $I^2 = 30\%$).

4. Discussion

4.1. *The effect of different types of regular leisure-time physical activities and pooled the effect sizes of those activities on lowering HbA1c levels*

Subgroup analyses explored the effects of specific types of regular leisure time physical activity. The result showed that yoga was the most effective activity for lowering HbA1c levels, followed by tai chi and walking. The benefits may be due to both tai chi and yoga being aerobic physical activities incorporating breathing techniques and body movement that burn calories. This result is consistent with other major studies that support the benefits of aerobic physical activities in patients with diabetes [13,36–39].

However, it should be noted that, the I^2 statistic was highly significant for heterogeneity for the pooled estimate of effect for yoga and walking. Heterogeneity decreased when subgroup analysis was based upon the frequency per week of the physical activity in the yoga and walking groups (Table 2). Each sub group analysis with higher frequency may cause an increase in the effect variance related to frequency of the each intervention study, which may then increase in the variance and thus lead to greater heterogeneity [45]. The higher the frequency of these activities the more effective they were in reducing HbA1c levels.

Table 1 – Characteristics of the included studies.

First author(year)/ country	Type	Design/ recruitment method	Number of group	Sex (N)	Age (y/o)	Duration/ frequency
Gram(2010)/ Denmark [17]	Walking	RCT/Clinics	Experimental group (N = 22) Control group (N = 22)	Experimental group F/M 12/10 Control group F/M 9/13	Age 62 ± 10 Age 61 ± 10	24 weeks/30 min per session, 5 times a week
Shenoy(2010)/India [18]	Walking	RCT/Community	Experimental group (N = 20) Control group (N = 20)	Experimental group F/M 5/15 Control group F/M 6/14	Age 53.15 ± 4.4 Age 51 ± 5.4	8 weeks/35–40 min per session, 5 times a week
Sung(2012)/Korea [19]	Walking	RCT/Clinics	Experimental group (N = 22) Control group (N = 18)	Experimental group F/M 15/7 Control group F/M 11/7	Age 70.2 ± 4.7 Age 70.1 ± 3.6	24 weeks/50 min per day, thrice a week
Karstoft(2013)/ Denmark [20]	Walking	RCT/ Advertisement and diabetes organization	Experimental group (N = 12) Control group (N = 8),	Experimental group F/M 4/8 Control group F/M 3/5	Age 60.8 ± 2.2 Age 57.1 ± 3.0	24 weeks/60 min per session, 5 times a week
Arora(2009)/India [21]	Walking	RCT/Clinics	Experimental group (N = 10) Control group (N = 10)	Experimental group F/M 4/6 Control group F/M 4/6	Age 65.8 ± 3.2 Age 64.4 ± 3.8	8 weeks/30 min per day, thrice a week
Negri(2010)/Italy [22]	Walking	RCT/Clinics	Experimental group (N = 21) Control group (N = 21)	Experimental group Age 65.7 ± 4.9 Control group Age 65.7 ± 5.2		16 weeks/45 min per day, thrice a week
Ku(2010)/Korean [23]	Walking	RCT/Clinics	Experimental group (N = 15) Control group (N = 16)	Experimental group F/M 15/0 Control group F/M 16/0	Age 55.7 ± 7.0 Age 57.8 ± 8.1	12 weeks/60 min per session, 5 times a week
Koo(2010)/Korean [24]	Walking	RCT/Clinics	Experimental group (N = 13) Control group (N = 18)	Experimental group F/M 13/0 Control group F/M 18/0	Age 59 ± 4 Age 57 ± 8	12 weeks/120 min every day
Vaishali(2008)/India [25]	Yoga	RCT/Clinics	Experimental group (N = 27) Control group (N = 30)	Experimental group F/M 13/14 Control group F/M 8/22	Age 65.8 ± 3.2 Age 64.4 ± 3.8	12 weeks/45–60 min per session, 6 times a week
Skoro-Kondza(2009)/ United Kingdom [26]	Yoga	RCT/ Community	Experimental group (N = 29) Control group (N = 30)	F/M 36/13	Age 60 ± 10	12 weeks/90 min per session, twice a week
Gordon(2008)/India [27]	Yoga	RCT/Clinics	Experimental group (N = 77) Control group (N = 77)	Experimental group F/M 62/15 Control group F/M 62/15	Age 63.8 Age 63.8	24 weeks/60 min per session, 3–4 times a week
Hegde(2011)/India [28]	Yoga	RCT/Clinics	Experimental group (N = 60) Control group (N = 63)	Experimental group Age 59.8 ± 9.9 Control group Age 57.5 ± 8.9		12 weeks/At least 3 days a week
Jyotsna(2012)/India [29]	Yoga	RCT/Clinics	Experimental group (N = 27) Control group (N = 22)	Experimental group F/M 9/18 Control group F/M 10/12	Age 50.59 ± 10.11 Age 45.27 ± 10.31	12 weeks/60 min per day, thrice a week
Lam(2008)/Australian [30]	Tai chi	RCT/ Advertisement	Experimental group (N = 28) Control group (N = 25)	Experimental group F/M 13/15 Control group F/M 16/9	Age 63.2 ± 8.6 Age 60.7 ± 12.2	24 weeks/60 min per session, twice a week
Youngwanichsetha(2013)/ Thailand [31]	Tai chi	RCT/ Clinics	Experimental group (N = 32) Control group (N = 32)	Experimental group F/M 32/0 Control group F/M 32/0	Age 35.0 ± 5.63 Age 36.16 ± 4.84	12 weeks/50 min per session, 3 times a week

Table 1 (*Continued*)

First author(year)/ country	Type	Design/ recruitment method	Number of group	Sex (N)	Age (y/o)	Duration/ frequency
Sun(2010)/ United States [32]	Qigong	RCT/community	Experimental group (N = 11) Control group (N = 11)	Sex- and age-matched Age 56.3 ± 8.1		12 weeks/30 min per session, twice a week
Liu(2011)/ Australia [33]	Qigong	RCT/community	Experimental group (N = 20) Control group (N = 21)	Experimental group F/M 9/11 Control group F/M 16/5	Age 41–71 Age 41–71	12 weeks/60–90 min per session, every day
Tsujiuchi(2002)/ Japan [34]	Qigong	RCT/Clinics	Experimental group (N = 16) Control group (N = 10)	Experimental group Age 65.3 ± 7.7 Control group Age 59.1 ± 9.0		24 weeks/60 min per session, twice a week

The random control studies included in this study all lasted more than 8 weeks, and we thus inferred that intervention measures for leisure physical activities must be longer than 8 weeks to effectively lower glycated haemoglobin levels. Therefore, our study strengthens the evidence that the duration of physical activity should be greater than 8 weeks in order to effectively lower HbA1c levels [40,41]. In addition, the majority of the articles included in this study had a weekly physical activity time close to or greater than 150 min. This corresponds to the recommendation by the World Health Organization that patients with type 2 diabetes should maintain a weekly physical activity time of more than 150 min [2]. The results also showed that qigong had no effect on glycemic control in type 2 diabetes patients. This might be due to the limited number of studies or the small sample sizes in the included studies. Due to the limited number of studies on qigong, further randomized controlled trials with larger sample sizes are recommended to increase the certainty of this finding.

We also pooled the effect sizes of those activities on lowering HbA1c levels. This review showed that by engaging in regular leisure-time physical activities, the experimental group's HbA1c levels were 0.60% lower than that of the control group, indicating that regular leisure-time physical activities effectively aid long-term glycemic control.Therefore, this review provides evidence of the beneficial complementary effects of regular leisure-time physical activities compared with the routine care on lowering blood sugar in people with type 2 diabetes.

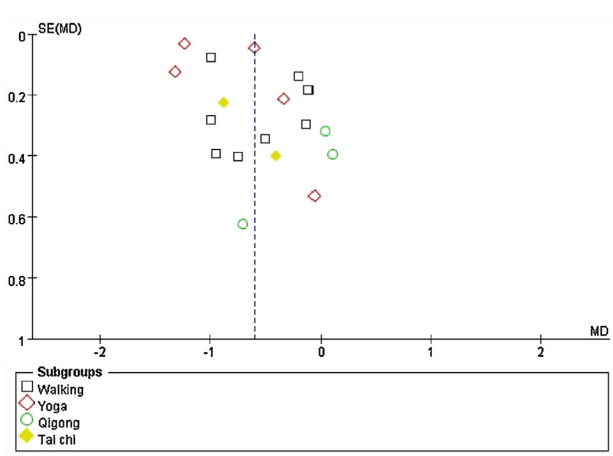

Fig. 2 – Analysis of publication bias on a funnel plot. MD = mean difference, SE = standard error.

4.2. *Discussion of correlation between gender and participation in regular leisure-time physical activities*

As reported in Table 1, there were more females (65%) than males (35%) who participated in regular leisure-time physical activities. This might be due to a higher prevalence of type 2 diabetes in females than males [42], or that males have a lower usage rate of healthcare resources than females. Krämer et al. [43] conducted a study on the rate of healthcare usage across 1146 patients with type 2 diabetes. Study results showed that males had a lower healthcare resource usage rate than females, and more males (23%) had poorer glycemic control than females (18%) [43].

Therefore, it is recommended that healthcare professionals must pay more attention to male patients with type 2 diabetes and encourage them to participate in regular leisure-time physical activities. This could help increase the participation rate of males in regular leisure-time physical activities and help achieve ideal glycemic control.

4.3. *Study limitations*

Among the randomized controlled studies that were included in this study, the majority compared the before and after HbA1c levels within the experimental and control group without comparing the difference in the before-and-after HbA1c levels between the two groups. It is suggested that future studies compare the difference in the before-and-after HbA1c levels between the two groups to increase the quality and reliability of trial outcomes. Further to this, the inclusion criteria in this systematic review were quite strict when comparing the effect of single regular leisure-time physical activity to routine care on lowering HbA1c levels; this reduced the number of articles able to be pooled, which affected statistical power. Finally, this review only included Chinese and English articles. Therefore, local databases in other countries were not used in the search, thus limiting the inference of the study.

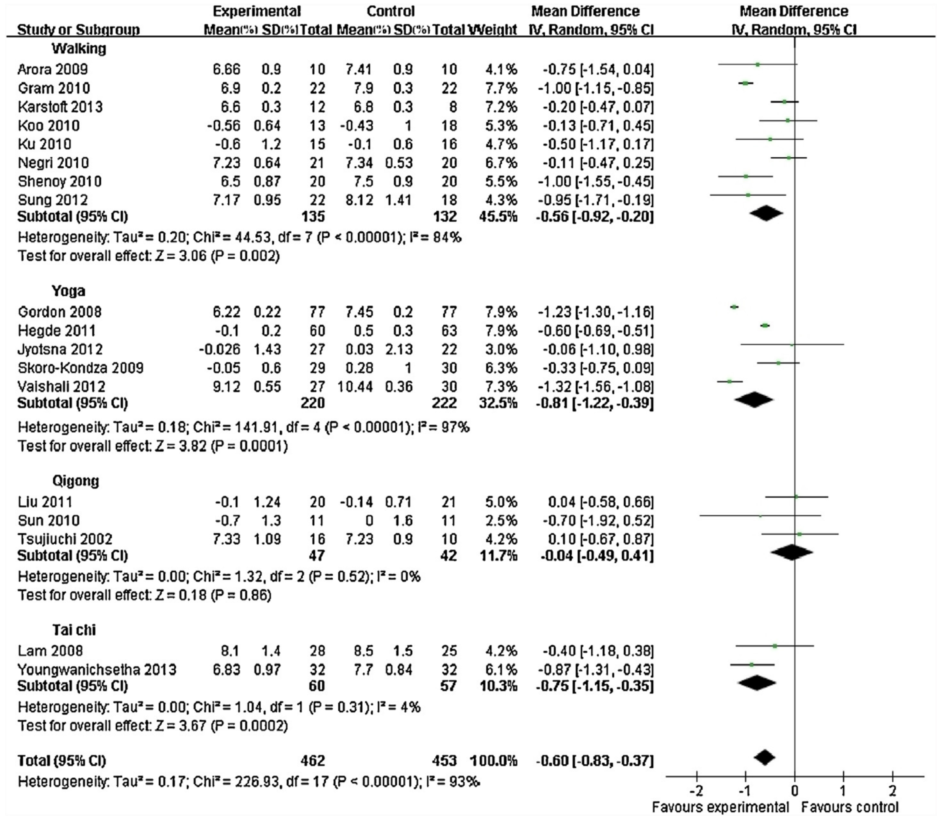

Fig. 3 – Effect of regular leisure-time physical activities on HbA1c levels.

Table 2 – Analysis of the effect of different types of regular leisure-time physical activities on glycemic control in type 2diabetic subjects based on subgroups.

Variable	Subgroup	N	SMD[b] (95% CI)	I^2	*df*	*P*
HbA1C[a]						
Walking	<5 times/per week	3	−0.52 (−1.09,0.06)	61%	2	0.08
	≧5 times/per week	5	−0.58 (−1.04,−0.12)	88%	4	<0.01
Yoga	≦3 times/per week	2	−0.29 (−0.68,0.10)	0%	1	0.63
	>3 times/per week	3	−1.04 (−1.53,−0.56)	98%	2	<0.01
Tai chi	2	−0.75 (−1.15,−0.35)	4%	1	0.31	
Qigong	3	−0.04(−0.49,0.41)	0%	2	0.52	

[a] HbA1C = glycated haemoglobin A1c (%).
[b] SMD = standardized mean difference.

Conflict of interest statement

No actual or potential conflicts of interest exist.

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