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RESEARCH ARTICLE

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Effect of different training modalities on lipid metabolism in patients with type ii diabetes mellitus: a network meta-analysis

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ABSTRACT

Background/Aims: This study to evaluate the effects of different training modalities on blood lipids in type II diabetic patients by Network Meta-analysis, and provide a relevant basis for patients to develop exercise prescriptions to regulate blood lipids.

Methods: Randomized controlled trials (RCTs) were retrieved from Zhiwang, Wanfang, Wipu, PubMed, EBSCO, Cochrane Library, and Web of Science that were published from the establishment to February 2023. Relevant statistical analyses were performed using Stata 17.0 software and Revman 5.4.

Results: A total of 35 randomized controlled trials with 2771 patients with type II diabetes were finally included. The results of Network Meta-analysis showed that, compared with the control group, Chinese traditional fitness exercise (CTF), resistance training (RT), and aerobic training (AT) could reduce total cholesterol (TC) levels; CTF, RT, whole body vibration training (WBV), and AT could reduce triacylglycerol (TG) levels; CTF, WBV and AT could increase High-density lipoprotein cholesterol (HDL) levels; CTF, RT and AT could reduce Low-density lipoprotein cholesterol (LDL) levels. SUCRA probability ranking results showed that CTF was the most effective in reducing TC[SMD=−0.57, 95% CI (−0.83, −0.31), $p<0.001$], TG[SMD=−0.24, 95% CI (−0.36, −0.12), $p<0.001$], LDL[SMD=−0.52, 95% CI (−0.70, −0.35), $p<0.001$]; RT was the most effective in increasing HDL[SMD = 0.14, 95% CI (0.03, 0.26), $p<0.05$].

Conclusions: CTF is more effective in improving TC, TG and LDL levels, while RT is most effective in improving HDL levels.

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KEYWORDS
Training modalities; type II diabetes mellitus; blood lipids; network meta-analysis

Introduction

With the rapid development of social economy, people's lifestyle and diet structure have undergone radical changes. At the same time, the prevalence of diabetes related to human lifestyle has also increased linearly year by year, which was mainly manifested by the increase of total cholesterol (TC), triacylglyceride (TG), low-density lipoprotein cholesterol (LDL) and the reduce of high-density lipoprotein cholesterol (HDL) in blood [1]. It has been reported that by 2030, the number of people with diabetes is expected to reach 552 million worldwide, of which about 90% will be type II diabetes [2]. Therefore, the prevention and treatment of diabetes through exercise is gradually becoming a common concern in today's society.

Currently, the glucose tolerance test stands as the benchmark for diagnosing type 2 diabetes. In accordance with the 2017 iteration of China's Guidelines for the Prevention and Treatment of Type 2 Diabetes, the stipulated thresholds for normal fasting blood glucose are below 6.1 mmol/L, and postprandial blood glucose should not exceed 7.8 mmol/L. A diagnosis of type 2 diabetes is established when fasting blood glucose levels reach or exceed 7.0 mmol/L, or when blood glucose surpasses 11.1 mmol/L two hours post a meal. The main treatments methods include pharmacological and non-pharmacological treatments. Traditional pharmacological treatments can play a good role in lowering glucose and lipids, but have a lot of side effects and adverse reactions. In contrast, non-pharmacological treatments are receiving high attention from the medical community because of their simplicity and efficiency. Studies have shown that traditional fitness training (BaDuanJin, Taijiquan, YiJinJing, Qigong, etc.),

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vibration training, resistance training, aerobic training and other training have positive effects on lipid regulation and improving the quality of life of diabetic patients. Liu et al. [3] implemented an aerobic exercise regimen lasting between 30 to 60 min, without specifying a prescribed exercise intensity. Their findings revealed a discernible impact of aerobic training on ameliorating blood lipid profiles in individuals with type 2 diabetes In a separate study. Geirsdottir et al. [4] employed a resistance training protocol characterized by an initial exercise intensity below 60% of the one-repetition maximum (1RM) during the initial week. Subsequently, the exercise intensity escalated to 75%–80% of 1RM for three groups, each performing 6–8 repetitions at least three times a week. Wu et al. [5]. found that blood lipid levels decreased after exercise, the possible mechanism was that exercise could increase the activity of lipoprotein lipase, which led to enhanced β-oxidation pathway and greater muscle uptake and utilization of free fatty acids and cholesterol. Zhu Shengling et al. [6] suggested that Baduanjin may improve patients' glucolipid metabolism levels by reducing TC, TG, and LDL concentrations and thus play a role in the prevention and treatment of diabetes.

Utilizing data from pertinent randomized controlled trials (RCTs), an exhaustive search of the literature was conducted to assess the impact of four distinct rehabilitation training methods on individuals with type II diabetes. The comprehensive evaluation encompassed the efficacy of various rehabilitation training approaches on diverse outcome indicators, quantitatively synthesizing the results to derive optimal effect sizes. By comparing these effect sizes, the objective was to offer a quantitative synthesis of multiple research findings, thereby furnishing more robust quantitative results. The ultimate goal is to recommend the most effective rehabilitation methods based on individual patient conditions, providing a theoretical and practical reference for the treatment and preventative strategies applicable to individuals with type II diabetes [7].

Methods

The network meta-analysis conducted adhered to the guidelines set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The systematic review's protocol was formally documented and made publicly accessible through registration in the International Prospective Register of Systematic Reviews (PROSPERO- CRD42023446718).

Search strategy

Randomized controlled trials (RCTs) investigating the impact of diverse training modalities on lipid profiles in individuals with Type II diabetes mellitus were systematically sought through electronic databases, including PubMed, EBSCO, Cochrane Library, Web of Science, China Knowledge Network, Zhiwang, Wipu, VIP, and Wanfang, spanning from January 1, 2005, to August 31, 2023. To augment access to pertinent literature, the references of incorporated studies were also retrospectively reviewed. Employing a meticulous combination of subject terms and free words, the search encompassed specific terms such as Tai Chi, Yijinjing, Baduanjin, Qigong, resistance training, aerobic training, vibration intervention, Diabetes Mellitus Type 2, and randomized controlled trials. The search, confined to articles published in English and Chinese, was executed using the stipulated search terms. Illustratively, the detailed retrieval process for PubMed is delineated in Figure 1.

Inclusion and exclusion criteria

Inclusion criteria: (1) Exclusively randomized controlled trials (RCTs) that examined the impact of four distinct training modalities on blood lipids in individuals diagnosed with Type II diabetes mellitus; (2) Study participants exclusively constituted individuals diagnosed with Type II diabetes; (3) The intervention group underwent conventional treatment supplemented with Comprehensive Traditional Chinese Exercises (CTF) including Tai Chi, Yijinjing, Baduanjin, and Qigong, along with resistance training (RT), aerobic training (AT), and whole-body vibration training (WBV), while the control group received conventional treatment. The specifics of treatment modalities for both groups are elucidated in Table 1; (4) Outcome indicators encompassed total cholesterol (TC), triacylglycerol (TG),

#1 Tai Chi
#2 Yijinjing
#3 Baduanjin
#4 Qigong
#5 resistance training
#6 aerobic training
#7 whole body vibration training
#8 Diabetes Mellitus Type 2
#9 randomized controlled trials
#10 #1 AND #2 AND#3 AND #4 AND #8 AND #9
#11 #5 AND #8 AND #9
#12 #6 AND #8 AND #9
#13 #7 AND #8 AND #9

Figure 1. Pubmed retrieval strategy diagram.

high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL), with detailed explanations provided in Table 2; (5) The study design adhered to the search strategy advocated by Cochrane, entailing the inclusion of Randomized Controlled Trials (RCTs) and quasi-experimental studies. This overarching search strategy was subsequently tailored to each distinct database for comprehensive coverage.

Exclusion criteria: (1) Instances of duplicated literature in published sources; (2) Unavailability of full-text literature for comprehensive analysis; (3) Randomized controlled trials that did not adhere to standardized methodologies; (4) Literature that solely presented abstracts without accompanying full-text content; (5) Instances where the original study data were either unavailable or subjected to transformative alterations; (6) Exclusion of literature not presented in either the Chinese or English language to maintain linguistic consistency within the review.

Assessment of methodological quality

Two independent reviewers meticulously evaluated the methodological rigor of the incorporated studies utilizing the refined Cochrane's risk of bias tool. The literature was evaluated from five aspects: randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported result. (randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported result). In cases where disparities arose between the initial evaluations of the reviewers, resolution ensued through discourse. However, if consensus could not be reached, a third reviewer was engaged to provide a decisive assessment.

Data extraction

The two authors independently extracted pertinent variables from the encompassed studies, encompassing: (1) Study characteristics, including authorship, year of publication, and study design, along with sample details such as size and age; (2) A comprehensive elucidation of the training program executed by both the intervention and control groups; (3) Primary outcome variables, specifically total cholesterol (TC), triacylglycerol (TG), high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL); (4) The cumulative impact of the outcomes of interest. In instances where the published article or supplementary material lacked sufficient data, the corresponding author was contacted to solicit additional information. Studies that did not

Table 1. Definition of exercise intervention and control group.

Group	Intervening measure	Definition
Training modalities group	Chinese traditional fitness	It is a traditional national sports event that combines physical activity, breathing, breathing and psychological adjustment as the main form of sports, and is an important part of the long Chinese culture.
	aerobic training	Is the activity energy comes mainly from aerobic metabolism training. Generally moderate or small intensity, long duration of dynamic exercise.
	resistance training	Also known as strength training, is the body relies on skeletal muscle muscle strength to overcome external resistance.
	Whole-body vibration training	By stimulating the body with mechanical vibration and external resistance load, muscle oscillation and adaptive response of nervous system can be induced to improve musculoskeletal function.
Control group	conventional treatment	Conventional medical treatment, such as Metformin, Atorvastatin, Amlodipine, as well as some routine care, daily therapy and other non-exercise interventions. No additional high intensity physical activity was added during the trial.

Table 2. Relevant outcome indicator information.

Outcome indicators	Definition
Total cholesterol(TC)	Refers to the total amount of cholesterol contained in all lipoproteins in the blood, TC increase will cause hyperlipoproteinemia, atherosclerosis, etc., decrease will cause hyperthyroidism, anemia and other symptoms. Health experts recommend that the ideal cholesterol level for adults is <5.2 mmol/L.
Total cholesterol(TC)	It is a kind of organic compound, glycerol ester produced by esterification of 3 hydroxyl groups of glycerol and 3 fatty acid molecules. Its value is affected by age, gender and diet. If it rises, diabetes, pancreatitis and atherosclerosis will be caused; if it falls, it will cause low liver function and thyroid function. Normal reference values range from 0.45 to 1.69 mmol/L.
High-density lipoprotein cholesterol (HDL)	As one of the serum proteins, it is a complex lipoprotein composed of lipids and proteins and the regulatory factors carried by them, which can promote cholesterol metabolism, and is also an anti-atherosclerotic plasma lipoprotein, which is a protective factor for coronary heart disease.
Low-density lipoprotein cholesterol (HDL)	It is a kind of lipoprotein particles that carry cholesterol into peripheral tissue cells. When LDL is excessive in the body, the cholesterol it carries accumulates in the artery wall, which is easy to cause arteriosclerosis for a long time.

furnish relevant outcome indicators were subsequently excluded from consideration.

Statistical analysis

In this investigation, the statistical analysis was performed employing Stata 17.0 and Revman 5.4 software for the network meta-analysis. The study meticulously adhered to the guidelines set forth in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020). Effect sizes for continuous variables' outcome indicators were expressed as standardized mean difference (SMD) along with their corresponding 95% confidence intervals (CIs). The assessment of heterogeneity among independent studies was conducted based on the I^2 statistic and the significance level (P-value). Specifically, $I^2 < 50\%$ and $p > 0.1$ indicated an absence of significant heterogeneity, warranting the application of a fixed-effects model; conversely, $I^2 \geq 50\%$ and $p < 0.1$ signified substantial heterogeneity, prompting a sensitivity analysis. To address data with disparate units, a unit conversion was executed using the calculator function in RevMan 5.4. The ranking and comparison of multiple exercise interventions were facilitated by assessing the surface under the cumulative ranking (SUCRA) through a cumulative probability plot, where the range of $0 \leq \text{SUCRA} \leq 100$ was utilized. A score of 100 denoted optimal effectiveness, 0 was indicative of the least effective or ineffective, and higher SUCRA values signified superior intervention efficacy. The SUCRA values for total cholesterol, triglyceride, high-density lipoprotein, and low-density lipoprotein were systematically evaluated across diverse exercise methods. The determination of the optimal exercise intervention was accomplished through cluster stratification analysis, ensuring a comprehensive assessment and comparison of interventions. This systematic approach equips researchers to discern the most efficacious exercise strategies for ameliorating lipid levels in individuals with diabetes.

Results

Literature search results

The comprehensive electronic search strategy yielded a total of 2130 potentially pertinent articles. Following the meticulous removal of duplicate entries, a judicious screening process was applied to the remaining 1477 articles based on their titles and abstracts. Subsequently, the full texts of 121 articles were meticulously scrutinized for eligibility in accordance with the predefined inclusion and exclusion criteria. Ultimately, a discerning selection process led to the inclusion of 35 articles that rigorously met the predefined criteria for this systematic review (Figure 2).

Basic characteristics of the included literature

This study encompassed a comprehensive analysis of 35 randomized controlled trials, with 20 studies sourced from Chinese literature and 15 from English literature. Notably, among these, three studies adopted a multi-arm design involving multiple interventions. The collective participation of 2771 individuals diagnosed with type II diabetes was observed across the entirety of these 35 trials. The foundational characteristics of the included literature are systematically presented in Table 3 for elucidation and reference.

Assessment of methodological quality

The evaluation of risk of bias across the comprehensive spectrum of 35 Randomized Controlled Trials (RCTs) yielded a rating of 'having some concerns'. This assessment was primarily driven by a dearth of information concerning outcome measurement and instances of missing outcome data, as visually depicted in Figure 3.

Consistency analysis results

The included 35 RCTs were tested for inconsistency using nodal analysis. The nodal analysis model showed that the TC results ($p = 0.903$), TG results ($p = 0.776$), HDL results ($p = 0.956$), and LDL results ($p = 0.991$) were all greater than 0.05. This signifies that the outcomes of both direct and indirect comparisons for the four lipid indicators were in alignment, thus validating the application of the consistency model for further analysis.

Network meta-analysis

A total of 35 RCTs were included, including 12 studies comparing CTF with CG [8–19], 11 studies comparing RT with CG [20–30], 9 studies comparing AT with CG [20, 25, 26, 31–36], and 6 studies comparing WBV with CG [37–42].

Network meta-analysis of TC

This investigation encompassed a comprehensive analysis of 26 publications, involving a total of 2240 subjects. The outcomes of the network meta-analysis showed that CTF [SMD=−0.57, 95%CI (−0.83, −0.31), $p < 0.001$], RT [SMD=−0.34, 95%CI (−0.58, −0.10),

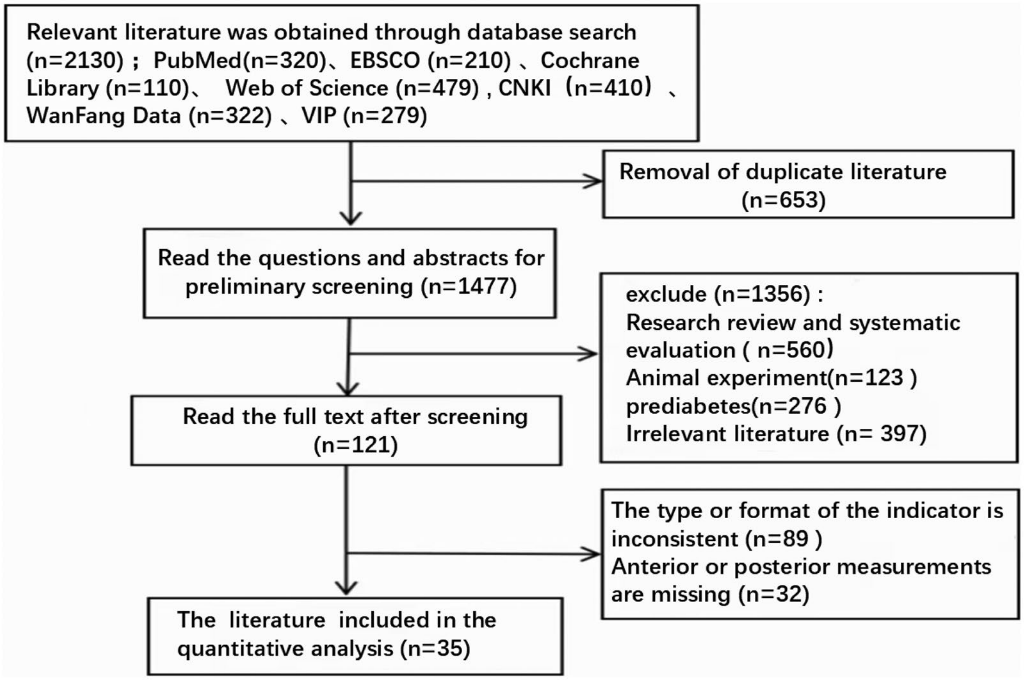

Figure 2. Flow chart of literature screening and inclusion.

$p<0.001$], and AT [SMD=−0.39, 95%CI (−0.68, −0.10), $p<0.001$] exhibited a salutary impact on TC. Conversely, WBV [SMD=−0.15, 95%CI (−0.89, 0.59), $p>0.05$] did not manifest a statistically significant improvement. The comparative analysis among various exercise modalities did not yield statistically significant differences ($p>0.05$; Figures 4 and 5). The results of SUCRA probability showed in terms of reducing TC: CTF (96.3%) >RT (53.5%)>AT (50.9%)> WBV (39.7%)>CG (9.6%) (Table 4).

Network meta-analysis of TG

This investigation encompassed a comprehensive analysis of 26 publications, involving a total of 2089 subjects. The outcomes of the network meta-analysis showed that CTF [SMD=−0.24, 95%CI(−0.36, −0.12), $p<0.001$], RT [SMD=−0.10, 95%CI(−0.16, −0.13), $p<0.05$], WBV [SMD=−0.16, 95%CI(−0.25, −0.07), $p<0.0001$] and AT [SMD=−0.26, 95%CI(−0.45, −0.07), $p<0.001$] exhibited a salutary impact on TG. The comparative analysis among various exercise modalities did not yield statistically significant differences ($p>0.05$; Figure 4 and 5). The results of SUCRA probability showed in terms of reducing TG: CTF (86.8%)>AT (63.2%)>WBV (62.0%)> RT (36.1%)>CG (1.8%) (Table 4).

Network meta-analysis of HDL

This investigation encompassed a comprehensive analysis of 25 publications, involving a total of 1906 subjects. The outcomes of the network meta-analysis showed that CTF [SMD = 0.13,95%CI (0.07,0.18), $p<0.001$], RT [SMD = 0.14,95%CI (0.03,0.26),$p<0.05$] and AT [SMD = 0.07,95%CI (0.01,0.13),$p<0.0001$] exhibited a salutary impact on HDL. The comparative analysis among various exercise modalities did not yield statistically significant differences ($p>0.05$; Figure 4 and 5). The results of SUCRA probability showed in terms of reducing HDL: RT (83.9%)>AT (55.6%)>WBV (52.2%)> CTF (45.4%)>CG (12.9%) (Table 4).

Network meta-analysis of LDL

This investigation encompassed a comprehensive analysis of 28 publications, involving a total of 2203 subjects. The outcomes of the network meta-analysis showed that CTF [SMD=−0.52, 95% CI (−0.70, −0.35), $p<0.001$], RT [SMD=−0.23, 95%CI (−0.37, −0.08), $p<0.001$], AT [SMD=−0.17, 95%CI (−0.33, −0.01), $p<0.05$] exhibited a salutary impact on LDL, while WBV [SMD=−0.34, 95%CI (−0.67, 0.00), $p=0.05$] had no significant improvement. The comparative analysis among various exercise modalities did not yield statistically significant differences ($p>0.05$; Figure 4 and 5). The results of SUCRA probability showed in terms of reducing LDL:CTF (96.3%) >RT (53.5%)>AT (50.9%)>WBV (39.7%)>CG (1.1%) (Table 4).

Publication bias analysis

The evaluation of the Total Cholesterol (TC) effect was undertaken subsequent to the comparison of exercise interventions, as depicted in Figure 6. It was observed

Table 3. Basic characteristics of the included literature.

		Experimental period	Average age		Group		
Study	Sample size		IE	CG	IE	CG	Outcomes
He et al. [8]	24/24	48 weeks	51.83 ± 14.32	51.59 ± 11.46	BDJ	No Exercise	①②③④
Li et al. [9]	50/50	24 weeks	62.91 ± 2.48	63.27 ± 2.86	TJQ	No Exercise	①②③④
Lu et al. [10]	60/60	12 weeks	66.5 ± 3.68	67.17 ± 2.86	YJJ	No Exercise	②③④
Yang [11]	17/18	24 weeks	57.28 ± 4.86	56.91 ± 6.32	BDJ	No Exercise	②③④
Zhao et al. [12]	8/8	16 weeks	54.75 ± 6.09	52.38 ± 7.65	TJQ	No Exercise	①②③④
Liu et al. [13]	20/20	24 weeks	57.2 ± 5.4	57.2 ± 5.4	BDJ	No Exercise	③
Wang et al. [14]	40/39	24 weeks	57.8 ± 7.5	56.5 ± 6.9	BDJ	No Exercise	①
Li [15]	12/10	24 weeks	64.27 ± 4.45	62.40 ± 6.06	BDJ	No Exercise	①②④
	11/10				RT	No Exercise	①②③④
Zhang [16]	40/40	24 weeks	53.22 ± 2.21	53.12 ± 2.25	BDJ	No Exercise	①
Li [17]	40/39	24 weeks	57.8 ± 7.5	56.5 ± 6.9	BDJ	No Exercise	①
Ludvik [18]	6/6	24 weeks	58 ± 8	58 ± 8	YJJ	No Exercise	①②③④
Xiaojun Ma et al. [19]	34/34	24 weeks	59.18 ± 3.93	59.09 ± 5.25	BDJ	No Exercise	①②③④
Li [20]	20/20	12 weeks	55.63 ± 6.78	56.28 ± 6.38	RT	No Exercise	①②③④
					AT	No Exercise	①②③④
Gu [21]	23/21	12 weeks	63.5 ± 6.3	64.5 ± 7.6	RT	No Exercise	①②③④
Chen [22]	46/46	16 weeks	56.35 ± 4.92	56.33 ± 4.86	RT	No Exercise	①②④
Yan [23]	53/52	12 weeks	41~75	41~75	RT	No Exercise	①②
Liu [24]	69/69	12 weeks	56.64 ± 12.46	54.67 ± 14.15	RT	No Exercise	①③④
Li [25]	15/15	18 weeks			RT	No Exercise	②④
					AT	No Exercise	②③④
Donges et al. [26]	35/26	10 weeks			RT	No Exercise	①②③④
	41/26	24 weeks			AT	No Exercise	①②③④
Zheng et al. [27]	165/100	12 weeks	65.66 ± 8.58	66.72 ± 8.68	RT	No Exercise	①②④
Bacchi et al. [28]	20/20	16 weeks	55.6 ± 1.7	57.2 ± 1.6	RT	No Exercise	①④
Silva [29]	14/14	16 weeks	68 ± 6	68 ± 6	RT	No Exercise	①②④
Egger et al. [30]	16/16	8 weeks	64.5 ± 7.1	65.2 ± 8.6	RT	No Exercise	②③④
Zhong et al. [31]	30/30	4 weeks	36~63	38~62	AT	No Exercise	①②③④
Zhou [32]	33/32	24 weeks	64.09 ± 5.80	60.69 ± 8.57	AT	No Exercise	①②
Praet [33]	49/43	48 weeks	61 ± 9	59 ± 9	AT	No Exercise	②③④
Andrews [34]	246/248	24 weeks	60.0 ± 9.7	60.1 ± 10.2	AT	No Exercise	①②③④
Kadoglou N et al. [35]	26/27	12 weeks	58.4 ± 5.7	62.9 ± 4.2	AT	No Exercise	①②③④
Yanjiang et al. [36]	14/11	12 weeks	63.9 ± 6.1	62.6 ± 3.8	AT	No Exercise	①②③④
Huang [37]	20/20	12 weeks	83.05 ± 1.50	82.75 ± 1.65	WBV	No Exercise	①②④
Zhang [38]	60/60	48 weeks	59.2 ± 10.4	56.3 ± 12.6	WBV	No Exercise	③
Cruz et al. [39]	19/20	12 weeks	71.60 ± 8.54	66.80 ± 10.83	WBV	No Exercise	②③④
Muñoz et al. [40]	45/45	8 weeks	40~85	40~85	WBV	No Exercise	①③④
Kitamoto et al. [41]	14/12	24 weeks	69.6 ± 3.3	68.8 ± 3.8	WBV	No Exercise	②③④
Ponirakis et al. [42]	13/28	48 weeks	57.6 ± 5.1	50.7 ± 9.4	WBV	No Exercise	②③④

Note: ①Total cholesterol (TC), ②Triacylglycerol (TG), ③High density lipoprotein (HDL), ④Low density lipoprotein (LDL); CTF: Chinese Traditional Fitness Exercises; RT: Resistance training; AT: Aerobic training; WBV: Whole-body vibration training.

that each study site was predominantly distributed on both sides of the vertical line ($X=0$). However, a few study sites exhibited dispersion, possibly influenced by small sample sizes.

Discussion

Type 2 diabetes, recognized as a global epidemic, has emerged as a paramount health challenge on a worldwide scale. As of 2022, the global prevalence of diabetes among adults stands at 9% [43]. A comprehensive analysis conducted in 2017 as part of the Global Burden of Disease study indicated that the global population affected by type 2 diabetes totalled approximately 462.97 million, with 37.61 million individuals experiencing disability as a consequence of this condition. This highlights diabetes as a significant contributor to global disability [44]. The majority of diabetes cases, constituting 93.7%, are of the type 2 variant. Research has elucidated that individuals who are obese or overweight face twice the likelihood of developing type 2 diabetes compared to those with normal body weight, establishing obesity as a prominent risk factor. Moreover, individuals with type 2 diabetes mellitus face an elevated risk of osteoporosis and falls, wherein body mass index and blood lipid levels emerge as pivotal regulatory indicators influencing the pathological progression of osteoporosis in diabetic patients [45].

Furthermore, during the examination of pertinent research on lipid metabolism in individuals with and

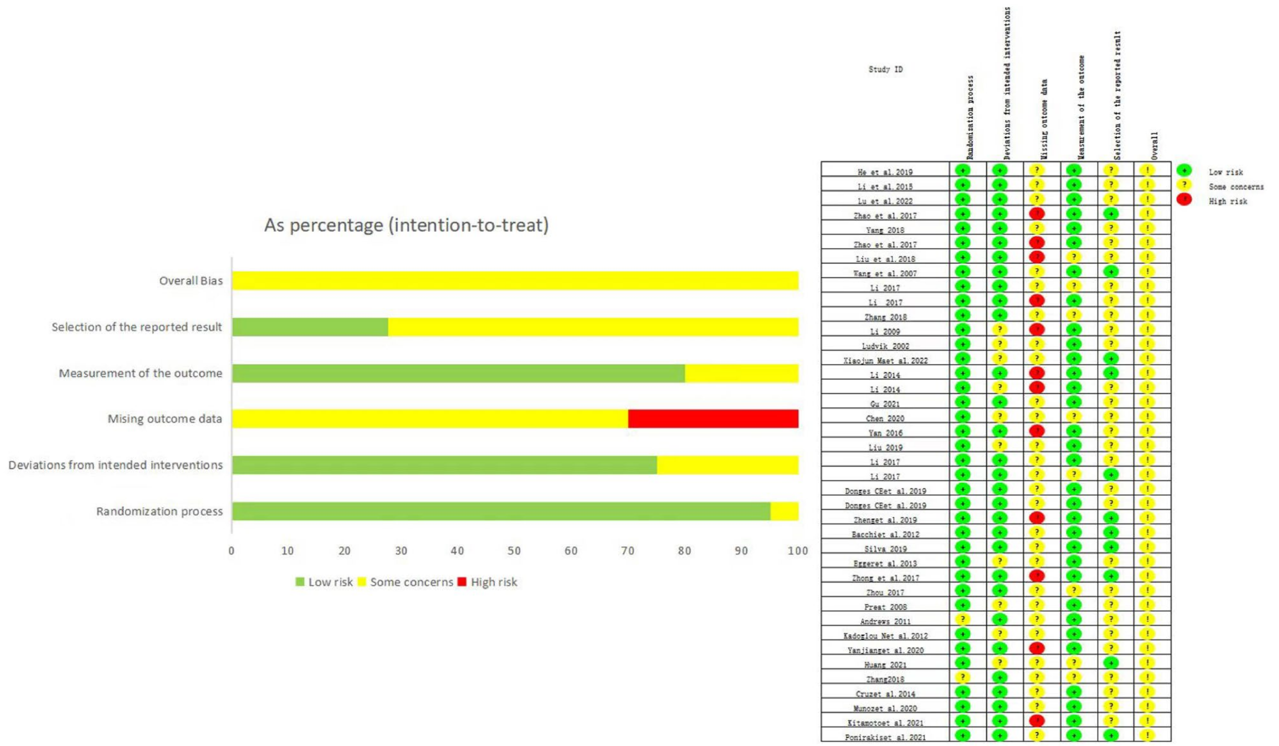

Figure 3. Risk bias assessment chart of the included literature.

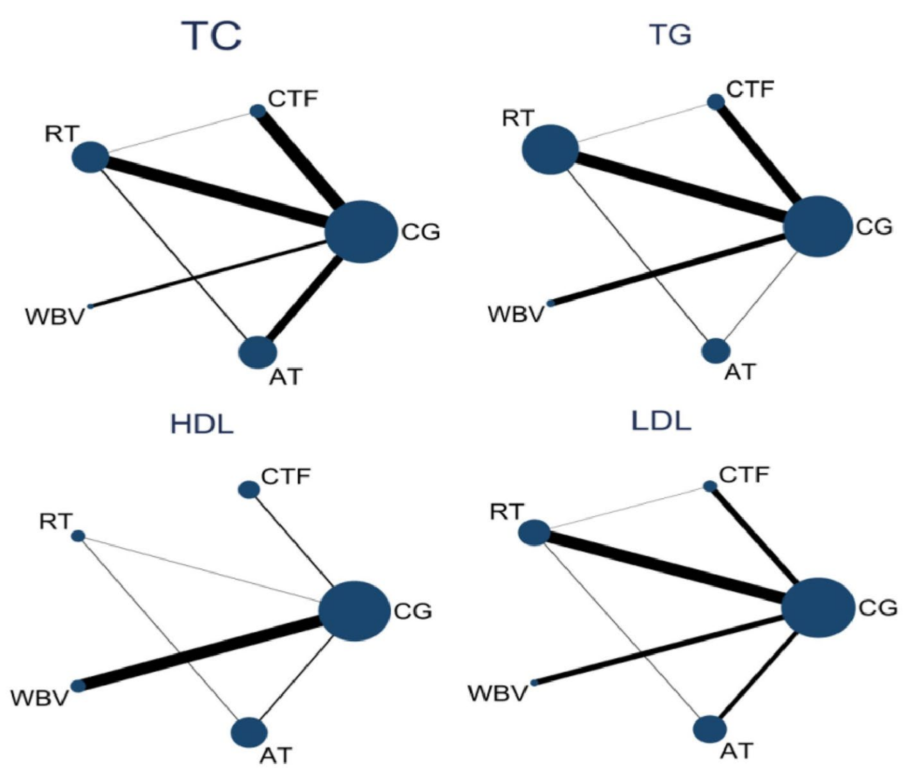

Figure 4. Network meta-analysis among exercise interventions.

without diabetes, notable distinctions emerge. Individuals with diabetes exhibit a greater susceptibility to hyperlipidaemia and aberrant lipid metabolism, characterized by heightened levels of TC, TG, and LDL, alongside diminished levels of HDL. Such deviations in lipid metabolism in diabetic individuals are predisposed to elevate the risk of cardiovascular diseases. Moreover, variations exist in the impact of distinct exercise

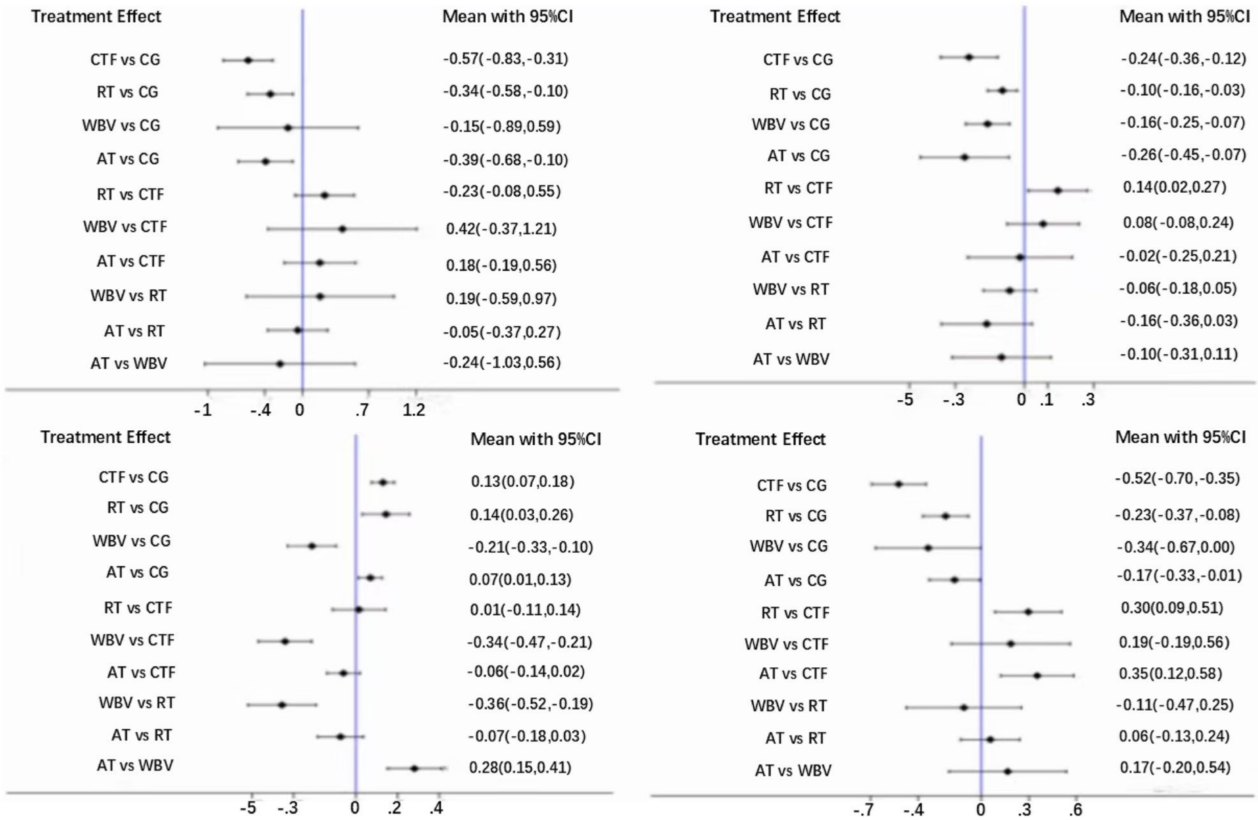

Figure 5. Summary of network geometry of TC, TG, HDL and LDL.

Table 4. Ranking table of SUCRA probability results by rehabilitation training modality.

	TC	TG	HDL	LDL
Intervention	Area under the curve	Area under the curve	Area under the curve	Area under the curve
CTF	96.3	86.8	45.4	95.8
CG	9.6	1.8	12.9	1.1
RT	53.5	36.1	83.9	50.1
WBV	39.7	62.0	52.2	66.8
AT	50.9	63.2	55.6	36.3

Note: Total cholesterol (TC), Triacylglycerol (TG), High density lipoprotein (HDL), Low density lipoprotein (LDL); CTF: Chinese Traditional Fitness Exercises; RT: Resistance training; AT: Aerobic training; WBV: Whole-body vibration training.

modalities on blood lipids between diabetic and non-diabetic individuals. Exercise has demonstrated the ability to enhance lipid metabolism, decrease cholesterol and triglyceride levels, and elevate HDL levels in individuals with diabetes, consequently mitigating the risk of cardiovascular disease. Conversely, when examining exercise effects on non-diabetic individuals, diverse perspectives among scholars regarding specific exercise regimens are apparent. Chen Shan [46] conducted a comparative analysis of lipid metabolism in overweight female college students, determining that a 10-week cross-point exercise regimen proved more efficacious in enhancing lipid health and reducing cardiovascular disease risk than high-intensity interval training. Additionally, Li Wenyu [47] highlighted that prolonged aerobic exercise intervention led to a decline in body fat percentage among obese adolescents. This outcome is attributed to the dual effects of aerobic exercise: firstly, heightened energy consumption and the mobilization of substantial fat lipolysis, thereby diminishing fat cell volume and count, and secondly, an increase in the body's basal metabolic rate, augmenting overall energy expenditure.

According to the meta-analysis and SUCRA probability ranking results of this study, CTF can be used for rehabilitation intervention in improving TC, TG and LDL related indexes in type 2 diabetes patients, while RT has a better effect in improving HDL in patients with type II diabetes.

Regarding the underlying mechanisms by which Chinese Traditional Fitness (CTF) influences blood lipids, extant research indicates that the characteristic movements associated with CTF are characterized by a slower and gentler nature compared to conventional exercises. Within the exercise regimen, CTF facilitates the coordinated traction of internal organs and muscles, fostering gastrointestinal peristalsis and enhancing digestive function. Consequently, the expulsion of moist turbidity from the body is facilitated, contributing to the regulation of blood lipids [48]. Notably, in contrast to standard exercise, the respiratory features

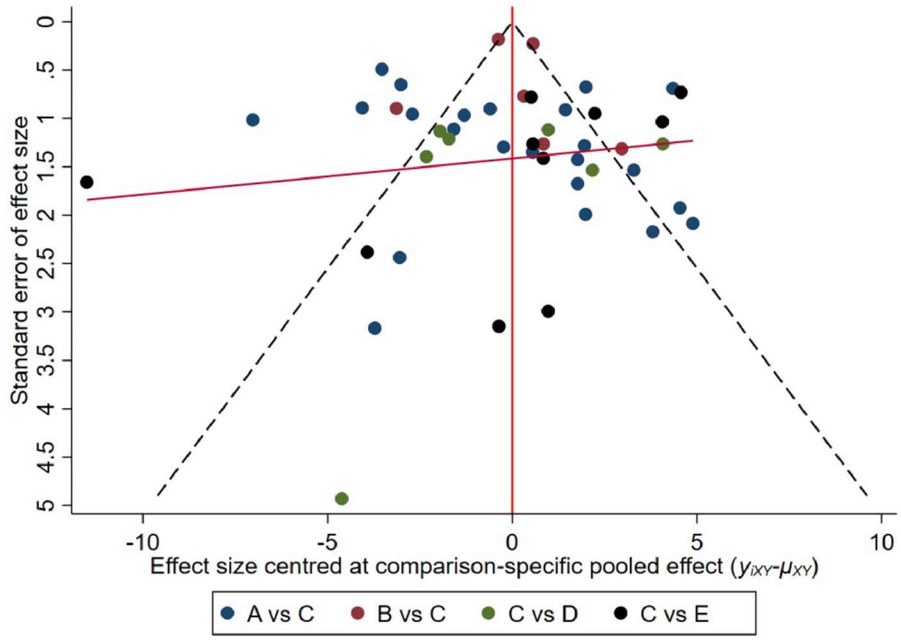

Figure 6. Comparison – Correct funnel diagram.

of CTF emphasize deeper, thinner, more even, and prolonged breathing patterns. Through the regulation of respiration during exercise, a balance in the vegetative nerve system can be achieved, leading to an increased activity of the sympathetic nervous system. This, in turn, regulates hormone-sensitive lipase and ultimately impacts lipid metabolism [49]. Corroborating findings are evident in the meta-analysis by Junmao Wen et al. [50] affirming that the integration of Baduanjin exercise with conventional treatment effectively reduces Total Cholesterol (TC), Triglycerides (TG), and Low-Density Lipoprotein (LDL) levels while elevating High-Density Lipoprotein (HDL) levels in patients with type 2 diabetes. Consistently, Chao Mengyao et al. [51]. Emphasized in their meta-analysis that Qigong, compared to no exercise intervention, positively influences TC, TG, and HDL levels. Furthermore, Taijiquan was identified as an effective means to lower overall blood lipid levels in patients. Wang Meijie et al. [52] underscored in their meta-analysis that the Baduanjin group surpasses conventional treatment in reducing TC ($p = 0.002$), TG ($p = 0.001$), HDL ($p < 0.00001$), and LDL ($p = 0.04$), underscoring the effectiveness of Baduanjin in ameliorating blood lipid levels in individuals with type 2 diabetes. In the scope of this study, CTF exercises, encompassing Taijiquan, Yijin Jing, Qigong, and Baduanjin, were examined. In comparison to Aerobic Training (AT) and Resistance Training (RT), CTF exercises are characterized by lower difficulty levels, and their exercise quantity and duration are flexible, aligning well with the exercise requirements of the majority of diabetic patients.

Concerning the impact of Resistance Training (RT) on blood lipid levels in individuals with type 2 diabetes, pertinent research indicates that Aerobic Training (AT) achieves therapeutic outcomes for type 2 diabetes by engaging skeletal muscle. This engagement results in increased fat absorption by skeletal muscles, along with heightened capillary hyperplasia. Importantly, this process plays a pivotal role in enhancing High-Density Lipoprotein (HDL) levels among patients with type 2 diabetes. Noteworthy findings from both domestic and international meta-analyses support these assertions. According to relevant domestic and foreign meta-analysis, Chen Ying et al. [53] conducted a study involving 1735 patients with type 2 diabetes, comparing AT and RT as two distinct forms of exercise. All three exercise modalities proved effective in reducing glucose and lipid metabolism levels. Specifically, AT demonstrated superior efficacy in enhancing fasting blood glucose, Triglycerides (TG), and HDL levels—a parallel observation to the outcomes of the current investigation. In a mesh meta-analysis encompassing 14 Randomized Controlled Trials (RCTs), Lukas Schwingshackl et al. [54] reported that, in comparison to AT and combined exercise, RT exhibited greater efficacy in reducing Total Cholesterol (TC) levels and increasing HDL levels. However, it is essential to acknowledge certain limitations in the existing literature. Notably, the quality of the included articles tends to be mostly rated as low to moderate. In the meta-analysis findings, Liang Min et al. [55] underscored that, relative to a lack of exercise, RT effectively reduces TG levels and enhances HDL levels among patients, exerting a positive influence on various blood lipid indicators in individuals with type 2 diabetes.

Moreover, this study delved into the correlation between blood glucose and lipid indices. Key indicators for diagnosing blood glucose in diabetic patients encompass fasting blood glucose (FPG), glycosylated haemoglobin (HbA1c), and blood glucose (2hPG) measured two hours after a meal. Presently, pertinent studies in China are exploring the impact of blood sugar and blood fat on individuals with diabetes. Ye Chunson [56] highlighted that both hyperlipidaemia and hyperglycaemia serve as predisposing factors for the onset of diabetes, and these two indices were previously interconnected to a certain degree. Elevated blood sugar levels may influence the metabolism of blood fats, resulting in the accumulation of lipids in the body and heightening the risk of atherosclerosis. Simultaneously, heightened blood sugar levels may induce alterations in blood lipids, elevating LDL levels and diminishing HDL, consequently amplifying the susceptibility to cardiovascular disease. Ni Xian [57] emphasized that the prolonged consumption of high-fat and high-sugar foods by diabetic individuals exerts an impact on the body's lipid metabolism, leading to metabolic irregularities and resultant health issues. Consequently, diverse forms of exercise may yield distinct effects on both blood glucose and lipid metabolism. Certain exercises may be more conducive to enhancing blood glucose control, while others may be more effective in improving lipid metabolism. The interplay between blood glucose and blood lipid indices, as explored in this study, represents a limitation. Future investigations should incorporate a comprehensive consideration of alterations in both blood glucose and blood lipid indices, facilitating a thorough assessment of the impact of diverse exercise modalities on lipid metabolism in diabetic patients.

There are limitations in this study: (1) Insufficient data were available regarding the prevalence year and body mass index (BMI) of diabetic patients, precluding the performance of subgroup analyses based on these parameters; (2) The influence of glycaemic and lipid indicators in patients with type II diabetes mellitus on this study was not conclusively established, introducing limitations to the study's findings. Future research endeavours could explore the interplay between these two indicators, ensuring a comprehensive and systematic evaluation; (3) The analysis in this study focused solely on different types of exercise, yet the included studies exhibited data gaps and inconsistencies in the duration and frequency of exercise interventions, hindering in-depth analyses. Subsequent studies may benefit from employing more standardized data collection methods to facilitate comprehensive subgroup analyses aimed at determining the optimal duration.

Conclusion

This study aimed to systematically compare various training methods utilizing a network metanalysis, providing a more precise evaluation of their roles and applicability in the context of patients with type 2 diabetes. Utilizing Surface Under the Cumulative Ranking (SUCRA) to conduct probability ranking, we sought to identify the exercise method with the most favourable impact on blood lipids. The outcomes revealed that Coordinated Training (CTF) exhibited superior effectiveness in ameliorating Total Cholesterol (TC), Triglycerides (TG), and Low-Density Lipoprotein (LDL) levels. Meanwhile, Resistance Training (RT) emerged as the most effective approach for elevating High-Density Lipoprotein (HDL) levels. To optimize outcomes, future research endeavours should consider the nuanced factors of exercise interventions, including intensity, frequency, and duration. Such considerations are essential for furnishing clinicians and patients with evidence-based insights to select the most suitable exercise modality, thereby offering personalized guidance to enhance lipid metabolism in individuals with type 2 diabetes and elevate their overall quality of life.

Author contributions

Yaming Xie, Yifan Zhang and Runze Zhang searched the literatures, Yaming Xie and Shuangtao Xing analyzed data and wrote manuscript. Xianfeng Yue and Dan Zeng supported writing manuscript. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Data availability statement

All data are available within the manuscript. The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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