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REVIEW ARTICLE

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EFFECTS OF TAI CHI ON PHYSIOLOGY, BALANCE AND QUALITY OF LIFE IN PATIENTS WITH TYPE 2 DIABETES: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Objective: **To systematically synthesize and critically evaluate evidence on the effects of tai chi for patients with type 2 diabetes mellitus.**

Data sources: **Seven electronic databases (Wan Fang, SinoMed, China National Knowledge Infrastructure, VIP, PubMed, Embase, and Cochrane Library) were systematically searched from their inception to March 2018.**

Study selection: **Randomized controlled trials investigating the effects of tai chi on individuals with type 2 diabetes mellitus were eligible.**

Data extraction: **Biomedical outcomes (fasting plasma glucose, glycosylated haemoglobin (HbA1c), fasting insulin, insulin resistance, body mass index, total cholesterol, blood pressure) as well as balance and quality of life-related outcomes were extracted independently by 2 reviewers. Stata 12.0 software was used to synthesize data if there was no or moderate heterogeneity across studies. Otherwise, narrative summaries were performed.**

Data synthesis: **A total of 23 studies (25 articles) involving 1,235 patients were included in this meta-analysis. Significant changes in tai chi-related effects were observed in lowering fasting plasma glucose (standardized mean difference; SMD −0.67; 95% confidence interval (95% CI) −0.87 to −0.47; $p<0.001$), HbA1c (mean difference; MD−0.88%; 95% CI −1.45% to −0.31%; $p=0.002$) and insulin resistance (MD −0.41; 95% CI −0.78 to −0.04; $p=0.029$). Beneficial effects of tai chi were also found in decreasing body mass index (MD −0.82 kg/m²; 95% CI −1.28 to −0.37 kg/m²; $p<0.001$) and total cholesterol (SMD −0.59; 95% CI −0.90 to −0.27; $p<0.001$). In addition, tai chi reduced blood pressure (systolic blood pressure (MD −10.03 mmHg; 95% CI −15.78 to −4.29 mmHg; $p=0.001$), diastolic blood pressure (MD −4.85 mmHg; 95% CI −8.23 to −1.47 mmHg; $p=0.005$)) and improved quality of life-related outcomes (physical function (MD 7.07; 95% CI 0.79–13.35; $p=0.027$), bodily pain (MD 4.30; 95% CI 0.83–7.77; $p=0.015$) and social function (MD 13.84; 95% CI 6.22–21.47; $p<0.001$)). However, no impact was exerted on fasting insulin (SMD −0.32; 95% CI −0.71 to 0.07; $p=0.110$) or balance (MD 2.71 s; 95% CI −3.29 to 8.71 s; $p=0.376$).**

Conclusion: **Tai chi is effective in controlling biomedical outcomes and improving quality of life-related outcomes in individuals with type 2 diabetes mellitus, although no effects were observed on balance and fasting insulin. Further high-quality research is needed to elucidate the effects of different types of tai chi, the long-term effects of tai chi, the impact on respiratory function, and the association between tai chi and the risk of developing type 2 diabetes mellitus in healthy individuals.**

Key words: tai chi; type 2 diabetes mellitus; meta-analysis; systematic review.

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A review of research into the effects of tai chi for patients with type 2 diabetes mellitus was carried out. The results indicate that tai chi is favourable in improving outcomes in some areas, e.g. fasting plasma glucose, glycosylated haemoglobin (HbA1c), total cholesterol, balance, and quality of life. However, differences between study methods limit the conclusions regarding some outcomes. Tai chi might be a suitable complementary therapy for individuals with type 2 diabetes mellitus.

Diabetes mellitus (DM) is a metabolic disturbance characterized by an increase in blood glucose levels due to insulin deficiency and/or resistance. During the past decades, there has been a sharp increase in the prevalence of DM worldwide (1). In 2003, the World Health Organization (WHO) predicted that the number of patients with diabetes would increase to 370 million by 2030 (2). DM is regarded as one of the major threats to public health (3). There are 2 main types of DM: type 1 diabetes mellitus (T1DM), caused by the

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destruction of pancreatic β-cells; and type 2 diabetes mellitus (T2DM) caused by insulin resistance or impaired insulin secretion. T2DM is the most prevalent form of diabetes, patients are more likely to usually develop diabetic ketoacidosis (4) and damage can occur to tiny blood vessels and nerves. For patients with T2DM, the duration of the disease influences the severity of diabetic neuropathy, increasing activity limitations (5). In addition, patients are more likely to develop cardiovascular and Alzheimer's disease, as well as various cancers (1). T2DM is a chronic disease, exerting an adverse influence on the daily life of patients and imposing a burden on their finances. Therefore, great emphasis should be placed on disease nursing for patients with diabetes.

Tai chi (also known as tai ji or tai chi quan), originating from ancient China, is a mind-body exercise characterized by mild or moderate aerobic activity. It is also an effective muscle strength training for the upper and lower extremities. Tai chi is currently often recognized as a physical fitness technique in our society, especially for middle-aged or elderly people (6). There are several styles of tai chi; Yang, Chen, Sun and Wu styles are commonly practiced in daily life, and the Yang style is the most popular among the public, while the Chen style is viewed as the oldest (7). The Yang style is typical of its concise movement, while the Wu style is more notable for gentle action. Movement in the Chen style varies during the whole process, while the Sun style is well known for coherence (8). However, different types of tai chi have a common method. All of the styles involve continuous, gentle and slow movements involving balance, strengthening, breath control, mental concentration and relaxation (9). Tai chi can therefore play a role in both physical and mental rehabilitation. Some studies have suggested that tai chi has favourable effects on a variety of factors, including cardiovascular protection (10), fall prevention (11), balance (12), flexibility (13), depression (14) and quality of life (QoL) (15). Tai chi has potential benefits in treating different diseases, including chronic obstructive pulmonary disease (16), Parkinson's disease (17), osteoarthritis (18) and stroke (19). Thus, tai chi may be a suitable exercise for individuals with chronic diseases (9, 20).

Compared with pharmacological therapy, tai chi is an economical treatment, and can be performed wherever convenient, and is less likely to result in adverse effects (21). As a mind-body exercise, tai chi may have effects on both physical and mental well-being. Individuals who perform tai chi are reported to tend to have better psychological health (7). Given the above strengths, tai chi may be a suitable complementary treatment for patients with T2DM; thus it is critical to elucidate its effects on such patients. Although some systematic reviews (22–25) have been performed to evaluate the effectiveness of tai chi for patients with T2DM, no definite conclusions have been drawn. First, discrepancies existed in the conclusions of those reviews. Lee et al. (22), Yan et al. (23) and Lee et al. (24) reported that tai chi did not reduce fasting plasma glucose (FPG), glycosylated haemoglobin (HbA1c), or insulin resistance (IR), and they did not find that tai chi was an effective rehabilitation therapy for T2DM. On the other hand, Huang & Yeh (25) indicated that tai chi was effective in improving HbA1c and FPG. Furthermore, it is inappropriate for some reviews (23, 24) to combine data from studies with different designs or methods, as this might lead to high heterogeneity. In addition, since these reviews were published a long time ago, the evidence should be updated.

For some patients with T2DM, the main pathological change is IR, which in turn contributes to the high concentration of fasting insulin (FIN) in peripheral blood. Therefore, FIN may be regarded as a medical indicator reflecting IR to a certain degree. Patients with T2DM are more vulnerable to diabetic neuropathy, foot ulceration and nerve damage due to infection (26). Postural instability, which is common in diabetic sensory neuropathy, could increase the risk of minor foot trauma (27). Improvement in stability is a prerequisite for normal physical activity. Moreover, patients with T2DM are under great pressure to treat themselves, and they usually have lower QoL compared with healthy individuals (28). QoL is one of the comprehensive indicators for evaluating self-management of disease and therapeutic effects, and thus QoL may be an appropriate target for treatments in patients with T2DM. However, whether tai chi training could improve these outcomes remains controversial, and no relevant content was reported in the above reviews.

The objective of this review was therefore to synthesize and critically evaluate the published evidence on the effects of tai chi on FPG, HbA1c, IR, FIN, body mass index (BMI), total cholesterol (TC), blood pressure (BP), balance and QoL among individuals with T2DM.

METHODS

Data sources

Seven electronic databases (Wan Fang, SinoMed, China National Knowledge Infrastructure, VIP, PubMed, Embase, and Cochrane Library) were searched for eligible publications from their inception to March 2018. The following search terms were used: "tai ji", "tai ji quan", "tai chi", "tai chi chuan", "type 2 diabetes mellitus", "noninsulin-dependent diabetes", "maturity-onset diabetes". Variations and synonyms of these search terms were used in order to perform an overall and systematic search. In addition, the reference lists of all related literature were reviewed to identify potentially eligible studies. The detailed search strategy for PubMed is shown in Table I.

Study selection

Titles and abstracts of retrieved literature were independently screened by 2 reviewers (ZL. Z and RZ. Z) according to predefined eligibility criteria. Full-text reading was performed for studies whose relevance could not be determined from their titles and abstracts. During study selection, discrepancies were discussed until consensus was reached.

More specifically, included studies had the following features (PICOS criteria: Participants, Interventions, Comparisons, Outcomes, Study design).

Participants

Patients diagnosed with T2DM age > 18 years.

Study design

Only randomized controlled trials (RCTs) published in Chinese or English were included in this meta-analysis. Systematic reviews, meta-analyses or reference papers were excluded. Studies were also excluded if outcome data were not available even though attempts were made to contact the authors.

Interventions

Tai chi, regardless of type, must be performed by participants in the intervention group of included studies. Studies were excluded if the intervention was tai chi combined with other treatments. No restriction was imposed on location (community/hospital, outdoors/indoors), format (group/individual), intensity, frequency or duration of treatment.

Comparisons

The control group received "usual care or exercise", "sham exercise", or "no intervention". All the conditions except the treatment of intervention group should be comparable with those of control group.

Table I. Search strategy for PubMed

Search	Query
#1	Diabetes Mellitus, Noninsulin-Dependent [Title/Abstract] OR Diabetes Mellitus, Ketosis-Resistant [Title/Abstract] OR Ketosis-Resistant Diabetes Mellitus [Title/Abstract] OR Diabetes Mellitus, Non-Insulin-Dependent [Title/Abstract] OR Non-Insulin-Dependent Diabetes Mellitus [Title/Abstract] OR Diabetes Mellitus, Stable [Title/Abstract] OR Stable Diabetes Mellitus [Title/Abstract] OR Diabetes Mellitus, Type II [Title/Abstract] OR NIDDM [Title/Abstract] OR Diabetes Mellitus, Maturity-Onset [Title/Abstract] OR Maturity-Onset Diabetes Mellitus [Title/Abstract] OR MODY [Title/Abstract] OR Diabetes Mellitus, Slow-Onset [Title/Abstract] OR Slow-Onset Diabetes Mellitus [Title/Abstract] OR Type 2 Diabetes Mellitus [Title/Abstract] OR Noninsulin-Dependent Diabetes Mellitus [Title/Abstract] OR Maturity-Onset Diabetes [Title/Abstract] OR Diabetes, Maturity-Onset [Title/Abstract] OR Type 2 Diabetes[Title/Abstract] OR Diabetes, Type 2 [Title/Abstract] OR Diabetes Mellitus, Adult-Onset [Title/Abstract] OR Adult-Onset Diabetes Mellitus [Title/Abstract]
#2	Diabetes Mellitus, Type 2 [Mesh]
#3	#1 OR #2
#4	Tai-ji [Title/Abstract] OR Tai Chi [Title/Abstract] OR Chi, Tai [Title/Abstract] OR Tai Ji Quan [Title/Abstract] OR Ji Quan, Tai [Title/Abstract] OR Quan, Tai Ji [Title/Abstract] OR Taijiquan [Title/Abstract] OR T'ai Chi [Title/Abstract] OR Tai Chi Chuan [Title/Abstract]
#5	Tai Ji [Mesh]
#6	#4 OR #5
#7	#3 AND #6

Outcomes

FPG, HbA1c, FIN, IR, BMI, TC, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were used to evaluate the effects of tai chi on biomedical outcomes. Among these indicators, IR should be evaluated by homeostasis model assessment (HOMA) version 1 or 2. In addition, QoL and balance (measured with the 36-item Short-Form (SF-36) scale (29) and duration of single-leg stance, respectively) as well as BMI, were assessed.

Data extraction

Data were independently extracted by 2 reviewers (ZL. Z and Y. Z) according to a pre-specified data extraction table, which comprised the following items: first author, publication year, region, sample size, characteristics of participants (disease status, age, FPG at baseline, disease duration). Outcomes at baseline and follow-up were also recorded. Data on intervention regimens, including type of tai chi, training time, frequency and duration, were extracted. A mutual check on extracted data was performed by 2 reviewers. Disputes and disagreements were solved by discussion or referral to a third reviewer (KP. L).

Risk of bias assessment

Two reviewers (ZL. Z and RZ. Z) independently assessed the risk of bias in individual studies by using the Physiotherapy Evidence Database (PEDro) scale (30), which was commonly used to judge the quality of RCTs regarding physical therapy. Studies with a PEDro score over 4 points were regarded as high quality. Any discrepancies were resolved through discussion. If consensus was not reached, a third reviewer (RS. L) was consulted.

Data synthesis

Pooled analyses were performed using Stata 12.0 software. Mean changes from baseline to follow-up were synthesized for continuous data, and 3 aspects of QoL were evaluated: physical function, bodily pain and social function. Mean difference (MD) or standardized mean difference (SMD) with 95% confidence interval (95% CI) were summarized for continuous outcomes evaluated, respectively, by identical measurement or different measurements. Heterogeneity across studies was assessed by I^2 statistic. A fixed-effects pooled analysis was conducted if no or low heterogeneity ($I^2 < 50\%$) existed, and when there was high heterogeneity among studies ($I^2 > 50\%$), a random-effects meta-analysis was performed. Sensitivity analysis was performed to explore the impact of methodological quality of included studies on results by removing low-quality studies (PEDro score ≤ 4). In addition, data were synthesized after excluding studies in turn to test the stability of results, if necessary. Funnel plot and Egger's test (31) were used to assess the possibility of publication bias, if appropriate.

RESULTS

Search results

A total of 487 articles were retrieved according to the search strategy, and no articles were obtained from other sources (Fig. 1). A total of 292 articles remained after removing duplicates. After removal of irrelevant articles through titles and abstracts, full-text reading of 50 articles was performed for further assessment. Of these, 25 articles were excluded for various reasons (see Fig. 1). Therefore, a final total of 23 studies reported in 25 articles (32–56) were included in this systematic review and meta-analysis.

Characteristics and risk of bias assessment in individual study

One RCT reported in 3 articles (49–51) was regarded as a study, which together with another study (48) originated from Australia (Table II). One of 23 studies originated from South Korea (43), one was conducted in Thailand (42) and the rest in China. The sample size ranged from 16 to 200, and mean age ranged from 35.6 to 69.5 years. The average duration of disease a ranged from 1 to 23 years, and the mean HbA1c before treatment from 6.9% to 11.9%. Four studies (33, 34, 36, 38) applied Chen style tai chi, and one (34) applied Yang style tai chi. A simplified style was used in 5 studies (45–47, 55, 56). Sun style and Yang style tai chi was used in 2 studies (4 articles) (48–51), Lin style was used in 1 study (42), and Da-yuan-jiang-tang style was used in 1 study (54). The mean time per session ranged from 15 to 120 min, mean intervention frequency from 2 to 14 sessions per week, and the mean duration of the intervention from 4 to 24 weeks.

The majority of studies reported inclusion criteria, except for 2 studies (38, 55). The treatment group and the control group were comparable at baseline for all studies, and point estimates and variability were all reported. All studies except 4 (32, 36, 43, 56) were considered high quality. The risk of bias assessment is shown in Table III.

Effects of tai chi in patients with type 2 diabetes

Fasting plasma glucose. A total of 21 studies (32–45, 47, 51–56) evaluated the effects of tai chi on FPG. With high heterogeneity across studies, a random-effects pooled analysis was performed to synthesize the data. The results indicated that tai chi was potentially effective in reducing FPG (SMD –0.67; 95% CI –0.87 to –0.47; $p<0.001$; heterogeneity, $I^2=53.2\%$, $p=0.001$; Fig. 2).

Glycosylated haemoglobin (HbA1c). A total of 14 studies (35, 36–43, 45, 48, 49, 52–54) compared the effects of tai chi on HbA1c with a control group. Meta-analysis showed that tai chi was beneficial in lowering HbA1c (MD –0.88; 95% CI –1.45% to –0.31%; $p=0.002$; heterogeneity, $I^2=97.8\%$, $p<0.001$; Fig. 3A). Sensitivity analysis showed that 2 studies (37, 45) exerted great influence on the stability of synthesized results. The results after excluding these 2 studies also indicated that tai chi was effective in decreasing HbA1c (MD –0.53; 95% CI –0.62% to –0.44%; $p<0.001$; heterogeneity, $I^2=43.4\%$, $p=0.033$; Fig. 3B).

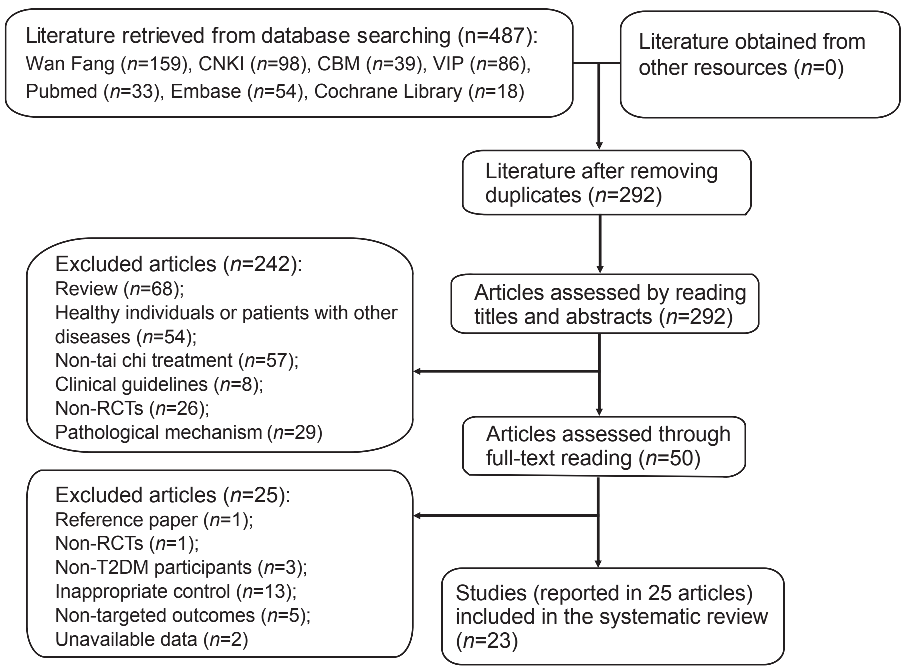

Fig. 1. Flow chart of study selection. T2MD: type 2 diabetes mellitus; RCT: randomized controlled trial.

Table II. Basic characteristics of included studies

Reference, region	Population, sample size (T:C)	Age and disease duration (years)	Baseline FPG (mmol/l)	Type of tai chi	Intervention		Index
					T (time/per week/ duration)	Controls	
Zhu et al. 2017 (32), China	T2DM 40 (20:20)	T: 64.5 (4.3), NA C: 65.2 (3.6), NA	T: 8.76 (3.15) C: 8.26 (2.56)	24 movements	1h/4/16w	Usual care	1,5
Zhao et al. 2017 (33), China	T2DM 16 (8:8)	T: 54.75 (6.09), NA C: 52.38 (7.65), NA	T: 6.79 (0.74) C: 6.98 (0.81)	Chen style	1h/7/16w	No active treatment	1,3,4,5,6
Wang et al. (a)(b), 2017 (34), China	T2DM Ta:Ca = 10:5 Tb:Cb = 10:5	NA, NA	Ta: 9.34 (1.35) Tb: 9.29 (1.03) C: 9.84 (1.08)	Ta:24 movements (Yang simplified version) Tb:56 movements (Chen style)	1h/5/12w	Usual care	1
Zhang et al., (a)(b)(c), 2016 (35), China	T2DM Ta:Ca = 10:4 Tb:Cb = 10:3 Tc:Cc = 10:3	Ta: 58.6, NA Tb: 59, NA Tc: 60, NA	Ta: 7.85 (0.93) Tb: 7.86 (0.94) Tc: 7.82 (0.9) C: 7.84 ± 0.92	Ta:24 movements (high gravity) Tb:24 movements (medium gravity) Tc:24 movements (low gravity)	50min/5/12w	Usual care	1,2,4,5
Li et al., 2016 (36), China	T2DM 82 (41:41)	T: 52.69 (5.57), 8.23 (1.78) C: 52.41 (6.27), 8.12 (1.59)	: 10.43 (2.4) C: 10.26 (2.54)	24 movements (Chen simplified version)	45min/7/4w	Usual treatment	1
Bao et al., 2016 (37), China	old patients with T2DM 107 (58:49)	T: 70.4 (6.9), NA C: 68.4 (7.1), NA	T: 10.13 (0.67) C: 10.15 (1.35)	NA	2h/14/24w	Usual care and education	1,2,5,6
Li et al., 2015 (38), China	male patients with T2DM 100 (50:50)	T: 62.91 (2.48), 7.83 (2.16) C: 63.27 (2.86), 8.14 (3.19)	T: 7.03 (3.12) C: 7.02 (3.04)	Chen style	40-50min/7/24w	Usual exercise	1,2,3,5,6,8,9
Zhang et al., 2014 (39), China	T2DM 40 (20:20)	T: 62.5 (6.65), NA C: 61.55 (4.84), NA	T: 8.2 (1.37) C: 8.29 (1.29)	24 movements (simplified version)	1h/3/14w	Usual exercise	1,2
Tang et al., 2014 (40), China	T2DM Ta:Ca = 14:5 Tb:Cb = 15:5 Tc:Cc = 13:4	Ta: 61.4 (5.08), NA Tb: 62.73 (7.17), NA Tc: 59.4 (6.68), NA C: 61.53 (6.23), NA	Ta: 6.87 (1.72) Tb: 7.47 (0.92) Tc: 7.72 (0.89) C: 7.27 (1.34)	NA	Ta: 1 time/5/24w Tb: 2 repeats/5/24w Tc: three repeats/5/24w	Usual care	1,2
Meng et al., 2014 (41), China	T2DM 200 (100:100)	68.4 (3.2), 2~23	T: 6.83 (2.17) C: 7.13 (1.96)	NA	NA/NA/12w	Usual treatment	1,2,3,4,5,10
Youngwanichsetha et al., 2013 (42), Thailand	postpartum women with T2DM 64 (32:32)	T: 35 (5.63), 2.47 (1.24) C: 36.2 (4.48), 2.8 (1.18)	T: 7.35 (0.84) C: 7.33 (0.91)	18 movements (Lin Housheng style)	50min/3/12w	Usual care	1, 2,6,8,9
Ahn et al., 2012 (43), South Korea	T2DM with neuropathy 39 (20:19)	T: 66.1 (6.42), 12.3 (8.8) C: 62.73(7.53), 13(10.03)	T: 7.66 (2.51) C: 7.97 (2.64)	NA	1h/2/12w	Usual care	1, 2,7,10
Xiao et al. (a)(b), 2011 (44), China	T2DM Ta:Ca = 12:12 Tb:Tb = 12:12	55 (4.12), 6.8 (1.3)	Ta: 10.1 (2.2) Tb: 10.4 (2.8) Ca: 9.8 (1.5) Cb: 9.9 (2.3)	Ta:24 movements Tb: tai chi and intravenous drip of Puerarin	1h/6/24w	Ca: Usual care Cb: Usual care and intravenous drip of Puerarin	1
Wu et al., 2010 (45), China	T2DM 40 (20:20)	T: 51.3 (7.9), 1.35 (0.62) C: 52.4 (5.5), 1.36 (0.71)	T: 9.73 (1.72) C: 9.69 (1.82)	24 movements (simplified version)	^{3}1h/^{3}3/24w	No active exercise	1,2,3,8,9,10
Wang et al., 2009 (46), China	middle or old patients with T2DM 64 (34:30)	T: 48.24 (10.06), 1~18 C: 47.86 (11.12), 1~17	NA	24 movements (simplified version)	45~60min/5~7/24w	Usual care	10
Zhang et al., 2008 (47), China	Women with T2DM 20 (10:10)	57.4 (6.2), 4.4 (2.2)	T: 10.43 (3.13) C: 9.7 (2.58)	24 movements (simplified version)	1h/5/14w	Usual care	1,3,5
Lam et al., 2008 (48), Australia	T2DM 53 (28:25)	T: 63.2 (8.6), ≥0.5 C: 63.2 (8.6), ≥0.5	NA	20-form (Yang and Sun style)	1h/2/12w	Usual exercise	2,4,5,8,9,10
Tsang and Orr et al., 2008, 2007, 2006 (49-51), Australia	older adults with T2DM 38 (18:20)	T: 66 (8), 8.5 C: 65 (8), 9	T: 7.6 C: 7.9	12 movements (Sun and Yang style)	1h/2/16w	Sham exercise	1,2,4,6,7
Jiang et al., 2007 (52), China	T2DM 18 (10:8)	T: 57.2 (4.2), 3.2 (0.8) C: 55.0 (6.2), 2.9 (0.7)	T: 11.41 (2.92) C: 11.63 (2.61)	24 movements	30~45min/7~14/20w	Usual care	1,2,3,5
Yu et al., 2004 (53), China	T2DM and hypertension 40 (25:15)	T: 50 (5.8), NA C: 49 (5.6), NA	T: 8.44 (1.36) C: 8.36 (1.24)	NA	1h/7/12w	Usual care	1,2,3,8,9
Yan et al., 2004 (54), China	T2DM 18 (10:8)	T: 51.8 (7.4), 2.9 (1.6) C: 53.1 (7.8), 3 (1.8)	T: 12.1 (4.2) C: 11.7 (4.51)	Da yuan jiang tang style	15~30min/14/24w	Usual care	1,2
Kan et al., 2004 (55), China	T2DM 48 (26:22)	52 (6.7), ≥3	T: 9.94 (4.13) C: 9.83 (3.41)	24 movements (simplified version)	1h/7/12w	Usual exercise	1,3,5,6
Wang et al., 2003 (56), China	T2DM 16 (10:6)	60~70, ≥2	T: 9.8 (1.9) C: 9.6 (2.0)	24 movements (simplified version)	1h/7/12w	Usual exercise	1,6

T: treatment group; T2DM: type 2 diabetes mellitus; NA: not available.
1: fasting plasma glucose; 2: glycosylated haemoglobin; 3: fasting insulin; 4: insulin resistance; 5: total cholesterol; 6: body mass index; 7: balance; 8: systolic blood pressure; 9: diastolic blood pressure; 10: quality of life.
Value was presented as mean (SD) where appropriate.

Table III. Assessment of bias risk in individual study

Studies	Items of PEDro scale 1	2	3	4	5	6	7	8	9	10	11	Total score
Zhu et al. (32)	Yes	0	0	1	0	0	0	1	0	1	1	4
Zhao et al. (33)	Yes	1	0	1	0	0	0	1	0	1	1	5
Wang et al. (34)	Yes	1	0	1	0	0	0	1	0	1	1	5
Zhang et al. (35)	Yes	1	0	1	0	0	0	1	0	1	1	5
Li et al. (36)	Yes	0	0	1	0	0	0	1	0	1	1	4
Bao et al. (37)	Yes	1	0	1	0	0	0	1	0	1	1	5
Li et al. (38)	No	1	0	1	0	0	0	1	0	1	1	5
Zhang et al. (39)	Yes	1	0	1	0	0	0	1	0	1	1	5
Tang et al. (40)	Yes	1	0	1	0	0	0	1	0	1	1	5
Meng et al. (41)	Yes	1	0	1	0	0	0	1	0	1	1	5
Youngwanichsetha et al. (42)	Yes	1	1	1	0	0	0	1	0	1	1	6
Ahn et al. (43)	Yes	0	0	1	0	0	1	0	0	1	1	4
Xiao et al. (44)	Yes	1	0	1	0	0	0	1	0	1	1	5
Wu et al. (45)	Yes	1	0	1	0	0	0	1	0	1	1	5
Wang et al. (46)	Yes	1	0	1	0	0	0	1	0	1	1	5
Zhang et al. (47)	Yes	1	0	1	0	0	0	1	0	1	1	5
Lam et al. (48)	Yes	1	0	1	0	1	1	1	0	1	1	7
Tsang and Orr et al. (49–51)	Yes	1	1	1	1	0	1	1	1	1	1	9
Jiang et al. (52)	Yes	1	0	1	0	0	0	1	0	1	1	5
Yu et al. (53)	Yes	1	0	1	0	0	0	1	0	1	1	5
Yan et al. (54)	Yes	1	0	1	0	0	0	1	0	1	1	5
Kan et al. (55)	No	1	0	1	0	0	0	1	0	1	1	5
Wang et al. (56)	Yes	0	0	1	0	0	0	1	0	1	1	4

Items of PEDro scale, 1: specification of inclusion criteria; 2: random distribution; 3: allocation concealment; 4: similarity at baseline; 5: blind participants; 6: blind therapists; 7: blind assessor; 8: over 85% subjects at follow-up; 9: intention-to-treatment analysis; 10: comparison between groups; 11: point estimates and variability.
For item 2–11: 1 refers to a satisfied criterion; 0 indicates the criterion is unclear or unsatisfied.

Fasting insulin. Eight studies (33, 38, 41, 45, 47, 52, 53, 55) evaluated the impact of tai chi on FIN. The pooled analysis suggested that tai chi failed to show favourable influence on FIN (SMD –0.32; 95% CI –0.71 to 0.07; $p=0.110$; heterogeneity, $I^2=73.3\%$, $p<0.001$; Fig. 4).

Insulin resistance. The effects of tai chi on IR measured by HOMA were reported in 5 studies (33, 35, 41, 48, 49). A fixed-effects pooled analysis showed favourable effects of tai chi on reducing IR (MD –0.41; 95% CI –0.78 to –0.04; $p=0.029$; heterogeneity $I^2=0.0\%$, $p=0.5$; Fig. 5).

Total cholesterol. Ten studies (32, 33, 35, 37, 38, 41, 47, 48, 52, 55) evaluated the effects of tai chi on TC. A random-effects pooled analysis demonstrated positive effects of tai chi on decreasing TC (SMD –0.59; 95% CI –0.90 to –0.27; $p<0.001$; heterogeneity, $I^2=66.6\%$, $p=0.001$; Fig. 6).

Body mass index. Seven studies (33, 37, 38, 42, 49, 55, 56) compared the effects of tai chi on BMI with control group. A fixed-effects pooled analysis indicated that there was a statistically significant reduction in BMI (MD –0.82 kg/m^2; 95% CI –1.28 to –0.37 kg/m^2; $p<0.001$; heterogeneity, $I^2=26.3\%$, $p=0.228$; Fig. 7A).

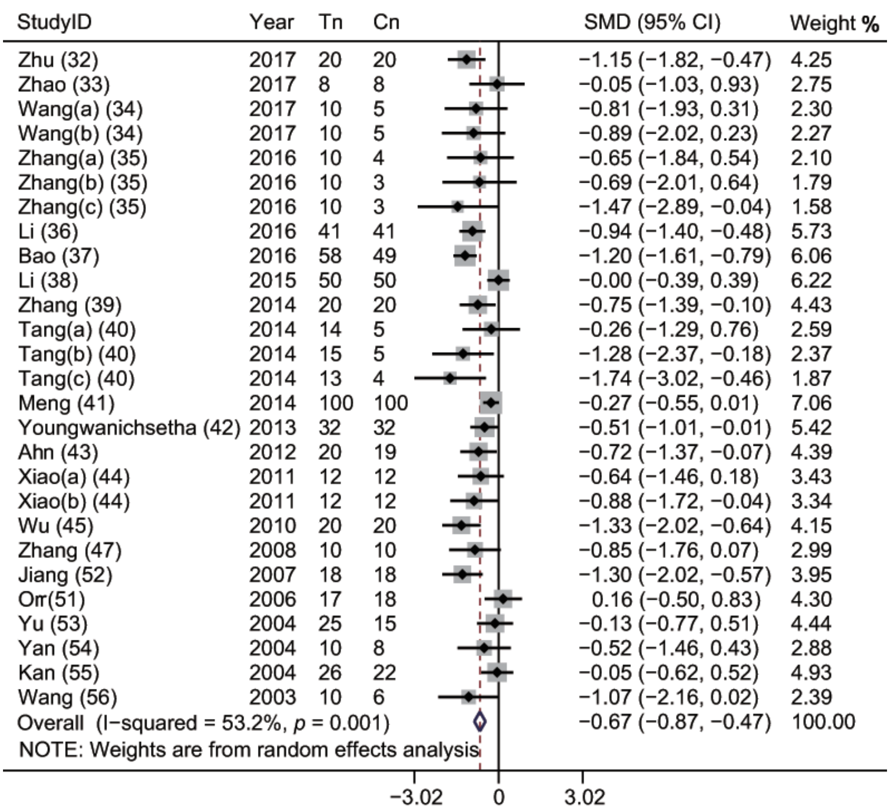

Fig. 2. Forest plot of the effects of tai chi on fasting plasma glucose. StudyID: study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; SMD: standardized mean difference; 95% CI: 95% confidence interval.

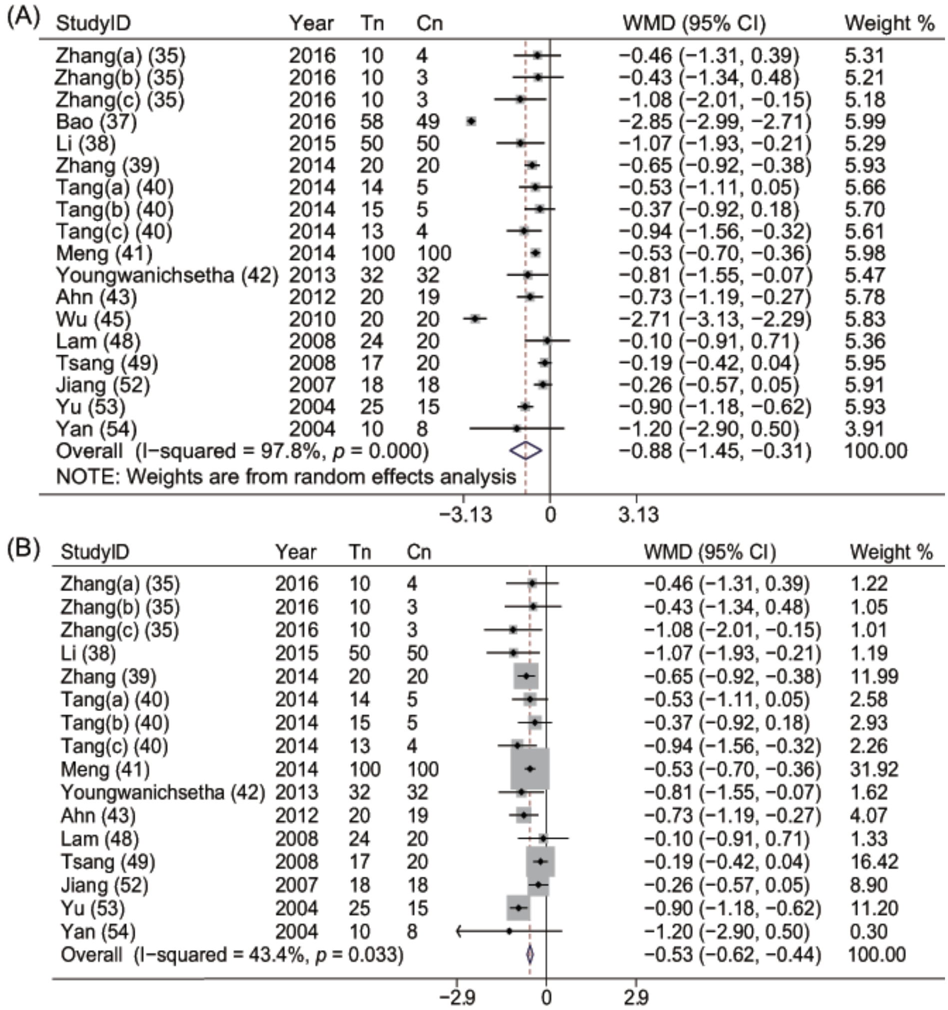

Fig. 3. Forest plot of the effects of tai chi on glycosylated haemoglobin. (A) All included studies; (B) all studies except for Bao's and Wu's research; StudyID: study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; WMD: weighted mean difference; 95% CI: 95% confidence interval.

Balance. Two studies (43, 50) comprising 3 intervention groups evaluated the effects of tai chi on balance according to the duration of single-leg stance. A random-effects pooled analysis revealed no effects of tai chi on increasing the duration of single-leg stance (MD 2.71s; 95% CI –3.29 to 8.71 s; $p=0.376$; heterogeneity, $I^2=63.8\%$, $p=0.063$; Fig. 7B).

Blood pressure. Five studies (38, 42, 45, 48, 53) compared the effects of tai chi on BMI with a control group. The results of meta-analysis indicated there was a statistically significant reduction in SBP (MD –10.03 mmHg; 95% CI –15.78 to –4.29 mmHg; $p=0.001$; heterogeneity, $I^2=55.4\%$, $p=0.062$; Fig. 8A) and DBP (MD –4.85 mmHg; 95% CI –8.23 to –1.47 mmHg; $p=0.005$; heterogeneity, $I^2=33.1\%$, $p=0.201$; Fig. 8B).

Quality of life. Five studies (41, 43, 45, 46, 48) compared the effects of tai chi on QoL with a control group. A pooled analysis suggested that tai chi improved physical function (MD 7.07; 95% CI 0.79–13.35; $p=0.027$; heterogeneity, $I^2=79.6\%$, $p=0.001$; Fig. 9A), bodily pain (MD 4.30; 95% CI 0.83–7.77; $p=0.015$; heterogeneity, $I^2=39.2\%$, $p=0.160$; Fig. 9B) and social function (MD 13.84; 95% CI 6.22—21.47; $p<0.001$; heterogeneity, $I^2=86.0\%$, $p=0.063$; Fig. 9C).

Publication bias and sensitivity analysis

The results of funnel plot (Fig. 10) and Egger's test ($t=-1.93$, $p=0.064$) suggested there was no publication bias across studies. Sensitivity analysis revealed that tai chi potentially had beneficial effects in reducing FPG (SMD –0.62; 95% CI –0.84 to –0.39; $p<0.001$), decreasing HbA1c (MD –0.89%; 95% CI –1.49% to –0.29%; $p=0.003$), lowering BMI (MD –0.83 kg/m^2; 95% CI –1.30 to –0.37 kg/m^2; $p=0.001$; heterogeneity, $I^2=38.1\%$, $p=0.152$) and TC (SMD –0.45; 95% CI

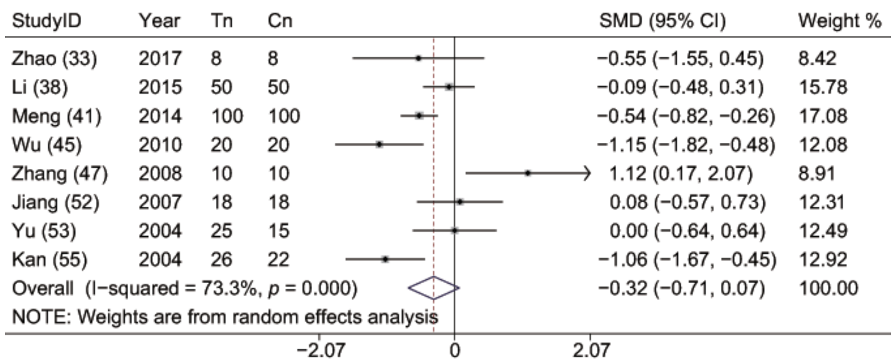

Fig. 4. Forest plot of the effects of tai chi on fasting insulin. StudyID: study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; SMD: standardized mean difference; 95% CI: 95% confidence interval.

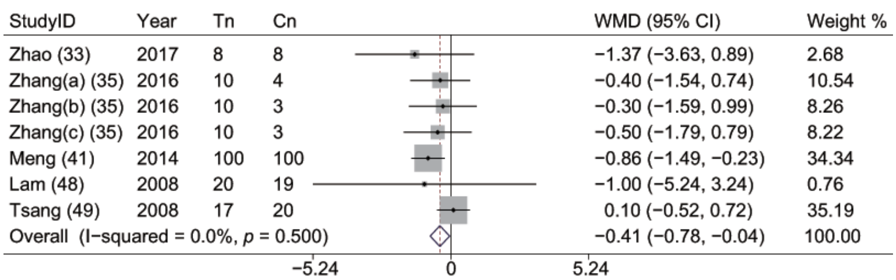

Fig. 5. Forest plot of the effects of tai chi on insulin resistance. StudyID: study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; WMD: weighted mean difference; 95% CI: 95% confidence interval.

–0.67 to –0.24; $p<0.001$) as well as improving social function (MD 11.92; 95% CI 4.02–19.83; $p=0.003$). However, there was no effect on balance (MD –0.63 s; 95% CI –3.29 to 8.71 s; $p=0.563$), physical function (MD 6.33; 95% CI –0.67 to 13.34; $p=0.076$) or bodily pain (MD 3.44; 95% CI –0.11 to 6.99; $p=0.058$).

DISCUSSION

The aim of this systematic review was to evaluate the effects of tai chi in patients with T2DM. The review was performed following the procedures recommended by the Cochrane Handbook (57). The results indicate that tai chi has beneficial effects on controlling some biomedical outcomes (FPG, HbA1c, IR, BMI, TC, BP) and QoL-related outcomes (physical function, bodily pain, and social support), but did not improve FIN and balance.

A total of 23 studies (26 articles) were included in this meta-analysis, and no publication bias existed. In this systematic review, tai chi was found to be effective in lowering FPG (SMD –0.67; 95% CI –0.87 to –0.47; $p<0.001$) and HbA1c (MD –0.88%; 95% CI –1.45% to –0.31%; $p=0.002$). Compared with usual treatments,

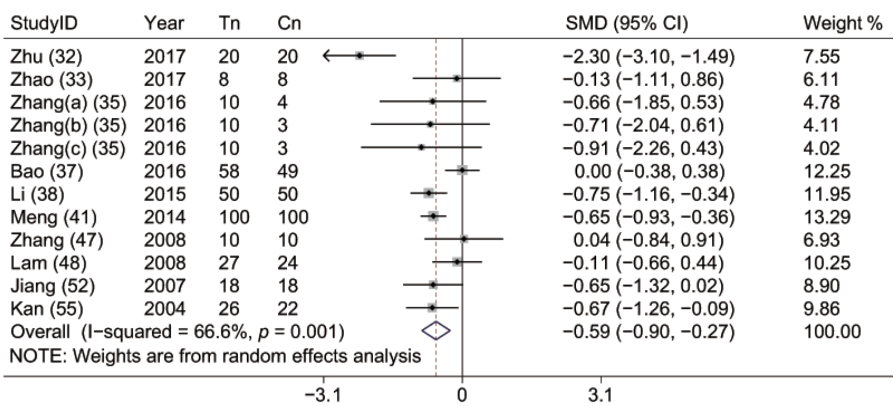

Fig. 6. Forest plot of the effects of tai chi on total cholesterol. StudyID: study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; SMD: standardized mean difference; 95% CI: 95% confidence interval.

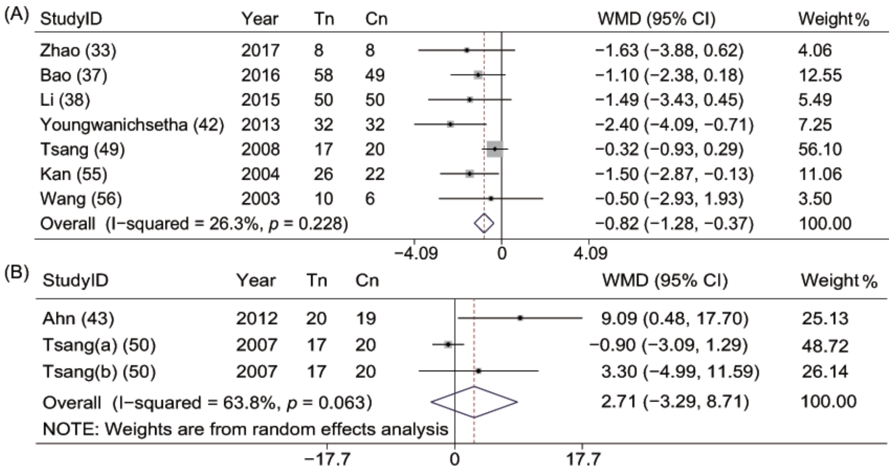

Fig. 7. Forest plot of the effects of tai chi on: (A) body mass index; (B) balance. StudyID:study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; WMD: weighted mean difference; 95% CI: 95% confidence interval.

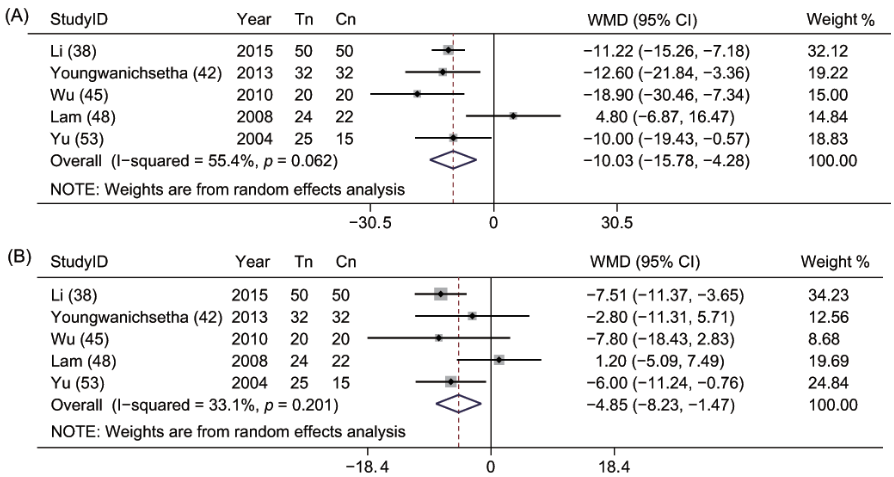

Fig. 8. Forest plot of the effects of tai chi on blood pressure. (A) systolic blood pressure; (B) diastolic blood pressure; StudyID: study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; WMD: weighted mean difference; 95% CI: 95% confidence interval.

tai chi could reduce HbA1c by 0.88%. Previous study found tai chi could contribute to increased CD4+/CD25+ T-lymphocytes, and the latter was related to the decrease in HbA1c (58). Consistent with our findings, Huang & Yeh (25) also suggested favourable effects of tai chi in decreasing FPG and HbA1c. Due to high heterogeneity of HbA1c across studies, the stability of the results was tested by excluding included studies in turn to detect the sources. Analysis showed that 2 studies (37, 45) carried huge weight in the stability of results. Detailed analyses were performed, in which remarkable differences were found in the intervention regimens between these 2 studies and the others. In Bao's study (37) the duration of intervention was up to 24 weeks, with a frequency of 14 sessions per week and 2 h per session, which was the longest among included studies. Similarly, in Wu's study (45) the shortest session was over 1 h, with at least 3 sessions per week; thus it is impossible to specify the total time of practicing tai chi. It was therefore assumed that the total time of treatment might be the main source of heterogeneity.

Further analyses found favourable effects of tai chi, in reducing IR (MD –0.41; 95% CI –0.78 to –0.04; $p=0.029$), TC (SMD –0.59; 95% CI –0.90 to –0.27; $p<0.001$) and BMI (MD –0.82 kg/m^2; 95% CI –1.28 to –0.37 kg/m^2; $p<0.001$). The relatively small magnitude of the above outcomes may be due to the short duration of intervention (59). Tai chi also decreased BP (SBP (MD –10.03 mmHg; 95% CI –15.78 to –4.29 mmHg; $p=0.001$) and DBP (MD –4.85mmHg; 95% CI –8.23 to –1.47 mmHg improved; $p=0.005$)), QoL (physical function (MD 7.07; 95% CI 0.79–13.35; $p=0.027$) decreased, bodily pain (MD 4.30; 95% CI 0.83–7.77; $p=0.015$) and increased social function (MD 13.84; 95% CI 6.22–21.47; $p<0.001$)). Thus, tai chi was more

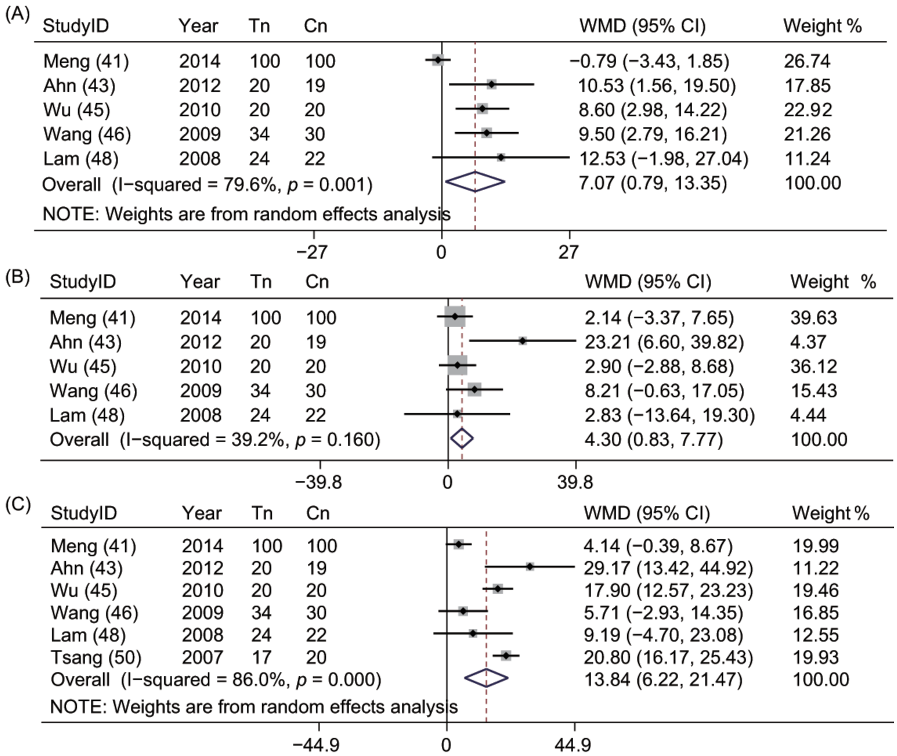

Fig. 9. Forest plot of the effects of tai chi on quality of life. (A) Physical function; (B) bodily pain; (C) social function; StudyID: study reference; Tn: number of participants in treatment group; Cn: number of participants in control group; WMD: weighted mean difference; 95% CI: 95% confidence interval.

efficient in improving BP and QoL-related outcomes compared with usual care of treatments, which is in agreement with the results of a previous study (60). A beneficial trend was also observed in reducing FIN (SMD –0.32; 95% CI –0.71 to 0.07; $p=0.110$) and improving balance (MD 2.71s; 95% CI –3.29 to 8.71 s; $p=0.376$), although no significant difference was achieved. One important reason for the insignificant effects of tai chi on FIN was heterogeneity. Included studies varied in sample size, population, types of tai chi, intervention regimens and study design. In addition,

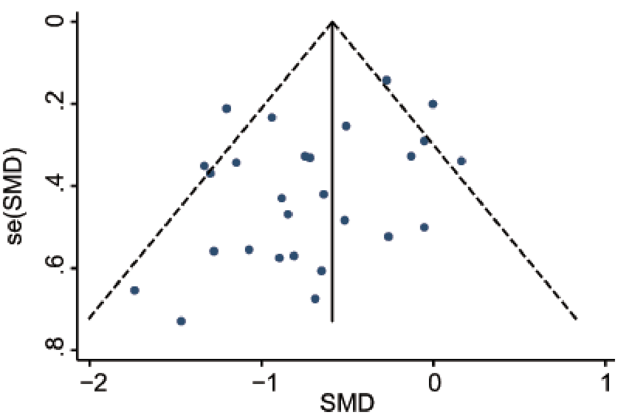

Fig. 10. Funnel plot of publication bias. SMD: standardized mean difference; se(SMD): standard error of standardized mean difference.

allocation concealment and blinding were not clear or applied in the majority of included studies, which might give rise to the bias. The results of the current review are consistent with a previous study of balance (61). When practicing tai chi, patients need to control their body balance while continuously changing position and bodily center of gravity. In addition, tai chi helps improve the ability of controlling muscles and joints, which is associated with better balance control (62). Moreover, the results of sensitivity analysis based on the PEDro scale score were consistent with the previous findings, except for physical function and bodily pain, which might be due to insufficient eligible studies. The contrary findings indicated the results of these two outcomes were unstable, which should be taken into consideration when interpreting our conclusions.

There are several theories that could account for the effects of tai chi. Chen et al. (63) reported the main beneficial effects of tai chi are to enhance metabolism, anti-inflammatory activation and cardiopulmonary regulation, rather than consume calories. DM was also regarded as an inflammatory disease (27), and previous studies have found that tai chi is beneficial for regulatory T-cell function (64) and the reaction of type 1 helper (Th1) cells (27). As a type of moderate exercise, tai chi could improve basic metabolism and it has been shown to be beneficial for glucose absorption and glycogen synthesis, which in turn benefits glycaemic control (65). Furthermore, the bioactivity of insulin receptors on cytomembrane was also enhanced through tai chi (53).

In view of the beneficial effects of tai chi on many outcomes, we recommend that patients with T2DM should practice tai chi as a complementary rehabilitation therapy, especially those patients who also have obesity or hypertension. Considering that the effects of single aerobic exercise last less than 72 h (59), we also suggest that patients should practice tai chi at least 3 times per week.

This review has several limitations. First, some studies fulfilling the inclusion criteria might not have been included in the meta-analysis. Unpublished articles, such as grey literature, were not attainable despite the exhaustive search strategy. In addition, there was a possibility of language bias, since only English and Chinese literature was searched. Furthermore, the baseline information in some studies was incomplete, which might result in difficulty in performing further analysis, with misleading results. In addition, there was heterogeneity in several results due to different intervention regimens, baseline characteristics of patients, and duration of follow-up. The heterogeneity across studies and insufficient sample size might weaken the strenght of our conclusions for some outcomes; thus, there is a need for multi-centre, high-quality RCTs to further investigate the effects of tai chi on T2DM.

The current review also provides additional information for further study in related topics. First, tai chi could be categorized into many types (e.g. Chen style, Yang style, etc.) but insufficient evidence regarding differing effects of different types of tai chi makes it difficult to determine which style of tai chi should be practiced. Secondly, since the longest follow-up duration studied was 24 weeks, it is impossible to observe the long-term effects of tai chi. Thirdly, one needs to control breath when performing tai chi, and this indicates that tai chi might be associated with respiratory function, although most studies did not explore the related outcomes. Other outcomes, such as immune function, nerve modulation, and survival time, were rarely investigated in these studies. Lastly, most previous studies focus on the therapeutic effects of tai chi on T2DM, but whether performing tai chi could reduce the risk of T2DM in healthy individuals remains unclear. For the reasons described above, further research is suggested to investigate the effects of various styles of tai chi, the long-term effects of tai chi, the impact on the above outcomes, and the association between tai chi training and risk of developing T2DM

In conclusion, tai chi may be a suitable mind-body therapy for individuals with T2DM, since it is beneficial in reducing FPG, decreasing HbA1c and improving a variety of other outcomes.

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The authors have no conflicts of interest to declare.

REFERENCES

1. Beidokhti MN, Jäger AK. Review of antidiabetic fruits, vegetables, beverages, oils and spices commonly consumed in the diet. J Ethnopharmacol 2007; 201: 26–41.
2. Lin HC, Su CT, Wang PC. An application of artificial immune recognition system for prediction of diabetes following gestational diabetes. J Med Syst 2011; 35: 283–289.
3. Ezuruike UF, Prieto JM. The use of plants in the traditional management of diabetes in Nigeria: pharmacological and toxicological considerations. J Ethnopharmacol 2014; 155: 857–924.
4. Ozougwu O. The pathogenesis and pathophysiology of type 1 and type 2 diabetes mellitus. J Physiol Pathophysiol 2013; 4: 46–57.
5. Cederlund RI, Dahlin LB, Thomsen NO. Activity limitations before and after surgical carpal tunnel release among patients with and without diabetes. J Rehabil Med 2012; 44: 261–267.
6. Lan C, Chen SY, Lai JS. Relative exercise intensity of tai chi chuan is similar in different ages and gender. Am J Chin Med 2004; 32: 151–160.
7. Lan C, Lai JS, Chen SY. Tai Chi Chuan: an ancient wisdom on exercise and health promotion. Sports Med 2002; 32: 217–224.
8. Yang AB. [The feasibility study of taijiquan unified sects.] Yangzhou: Yangzhou University; 2010 (in Chinese).
9. Chen YW, Hunt MA, Campbell KL, Peill K, Reid WD. The effect of tai chi on four chronic conditions – cancer, osteoarthritis, heart failure and chronic obstructive pulmonary disease: a systematic review and meta-analyses. Br J Sports Med 2016; 50: 397–407.
10. Huang YT, Wang CH, Wu YF. Adhering to a tai chi chuan exercise program improves vascular resistance and cardiac function. Int J Gerontol 2011; 5: 150–154.
11. Li F, Harmer P, Fisher KJ, Mcauley E, Chaumeton N, Eckstrom E, et al. Tai chi and fall reductions in older adults: a randomized controlled trial. J Gerontol 2005; 60: 187–194.
12. Zhao Y, Wang Y. Tai chi as an intervention to reduce falls and improve balance function in the elderly: a meta-analysis of randomized controlled trials. Chin Nurs Res 2016; 3: 28–33.
13. Hong Y, Li JX, Robinson PD. Balance control, flexibility, and cardiorespiratory fitness among older tai chi practitioners. Br J Sports Med 2000; 34: 29–34.
14. Siu KC, Padilla C, Rajaram SS. The interrelationship between balance, tai chi and depression in Latino older adults. Aging Clin Exp Res 2017; 29: 395–401.
15. Mustian KM, Katula JA, Gill DL, Roscoe JA, Lang D, Murphy K. Tai chi chuan, health-related quality of life and self-esteem: a randomized trial with breast cancer survivors. Support Care Cancer 2004; 12: 871–876.
16. Wang L, Wu K, Chen X, Liu Q. The effects of tai chi on lung function, exercise capacity and health related quality of life for patients with chronic obstructive pulmonary disease: a pilot study. Heart Lung Circ 2018 Aug 2. pii: S1443-9506. [Epub ahead of print].
17. Li F, Harmer P, Fisher KJ, Xu J, Fitzgerald K, Vongjaturapat N. Tai chi-based exercise for older adults with Parkinson's disease: a pilot-program evaluation. J Aging Phys Act 2007; 15: 139–151.
18. Wang C, Schmid C, Hibberd P, Kalish R, Roubenoff R, Rones R, et al. Tai chi is effective in treating knee osteoarthritis: a randomized controlled trial. Arthritis Rheum 2009; 61:

1545–1553.
19. Kim H, Kim YL, Lee SM. Effects of therapeutic tai chi on balance, gait, and quality of life in chronic stroke patients. Int J Rehabil Res 2015; 38: 156–161.
20. Sun J, Buys N. A comparison between a tai chi program and a usual medical care program in chronic cardiovascular disease participants in quality of life, psychological health, resilience, blood pressure and body mass index. Int J Disabil Hum Dev 2014; 13: 113–120.
21. Wayne PM, Berkowitz DL, Litrownik DE, Buring JE, Yeh GY. May 27.What do we really know about the safety of tai chi?: A systematic review of adverse event reports in randomized trials. Arch Phys Med Rehabil 2014; 95: 2470-2483.
22. Lee MS, Lee MS, Choi TY, Lim HJ, Ernst E. Tai chi for management of type 2 diabetes mellitus: a systematic review. Chin J Integr Med 2011; 17: 789–793.
23. Yan JH, Gu WJ, Pan L. Lack of evidence on tai chi-related effects in patients with type 2 diabetes mellitus: a meta-analysis. Exp Clin Endocrinol Diabetes 2013; 121: 266–271.
24. Lee MS, Pittler MH, Kim MS, Ernst E. Tai chi for type 2 diabetes: a systematic review. Diabet Med 2008; 25: 240–241.
25. Huang JP, Yeh ML. The qigong effect on blood glucose control in people with type 2 diabetes: a systematic review and meta-analysis. J Nurs Healthcare Res 2013; 9: 199–209.
26. Corriveau H, Prince F, Hébert R, Raîche M, Tessier D, Maheux P, et al. Evaluation of postural stability in elderly with diabetic neuropathy. Diabetes Care 2000; 23: 1187–1191.
27. Hung JW, Liou CW, Wang PW, Yeh SH, Lin LW, Lo SK, et al. Effect of 12-week tai chi chuan exercise on peripheral nerve modulation in patients with type 2 diabetes mellitus. J Rehabil Med 2009; 41: 924–929.
28. Schram M, Baan C, Pouwer F. Depression and quality of life in patients with diabetes: a systematic review from the European depression in diabetes (EDID) research consortium. Curr Diabetes Rev 2009; 5: 112–119.
29. Jr WJ, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992; 30: 473–483.
30. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther 2003; 83: 713–721.
31. Egger M, Davey SG, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ 1997; 315: 629–634.
32. Zhu H, Tan L, Li RJ, Zhou HM, Fei JM. [The effects of 24-movement tai chi exercise on elderly patients with type 2 diabetes mellitus.] Chin J Gerontol 2017; 3: 737–738 (in Chinese).
33. Zhao G, Chen MS, Zhuang L, Shun WP. [Effects of taijiquan on the physique, blood lipid, insulin resistance of patients with type 2 diabetes.] J Nanjing Sports Inst 2017; 16: 1–7 (in Chinese).
34. Wang YG, Zhu N, Zhao YY. [Comparative study of effects between Yang's and Chen's tai chi on middle-aged and elderly T2DM patients.] Sci File 2017; 14: 184–185 (in Chinese).
35. Zhang XJ. [Provide shelf taijiquan exercise influence on the effect of adjuvant therapy in patients with type 2 diabetes]. Liaoning Sheng: Liaoning Normal University; 2016 (in Chinese).
36. Li JB. [Clinical study of taijiquan for patients with diabetic gastroparesis.] Chin Health Care Nutr 2016; (6): 50 (in Chinese).
37. Bao QW, Gong C, Shen XZ, Wang X. [Preventive effects of tai chi exercise on osteoporosis in elderly patients with type 2 diabetes mellitus.] Chin J Gerontol 2016; (13): 3246–3248 (in Chinese).
38. Li HC, Qiu Y, Tie Y. [Effects of Chen-style tai chi on blood biochemical indexes of patients with heart and lung function in elderly type 2 diabetes mellitus.] Chin J Gerontol 2015; (5): 1293–1294 (in Chinese).
39. Zhang EM. [Research on the Effects of 24-style taijiquan on depression of middle-aged and elderly patients with diabetes.] Beijing: Beijing Sport University; 2014 (in Chinese).
40. Tang YB. [Health qigong tai ji quan adjuvant therapy in patients with type 2 diabetes clinical observational studies.] Nanjing: Nanjing University of Chinese Medicine; 2014 (in Chinese).
41. Meng E. [Effects of tai chi on blood lipids and insulin resistance in patients with type 2 diabetes mellitus.] Chin J Gerontol 2014; 34: 5358–5360 (in Chinese).
42. Youngwanichsetha S, Phumdoung S, Ingkathawornwong T. The effects of tai chi qigong exercise on plasma glucose levels and health status of postpartum Thai women with type 2 diabetes. Focus Altern Complement Ther 2013; 18: 182–187.
43. Ahn S, Song R. Effects of Tai Chi Exercise on glucose control, neuropathy scores, balance, and quality of life in patients with type 2 diabetes and neuropathy. J Altern Complement Med 2012; 18: 1172–1178.
44. Xiao L, Zhou Y, Li J. [Effects of fasting blood sugar nitrogen monoxide content and nitric oxide synthase activity in blood serum content in patients with diabetes after intervention of taijiquan exercise and puerarin.] J Shaanxi Norm U 2010; 39: 104–108 (in Chinese).
45. Wu F, Song EF, Bao Y, Xiang JW, Jia RH. Tai chi for the treatment of type 2 diabetes. Chin J Phys Med Rehabil 2010; 32: 205–207.
46. Wang P, Han QY, Liang RR. [The effect of taijiquan exercise on health-related quality of life in patients with type 2 diabetes in community.] Chin Mod Med 2009; 16: 108–109 (in Chinese).
47. Zhang Y, Fu F. Effects of 14-week tai ji quan exercise on metabolic control in women with type 2 diabetes. Am J Chin Med 2008; 36: 647–654.
48. Lam P, Dennis S, Diamond T, Zwar N. Improving glycaemic and BP control in type 2 diabetes. The effectiveness of tai chi. Aust Fam Physician 2008; 37: 884–887.
49. Tsang T, Orr R, Lam P, Comino E, Singh M. Effects of tai chi on glucose homeostasis and insulin sensitivity in older adults with type 2 diabetes: a randomised double-blind sham-exercise-controlled trial. Age Ageing 2008; 37: 64–71.
50. Tsang T, Orr R, Lam P, Comino E, Singh M. Health benefits of tai chi for older patients with type 2 diabetes: the "Move It For Diabetes study" – a randomized controlled trial. Clin Interv Aging 2007; 2: 429–439.
51. Orr R, Tsang T, Lam P, Comino E, Singh M. Mobility impairment in type 2 diabetes: association with muscle power and effect of tai chi intervention. Diabet Care 2006; 29: 2120–2122.
52. Jiang RK. [Effects of taijiquan on blood lipids and insulin resistance in patients with type 2 diabetes mellitus.] Wushu Sci 2007; 4: 35–36 (in Chinese).
53. Yu Y. [Effects and Mechanism of physical exercise on type II diabetes mellitus associated with hypertension.] J Shenyang Inst Phys Edu 2004; 23: 444–445 (in Chinese).
54. Yan J, Chen XJ, Ren SL, Mao ZY, Yang JY, Li Z. [Effects of dayuanjiangtang on blood glucose in patients with type 2 diabetes mellitus.] Guangming J Chin Med 2004; 19: 16–17 (in Chinese).
55. Kan Y, Zhao Y, Shao H. [Effects of shadowboxing on insulin sensitivity in obese patients with type 2 diabetes mellitus.] Jilin J Tradit Chin Med 2004; 24: 11 (in Chinese).
56. Wang JH, Cao Y. [Effect of tai chi exercise on plasma neuropeptide Y of old obese type 2 diabetes mellitus.] J Sports Sci 2003; 24: 67–68, 72 (in Chinese).
57. Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions Version 5.1.0. Hoboken, NJ: Wiley-Blackwell 2011; 5: 102–108.
58. Yeh SH, Chuang H, Lin LW, Hsiao CY, Wang PW, Yang KD. Tai chi chuan exercise decreases A1C levels along with increase of regulatory T-cells and decrease of cytotoxic T-cell population in type 2 diabetic patients. Diabetes Care

2007; 30: 716–718.
59. Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement executive summary. Diabetes Care 2010; 42: 2692–2696.
60. Pan X, Zhang Y, Tao S. Effects of tai chi exercise on blood pressure and plasma levels of nitric oxide, carbon monoxide and hydrogen sulfide in real-world patients with essential hypertension. Clin Exp Hypertens 2015; 37: 8–14.
61. Geib RW, Li H, Oggeo E, Pagnacco G, Lam P, Moga M, et al. Using computerized posturography to explore the connection between BMI and postural stability in long-term tai chi practitioners. Biomed Sci Instrum 2011; 47: 288–293.
62. Li GY, Wang W, Liu GL, Zhang Y. Effects of tai chi on balance and gait in stroke survivors: A systematic meta-analysis of randomized controlled trials. J Rehabil Med 2018; 50: 582–588.
63. Chen SC, Ueng KC, Lee SH, Sun KT, Lee MC. Effect of t'ai chi exercise on biochemical profiles and oxidative stress indicators in obese patients with type 2 diabetes. J Altern Complement Med 2010; 16: 1153–1159.
64. Yeh SH, Chuang H, Lin LW, Hsiao CY, Eng HL. Regular tai chi chuan exercise enhances functional mobility and CD4CD25 regulatory T cells. Brit J Sport Med 2006; 40: 239–243.
65. Wei AL. [Study on the mechanism of tai chi in the treatment of diabetes mellitus.] Sports Time 2017; (10): 28–31 (in Chinese).