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Effects of Baduanjin Exercise on Glucose and Lipid Metabolism in Type 2 Diabetes Mellitus: A Systematic Review and Meta-Analysis

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Abstract

Background: Type 2 diabetes mellitus (T2DM) refers to a metabolic disorder characterized by persistent hyperglycemia. Uncontrolled blood glucose levels over time may lead to serious complications, possibly even death. As an adjunctive treatment for T2DM, increasing numbers of clinical studies have demonstrated that Baduanjin (the Eight Section Brocades)—one of Traditional Asian exercise may effectively control fasting plasma glucose (FPG), glycosylated hemoglobin (HbA1c), and 2h postprandial plasma glucose (P2hPG) as well as blood lipid levels of diabetic patients. However, the primary evidence demonstrating the clinical benefit of Baduanjin exercise in diabetic patients remains insufficient, especially the intervention effect on glucose and lipid metabolism is not fully understood. ***Objectives:*** The purpose of this study is to examine the effects of Baduanjin exercise on glucose and lipid metabolism in individuals with type 2 diabetes in randomized controlled trials (RCTs). ***Methods:*** Nine electronic databases were searched from the database's inception until January 31th, 2023, without regard to language constraints (PubMed, Web of Science, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, China National Knowledge Infrastructure (CNKI), Wanfang Data Knowledge Service Platform (WAN FANG), VIP information resource integration service platform (CQVIP) and China Biology Medicine (CBM)). Furthermore, information concerning unpublished or continuing clinical trials was searched within the National Institutes of Health clinical registry Clinical Trials, the International Clinical Trials Registry Platform, and the Chinese Clinical Trials Registry. RCTs that examined the effect of Baduanjin exercise on glucose and lipid metabolism were identified. The primary outcomes of this study were fasting plasma glucose (FPG), 2h postprandial plasma glucose (P2hPG) and glycosylated hemoglobin (HbA1c). The literature was chosen based on inclusion and exclusion criteria, with the Baduanjin exercise serving as the primary method for the experimental group. Selection, data collection and extraction of studies were

conducted separately by at least two reviewers, with disagreements resolved through discussion. The mean difference (MD) with a 95% confidence interval (CI) was employed for continuous outcomes. Analysis of data and subgroups, as well as sensitivity analysis, were performed utilizing Review Manager V.5.4.1 (RevMan V.5.4.1) and Stata/MP 17.0. ***Results:*** This meta-analysis comprised twenty-six original studies with 1,779 individuals. Glucose metabolism: As a result of the pooled analysis, it demonstrated that combination treatment resulted in a reduction in the HbA1c (MD: -0.73, 95% CI: -0.91 to -0.55, P<0.00001), FPG (MD −1.14, 95% CI −1.38 to −0.90, P<0.00001), P2hPG (MD: -1.22, 95% CI: -1.66 to -0.78, P<0.00001), Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) (MD: -0.59, 95% CI: -1.07 to -0.11, P＝0.02), and Fasting Insulin (FINS) (MD: -2.63, 95% CI: -3.81 to -1.45, P<0.0001). Lipid metabolism: The results revealed that Baduanjin exercise could help T2DM patients improving the level of lipid metabolism, which reduced the level of Total cholesterol (TC) (MD: -0.36, 95% CI: -0.52 to -0.21, P<0.00001), Triglycerides (TG) (MD: -0.56, 95% CI: -0.82 to -0.30, P<0.0001), Low density lipoprotein (LDL-C) (MD: -0.19, 95% CI: -0.29 to -0.10, P＝0.0001) and increased the level of High-density lipoprotein (HDL-C) (MD: 0.11, 95% CI: 0.06 to 0.16, P<0.0001). Simultaneously, the combined findings also demonstrated that the interventions were efficacious in decreasing Body Mass Index (BMI) (MD: -1.14, 95% CI: -1.90 to -0.37, P＝0.004) and Waist-Hip Ratio (WHR) (MD: -0.07, 95% CI: -0.13 to -0.01, P＝0.02). Sensitivity analyses indicated that these results were robust. ***Conclusions:*** Current low-quality evidence demonstrated that T2DM patients through Baduanjin exercise could significantly improve the level of glucose and lipid metabolism. The evidence available was insufficient to establish the effects of Baduanjin exercise on T2DM patients. Further high-quality studies are needed to explore its effects of Baduanjin exercise on T2DM patients. ***Systematic review registration:*** https://www.crd.york.ac.uk/PROSPERO/display_record.php?Record ID=325538.

Keywords: Baduanjin exercise, Type 2 diabetes mellitus, glucose metabolism, lipid metabolism, meta-analysis

1. Introduction

Type 2 diabetes mellitus (T2DM), a metabolic condition with numerous etiologies, is defined by chronic hyperglycemia caused by inadequate insulin production and/or insulin action (Moran GM, Bakhai C, Song SH, et al., 2022); J Javeed N & Matveyenko AV, 2018; Taylor R., 2013). In 2045, the prevalence of diabetes among adults aged 20-79 is estimated to rise to 12.2 percent (783.2 million), up from 10.5 percent in 2021. (or 536.6 million). The incidence of diabetes was similar among men and women, with the highest frequency among those aged 75 to 79. In 2021, a greater frequency was observed in urban regions (12.1 percent) than in rural areas (8.3 percent) as well as in high-income countries (11.1 percent) than in low-income countries (5.5 percent). By 2045, diabetes-related health costs are projected to increase from 966 billion USD in 2021 to 1,054 billion USD (Sun H, Saeedi P, Karuranga S, et al., 2022; Tinajero M G & Malik V S., 2021; Chen L, Magliano D J & Zimmet P Z., 2011). Diabetic patients are at risk for developing complications such as cardiovascular disease, kidney disease, and diabetic neuropathy (Kautzky-Willer A, Harreiter J & Pacini G., 2016). Dietary management, moderate exercise, hypoglycemic and lipid-lowering medications are the most common treatments for treating T2DM. Despite the therapeutic benefits of the pharmaceuticals used to treat T2DM, the majority of these medications might have undesirable side effects (Padhi S, Nayak A K & Behera A., 2020; Xu L, Li Y, Dai Y, et al., 2018; Gloyn A L & Drucker D J., 2018). Physical activities, such as aerobic exercise and resistance exercise, are non-drug and cost-effective interventions for the treatment of T2DM that can decrease long-term morbidity and mortality as well as increase insulin sensitivity (Kanaley J A, Colberg S R, Corcoran M H, et al., 2022).

According to modern pharmaceutical research, traditional Chinese medicine (TCM) may be effective in the treatment of T2DM by lowering blood glucose and lipid levels in multiple channels and through multiple targets (Zheng Y, Ding Q, Wei Y, et al., 2021; Zhang Y, Yang Y, Ding L, et al., 2021; Pan L, Li Z, Wang Y, et al., 2020; Yu X, Chau J & Huo L., 2018; Pang B, Zhou Q, Zhao T Y, et al., 2015). As an intrinsic element of TCM, Baduanjin (the Eight Section Brocades) — Among the most common forms of Qigong (a

Chinese mind-body form of exercise) — consists of eight separate movements, each bringing certain advantages in various physical parts of the body or particular organs. It is a traditional cultivation health method that is simple to administer and a practical intervention that can exert beneficial effects on T2DM patients (Zhou J, Li L, Deng W, et al., 2021; Zhou J, Yu Y, Cao B, et al., 2020). Randomized controlled trials (RCTs) indicate that Baduanjin exercise is promising as an alternative intervention for glucose and lipid metabolism in individuals with T2DM (Zhang B, Wang Z, Peng F, et al., 2022; Yu D D, You L Z, Huang W Q, et al., 2020; Wen J, Lin T, Cai Y, et al., 2017; Yu T T, Yu X L, Zeng L M, et al., 2014). Huang 2021 (Huang L & Ma Q., 2021) demonstrated that the third and overall formula of Baduanjin exercise enhanced the patients' body shape and metabolic index. Meanwhile, Yi 2019 (Yi WM, Zhang XH, Xie PF, et al., 2019) revealed that Baduanjin exercise prescription might improve the function of islet β cells, thereby dramatically reducing the levels of fasting blood glucose, glycated hemoglobin and triglyceride in patients with T2DM. The mechanism of action might involve an increase in basal insulin secretion and an improvement in insulin resistance. The specific composition of Baduanjin exercise was described in detail in the table below (Table 1).

However, it is still unclear whether Baduanjin exercise has comparable effectiveness for patients with T2DM. Accordingly, this systematic review and meta-analysis will summarize the current evidence concerning Baduanjin exercise for glucose and lipid metabolism used in treating T2DM.

Table 1. Specific composition of Baduanjin exercise—one of Traditional Asian exercise

Techniques		Pin yin
First posture	Propping up the Sky	*shuāng shǒu tuō tiān lǐ sān jiāo*
Second posture	Draw Bows Left and Right resembling Shooting Eagle Owl	*zuǒ yòu kāi gōng sì shè diāo*
Third posture	Raising One Hand to Regulate Spleen and Stomach	*tiáo lǐ pí wèi xū dān jǔ*
Forth posture	Looking over the Shoulders	*wǔ láo qī shāng wǎng hòu qiáo*
Fifth posture	Swaying Head and Buttocks to Release Heart-Fire	*yáo tóu bǎi wěi qù xīn huǒ*
Sixth posture	Hands Rub the Back to Legs to Stabilize Kidney and Waist	*shuāng shǒu pān zú gù shèn yāo*
Seventh posture	Clenching Fists and Looking Forward with Eyes Wide Open	*cuán quán nù mù zēng qì lì*
Eighth posture	Jolting	*bèi hòu qī diān bǎi bìng xiāo*

2. Materials and Methods

The actual reporting for this systematic review and meta-analysis adheres to the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) standard (Page M J, McKenzie J E, Bossuyt P M, et al., 2021), and it was registered with the International Prospective Register of Systematic Reviews (Sideri S, Papageorgiou S N, Eliades T., 2018) (PROSPERO) database (registration number, CRD42022325538). Any modifications made to this study will be reflected on PROSPERO. To ensure the validity of this study, we conducted this meta-analysis in accordance with the guidelines provided by the most recent Cochrane Handbook for Systematic Reviews of Interventions version 6.3 (updated February 2022) (Higgins JPT, Thomas J & Chandler J., 2022), Methodological Expectations for Cochrane Intervention Reviews (MECIR) (Julian H, Toby L & Jackie C., 2022). Supplementary Material S1 presents the PRISMA 2020 checklist.

2.1 Selection Criteria

2.1.1 Inclusion and Exclusion Criteria for Meta-Analysis

2.1.1.1 Inclusion Criteria

(1) Type of Studies: RCTs measuring the effects of Baduanjin exercise on glucose and lipid metabolism in individuals with T2DM without restrictions concerning randomization generation, blinding, or publication language;

(2) Participants: Patients with specified diagnosis criteria of T2DM without restriction of age, gender, race, ethnicity region, and disease stage;

(3) Intervention measures:

1) Experiment group: Baduanjin exercise without limitation to duration and frequency including only Baduanjin exercise, Baduanjin exercise plus western medicine and Baduanjin exercise plus lifestyle intervention or excerise.

2) Control group: Routine rehabilitation like blank, placebo, western medicine, lifestyle intervention and exercise.

(4) Data: Those studies from which raw data like data on the baseline, the observation number, the case source, the follow-up period, and other variables could not be extracted, we would contact the author. In the event that it was not possible to obtain it at the end, it would be written off as not reported (NR);

(5) Others: A meta-analysis of multiple studies, some of which include overlapping groups of patients, would include only the study with the greatest number of participants.

2.1.1.2 Exclusion Criteria

(1) Type of Studies: Observational studies due to their potential high risk of bias and confounding factors including cohort studies, case-control studies, cross-sectional studies, case series, and so forth;

(2) Participants: Patients with severe diabetic complications, cardiovascular or liver and kidney diseases, pregnant women, postoperative infections, and psychiatric patients;

(3) Unable to determine whether the curative effect was due to Baduanjin exercise for T2DM patients, and research without relevant indicators would be excluded from the study;

(4) No indicators concerned in study.

2.2 Database and Search Strategies

2.2.1 Electronic Searches

Five English language databases (PubMed, Web of Science, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL) and Scopus) were searched along with four Chinese language databases (China National Knowledge Infrastructure CNKI), Wanfang Data Knowledge Service Platform (WAN FANG), VIP information resource integration service platform (CQVIP) and China Biology Medicine (CBM) from the database's inception to January 31th, 2023, with no restrictions on language, publication date, or publication status. All retrievals were implemented using MeSH and free word. The search strategies were described in detail in Supplementary Material S3. Before the final analyses were conducted, searches were repeated and additional studies were retrieved for inclusion in the analysis. Study selections were carried out independently by two or more reviewers, with disagreements being resolved through discussion.

2.2.2 Searching Other Resources

Additionally, for data on unpublished or ongoing trials, we searched for data in the National Institutes of Health clinical registry Clinical Trials, the International Clinical Trials Registry Platform, and the Chinese Clinical Trials Registry. The acquisition of full-text documents was also be assisted by Baidu academic and Google Scholar.

2.3 Type of Outcome Measures

2.3.1 Primary Outcomes

The primary outcome measures would include fasting plasma glucose (FPG), 2h postprandial plasma glucose (P2hPG) and glycosylated hemoglobin (HbA1c). Based on the results of blood test, the three indicators listed above were calculated.

2.3.2 Secondary Outcomes

Secondary outcome measures included Homeostasis Model Assessment of Insulin Resistance (HOMA-IR), Fasting Insulin (FINS), Total cholesterol (TC), Triglycerides (TG), Low density lipoprotein (LDL), High-density lipoprotein (HDL), Body Mass Index (BMI), Waist-Hip Ratio (WHR).

2.3.3 Safety Outcome

Include any adverse events that occurred throughout the trials.

2.4 Patient and Public Involvement

No patients or members of the general public

will be actively engaged. In this meta-analysis, only data already present in the literature from the aforementioned sources were utilized.

2.5 Selection and Management of Studies

Two researchers (Meixuan Guo and Mengyuan Cai) independently evaluated the eligibility of all articles identified through an electronic literature search by title and abstract, based on the inclusion and exclusion criteria. Eligible articles with full texts were further evaluated for inclusion. Disputes were resolved through discussion with the third author (Zhipeng Hu). As shown in Figure 1, the process and results of the selection of the studies were presented.

2.6 Data Extraction

After a review of the relevant literature, eligibility information was gathered from each study in relation to its identification. Below was the information that was included.

(1) Study information: First author, country, date of publication.

(2) Study design and study characteristics: Study types, disease diagnosis, average participant age (treatment/control; years), number of participants (treatment/control), gender (treatment/control; Male/Female), outcomes.

(3) Intervening measure: Intervention types, duration, frequency and total exercise time per week of Baduanjin exercise in TCM.

(4) Others: Adverse events, follow-up, funding information, and conflict of interest.

(5) An author extracted all of these data, which were then double-verified by another author in order to reduce human error. All disagreements were resolved through discussion with the third author (Zhipeng Hu). If further unpublished data was necessary, we contacted the authors through email. No transformation of reported data was conducted in this study.

2.7 Risk of Bias Assessment

To assess the risk of bias in the included studies, the Cochrane risk of bias tool was utilized (Higgins J P, Altman D G, Gøtzsche P C, et al., 2011). Risks of bias consisted of seven different domains, including the generation of random sequences, concealment of allocations, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. The specific bias risks were categorized as high risk, low risk, and unclear risk. The discrepancies were resolved through discussion with the third author (Zhipeng Hu).

2.8 Data synthesis and Analysis

Analyses of the data were carried out using the Cochrane Handbook for Systematic Reviews of Interventions version 6.3 (updated February 2022) (Higgins JPT, Thomas J & Chandler J., 2022). Statistical analysis was conducted primarily with RevMan V.5.4.1 and StataSE 16. For continuous variables, the 95% confidence interval (CI) and mean difference (MD) were computed, whereas, for dichotomous variables, the 95% CI and risk ratio (RR) were calculated. Statistics were considered significant at a P value<0.05. I^2 statistics were used to assess inconsistency among research, and I^2 values greater than 50% may indicate considerable heterogeneity. Taking into account the probability of heterogeneity, a random-effects model was applied to pool the studies, whilst a fixed-effects model utilizing for the sensitivity analysis. Analyses of subgroups were undertaken to identify the sources of heterogeneity. To determine the reliability of the results, sensitivity analyses were performed by recalculating pooled values after deleting one study at a time and employing a different statistical model (random-effects model or fixed-effect model). Forest plots were used to illustrate the results. If more than 10 trials were included, publication bias was evaluated using funnel plots (Choi S W & Lam D M., 2016). An outcome that was deemed inappropriate for data synthesis was presented in a narrative summary.

2.9 Subgroup Analyses

Subgroup analyses were conducted based on these predetermined subgroup assumptions:

- Treatment duration of Baduanjin exercise (≥6 months; <6 months);

- Interventions (Baduanjin alone; Combination of Baduanjin exercise and other exercises)

- Intensity of intervention (Total exercise time per week<300min; Total exercise time per week≥300min)

- Level of baseline (depending on data);

2.10 Assessment of Publication Bias

To analyze publication bias when more than 10 papers are included, it is required to utilize an inverted funnel plot. Whether or not publication bias exists relies on the symmetry of the funnel

plot (Choi S W & Lam D M., 2016).

2.11 Dealing with Missing Data

In the event of missing data, we contacted the corresponding authors.

3. Results

3.1 Database Search Results

From a search of 9 databases, 256 citations were obtained. 125 studies were omitted owing to redundancy. After reviewing the titles and abstracts, 72 references were eliminated. After reviewing the entire texts, 33 citations were removed, including 5 non-randomized controlled trials, 12 studies of diseases other than T2DM, 3 publications with inconsistent outcome indicators, 9 pieces of literature that had been previously published, and 4 studies of poor quality. A total of 26 studies were finally included in the quantitative analysis. (Huang 2021, Qi 2021, Luo 2021, Li 2020, Zhu 2020, He 2019, Yi 2019, Wang 2019, Wu 2019, Yang 2018, Li 2017, Li Peng 2017, Zhuang 2017, Li 2016, Hou 2016, Wang 2016, Wu 2015, Wang 2015, Guan 2012, Yang 2012, Huang 2011, Zhou 2011, Li 2009, Pan 2008, Wang 2007, Liu 2018). A detailed description of the process of study selection could be found in Figure 1.

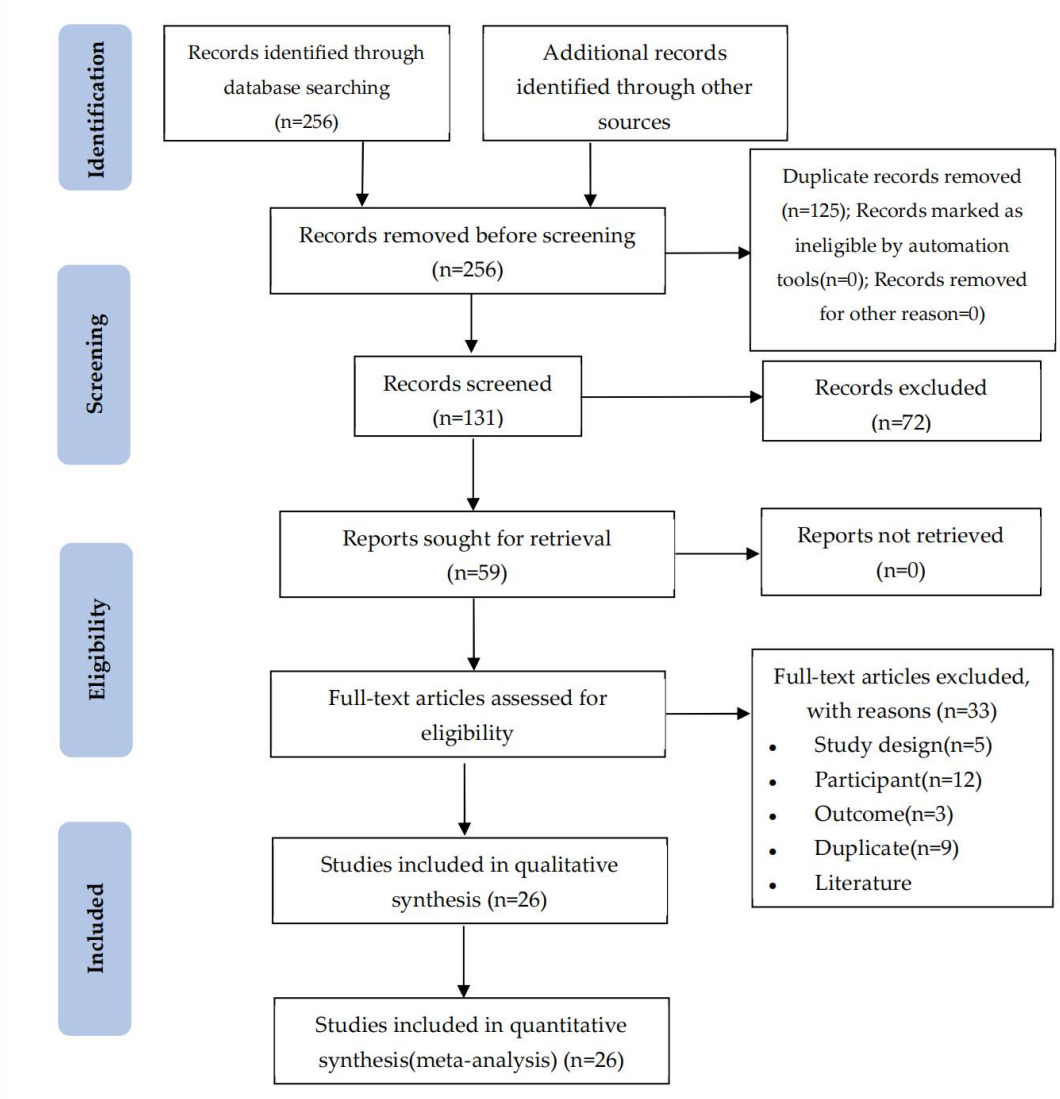

Figure 1. Flowchart of study selection and identification

3.2 Characteristics of the Included Studies

Twenty-six original RCTs were included in this meta-analysis. There were a total of 1779 participants, with 888 assigned to the treatment group and 891 to the control group. All of the studies were conducted in China during the period 2007 to 2021 with intervention time ranging from 3 weeks to 12 months.

Twenty-three (Huang 2021, Qi 2021, Li 2020, He 2019, Yi 2019, Wang 2019, Wu 2019, Yang 2018, Li 2017, Li Peng 2017, Zhuang 2017, Li 2016, Hou 2016, Wang 2016, Wu 2015, Wang 2015, Guan 2012, Yang 2012, Huang 2011, Zhou 2011, Li 2009, Pan 2008, Wang 2007) of the 26 studies included patients with T2DM, whereas 3 studies (Luo 2021, Zhu 2020, Liu 2018) included patients with T2DM with hypertension or obese. The intervention methods consisted mostly of Baduanjin plus regular treatment. Li 2020 and He 2019 expressed the combination of Baduanjin and resistance exercise while Zhuang 2017 (Zhuang Q, Shen B & Wang J., 2017) showed combination of Baduanjin and elastic band. Indicators were dispersed among the included research. Some research, for instance, incorporated simply glucose metabolism indicators, some only lipid metabolism indicators. When evaluating relevant individual indicators, there would be more indicators and less literature in subsequent meta-analyses. The study covered in this publication had a limited sample size and low comprehensive quality of literature, resulting in some heterogeneity in the data analyzed. All studies did not involve adverse events, funding information, and conflict of interest. Only Huang 2021 (Huang L & Ma Q., 2021) mentioned the follow-up using the way like WeChat group, telephone return visits and family visits. A list of the detailed characteristics of the 26 included studies were presented in Table 1.

Table 2. Characteristics of included studies

Studies	Huang 2021	Qi 2021	Luo 2021	Li 2020
Year	2021	2021	2021	2020
Country	China	China	China	China
Types	RCTs	RCTs	RCTs	RCTs
Inclusion	T2DM	T2DM	Elderly T2DM with hypertension	T2DM
E: Duration	3M	6M	12W	12W
E: Intervention	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT	Baduanjin+Resistance exercise
E: Frequency	30 minutes, twice a day	30 minutes, 3 times a week	40 minutes, 3 times a week	40 minutes, 5 times a week
E:Total exercise time per week	300min	90min	120min	200min
E: N	40	40	40	40
E: Age	53.25± 2.20	41-69	66.54 ± 10.32	57.63±6.59
E: Male/ Female	20/20	23/17	24/16	22/18
C: Intervention	Walking	RT	RT	Resistance exercise
C: N	40	40	40	40
C: Age	53.22±2.21	40-70	67.32 ± 9.46	57.23±6.23
C: Male/ Female	25/15	24/16	27/13	21/19
Outcomes	①②③⑥⑦⑧⑨⑩⑪	①②⑥⑦⑨	①②③	①②④⑥⑦⑧⑨⑩⑪
Adverse events	NR	NR	NR	NR
Follow-up	Wechat group; Telephone return	NR	NR	NR

	visits; Family visits			
Funding information and conflict of interest	NR	NR	NR	NR
Zhu 2020	He 2019	Yi 2019	Wang 2019	Wu 2019
2020	2019	2019	2019	2019
China	China	China	China	China
RCTs	RCTs	RCTs	RCTs	RCTs
Obese T2DM	T2DM	T2DM	T2DM	T2DM
3M	12M	12W	12M	3M
Baduanjin+RT	Baduanjin+Resistance exercise	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT
30-60 minutes, 5 times a week	Baduanjin exercise 30~60 min daily, resistance training 2~3 times a week	30 minutes, three times a day	30 minutes, 5 times a week	twice a day
225min	225min	450min	150min	≈300min
50	23	13	50	30
52.1±11.6	49.65 ±9.00	53.54±8.21	61.76±10.54	57.8±7.5
28/22	11/12	6/7	24/26	18/12
Walking	Walking+Resistance exercise	RT	RT	RT
50	27	13	50	30
52.4±11.9	49.36±11.54	54.11±9.06	61.67±10.51	56.5±6.9
27/23	14/13	5/8	25/25	20/10
①②③⑥⑦	①②③⑥⑦⑧⑨⑩	①②③④⑥⑦⑧⑨	①②⑩	①②⑤⑥⑦⑧⑨
NR	NR	NR	NR	NR
NR	NR	NR	NR	NR
NR	NR	NR	NR	NR

Studies	Yang 2018	Li 2017	Li Peng 2017	Zhuang 2017
Year	2018	2017	2017	2017
Country	China	China	China	China
Types	RCTs	RCTs	RCTs	RCTs
Inclusion	T2DM	T2DM	T2DM	T2DM
E: Duration	6M	3M	6M	24W
E: Intervention	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT	Combination of Baduanjin and Elastic Band+RT
E: Frequency	twice a day, 5 times a week	30 minutes, at least 4 days a week	twice a day, 5 times a week	60-70 minutes, 5 times a week
E: Total exercise time per week	150min	120min	150min	325min

E: N	17	43	12	40
E: Age	57.28±4.86	44.32±5.07	62.17±5.06	NR
E: Male/ Female	NR	23/20	NR	NR
C: Intervention	RT	RT	RT	RT
C: N	18	43	10	40
C: Age	56.91±6.32	42.91±6.10	62.40±6.06	NR
C: Male/ Female	NR	22/21	/	NR
Outcomes	①②③⑥⑦⑧⑨	①②③⑥⑦⑧⑨	①②③⑤⑥⑦⑧⑨	①②⑥⑦⑧⑨⑩
Adverse events	NR	NR	NR	NR
Follow-up	NR	NR	NR	NR
Funding information and conflict of interest	NR	NR	NR	NR

Li 2016	Hou 2016	Wang 2016	Wu 2015	Wang 2015
2016	2016	2016	2015	2015
China	China	China	China	China
RCTs	RCTs	RCTs	RCTs	RCTs
T2DM	T2DM	T2DM	T2DM	T2DM
12W	6M	3-4W	3M	6W
Baduanjin+RT	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT
45-50 minutes, 5 times a week	30 minutes, 5 times a week	30 minutes a day	three times a day, 5 times a week	20 minutes, 5 times a week
250min	150min	150min	225min	100min
30	31	54	20	30
60±3	58.82±6.78	47.25±9.15	63. 9±7. 6	61.7±6.9
18/12	22/9	29/25	NR	16/14
RT	RT	RT	RT	RT
30	31	54	20	30
59±4	58.93±6.47	49.26±8.15	65. 3 ±6. 0	61.3±8.4
17/13	23/8	28/26	NR	17/13
①②③⑪	①②⑥⑦⑨	①②③	①②	①②③⑥⑦⑧⑨
NR	NR	NR	NR	NR
NR	NR	NR	NR	NR
NR	NR	NR	NR	NR

Studies	Guan 2012	Yang 2012	Huang 2011	Zhou 2011
Year	2012	2012	2011	2011
Country	China	China	China	China

Types	RCTs	RCTs	RCTs	RCTs
Inclusion	T2DM	T2DM	T2DM	T2DM
E: Duration	4M	6M	6M	3M
E: Intervention	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT
E: Frequency	Once a day, each time for 1h	60 minutes, twice a week	Once a day, each time for 1h	30 minutes a day
E: Total exercise time per week	300min	120min	300min	60min
E: N	39	29	30	63
E: Age	59.20±8.8	60.83±5.20	57.8±7.5	67.4±9.23
E: Male/ Female	18/21	9/20	18/12	32/31
C: Intervention	RT	RT	RT	Fundamental Sports+RT
C: N	40	30	30	63
C: Age	58.70±8.3	58.1±7.92	56.5 ± 6.9	68.13 ± 10.64
C: Male/ Female	20/20	15/15	20/10	31/32
Outcomes	①②③⑦	①②⑥⑦⑧⑨	①②⑥⑦⑧⑨	①②③⑥⑦⑧⑨⑩⑪
Adverse events	NR	NR	NR	NR
Follow-up	NR	NR	NR	NR
Funding information and conflict of interest	NR	NR	NR	NR

Li 2009	Pan 2008	Wang 2007	Liu 2018
2009	2008	2007	2018
China	China	China	China
RCTs	RCTs	RCTs	RCTs
T2DM	T2DM	T2DM	Obese middle-aged woman with T2DM
6M	24W	6M	24W
Baduanjin+RT	Baduanjin+RT	Baduanjin+RT	Baduanjin+RT
60 minutes a day	twice a day, 5 times a week	60 minutes a day	90 minutes a day, 6 times a week
300min	450min	300min	540min
40	24	40	20
57.8±7.5	47± 7	57.8±7.5	NR
28/12	14/10	28/12	NR
RT	RT	RT	RT
39	24	39	20

56.5± 6.9	45± 9	56.5±6.9	NR
25/14	16/8	25/14	NR
①②③⑥⑦⑧⑨	①②⑥⑨⑩⑪	①②⑥⑦⑨	①②⑥⑦⑧⑨⑩⑪
NR	NR	NR	NR
NR	NR	NR	NR
NR	NR	NR	NR

① Fasting Plasma Glucose(FPG); ② Glycosylated Hemoglobin (HbA1c); ③ 2h Postprandial Plasma Glucose (P2hPG); ④ Homeostasis Model Assessment of Insulin Resistance (HOMA-IR); ⑤ Fasting Insulin (FINS); ⑥ Total Cholesterol(TC); ⑦ Triglycerides(TG); ⑧ Low Density Lipoprotein(LDL); ⑨ High Density Lipoprotein(HDL); ⑩ Body Mass Index(BMI); ⑪ Waist-Hip Ratio (WHR); E, experimental group; C, control group; RT, regular treatment; NR, not reported; RCTs, randomized controlled trials; T2DM, type 2 diabetes mellitus.

3.3 Risk of Bias Assessment

As shown in Figures 2 and 3, we assessed the risk of bias for each study by the Cochrane risk of bias tool (Higgins J P, Altman D G, Gøtzsche P C, et al., 2011). For random sequence generation, 14 studies (Huang 2021, Luo 2021, Li 2020, Yi 2019, Yang 2018, Li 2017, Li 2016, Hou 2016, Wang 2016, Wang 2015, Guan 2012, Yang 2012, Zhou 2011, Pan 2008) mentioned "random" and described the specific random assignment method and were therefore judged as low risk. The remaining 12 studies (Qi 2021, Zhu 2020, He 2019, Wang 2019, Wu 2019, Li Peng 2017, Zhuang 2017, Wu 2015, Huang 2011, Li 2009, Wang 2007) were classified as an unclear risk because they only mentioned randomization but did not specify the method used; For allocation concealment, 26 studies were assessed as unclear because of the absence of detailed information. For blinding of participants, personnel and outcome assessment, Baduanjin exercise was added to the experimental group on the basis of the control group. Due to the differences between the two groups, the blind method cannot be utilized. Therefore, all groups should be at high risk as determined by the blind method. Selective reporting should be determined according to the protocol. In the absence of a protocol, it should be evaluated as unknown risk. Finally, all studies regarding incomplete outcome data and other sources of bias were considered to be of low risk as no specific information as described.

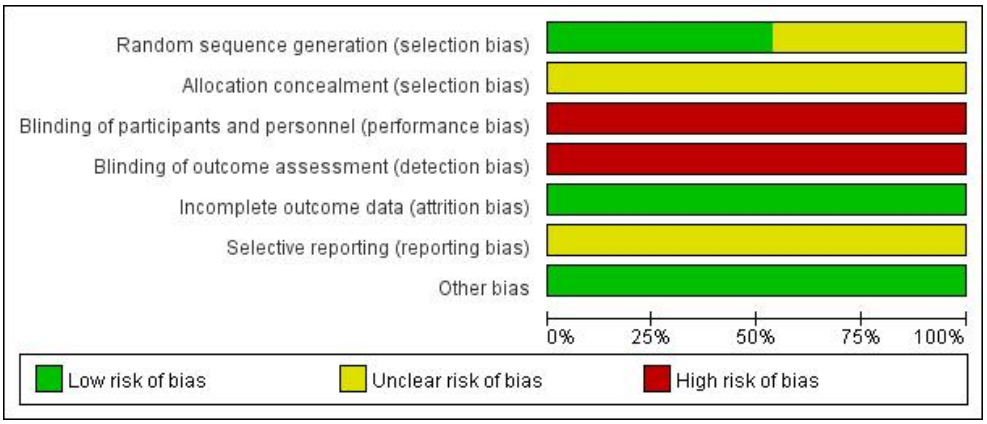

Figure 2. Risk of bias graph

Figure 3. Risk of bias summary

3.4 Effect of Glucose Metabolism on T2DM

3.4.1 Meta-Analysis of HbA1c

In twenty-six (Huang 2021, Qi 2021, Luo 2021, Li 2020, Zhu 2020, He 2019, Yi 2019, Wang 2019, Wu 2019, Yang 2018, Li 2017, Li Peng 2017, Zhuang 2017, Li 2016, Hou 2016, Wang 2016, Wu 2015, Wang 2015, Guan 2012, Yang 2012, Huang 2011, Zhou 2011, Li 2009, Pan 2008, Wang 2007, Liu 2018) of the included RCTs about 1779 participants, the results of Baduanjin exercise in TCM was reported in relation to HbA1c. Results using the randomized-effect model showed that, as compared with the control group, the experimental group was able to significantly decrease the level of HbA1c (MD: -0.73, 95% CI: -0.91 to -0.55, P<0.00001, I^2 =74%) (Figure 4). Sensitivity analyses indicated that this result was robust (Supplementary Material 4.5). The subgroup analysis according to treatment duration (≥6 months; <6 months) showed significant subgroup difference (P＝0.0005) and the heterogeneities in these two subgroups were decreased (I^2=53% and 56%, respectively) (Supplementary Material 4.6). Also, subgroup according to intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises) showed difference (P ＝ 0.001) (Supplementary Material 4.7) while subgroup analyses according to intensity of intervention (Total exercise time per week<300min; Total exercise time per week≥300min) showed unrelated interactions (P=0.12) (Supplementary Material 4.8).

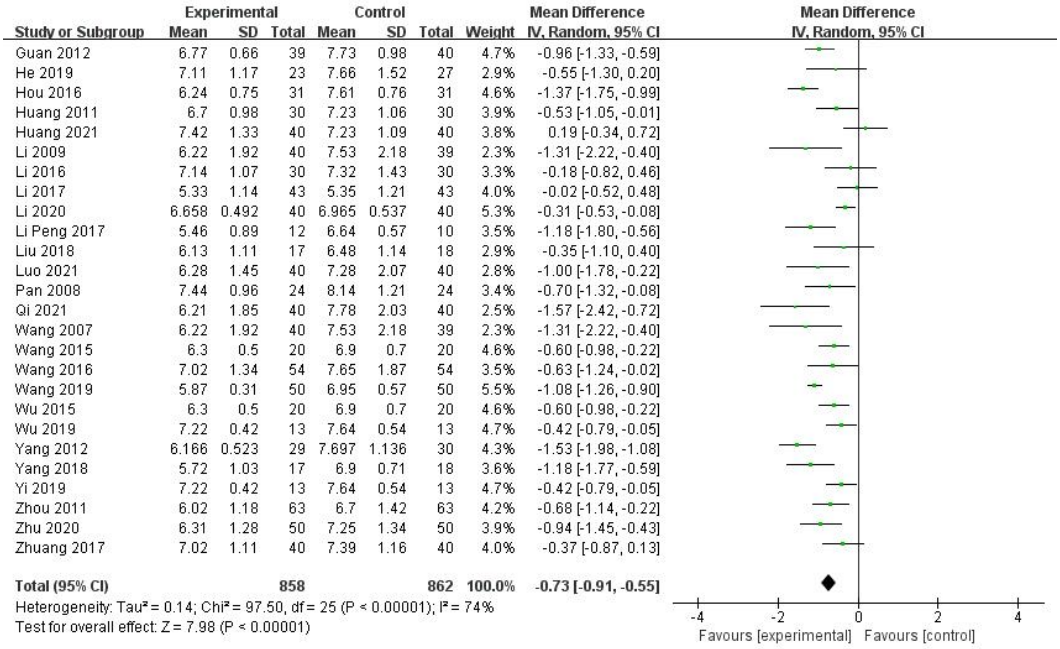

Figure 4. Forest plot for the HbA1c

3.4.2 Meta-Analysis of FPG

Among the included RCTs, twenty-six (Huang 2021, Qi 2021, Luo 2021, Li 2020, Zhu 2020, He 2019, Yi 2019, Wang 2019, Wu 2019, Yang 2018, Li 2017, Li Peng 2017, Zhuang 2017, Li 2016, Hou 2016, Wang 2016, Wu 2015, Wang 2015, Guan 2012, Yang 2012, Huang 2011, Zhou 2011, Li 2009, Pan 2008, Wang 2007, Liu 2018) studies including 1779 participants reported the outcomes of Baduanjin exercise interventions on the FPG. The results using the randomized effects model showed that compared with the control group, the experimental group was able to significantly reduce FPG, but the variation between studies was large (MD: -1.14, 95%CI: -1.38 to -0.90, P<0.00001, I^2 = 84%) (Figure 5). The sensitivity analysis based on a randomized-effects model had no significant effect on these results (Supplementary Material 4.1). Subgroup analyses according to treatment duration of Baduanjin exercise (≥6 months; <6 months) and intervention measures (Baduanjin alone; Combination of Baduanjin and other exercise) showed significant subgroup difference (P=0.02, P=0.04). (Supplementary Material 4.2-4.3). Subgroup analyses according to intensity of intervention (Total exercise time per week<300min; Total exercise time per week≥300min) showed no significant interaction with the factors (P=0.56). (Supplementary

Material 4.4)

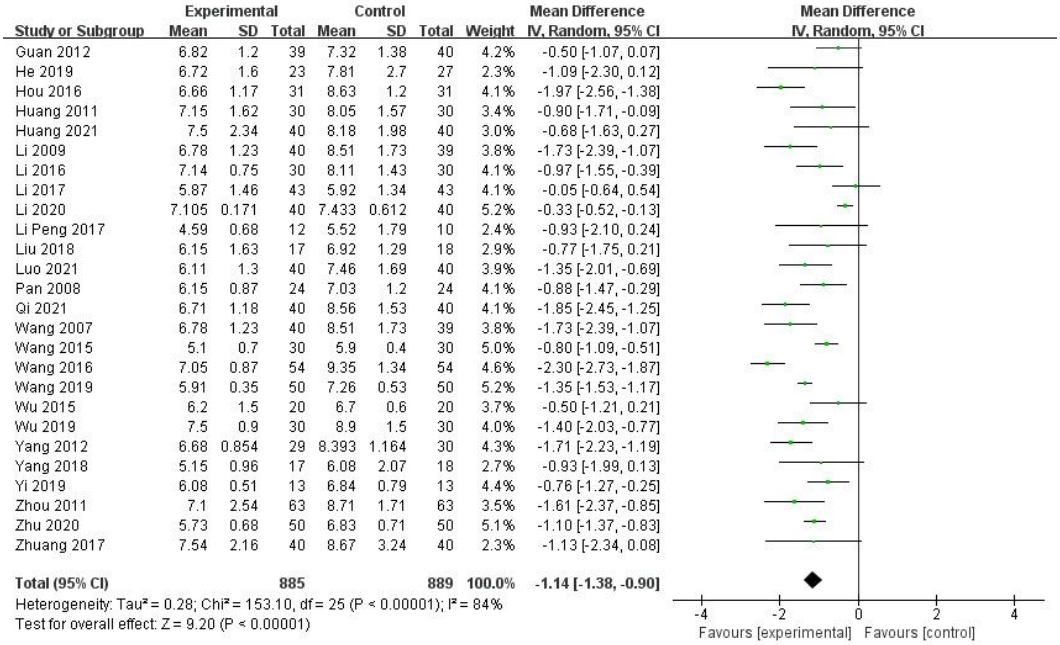

Figure 5. Forest plot for the FPG

3.4.3 Meta-Analysis of P2hPG

Fourteen studies (Huang L & Ma Q., 2021; Yi WM, Zhang XH, Xie PF, et al., 2019; Luo F., 2021; Zhu RL, Miu XQ & Li SJ., 2020; He K, Liu L, Bian RR, et al., 2019; Yang H., 2018; Li Y., 2017; Li P., 2017; Li QW, Ding WG, Pei JY, et al., 2016; Wang J., 2016; Wang CY & Zhang HY., 2015; Guan YX, Wang SS & Ma MN., 2012; Zhou LB, Zhang JQ, Zhao XL, et al., 2011; Li XH., 2009; Wang YG, Liu LJ, Kou ZJ, et al., 2007; Liu T, Bai S & Zhang R C., 2018) including 991 participants in this meta-analysis reported the P2hPG as the primary outcome. Evaluated by a random-effects model, the pooled results demonstrated that there was statistically significant difference (P<0.00001). Meanwhile, there was considerable heterogeneity between the studies. (RR: -1.22, 95% CI: -1.66 to -0.78, I^2 = 87%) (Figure 6). Sensitivity analyses indicated that the results were robust (Supplementary Material 4.9). Subgroup analyses showed unrelated interactions with treatment duration (≥6 months; <6 months), intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises) and intensity of intervention (Total exercise time per week<300min; Total exercise time per week≥300min) (P=0.46, P=0.13, P=0.25 respectively). (Supplementary Material 4.10-4.12)

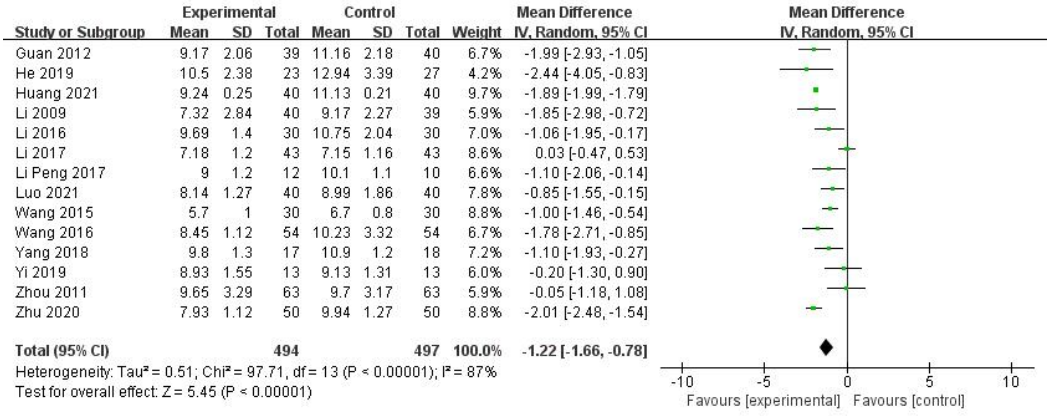

Figure 6. Forest plot for P2hPG

Table 3. Subgroup analyses in the association of FPG, P2hPG and HbA1c with the ex-ante parameters

Comparison	Subgroup	No. of studies	SMD [95% CI]	P for meta-analysis	I^2	P for heterogeneity
HbA1c						
Treatment duration of Baduanjin exercise	≥6 months	13	-1.00[-1.23,-0.78]	<0.00001	56%	0.007
	<6 months	13	-0.50[-0.67,-0.32]	<0.00001	53%	0.01
Intervention measures	Baduanjin alone	23	-0.78[-0.96,-0.59]	<0.00001	72%	<0.00001
	Combination of Baduanjin and other exercise	3	-0.33[-0.53,-0.14]	0.0010	0%	0.82
Intensity of intervention	Total exercise time per week<300min	16	-0.82[-1.06,-0.59]	<0.00001	78%	<0.00001
	Total exercise time per week≥300min	10	-0.55[-0.80,-0.31]	<0.0001	54%	0.02
FPG						
Treatment duration of Baduanjin exercise	≥6 months	13	-1.42[-1.63,-1.20]	<0.00001	84%	0.14
	<6 months	13	-0.95[-1.29,-0.60]	<0.00001	87%	<0.00001
Intervention measures	Baduanjin alone	23	-1.19[-1.41,-0.97]	<0.00001	75%	<0.00001
	Combination of Baduanjin and other exercise	3	-0.58[-1.13,-0.03]	<0.00001	84%	<0.00001
Intensity of intervention	Total exercise time per week<300min	16	-1.18[-1.51,-0.86]	<0.00001	89%	<0.00001
	Total exercise time per week≥300min	10	-1.05[-1.35,-0.76]	<0.00001	42%	0.08
P2hPG						
Treatment duration of Baduanjin exercise	≥6 months	4	-1.40[-1.93,-0.87]	<0.00001	3%	0.38
	<6 months	10	-1.12[-1.65,-0.59]	<0.0001	90%	<0.00001
Intervention measures	Baduanjin alone	13	-1.16[-1.61,-0.71]	<0.00001	88%	<0.00001
	Combination of Baduanjin and other exercise	1	-2.44[-4.05,-0.83]	0.003	/	/
Intensity of intervention	Total exercise time per week<300min	10	-1.09[-1.59,-0.58]	<0.0001	<0.00001	79%
	Total exercise time per week≥300min	4	-1.58[-2.25,-0.91]	<0.00001	0.03	67%

Abbreviations: EF: ejection fraction; FS: fractional shortening; HFD: high-fat diet; SIJ: single intraperitoneal injection; STZ: streptozotocin; SMD: standard mean difference; T1DM: Type 1 diabetes mellitus; T2DM: Type 2 diabetes mellitus.

3.4.4 Meta-Analysis of HOMA-IR and FINS

Two of the included RCTs (Yi WM, Zhang XH,

Xie PF, et al., 2019; Yi WM, Zhang XH, Xie PF, et al., 2019; Li FX., 2020) about 106 participants reported the effects of Baduanjin exercise on HOMA-IR. In comparison to the control group, the experimental group was able to substantially decrease HOMA-IR (MD:-0.59, 95% CI:-1.07 to -0.11, P=0.02, I^2 = 0%) based on the fixed-effects model (Figure 7). Analyses of sensitivity had shown that this result was robust (Supplementary Material 4.13).

Two of the included RCTs (Wu WZ., 2019; Li P., 2017) involving 82 participants reported the effects of Baduanjin exercise on FINS. Using a model with fixed effects, the experimental group was able to decrease FINS substantially more than the control group (MD:-2.63, 95% CI:-3.81 to -1.45, P<0.0001, I^2 = 0%). (Figure 8). The results of the sensitivity analysis indicate that this result was robust (Supplementary Material 4.14).

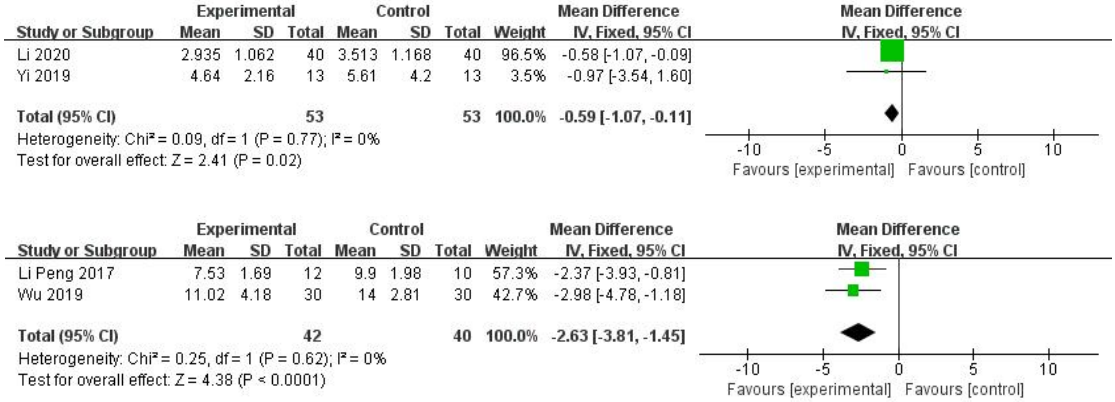

Figure 7-8. Forest plot for HOMA-IR and FINS

3.5 Effect of Lipid Metabolism on T2DM

3.5.1 Meta-Analysis of TC

Twenty of the listed RCTs (Huang L & Ma Q., 2021; Yi WM, Zhang XH, Xie PF, et al., 2019; Qi L., 2021; Li FX., 2020; Zhu RL, Miu XQ & Li SJ., 2020; He K, Liu L, Bian RR, et al., 2019; Wu WZ., 2019; Yang H., 2018; Li Y., 2017; Li P., 2017; Zhuang Q, Shen B & Wang J., 2017; Hou JY., 2016; Wang CY & Zhang HY., 2015; Yang MC., 2012; Huang RC & Deng XD., 2011; Zhou LB, Zhang JQ, Zhao XL, et al., 2011; Li XH., 2009; Pan HS & Feng YC., 2008; Wang YG, Liu LJ, Kou ZJ, et al., 2007; Liu T, Bai S & Zhang R C., 2018) including 1307 participants mentioned TC. Using a randomized-effects model, the experimental group was able to substantially decrease TC level relative to the control group (MD: -0.36, 95% CI: -0.52 to -0.21, P<0.00001, I^2 = 78%). (Figure 9). Based on the results of the sensitivity analysis, this result was robust (Supplementary Material 4.15). Subgroup analyses revealed interactions that were unrelated to treatment duration (6 months; 6 months), intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises), and intensity of intervention (Total exercise time per week 300min; Total exercise time per week 300min) (P=0.39, P=0.38, P=0.59, respectively) (Supplementary Material 4.16-4.18).

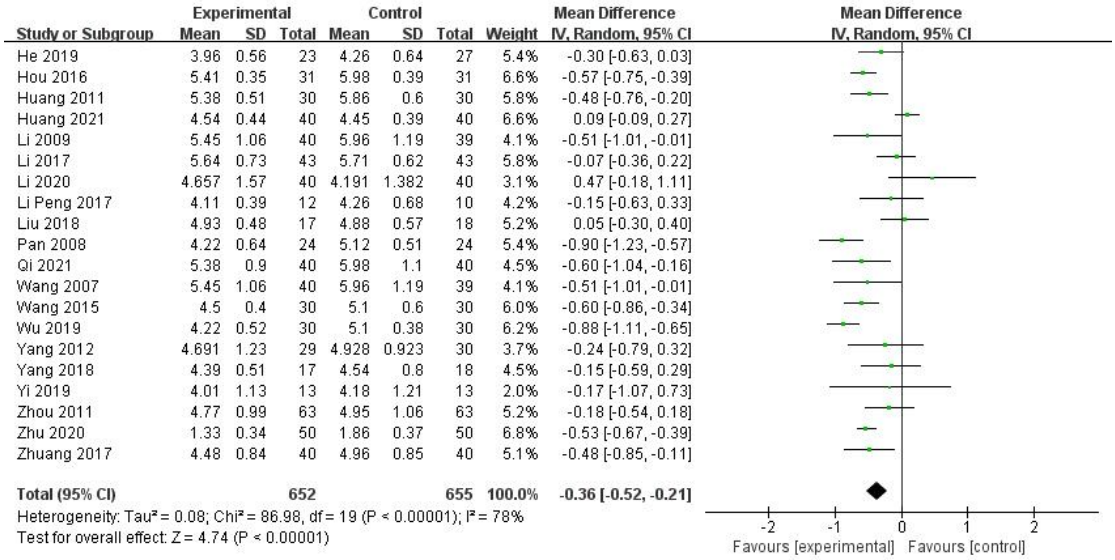

Figure 9. Forest plot for TC

3.5.2 Meta-Analysis of TG

The outcomes of Baduanjin exercise in TCM were reported in connection to the TG in twenty of the RCTs (Huang L & Ma Q., 2021; Yi WM, Zhang XH, Xie PF, et al., 2019; Qi L., 2021; Li FX., 2020; Zhu RL, Miu XQ & Li SJ., 2020; He K, Liu L, Bian RR, et al., 2019; Wu WZ., 2019; Yang H., 2018; Li Y., 2017; Li P., 2017; Zhuang Q, Shen B & Wang J., 2017; Hou JY., 2016; Wang CY & Zhang HY., 2015; Guan YX, Wang SS & Ma MN., 2012; Yang MC., 2012; Huang RC & Deng XD., 2011; Zhou LB, Zhang JQ, Zhao XL, et al., 2011; Li XH., 2009; Wang YG, Liu LJ, Kou ZJ, et al., 2007; Liu T, Bai S & Zhang R C., 2018) about 1338 participants that were included. In the comparison between the experimental group and the control group, the results obtained using the randomized-effect model demonstrated that the experimental group was able to achieve a lower TG (MD: -0.56, 95% CI: -0.82 to -0.30, P<0.00001, I^2 = 96%) (Figure 10). This result was robust as evidenced by the sensitivity analysis (Supplementary Material 4.19). Subgroup analyses revealed interactions that were unrelated to treatment duration (6 months; 6 months) and intensity of intervention (Total exercise time per week300min; Total exercise time per week 300min) (P=0.11, P=0.48 respectively). (Supplementary Material 4.20, 4.22) while it was associated with intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises) (P=0.002) (Supplementary Material 4.21).

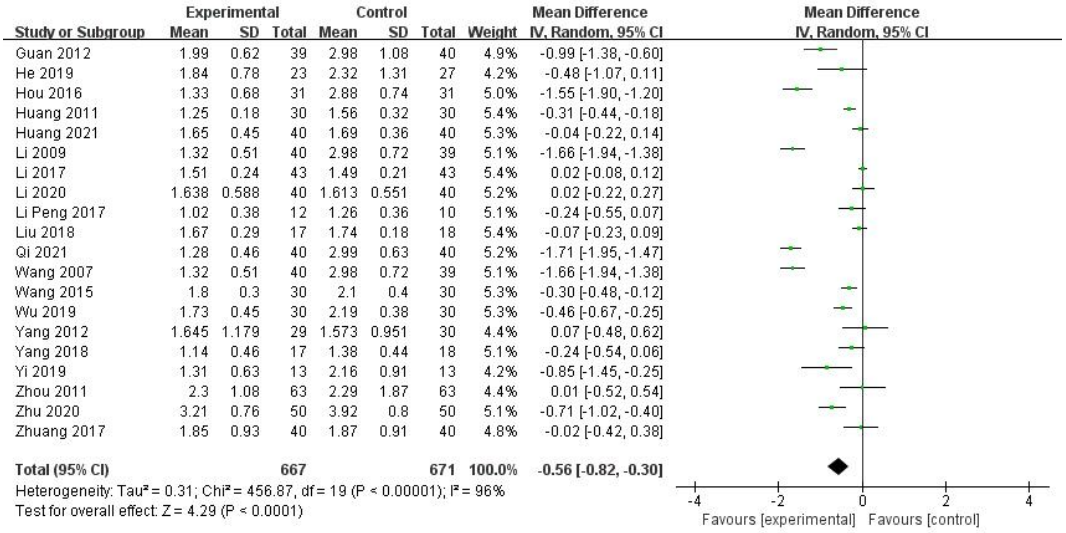

Figure 10. Forest plot for TG

3.5.3 Meta-Analysis of LDL-C

This particular meta-analysis comprised fifteen

studies (Huang L & Ma Q., 2021; Yi WM, Zhang XH, Xie PF, et al., 2019; Li FX., 2020; He K, Liu L, Bian RR, et al., 2019; Wu WZ., 2019; Yang H., 2018; Li Y., 2017; Li P., 2017; Zhuang Q, Shen B & Wang J., 2017; Wang CY & Zhang HY., 2015; Yang MC., 2012; Huang RC & Deng XD., 2011; Zhou LB, Zhang JQ, Zhao XL, et al., 2011; Li XH., 2009-52; Liu T, Bai S & Zhang R C., 2018-55;) including 938 participants that reported LDL-C. The results of the meta-analysis, which were evaluated using a randomized-effects model, demonstrated that the LDL-C of Baduanjin exercise in TCM decreased in comparison to that of the control group (MD: -0.19, 95% CI: -0.29 to -0.10, P=0.0001, I^2=53%) (Figure 11). This result was robust as evidenced by the sensitivity analysis (Supplementary Material 4.23). As a result of subgroup analyses, there were no significant interactions between the treatment duration (≥6 months; <6 months), the intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises) and the intensity of the intervention (Total exercise time per week<300min; Total exercise time per week≥300min) (P=0.76, P=0.88, P=0.71 respectively). (Supplementary Material 4.24-4.26).

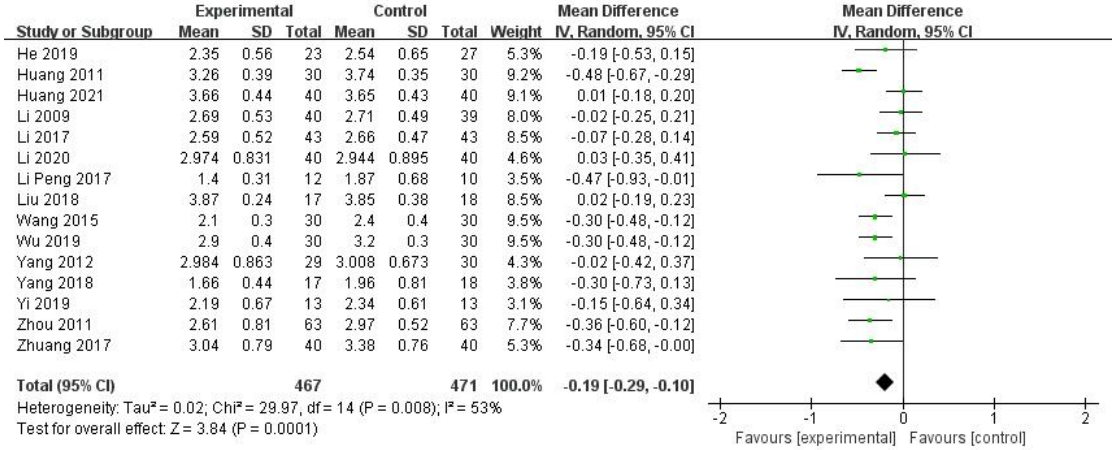

Figure 11. Forest plot for LDL-C

3.5.4 Meta-Analysis of HDL-C

The meta-analysis included nineteen studies (Huang L & Ma Q., 2021; Yi WM, Zhang XH, Xie PF, et al., 2019; Qi L., 2021; Li FX., 2020; He K, Liu L, Bian RR, et al., 2019; Wu WZ., 2019; Yang H., 2018; Li Y., 2017; Li P., 2017; Zhuang Q, Shen B & Wang J., 2017; Hou JY., 2016; Wang CY & Zhang HY., 2015; Yang MC., 2012; Huang RC & Deng XD., 2011; Zhou LB, Zhang JQ, Zhao XL, et al., 2011; Li XH., 2009; Liu T, Bai S & Zhang R C., 2018) about 1207 participants that reported on the presence of HDL-C. The meta-analysis results, which were assessed using a randomized-effects model, indicated that the HDL-C of Baduanjin exercise in TCM increased compared to that of the control group (MD: 0.11, 95% CI: 0.06 to 0.16, P<0.0001, I^2=82%) (Figure 12). This result was found to be robust through sensitivity analyses. (Supplementary Material 4.27). The subgroup analyses by intervention method demonstrated a statistical difference in treatment duration (≥6 months; <6 months) and intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises) (P=0.02, P=0.01 respectively). (Supplementary Material 4.28-4.29), which was not related to the intensity of intervention (Total exercise time per week<300min; Total exercise time per week≥300min) (P=0.57). (Supplementary Material 4.30).

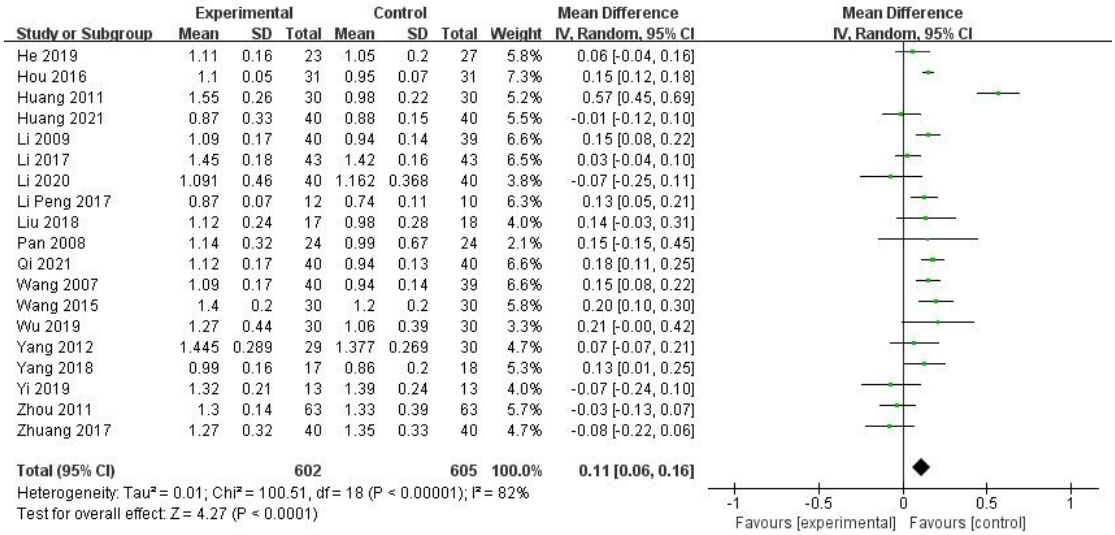

Figure 12. Forest plot for HDL-C

Table 4. Subgroup analyses in the association of TC, TG, LDL-C and HDL-C with the ex ante parameters

Comparison	Subgroup	No. of studies	SMD [95% CI]	P for meta-analysis	I^2	P for heterogeneity
TC						
Treatment duration of Baduanjin exercise	≥6 months	12	-0.42[-0.57,-0.27]	<0.00001	50%	0.02
	<6 months	8	-0.28[-0.57,0.01]	0.06	89%	<0.00001
Intervention measures	Baduanjin alone	17	-0.39[-0.56,-0.23]	<0.00001	80%	<0.00001
	Combination of Baduanjin and other exercise	3	-0.18[-0.62,0.25]	0.41	68%	0.04
Intensity of intervention	Total exercise time per week<300min	11	-0.34[-0.49,-0.18]	0.004	61%	<0.0001
	Total exercise time per week≥300min	9	-0.43[-0.74,-0.13]	0.006	87%	<0.00001
TG						
Treatment duration of Baduanjin exercise	≥6 months	11	-0.72[-1.16,-0.29]	0.001	97%	<0.00001
	<6 months	9	-0.33[-0.54,-0.11]	0.003	87%	<0.00001
Intervention measures	Baduanjin alone	17	-0.63[-0.91,-0.35]	<0.0001	96%	<0.00001
	Combination of Baduanjin and other exercise	3	-0.06[-0.29,0.17]	0.61	17%	0.30
Intensity of intervention	Total exercise time per week<300min	11	-0.47[-0.85,-0.10]	0.001	96%	<0.00001
	Total exercise time per week≥300min	9	-0.66[-1.05,-0.28]	0.0008	96%	<0.00001
LDL-C						

Treatment duration of Baduanjin exercise	≥6 months	8	-0.21[-0.38,-0.04]	0.01	61%	0.01
	<6 months	7	-0.18[-0.30,-0.06]	0.004	49%	0.07
Intervention measures	Baduanjin alone	12	-0.20[-0.31,-0.08]	0.0006	61%	0.003
	Combination of Baduanjin and other exercise	3	-0.18[-0.38,0.02]	0.08	2%	0.36
Intensity of intervention	Total exercise time per week<300min	8	-0.22[-0.32,-0.11]	<0.0001	13%	0.33
	Total exercise time per week≥300min	7	-0.18[-0.35,-0.01]	0.04	72%	0.001
HDL-C						
Treatment duration of Baduanjin exercise	≥6 months	12	0.15[0.09,0.21]	<0.00001	82%	<0.00001
	<6 months	7	0.04[-0.04,0.12]	0.37	66%	0.007
Intervention measures	Baduanjin alone	16	0.13[0.08,0.19]	<0.00001	82%	<0.00001
	Combination of Baduanjin and other exercise	3	-0.01[-0.11,0.09]	0.80	37%	0.20
Intensity of intervention	Total exercise time per week<300min	10	0.10[0.05,0.15]	<0.0001	82%	0.0005
	Total exercise time per week≥300min	9	0.14[0.01,0.26]	0.03	89%	<0.00001

Abbreviations: EF: ejection fraction; FS: fractional shortening; HFD: high-fat diet; SIJ: single intraperitoneal injection; STZ: streptozotocin; SMD: standard mean difference; T1DM: Type 1 diabetes mellitus; T2DM: Type 2 diabetes mellitus.

3.5.5 Meta-Analysis of Basic Indicators on T2DM-BMI and WHR

Among the included randomized controlled trials, eight studies (Huang L & Ma Q., 2021; Li FX., 2020; He K, Liu L, Bian RR, et al., 2019; Wang XL., 2019; Zhuang Q, Shen B, Wang J., 2017; Zhou LB, Zhang JQ, Zhao XL, et al., 2011; Pan HS & Feng YC., 2008; Liu T, Bai S & Zhang R C., 2018) including 599 participants reported Baduanjin exercise that were applied in BMI. As indicated by the results using a randomized-effects model, the experimental group was able to significantly lower the level of BMI compared to the control group (MD: -1.14, 95% CI: -1.90 to -0.37, P=0.004, I^2 = 82%) (Figure 13). A sensitivity analysis using a randomized effect model indicated no significant difference in the results (Supplementary Material 4.31). Among the subgroup analyses, there was no apparent interaction between treatment duration (≥6 months; <6 months), intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises) and intensity of intervention (Total exercise time per week<300min; Total exercise time per week≥300min) (P=0.46, P=0.91, P=0.46 respectively). (Supplementary Material 4.32-4.34).

Six of the included RCTs (Huang L & Ma Q., 2021; Li FX., 2020; Li QW, Ding WG, Pei JY, et al., 2016; Zhou LB, Zhang JQ, Zhao XL, et al., 2011; Pan HS & Feng YC., 2008; Liu T, Bai S & Zhang R C., 2018) reported the effectiveness of Baduanjin exercise on WHR. Using a randomised effects model, the results demonstrated that, compared to the control group, the results were statistically significant. (MD: -0.07, 95% CI: -0.13 to -0.01, P= 0.02, I^2 = 98%) (Figure 14). Analysis of sensitivity revealed that Zhou 2011 produced substantial heterogeneity (Supplementary Material 4.35). Subgroup analyses showed unrelated

interactions with treatment duration (≥6 months; <6 months), intervention measures (Baduanjin alone; Combination of Baduanjin and other exercises) and intensity of intervention (Total exercise time per week<300min; Total exercise time per week≥300min) (P=0.37, P=0.11, P=0.63 respectively). (Supplementary Material 4.36-4.38)

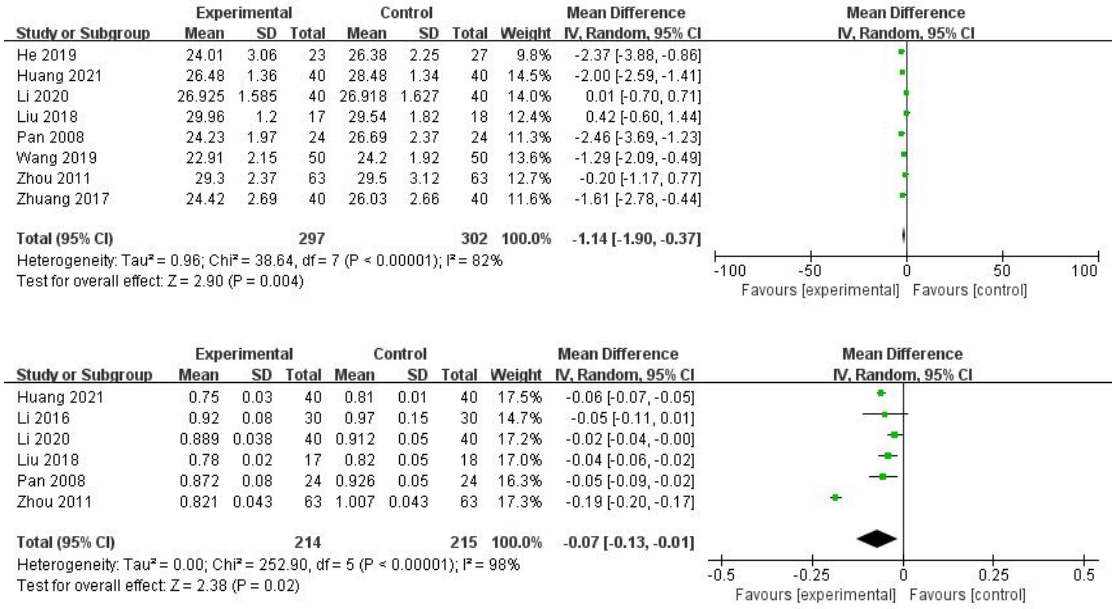

Figure 13-14. Forest plot for BMI and WHR

3.6 Publication Bias

The FPG, HbA1c, P2hPG, TC, TG, LDL-C, and HDL-C data funnel plots demonstrated poor symmetry, indicating that publication bias may occur. Inadequate research methodologies and limited sample size could be the primary causes of the bias. (Supplemental Materials 4.39 to 4.45).

3.7 Adverse Events

There were no reports of adverse events in the study in any of the 26 literature cited in this research.

4. Discussion

4.1 Main Results of This Research-Glucose Metabolism

This study aimed to systematize and analyze the clinical evidence regarding the effectiveness of Baduanjin exercise in the treatment of T2DM, providing better guidance for clinical practice. A number of important conclusions had been drawn from the analysis of data from 26 studies. Current research demonstrates that T2DM patients treated with Baduanjin exercise can dramatically reduce the level of FPG, HbA1c, P2hPG, HOMA-IR as well as FINS, which represent the level of glucose metabolism. In accordance with the sensitivity analysis, the results were stable, but the results of this study exhibited significant heterogeneity in FPG, HbA1c, P2hPG, which was investigated by subgroup analysis. According to the subgroup analyses of the FPG, the heterogeneity may be attributed either to the measures of intervention employed or to the duration of the intervention as for subgroup analyses of the HbA1c, the heterogeneity may be attributed to the treatment duration. Analyses of subgroups of other outcomes were unable to verify the source of heterogeneity.

4.2 Main Results of This Research-Lipid Metabolism and Basic Indicators

The study drew the conclusion that lipid metabolism indicators like TC, TG and LDL-C, BMI, WHR in T2DM patients performing Baduanjin exercise decreased respectively while the level of HDL-C increased due to the use of Baduanjin exercise. The results were robust as evidenced by the sensitivity analysis. The results of this study exhibit significant heterogeneity in TC, TG, LDL-C, HDL-C, BMI, WHR which was investigated by subgroup analysis. According to the subgroup analyses of the TG, the heterogeneity may be attributed to the intervention measures as for subgroup analyses of the HDL-C, the heterogeneity may be attributed either to the treatment duration or to

the intervention measures. Analyses of subgroups of other outcomes were unable to verify the source of heterogeneity. Some indicators in this study had great heterogeneity. Heterogeneity could be a result of many practical difficulties encountered during the conduct of the study, which may result in fewer participants, additional difficulties, and additional confounding factors. Despite the inclusion of the subgroup analysis of intervention methods, treatment duration and intervention intensity in this literature, the level of heterogeneity was reduced to some extent. As 26 of these RCTs were single-center studies, it was also likely that regional differences in patients were contributing to statistical heterogeneity. The included studies were also flawed in terms of their trial design, as they lacked masking methods and allocation concealment, and there was no supervisor to oversee the investigation's quality. It was possible that all of these factors may contribute to heterogeneity in the results of studies.

4.3 Mechanism(s) of Baduanjin Exercise for T2DM

Exercise definitely plays a significant part in the overall management of type 2 diabetes patients, according to the recommendations for the prevention and treatment of the disease (American Diabetes Association, 2019). As it has been linked to therapeutic advantages for a number of disorders, baduanjin exercise is growing in acceptance throughout the world. It is currently made available in hospitals and public spaces all throughout China and the rest of the world to lessen clinical symptoms and enhance quality of life. The current systematic review (Zhou J, Yu Y, Cao B, et al., 2020) suggests that the risk of harm from Baduanjin exercise may be minimal, and older persons or patients with chronic illnesses are more likely to benefit from its clinical effects and accessibility. The thoracic, diaphragmatic, and abdominal muscles can all be expanded by engaging in these musculoskeletal stretching exercises in the upper body. In Baduanjin exercise, mental focus and relaxation are also incorporated. Patients may have less weariness and a more pleasant sensation, which may improve mental health and promote adherence to this exercise routine.

More and more clinical evidence (Huang L & Ma Q., 2021; Qi L., 2021; Li FX., 2020; Wu WZ., 2019) suggests that the combination of Baduanjin exercise and conventional Western medication can effectively reduce the glucose and lipid metabolism levels of diabetes patients, with more improvement than in the group receiving only conventional Western medicine. In addition, Baduanjin has a positive intervention impact on the general health and blood glucose level of prediabetes, and can prevent or delay the progression of impaired glucose tolerance to diabetes (Ren S., 2021; Wang WY., 2020; Wang Y., 2020). Research on the mechanism revealed that the highly dysregulated mRNAs were primarily engaged in immune function and inflammatory response pathways, as well as diverse signaling pathways, including IL-17 and TNF. Moreover, five differently expressed lncRNAs were chosen to form a lncRNA-mRNA regulation network, and a total of 1045 mRNAs were found to be connected with them (An T, He Z C, Zhang X Q, et al., 2019). Future studies can reference the aforementioned indicators to evaluate the therapeutic efficacy of Baduanjin exercise and conduct pertinent mechanistic studies. In the meanwhile, further optimization of research programs should be carried out to investigate the effects of Baduanjin on T2DM.

This study recommends that the General Administration of Sport of China collaborate with relevant departments to further develop and improve the internationally recognized and unified Baduanjin exercise standard in order to standardize the exercise frequency, duration, and movement requirements of different groups. At the same time, the completion of evaluation is imperfect. Future research can finish rate of the sport, including coherence, standard, the strength of the movement, sports oxygen uptake percentage, metabolic rate during motion etc., relying on modern science and technology means to make the research more scientific. Existing issues include an insufficient number of studies and inadequate methodological quality. In the future, it is envisaged that there will be more clinical trial literature with a sound methodological design, a large sample size, high quality, and a high impact factor that may be used to examine the long-term survival rate or complications of diabetes patients.

4.4 Risk of Bias

Based on the Cochrane handbook (Higgins J P, Altman D G, Gøtzsche P C, et al., 2011), we found that all the included studies had a high risk of bias, mainly caused by deviations from the intended intervention. It should be noted that our judgment of the overall results was in

doubt as a result of the clear methodological shortcomings of the included studies. The majority of studies did not provide details on how they conducted their randomizations, including the way randomized sequences were generated, and only two studies described how allocation concealment was conducted.

4.5 Strengths and Limitations of This Study

- This is the most up-to-date and comprehensive literature available to summarize the impact of Baduanjin exercise on the treatment of T2DM.
- Due to well established eligible criteria, rigorous data collection and quality assessment, standardised statistical analysis, subgroup and sensitivity analyses, study strength is increased and heterogeneity is reduced.
- The flawed retrieval approach may omit certain research and the irregularity of the Baduanjin exercise program in the included study may influence the outcomes between the two groups.
- The drawbacks of this study potentially reside in the changes in the frequency, duration and measures of treatment, which result in methodological heterogeneity.
- The majority of the included studies are published in Chinese journals, which could result in a bias associated with language.

5. Conclusion

Combining the existing evidence, we concluded that Baduanjin exercise was appropriate for T2DM patients. Current evidence was limited and inconsistent, preventing us from drawing definite conclusions. Therefore, additional research was required.

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Conflict of Interest

The authors state that no commercial or financial affiliations that might be interpreted as a potential conflict of interest existed during the conduct of the research.

Data Availability Statement

The original contributions reported in the study are included in the article as well as Supplementary Material. Any additional questions could be referred to the corresponding author.

Supplementary Material

https://kdocs.cn/l/crPvhj32RdQF

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