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ORIGINAL

COMPARATIVE EFFECTS OF EXERCISE INTERVENTIONS ON PHYSIOLOGICAL AND METABOLIC MARKERS IN ADULTS WITH OBESITY: A SYSTEMATIC REVIEW AND NETWORK META-ANALYSIS

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ABSTRACT

Background: The purpose of this research was to assess the results of eight exercise programs—Aerobic Training (AT), Resistance Training (RT), Combined Training (CBT), Electrical Muscle Stimulation Training (EMST), High-Intensity Interval Training (HIIT), Whole Body Vibration Training (WBVT), Stretching Training (STT), and Other Training (OT)—on anthropometric measurements and intermediate disease biomarkers in obese individuals aged 18 and above. **Methods:** A systematic review was undertaken, searching databases such as CNKI, Web of Science, PubMed, Embase, Cochrane Library. Only Randomized Controlled Trials (RCTs) focusing on the influence of these eight exercise interventions on anthropometric outcomes and intermediate disease markers in obese patients were included. The methodological quality of the chosen studies was evaluated using the Cochrane Risk of Bias Assessment Tool. Specialized data analysis software was then used for subsequent analyses. **Results:** Clinical trials conducted from May 2009 to August 2023 were considered. A total of 119 studies were incorporated, with an aggregate sample size of 5,537 participants. Network meta-analysis showed that Resistance Training significantly improved LDL cholesterol levels (SUCRA: 60.4%); Combined Training prominently enhanced HDL cholesterol levels (SUCRA: 78.5%); and HIIT led to a substantial decrease in TC levels (SUCRA: 78.2%). **Conclusions:** Based on network ranking diagrams, combined training—merging aerobic and resistance exercises—seems optimal for obese patients. This modality demonstrates notable efficacy in reducing body weight and fat percentage, and concurrently improves HDL cholesterol, blood glucose levels, maximal oxygen uptake, and IL-6 levels.

KEYWORDS: Exercise Interventions; Obesity; Intermediate Disease Biomarkers; Network Meta-Analysis

1. INTRODUCTION

Over the last fifty years, there has been a notable rise in the worldwide incidence of obesity. The World Health Organization (WHO) reports that over 600 million individuals are obese and approximately 2 billion adults are overweight (WHO, 2017). Notably, the American and Canadian Medical Associations, the World Obesity Federation, and other organizations proclaimed obesity to be a chronic, progressive illness in 2017(Bray et al., 2017). For patients, obesity unquestionably poses a substantial health challenge as it considerably elevates the risk of obstructive sleep apnea, osteoarthritis, dementia, stroke, myocardial infarction, hypertension, fatty liver disease, type 2 diabetes and several types of cancer. Furthermore, obesity has the potential to a decline in quality of life, unemployment, decreased productivity, and adverse social circumstances. Clearly, this profoundly impacts the lives of individuals with obesity, placing a significant burden on their families (Blüher, 2019).

To address the obesity epidemic, it's crucial to understand its underlying causes. The core factor leading to obesity is a long-term energy imbalance—specifically, prolonged excessive calorie intake versus insufficient calorie expenditure(Lin & Li, 2021). Consequently, physical exercise, by boosting calorie consumption, is seen as an indispensable part of managing overweight or obesity (Celik & Yildiz, 2021).Numerous experimental studies and meta-analyses have furnished evidence on the impact of exercise on weight reduction and body composition. Moreover, prospective observational studies have provided insights into the relationship between physical activity and obesity, serving as a vital source for exercise training programs for primary prevention of chronic diseases. Nevertheless, considering the limitations of future research, such as effect size, measurement errors and confounding variables, research recommendations related to weight loss exercise regimens should be applied with caution (Schwingshackl et al., 2016). Similarly, numerous randomized controlled trials (RCTs) on exercise interventions to curb obesity have their own set of shortcomings, including artificial controls, varying sample sizes and study durations, differential effects of various interventions, cost and time factors, and standardization of study durations (Tennfjord et al., 2021). To bridge the evidence gap between meta-analyses generated from RCTs' often lacking evidence and prospective observational studies, an emergent approach is the use of meta-analyses of intervention trials. These trials are characterized by analyzing intermediate disease markers and adopting exercise interventions similar to those examined in prospective observational studies. Now, employing the Network Meta-Analysis (NMA) method, we can delve deeper into this approach. NMA is an evolution of pairwise meta-analysis, allowing us to compare multiple exercise interventions simultaneously (Rouse et al., 2017). In essence, NMA sorts direct evidence by directly comparing two exercise interventions or gathers indirect evidence through one or multiple intermediary comparisons. More crucially, this means that even if certain interventions have never been directly assessed in trials, through NMA, we can still infer the relationships between these unassessed interventions.

Thus, in this research, we utilized network meta-analysis to compare different intervention types (e.g., high-Intensity Interval Training, combined training, resistance training, aerobic training, Whole Body Vibration, Electrical Muscle Stimulation, stretching training, and other specified interventions) to evaluate the effects of varying exercise types on established intermediate markers of chronic diseases in randomized intervention studies, markers previously used prospective observational studies for meta-analysis.

2. Materials and Methods

2.1 Search Strategy

In this article, five electronic databases—Cochrane Central Register of Controlled Trials, Web of Science, EMBASE, Pubmed and CNKI—were searched by the researchers between May 2009 and August 2023. The search strategy, developed around the PICOS tool, was based on the following criteria: (P) Population: obese patients; (I) Intervention: exercise; (C) Comparison: control group with routine care and daily physical activity only; (O) Outcome: post-exercise physiological indices tested in obese patients; (S) Study type: RCTs. See Table 1 for detailed search strategy (in Pubmed).

2.2 Inclusion Criteria

(1) The experimental group addressed obesity by using several exercise techniques. (2) The control group only provided routine care and daily activities to the patients. (3) Randomized controlled clinical trial. (4) Outcome indices included at least one of the following: Weight, Body Fat Percentage, Hemoglobin A1c (HbA1c), Homeostasis Model Assessment-Insulin Resistance (HOMA-IR), Interleukin 6 (IL-6), C-reactive Protein (CRP), Maximal Oxygen Uptake, Insulin, Blood Glucose, Triglycerides, Total Cholesterol (TC), High Density Lipoprotein (HDL), Low Density Lipoprotein (LDL), Diastolic Blood Pressure (DBP), Systolic Blood Pressure (SBP), Fat Free Mass (FFM), Body

Mass Index (BMI).

2.3 Exclusion Criteria

(1) Subjects who are pregnant. (2) Subjects younger than 18 years of age. (3) Subjects with cancer. (4) research with unreported or insufficient data. (5) Research from non-randomized controlled trials (such as quasi-randomized controlled trials, case reports, conference abstracts, animal studies, protocol, correspondence and animal studies). (6) Articles that were published before May 2009.

2.4 Study Selection

EndNote, a literature management program, was used to filter and eliminate the material. First, two researchers looked over the titles to make sure they didn't include duplicates, non-randomized controlled trial studies, protocols, conference papers, review articles or letters. After that, the two researchers went over the abstracts to find papers that should be included and excluded. Ultimately, after reading the remaining papers through to the end, both researchers decided which ones to include. Both researchers separately screened the publications throughout this approach. The article was included if their choices coincided. In the event of a discrepancy, the disparities were settled by consulting a third researcher.

2.5 Data extraction

Data for the study were recorded under the following topics using a systematic pre-selected data extraction form with six elements, which the researchers used:(1) authors; (2) publication year; (3) research length; (4) sample number; (5) mean age; and (6) exercise intervention specifics.

2.6 Risk of Bias of Individual Studies

Using the Cochrane Handbook version 5.1.0 tool, two researchers independently evaluated the risk of bias (ROB) in RCTs. Randomized sequence creation (1), treatment allocation concealment (2), participant and staff blinding (3), inadequate outcome data (6), selective reporting (7), and other sources of bias were the seven domains that were taken into consideration. Based on the number of components for which high ROB may occur, trials were divided into three categories: low risk (two or less), moderate risk (three or four), and high risk (five or more)(Higgins et al., 2011). Research papers presenting sizable datasets that are stored in databases that are openly accessible must to indicate the location of the data storage as well as give the pertinent accession numbers. Please indicate that the accession numbers will be supplied during review if they were not yet received at the time of submission. They have to be given before the publishing. Research requiring ethical approval, such as interventional studies involving humans or animals, must include the ethical approval code and the organization that authorized the study.

2.7 Data Analysis

In studies where exercise serves as the intervention, all variables are continuous and are presented as means with standard deviation (SD)(Li & Chen, 2021). The continuous variables under investigation will be displayed as either the mean difference (MD = absolute difference between the means of two groups, defined as the difference in means between the treatment and control groups using the same scale) with 95% confidence intervals (CI) and analysis, or the standardized mean difference (SMD = mean difference between groups divided by the standard deviation of outcomes among subjects, used to combine data when trials have different scales). We chose not to do an analysis using a fixed effects model due to potential differences across studies (Jackson et al., 2011). We utilized Stata software (version 15.1) for NMA aggregation and analysis, following the instructions in the PRISMA NMA instruction manual. We used a Bayesian-based framework to Markov chain Monte Carlo simulation chains(Moher et al., 2015). The agreement between indirect and direct comparisons will be quantified and shown using the nodal technique, which is derived using the Stata software's instructions. A P-value greater than 0.05 indicates that the consistency test is successful (Ponce-Bordón et al., 2021; Salanti et al., 2011).

Stata software is used to show and describe network diagrams of different movement therapies. Direct head-to-head comparisons between the therapies are shown by the lines connecting the nodes in the network diagrams that were made. In the illustrations, every node stands for a different motor intervention and control situation. The size of each node and the length of the connecting lines indicate the number of studies (Chaimani et al., 2013). The intervention hierarchy was summed up and described using a P score. Considered a frequentist analog of the values at the surface under the cumulative ranking curve (SUCRA), the P score averages over all competing treatments. It indicates how certain one therapy is over another. A P value of 0 denotes the worst therapy with no ambiguity, and a P score of 1 denotes the best treatment with no doubt. Exercise therapies' efficacy or acceptability may be effectively expressed by the P score or SUCRA, however, until there are actual, clinically meaningful differences across therapies, these scores should be interpreted with caution (Marotta et al., 2020). In order to detect potential publication bias in NMA resulting from small-scale study bias, visual examination of the symmetry of the network funnel plot was done(Khera et al., 2016).

3. Results

3.1 Study and Identification and Selection

The total number of documents retrieved from the electronic databases was 17,895, with an additional 13 documents identified through manual searching. Following the removal of 1,257 duplicates, 1,616 documents were removed after the titles and abstracts of the 16,651 remaining papers were examined. Out of the 535 documents that were still in the database, 416 were eliminated for additional reasons, including non-randomized controlled trials, conference papers, missing data, and non-adherence to the interventions that were part of this study. As a result, 119 papers in total were included in the analysis. (Figure 1).

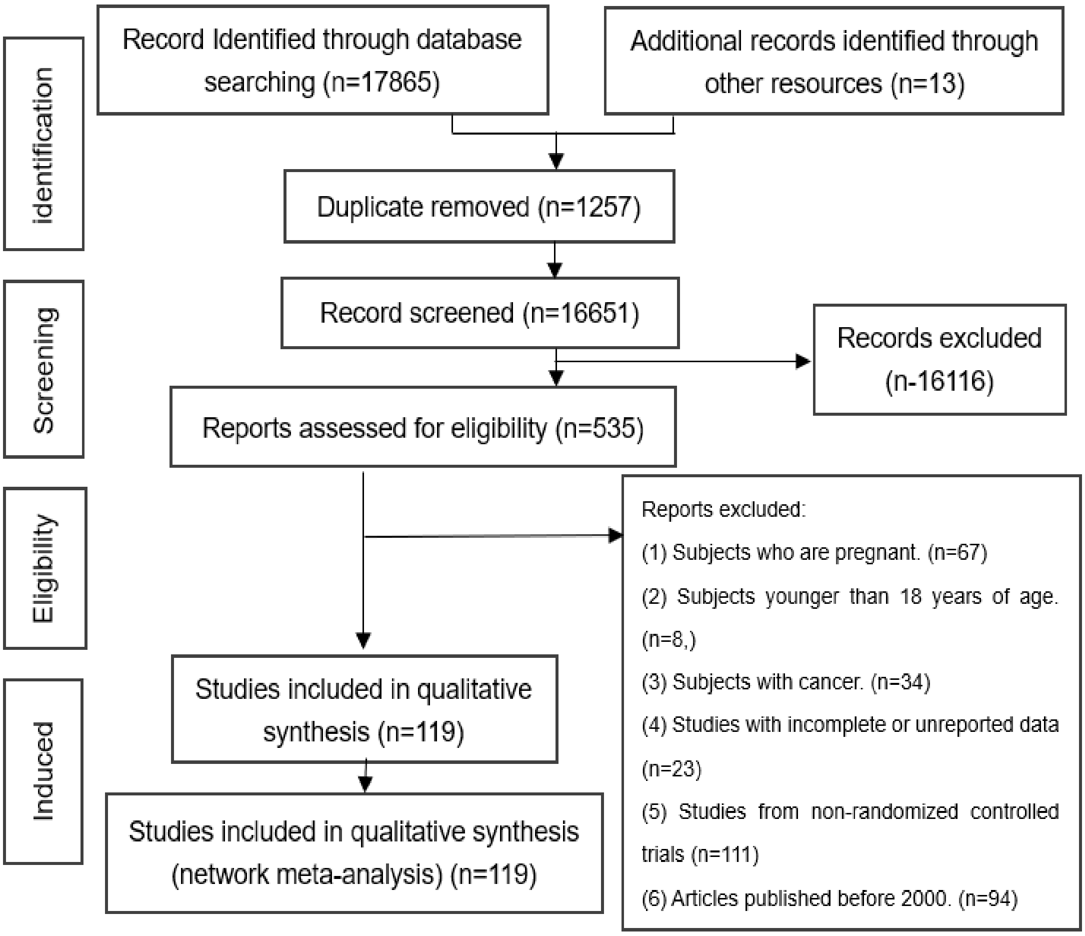


Figure 1: Flow Diagram of Literature Selection.

3.2 Quality Assessment of the Included Studies

There were twenty-one low risk studies, thirteen high risk studies, and eighty-five intermediate risk studies. It was difficult to blind participants and measurers simultaneously in these experiments since exercise was the intervention. Blinding was challenging since informed permission forms had to be signed by the patients' families as well as the participants before to the experiment. Table 1 provides specific information.

Table 1: Search Strategy on PubMed

#1	**"OBESITY"[MESH]**
#2	((((((Obesity[Title/Abstract] AND (review[Filter])) OR (overweight[Title/Abstract] AND (review[Filter]))) OR (Prader-Willi Syndrome[Title/Abstract] AND (review[Filter]))) OR (Obesity, Morbid[Title/Abstract] AND (review[Filter]))) OR (Obesity, Metabolically Benign[Title/Abstract] AND (review[Filter]))) OR (Obesity, Abdominal[Title/Abstract] AND (review[Filter]))) OR (Obesity Hypoventilation Syndrome[Title/Abstract]
#3	#1 OR #2
#4	"Exercise"[MeSH]
#5	(((((((Exercise [Title/Abstract]) OR exercise intervention [Title/Abstract]) OR exercise training [Title/Abstract]) OR training [Title/Abstract]) OR physical training [Title/Abstract]) OR physical exercise [Title/Abstract]) OR sports training [Title/Abstract]) OR nurse intervention [Title/Abstract]
#6	#4 OR #5
#7	Randomzied controlled trials [Publication Type]
#8	#3 AND #6 AND #7

3.3 Characteristics of the Included Studies

Included were 119 randomized controlled trials with a total of 5573 individuals who had an obesity diagnosis that was verified. Interventions in the control group included: aerobic training (72 studies), HIIT (27 studies), resistance training (32 studies), combined training (24 studies), WBV training (5 studies), stretching (3 studies), EMS training (1 study), and other training (1 study).

Body weight was used as an outcome indicator in 113 studies, body fat percentage in 81 studies, BMI in 106 studies, FFM in 42 studies, SBP in 43 studies, DBP in 41 studies, HDL in 57 studies, LDL in 56 studies, total cholesterol in 60 studies, triglycerides in 64 studies, blood glucose in 67 studies, insulin in 43 studies, maximal oxygen uptake in 44 studies, CRP in 25 studies, IL-6 in 17 studies, HOMA-IR in 24 studies, and HbA1c in 15 studies. Table 2 displays the features of the included studies.

Table 2: Characteristics of the Studies Included in the Meta-analysis

STUDY	YEAR	POPULATION	AGE (MEAN+SD)	TOTAL	INTERVENTION	INTERVENTION	CONTROL	OUTCOME
(YANG ET AL., 2023)	2023	Obese patients Non-alcoholic fatty liver disease	T:21.3(1.0) C:21.8(0.8)	T:27 C:27	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 60 min	CON	Weight, BFP,BMI
(SAEIDI ET AL., 2023)	2023	Obese patients	T+C: 27.5(9.4)	T: 11 C: 11	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 70 min	CON	Weight, BMI, FFM, LDL, HDL, TC, TG, Glucose, Insulin,CRP,VO2max
(ATASHAK ET AL., 2022)	2022	Obese patients	T: 24.55(3.21) C: 25.37(3.01)	T: 15 C: 15	HIIT Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 30 min	CON	Weight, BMI, BFP, TC, TG, HDL, LDL, Glucose, Insulin, HOMA-IR
(RELJIC ET AL., 2022)	2022	Obese patients Metabolic syndrome	T: 50.6(11.3) 52.7(11.5) 52.7(12.5) C:49.0(15.1)	T: 26/25/26 C: 26	Aerobic training Resistance training Combined training Length of Intervention: 16 weeks	Freq: 3 times a week Duration: 20 min	CON	Weight, BMI, BFP, SBP, DBP, TC, TG, HDL, LDL, Glucose, CRP, VO2max,IL-6
(MARILLIER ET AL., 2022)	2022	Obese patients	T: 48.5(7.6) C: 47.8(9.7)	T: 10 C: 10	HIIT Length of Intervention: 8 weeks	Freq: 3 times a week Duration: 45 min	AT	Weight, VO2max
(LI ET AL., 2022)	2022	Obese patients	T: 21.8(1.8) 22.1(2.0) 21.6(1.9) C: 21.5(1.5)	T: 18/17/16 C: 16	HIIT Aerobic training Blood flow restriction training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 40 min	CON	BFP, TC, TG, Glucose, Glucose, VO2max

(KIM ET AL., 2022)	2022	Obese patients	T: 81.6(4.78) C: 79.6(5.19)	T: 15 C: 15	Resistance training Length of Intervention: 24 weeks	Freq: 2 times a week Duration: 60 min	CON		BFP,FFM
(HU ET AL., 2022)	2022	Obese patients	T:19.2(1.1) C: 20.2(0.4)	T: 17 C: 13	HIIT Length of Intervention: 4 weeks	Freq: 5 times a week Duration: 20 min	CON		Weight, BFP, BMI, FFM
(ATAEINOSRAT ET AL., 2022)	2022	Obese patients	T: 27.5(9.4) C: 27.5(9.4)	T: 11 C: 11	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 70 min	CON		Weight, BFP, BMI, FFM, LDL, HDL, TC, TG, Glucose, Insulin, VO2max, HOMA-IR
(ZHANG ET AL., 2021)	2021	Obese patients	T: 19.7(1.1) 21(2.4) C: 21.2(2.2)	T: 12/11 C: 13	HIIT Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: NA	CON		Weight, BFP, TC, TG, Glucose, Insulin
(LEE ET AL., 2021)	2021	Obese patients	T: 56(2.9) C: 57.5(2.9)	T: 12 C: 12	Others Length of Intervention: 16 weeks	Freq: 3 times a week Duration: 60 min	CON		Weight, BFP, BMI, LDL, HDL, TC,TG
(SON & PARK, 2021)	2021	Obese patients	T: 68.2(1.6) C: 68.2(1.4)	T: 18 C: 17	Resistance training Length of Intervention: 12 weeks	Freq: 3times a week Duration: 60 min	CON		Weight, BFP, BMI, FFM,SBP,DBP, LDL, HDL, TG, Insulin, HOMA-IR
(RIBEIRO ET AL., 2021)	2021	Obese patients Polycystic ovary syndrome	T: 29.14 (5.26) C: 28.50 (5.76)	T: 28 C: 30	Aerobic training Length of Intervention: 16 weeks	Freq: 3 times a week Duration: 40 min	CON		Weight, BFP, BMI, SBP, DBP, LDL, HDL, TC, TG, Glucose, Insulin, CRP
(MENDHAM ET AL., 2021)	2021	Obese patients	T: 23(3) C: 24(4)	T: 27 C: 23	Combined training Length of Intervention:	Freq: 4 times a week	CON		Weight, BFP, BMI, FFM,VO2max

					12 weeks	Duration: 50 min		
(JAMKA ET AL., 2021)	2021	Obese patients	T+C: 55(7)	T: 44 C: 41	Combined training Length of Intervention: 3 months	Freq: 3 times a week Duration: 60 min	AT	FFM,SBP,DBP,LDL,HDL,TC,TG,Glucose,Insulin,HOMA-IR,HbA1c
(CHOW ET AL., 2021)	2021	Obese patients	T:19.9 (0.9) C: 19.4(0.5)	T: 11 C: 10	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 8-43min	CON	Weight, BFP, BMI, Glucose, Insulin, HOMA-IR, IL-6
(WONG ET AL., 2020)	2020	Obese patients	T: 23(1) C: 22(1)	T: 14 C: 14	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 60 min	CON	Weight, BFP, BMI, FFM, SBP, DBP
(POON ET AL., 2020)	2020	Obese patients	T: 49.6(7.8) C: 46.5(3.6)	T: 12 C: 12	HIIT Length of Intervention: 8 weeks	Freq: 3 times a week Duration: 10-20 min	AT	Weight, BFP, BMI, FFM, SBP, DBP, TC, TG, LDL, HDL, VO2max
(LEE ET AL., 2020)	2020	Obese patients Type 1 Diabetes	T: 40.5 (10) C: 46.1(10.5)	T: 12 C: 15	HIIT Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 20 min	CON	Weight, BFP, BMI, FFM,SBP,DBP,LDL,HDL,TC,TG,Glucose,VO2max,HOMA-IR,HbA1c,CRP
(LA SCALA TEIXEIRA ET AL., 2020)	2020	Obese patients	T: 41(6.3) C: 39(5.5)	T: 11 C: 19	Combined training Length of Intervention: 30 weeks	Freq: 3 times a week Duration: 60 min	CON	Weight, BFP, BMI, FFM,VO2max
(KUO ET AL., 2020)	2020	Obese patients	T: 37.6(8.8) C: 37.5(8.5)	T: 16 C: 12	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: NA	CON	BFP,BMI,LDL,HDL,TC,TG
(JUNG ET	2020	Obese patients	T: 43.8(8.6)	T: 12	Stretching training	Freq: 3 times a	CON	Weight, BFP, BMI,

AL., 2020)			C: 51.6(6.5)	C: 12	Length of Intervention: 8 weeks	week Duration: 60 min		FFM,SBP,DBP,LDL,HDL,TC,TG,Glucose,Insulin,HOMA-IR,VO2max
(FORTUIN-DE SMIDT ET AL., 2020)	2020	Obese patients Hyperinsulinemia	T: 22(21–24) C:23(21–27)	T: 20 C:15	Combined training Length of Intervention: 12 weeks	Freq: 4 times a week Duration: 40-60 min	CON	Weight, BMI, Glucose, HbA1c
(CORRES ET AL., 2020)	2020	Obese patients Primary hypertension	T+C: 54.3(7.3)	T: 47 C: 43	HIIT Length of Intervention: 16 weeks	Freq: 3 times a week Duration: 50 min	CON	Weight,BMI,FFM,SBP,DBP,VO2max
(BRENNAN ET AL., 2020)	2020	Obese patients	T: 52.5(8) 51.8(8.3) C: 55.1(6.6)	T: 24/30 C: 20	Aerobic training Length of Intervention: 24 weeks	Freq: 5 times a week Duration: 30-60 min	CON	Weight, BMI
(ROMAIN ET AL., 2019)	2019	Obese patients	T: 29.7(7.24) C: 32.12(7.1)	T: 38 C: 28	HIIT Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 60 min	CON	Weight, BFP, BMI, SBP,DBP,LDL,HDL,TC,TG,Glucose,HbA1c
(RSHIKESAN ET AL., 2018)	2018	Obese patients	T: 40.03(8.74) C: 42.2(12.06)	T: 37 C: 35	Stretching training Length of Intervention: 14 weeks	Freq: 5 times a week Duration: 90 min	CON	Weight, BFP, BMI, FFM
(NUHU & MAHARAJ, 2018)	2018	Obese patients Type 2 Diabetes	T: 39.5 (34.8-45.0) C: 39.0 (32.8-43.0)	T: 30 C: 30	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 20-30 min	CON	Weight, BMI, LDL, HDL, TC, TG, Glucose, Insulin
(KOH ET AL., 2018)	2018	Obese patients	T: 30(16) C: 25(8)	T: 15 C: 12	Aerobic training Length of Intervention: 8	Freq: 3 times a week	CON	Weight, BFP, BMI, LDL,HDL,TC,TG

					weeks	Duration: 60 min		
(COSTA ET AL., 2018)	2018	Obese patients Polycystic ovary syndrome	T: 27.6(4.5) C: 24.4(5)	T: 14 C: 13	Aerobic training Length of Intervention: 16 weeks	Freq: 3 times a week Duration: 40 min	CON	BMI,SBP,DBP,LDL,HDL,TC,TG,Glucose,Insulin,HOMA-IR,VO2max,IL-6,CRP
(BATRAKOULIS ET AL., 2018)	2018	Obese patients	T: 36.4(5) C: 36(4.2)	T: 14 C: 21	Combined training Length of Intervention: 40 weeks	Freq: 3 times a week Duration: 23-41 min	CON	Weight, BFP, BMI, FFM, VO2max
(H. J. ZHANG ET AL., 2017)	2017	Obese patients Nonalcoholic Fatty Liver Disease	T: 53.2(7.1) C: 54(6.8)	T: 66 C: 74	Aerobic training Length of Intervention: 12 months	Freq: 5 times a week Duration: 60 min	CON	Weight, BFP, SBP, DBP
(SEVERINO ET AL., 2017)	2017	Obese patients	T+C:58(1)	T: 13 C: 14	WBV training Length of Intervention: 6 weeks	Freq: 3 times a week Duration: 40 min	CON	Weight, BFP, BMI, FFM
(HUANG ET AL., 2017)	2017	Obese patients Sarcopenic Obesity	T: 68.89(4.91) C: 69.53(5.09)	T: 18 C: 17	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 55 min	CON	Weight, BFP, BMI, LDL,HDL, TC, TG, CRP
(GOMES ET AL., 2017)	2017	Obese patients Chronic kidney disease	T+C: 55.5(8.3)	T: 24 C: 15	Aerobic training Length of Intervention: 24 weeks	Freq: 3 times a week Duration: 30 min	CON	Weight, BMI, VO2max, CRP, IL-6
(BARRY ET AL., 2017)	2017	Obese patients	T: 48.6 (8.2) C: 44.7 (11.0)	T: 19 C: 18	HIIT Length of Intervention: 2 weeks	Freq: 10 times a week Duration: 30 min	AT	BFP,BMI
(WONG ET AL., 2016)	2016	Obese patients	T: 58(1) C: 59(1)	T: 13 C: 12	WBV training Length of Intervention: 8 weeks	Freq: 3 times a week Duration: 11-60 min	CON	Weight, BMI, SBP, DBP

(TOMELERI ET AL., 2016)	2016	Obese patients	T: 66.8(3.2) C:69.5(4.7)	T: 19 C: 19	Resistance training Length of Intervention: 8 weeks	Freq: 3 times a week Duration: NA	CON	BFP,TC,TG,LDL,HDL,IL-6,CRP,Glucose
(TAN ET AL., 2016)	2016	Obese patients Chronic insomnia	T: 51.2 (46.6–55.8) C: 52.6 (48.0–57.2)	T: 24 C: 21	Aerobic training Length of Intervention: 26 weeks	Freq: 1 times a week Duration: 54.5 min	CON	Weight,BMI,BFP,VO2 max
(SKRYPNIK ET AL., 2016)	2016	Obese patients	T: 48.2(11.2) C: 51.3(8.3)	T: 17 C: 21	Combined training Length of Intervention: 3 months	Freq: 3 times a week Duration: 45 min	AT	Weight, BMI
(NUNES ET AL., 2016)	2016	Obese patients	T: 62.0 (54.7–65.5) C: 60.0 (54.0–64.5)	T: 12 C: 13	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 60 min	CON	BFP,LDL,HDL,TC,TG,IL-6,HbA1c
(HIGGINS ET AL., 2016)	2016	Obese patients	T+C: 20.4(1.5)	T: 23 C: 29	HIIT Length of Intervention: 6 weeks	Freq: 3 times a week Duration: 10 min	AT	Weight, BFP, FFM, VO2max
(ALVAREZ ET AL., 2016)	2016	Obese patients Type 2 Diabetes	T: 45.6(3.1) C: 43.1(1.5)	T: 13 C: 10	HIIT Length of Intervention: 16 weeks	Freq: 3 times a week Duration: 22-37.5 min	AT	Weight, BMI, SBP, DBP, TC, TG, LDL, HDL
(KIM ET AL., 2015)	2015	Obese patients	T: 24.86(2.75) C: 26.6(2.8)	T: 29 C: 10	Aerobic training Length of Intervention: 8 weeks	Freq: 4 times a week Duration:NA	CON	Weight, BFP, BMI, HOMA-IR,TC, TG, LDL, HDL, Glucose, Insulin
(FRANKLIN ET AL., 2015)	2015	Obese patients	T: 30.3(5.4) C: 30.8(9)	T: 10 C: 8	Resistance training Length of Intervention: 8 weeks	Freq: 3 times a week Duration: 60 min	CON	Weight, BFP,BMI, SBP,DBP, TC, LDL, HDL, Glucose, CRP

(ARAD ET AL., 2015)	2015	Obese patients	T: 29(4) C: 30(7)	T: 9 C: 11	HIIT Length of Intervention: 14 weeks	Freq: 3 times a week Duration: 24 min	CON	Weight, BMI, FFM, BFP
(ABD EL-KADER ET AL., 2015)	2015	Obese patients Type 2 Diabetes	T: 43.62(6.17) C: 44.11(5.89)	T: 40 C: 40	Aerobic training Length of Intervention: 3 months	Freq: 2 times a week Duration: 90 min	CON	BMI,IL-6
(TELLES ET AL., 2014)	2014	Obese patients	T: 36(10.3) C: 36.8(12.1)	T: 34 C: 34	Stretching training Length of Intervention: 12 weeks	Freq: 5 times a week Duration: 45 min	AT	BFP,BMI,FFM,TC,TG,LDL,HDL
(ORDONEZ ET AL., 2014)	2014	Obese patients Intellectual disability	T: 24.7(3.6) C: 25.1(3.9)	T: 11 C: 9	Aerobic training Length of Intervention: 10 weeks	Freq: 3 times a week Duration: 40 min	CON	BFP,BMI,IL-6,CRP
(CHOO ET AL., 2014)	2014	Obese patients	T: 41.8 (6.6) 46(10) C: 42.2 (9.5)	T: 30/30 C: 50	Combined training Length of Intervention: 9 months	Freq: 3 times a week Duration: 60 min	AT	Weight,FFM,SBP,TC,HDL,LDL,VO2max,Glucose
(SKLERYK ET AL., 2013)	2013	Obese patients	T: 40.2(2.3) C: 37.1(1.4)	T: 8 C: 8	HIIT Length of Intervention: 2 weeks	Freq: 3 times a week Duration: 9 min	AT	BFP,BMI,SBP,DBP,VO2max,Glucose,Insulin
(ROMERO MORALEDA ET AL., 2013)	2013	Obese patients	T: 36.1(8.7) 35.8(8) 36(7.3) C: 36.8(8.9)	T: 24/26/24 C: 22	Resistance training Aerobic training Combined training Length of Intervention: 23 weeks	Freq: 3 times a week Duration: 51-64 min	CON	Weight,BFP,BMI,LDL,HDL,TC,TG,VO2max
(ROBERTS ET AL., 2013)	2013	Obese patients	T: 21.5 (20.0–23.0) C: 22.0 (20.8–22.8)	T: 28 C: 8	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration: 60 min	CON	Weight,BMI,FFM,Glucose,Insulin,HbA1c
(PHILLIPS	2012	Obese patients	T: 64.8(2.4)	T: 11	Resistance training	Freq: 3 times a	CON	Weight, BFP, BMI,

ET AL., 2012)			C: 66.4(2.8)	C: 12	Length of Intervention: 12 weeks	week Duration: 75 min		FFM, CRP
(MOGHADASI ET AL., 2012)	2012	Obese patients	T: 44.5(3.5) C: 45.3(3.2)	T: 8 C: 8	Aerobic training Length of Intervention: 12 weeks	Freq: 4 times a week Duration: 45 min	CON	Weight,BFP,BMI,FFM,VO2max,Glucose,Insulin,HOMA-IR
(HO ET AL., 2012)	2012	Obese patients	T: 55(1.2) 52(1.1) 53(1.3) C: 52(1.8)	T: 15/16/17 C: 16	Resistance training Aerobic training Combined training Length of Intervention: 12 weeks	Freq: 5 times a week Duration: 30 min	CON	Weight,BFP,BMI,VO2max,Glucose,Insulin,LDL,HDL,TC,TG
(BALDUCCI ET AL., 2012)	2012	Obese patients Type 2 Diabetes	T: 59.6(8.7) C: 61.6(7.8)	T: 36 C: 34	Combined training Length of Intervention: 12 months	Freq: 2 times a week Duration: 75 min	CON	BMI,SBP,DBP,HbA1c,LDL,HDL,TC,TG,CRP
(WAIB ET AL., 2011)	2011	Obese patients Hypertension	T: 49（47-52） C: 53（50-56）	T: 55 C: 24	Aerobic training Length of Intervention: 15 weeks	Freq: 5 times a week Duration: 60 min	CON	BMI,VO2max,SBP,DBP,HOMA-IR
(HERNÁN JIMÉNEZ & RAMÍREZ-VÉLEZ, 2011)	2011	Obese patients	T+C: 23.7(5.4)	T: 6 C: 8	Resistance training Length of Intervention: 6 weeks	Freq: 4 times a week Duration: NA	CON	Weight, BFP, BMI, Glucose, Insulin, TC, TG, LDL, HDL
(KU ET AL., 2010)	2010	Obese patients Type 2 Diabetes	T: 55.7(6.2) 55.7(7) C: 55.7(7)	T: 13/15 C: 16	Resistance training Aerobic training Length of Intervention: 12 weeks	Freq: 5 times a week Duration: 60 min	CON	Weight,BMI,Glucose,HbA1c
(JOHNSON ET AL., 2009)	2009	Obese patients	T: 49.1 (2.3) C: 47.3 (3.6)	T: 12 C: 7	Aerobic training Length of Intervention: 4 weeks	Freq: 3 times a week Duration: 30-45	CON	Weight,BMI,VO2max,Glucose,Insulin,TC,TG,HOMA-IR

						min		
(IRVING ET AL., 2009)	2009	Obese patients Metabolic syndrome	T: 49.2 (1.8) C: 47.3 (4.8)	T: 13 C: 10	Aerobic training Length of Intervention: 16 weeks	Freq: 5 times a week Duration: NA	CON	Weight,BFP,BMI,Glucose,HDL,TG,SBP,DBP,VO2max
(ARSENAULT ET AL., 2009)	2009	Obese patients	T: 57.3 (6.6) C: 57.2 (6.1)	T: 267 C: 82	Aerobic training Length of Intervention: 16 weeks	Freq: 3-4 times a week Duration: 72.2 min	CON	Weight,BMI,Glucose, LDL,HDL,TC,TG,SBP,DBP,VO2max,CRP,Insulin,IL-6
(DE OLIVEIRA JÚNIOR ET AL., 2021)	2021	Obese patients	T: 47.5 (11.6) C: 47.3 (10.9)	T: 33 C: 37	Resistance training Length of Intervention: 3 months	Freq: 3 times a week Duration:30 min	CON	Weight,BMI,SBP,DBP,LDL,HDL,TC,TG,Glucose,Insulin,VO2max,CRP,HbA1c
(BITELI ET AL., 2021)	2021	Obese patients	T: 58.5 (6.5) C: 61.2 (7.7)	T: 11 C: 13	Aerobic training Length of Intervention: 20 weeks	Freq: 3 times a week Duration:75 min	CON	BFP,LDL,HDL,TC,TG,Glucose,IL-6
(BANITALEBI ET AL., 2021)	2021	Obese patients Osteosarcopenic	T: 64.11 (3.81) C: 64.05 (3.35)	T: 32 C: 31	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:60 min	CON	Weight, BFP, BMI
(BAK-SOSNOWSKA ET AL., 2021)	2021	Obese patients	T+C: 18-65	T: 21 C: 17	Combined training Length of Intervention: 3 months	Freq: 3 times a week Duration:60 min	AT	Weight, BMI
(H AL-JIFFRI & M ABD EL-KADER, 2021)	2021	Obese patients Chronic insomnia syndrome	T: 43.64 (3.97) C: 41.15 (4.26)	T: 30 C: 30	Aerobic training Length of Intervention: 6 months	Freq: 3 times a week Duration:NA	RT	BMI
(SUN ET AL.,	2020	Obese patients	T: 21.78 (1.47)	T: 150	HIIT	Freq: 5 times a	AT	Weight, BFP, BMI,

2020)			C: 21.63 (1.39)	C: 150	Length of Intervention: 12 weeks	week Duration:40 min		LDL, HDL, TC, TG, Glucose, Insulin
(SAFARZADE ET AL., 2020)	2020	Obese patients	T+C: 36 (7.7)	T: 14 C: 14	Resistance training Length of Intervention: 8 weeks	Freq: 3 times a week Duration:80 min	CON	Weight, BFP, BMI, Glucose, Insulin, HOMA-IR
(SABAG ET AL., 2020)	2020	Obese patients Type 2 Diabetes	T: 56.9 (2.1) C: 54.8 (2.4)	T: 12 C: 12	HIIT Length of Intervention: 12 weeks	Freq: 3 times a week Duration:30 min	AT	Weight,BMI,LDL,HDL,TC,TG,Glucose,IInsulin,VO2max,CRP,HOMA-IR,HbA1c
(RYAN ET AL., 2020)	2020	Obese patients	T: 32 (7) C: 30 (6)	T: 16 C: 15	HIIT Length of Intervention: 12 weeks	Freq: 3 times a week Duration:NA	AT	Weight,BMI,FFM,SBP,DBP,TG,Glucose,Insulin,VO2max,CRP,IL-6,HbA1c
(RIBEIRO ET AL., 2020)	2020	Obese patients	T: 69 (6.7) C: 67.1(4.1)	T: 18 C: 15	Resistance training Length of Intervention: 16 weeks	Freq: 3 times a week Duration:NA	CON	BFP,FFM
(PARK ET AL., 2020)	2020	Obese patients	T: 69.1 (0.9) C: 68.5 (0.9)	T: 10 C: 10	Combined training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:30-40 min	CON	Weight,BFP,BMI,FFM,SBP,DBP,LDL,HDL,TC,TG,Glucose,IL-6
(MENDHAM ET AL., 2020)	2020	Obese patients	T: 22 (21, 24) C: 23 (21, 27)	T: 20 C: 15	Combined training Length of Intervention: 12 weeks	Freq: 4 times a week Duration:40-60 min	CON	Weight,BMI,VO2max
(KOGURE ET AL., 2020)	2020	Obese patients Polycystic ovary syndrome	T: 29 (5.2) C: 28.5(5.7)	T: 28 C: 30	Aerobic training Length of Intervention: 16 weeks	Freq: 3 times a week Duration:33 min	CON	Weight, BMI

(ERCIN ET AL., 2020)	2020	Obese patients Chronic obstructive pulmonary disease	T: 60.8(9.4) C: 59.7(9.7)	T: 24 C: 23	HIIT Length of Intervention: 8 weeks	Freq: 3 times a week Duration:30 min	AT	Weight,BMI,VO2max
(CLARK ET AL., 2020)	2020	Obese patients	T: 30(6) C: 26(8)	T: 16 C: 12	HIIT Length of Intervention: 6 weeks	Freq: 3 times a week Duration:30 min	AT	SBP,DBP
(BENITO ET AL., 2020)	2020	Obese patients	T+C: 18-50	T: 19/25/22 C: 18	Resistance training Aerobic training Combined training Length of Intervention: 22 weeks	Freq: 3 times a week Duration:NA	CON	Weight, BMI
(BANITALEBI ET AL., 2020)	2020	Obese patients	T: 64.11(3.81) C: 64.05(3.35)	T: 32 C: 31	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:60 min	CON	Weight, BFP, BMI
(RATAJCZAK ET AL., 2019)	2019	Obese patients	T: 49(10) C: 51(8)	T: 17 C: 22	Combined training Length of Intervention: 3 months	Freq: 3 times a week Duration:NA	AT	Weight,BMI,LDL,HDL,TC,TG,VO2max,CRP
(NUNES ET AL., 2019)	2019	Obese patients	T: 58.5-67.3 C: 57.1-68.8	T: 12 C: 12	HIIT Length of Intervention: 12 weeks	Freq: 3 times a week Duration:60 min	AT	Weight, BFP, BMI, FFM
(NIE ET AL., 2019)	2019	Obese patients	T: 20 (1) C: 21.2(2)	T: 12 C: 12	HIIT Length of Intervention: 12 weeks	Freq: 3-4 times a week Duration:NA	AT	Weight,BFP,BMI,VO2max
(LEE ET AL., 2019)	2019	Obese patients	T: 53 (38, 68) C: 52 (37, 66)	T: 46 C: 45	Combined training Length of Intervention: 16 weeks	Freq: 3 times a week Duration:NA	CON	LDL,HDL
(KIM ET AL.,	2019	Obese patients	T: 69.1 (0.88)	T: 10	Combined training	Freq: 3 times a	CON	Weight, BFP, FFM,

2019)			C: 68.5 (0.85)	C: 10	Length of Intervention: 12 weeks	week Duration:90-120 min		Glucose, Insulin, HOMA-IR
(CHRISTENSEN ET AL., 2019)	2019	Obese patients	T: 39 (14) 38 (14) C: 47 (12)	T: 14/13 C: 12	Aerobic training Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:45 min	CON	Weight, BFP, BMI
(CAO ET AL., 2019)	2019	Obese patients	T: 63.8 (5.9) C: 64 (4.6)	T: 13 C: 15	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:20-40 min	CON	Weight,BFP,BMI,FFM,LDL,HDL,TC,TG,VO2max
(GROSSMAN ET AL., 2018)	2019	Obese patients	T+C: 59 (5.33)	T: 5 C: 4	HIIT Length of Intervention: 16 weeks	Freq: 3-5 times a week Duration:20-50 min	AT	BMI
(COWAN ET AL., 2018)	2018	Obese patients	T: 51.8 (8.3) C: 55.1 (6.6)	T: 30 C: 40	Aerobic training Length of Intervention: 24 weeks	Freq: 5 times a week Duration:30-60 min	CON	Weight, BMI
(CAVALCANTE ET AL., 2018)	2018	Obese patients	T: 66.5 (6) C: 66.7 (4.1)	T: 20 C: 19	Resistance training Length of Intervention: 12 weeks	Freq: 2-3 times a week Duration:45-60 min	CON	Weight, FFM
(H. ZHANG ET AL., 2017)	2017	Obese patients	T+C: 18-22	T: 15/15 C: 13	Aerobic training Resistance training Length of Intervention: 12 weeks	Freq: 3-4 times a week Duration:NA	CON	Weight, BFP
(VILLAREAL	2017	Obese patients	T: 70 (4)	T:	Aerobic training	Freq: 3 times a	CON	Weight,FFM,VO2max

ET AL., 2017)			70 (5) 70 (5) C: 70 (5)	40/40/4 0 C: 40	Resistance training Combined training Length of Intervention: 6 months	week Duration:60-90 min		
(VELLA ET AL., 2017)L	2017	Obese patients	T: 23.1 (6.6) C: 28.9 (8.1)	T: 8 C: 9	HIIT Length of Intervention: 8 weeks	Freq: 4 times a week Duration:20 min	AT	SBP,DBP,LDL,HDL,TC,TG,Glucose,VO2max,CRP,IL-6
(SAID ET AL., 2017)	2017	Obese patients	T+C: 18-30	T:16 C:16	Combined training Length of Intervention: 24 weeks	Freq: 4 times a week Duration:NA	AT	Weight, BFP, BMI, FFM, SBP, DBP, LDL, HDL, TC, TG, Glucose
(PARK ET AL., 2017)	2017	Obese patients	T: 73.5 (7.1) C: 74.7 (5.1)	T:25 C:25	Combined training Length of Intervention: 24 weeks	Freq: 5 times a week Duration:50-80 min	CON	BFP,SBP,DBP,LDL,HDL,TC,TG,CRP
(MORA-RODRIGUEZ ET AL., 2017)	2017	Obese patients	T+C: 54(9)	T:18 C:16	HIIT Length of Intervention: 6 months	Freq: 3 times a week Duration:NA	CON	TG, Glucose
(LIAO ET AL., 2017)	2017	Obese patients Sarcopenic obesity	T: 66.39 (4.49) C: 68.42 (5.86)	T:25 C:21	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:35-40 min	CON	BFP,FFM
(GRAM ET AL., 2017)	2017	Obese patients	T: 33 (30;35) C: 35 (31;39)	T:31 C:16	Aerobic training Length of Intervention: 6 months	Freq: 3 times a week Duration:50-60 min	CON	Weight, BMI
(CHIU ET AL., 2017)	2017	Obese patients	T: 66.39 (4.49) C: 68.42 (5.86)	T:12 C:12	Aerobic training Length of Intervention:	Freq: 3 times a week	CON	Weight, BFP, BMI, FFM

					12 weeks	Duration:60 min		
(CHUNG ET AL., 2017)	2017	Obese patients	T: 21.75 (0.74) C: 20.83 (0.71)	T:12 C:12	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:50 min	CON	Weight, BFP, BMI, FFM, SBP, DBP, LDL, HDL, TC, TG, Glucose
(CHEN ET AL., 2017)	2017	Obese patients Sarcopenic obesity	T: 68.9 (4.4) 69.3 (3) 68.5 (2.7) C: 68.6 (3.1)	T:15/15/15 C:15	Resistance training Aerobic training Combined training Length of Intervention: 8 weeks	Freq: 3 times a week Duration:60 min	CON	Weight, BMI
(BONFANTE ET AL., 2017)	2017	Obese patients	T: 49.7 (5.35) C: 49.8 (6.33)	T:12 C:10	Combined training Length of Intervention: 24 weeks	Freq: 3 times a week Duration:60 min	CON	Weight,BFP,BMI,FFM,LDL,HDL,TC,TG,Glucose,Insulin,VO2max,HOMA-IR,HbA1c
(AZADPOUR ET AL., 2017)	2017	Obese patients	T: 56.58 (4.17) C: 57.58 (4.29)	T:12 C:12	Aerobic training Length of Intervention: 10 weeks	Freq: 3 times a week Duration:25 min	CON	Weight,BFP,BMI,FFM,SBP,DBP,VO2max
(NIKSERESHT ET AL., 2016)	2016	Obese patients	T+C: 34-46	T:10 C:11	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:55 min	CON	Weight, BFP, LDL, HDL, TC, TG, Glucose
(COOPER ET AL., 2016)	2016	Obese patients	T: 51.1 (5.7) C: 51.2 (7)	T:15 C:14	Aerobic training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:150-180 min	CON	Weight,BFP,FFM,CRP,IL-6
(SMITH-RYAN ET AL., 2015)	2015	Obese patients	T: 36.5 (12.3) C: 37.2 (9.9)	T:10 C:5	HIIT Length of Intervention: 3 weeks	Freq: 3 times a week Duration:9 min	CON	LDL, HDL, TC, TG, Glucose, Insulin, HOMA-IR
(LANZI ET	2015	Obese patients	T: 34.9 (3.4)	T:9	HIIT	Freq: 2 times a	CON	Weight,BMI,Glucose,I

AL., 2015)			C: 38.1 (2.3)	C:10	Length of Intervention: 5 weeks	week Duration:30 min		nsulin,HOMA-IR,VO2max
(KEATING ET AL., 2015)	2015	Obese patients	T: 45.5 (2.3) C: 39.1 (2.9)	T:12 C:12	Aerobic training Length of Intervention: 8 weeks	Freq: 3 times a week Duration:90-135 min	CON	Weight,BMI,SBP,DBP,LDL,HDL,TC,TG,Glucose,Insulin,VO2max,CRP
(NIKSERESHT ET AL., 2014)	2014	Obese patients	T+C: 34-46	T:15/15 C:15	Aerobic training Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:40-65 min	CON	Weight, Glucose, Insulin, HOMA-IR
(KEATING ET AL., 2014)	2014	Obese patients	T: 44.1 (1.9) 41.8 (2.7) C: 42.9 (2.8)	T:13/13 C:12	Aerobic training HIIT Length of Intervention: 12 weeks	Freq: 3 times a week Duration:20-48 min	CON	Weight,BFP,Glucose,Insulin,VO2max,CRP
(FIGUEROA ET AL., 2014)	2014	Obese patients Hypertension	T: 55.5 (0.7) C: 56.4 (1)	T:13 C:12	WBV training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:NA	CON	Weight, BFP, BMI, SBP, DBP
(CROYMANS ET AL., 2013)	2013	Obese patients	T: 21.5 (20-23) C: 22(20.8–22.8)	T:28 C:8	Resistance training Length of Intervention: 12 weeks	Freq: 3 times a week Duration:60 min	CON	Weight, BFP, BMI, FFM, LDL, HDL,TC,TG,CRP
(TSENG ET AL., 2013)	2013	Obese patients	T: 22.2(0.7) 22.1 (1.1) 21.3(0.6) C: 22.3 (1)	T:10/10/10 C:10	Aerobic training Resistance training Combined training Length of Intervention: 12 weeks	Freq: 5 times a week Duration:60 min	CON	Weight, BMI, SBP, DBP, TG, Glucose
(WILMS ET AL., 2012)	2012	Obese patients	T+C: 43.1(3.5)	T:7 C:7	WBV training Length of Intervention: 6 weeks	Freq: 3 times a week Duration:15-30	AT	Weight, BFP, FFM

						min		
(KIM & KIM, 2012)	2012	Obese patients	T+C: 53.46(2.4)	T:15 C:15	Aerobic training Length of Intervention: 16 weeks	Freq: 3 times a week Duration:60 min	CON	Weight, BFP, BMI, SBP, DBP, LDL, HDL, TC, TG, Glucose, Insulin, HOMA-IR
(FIGUEROA ET AL., 2012)	2012	Obese patients	T+C: 18-35	T:5 C:5	WBV training Length of Intervention: 6 weeks	Freq: 3 times a week Duration:NA	CON	Weight, SBP, DBP
(LUCOTTI ET AL., 2011)	2011	Obese patients Type 2 Diabetes	T: 61.5 (11.5) C: 58.1 (9.9)	T:20 C:27	Combined training Length of Intervention: 3 weeks	Freq: 5 times a week Duration:30 min	AT	Weight,BMI,FFM,SBP,DBP,TC,TG,HbA1c
(SAREMI ET AL., 2010)	2010	Obese patients	T: 43.1 (4.7) C: 42.2 (3.8)	T:9 C:9	Aerobic training Length of Intervention: 12 weeks	Freq: 5 times a week Duration:50-60 min	CON	Weight, BFP, BMI,SBP,DBP, LDL, HDL, TC, TG, Glucose, Insulin, HOMA-IR
(MEDIANO ET AL., 2010)	2010	Obese patients	T: 36.6 (5.4) C: 38.1 (5.5)	T:60 C:56	Aerobic training Length of Intervention: 12 months	Freq: 3 times a week Duration:40 min	CON	Weight, BFP, BMI, LDL, HDL, TC, TG, Glucose, Insulin, HOMA-IR

3.4 Body Weight

All P-values for direct and indirect comparisons across all studies were determined to be more than 0.05 after being checked for consistency, indicating that the influence of consistency across studies was judged to be acceptable. Figure 2A displays the NMA figure. The network meta-analysis's findings demonstrated that the no-training control group was outperformed in terms of body weight reduction by combined training [MD = -0.47, 95% CI = (-0.75, -0.19)], aerobic training [MD = -4.79, 95% CI = (-9.05, -0.53)], and resistance training [MD = -0.35, 95% CI = (-0.60, -0.11)] in comparison to the conventional measures in the control group.

When it came to the likelihood of various exercise treatments leading to weight loss, combined training came out on top in SUCRA (76.5%).

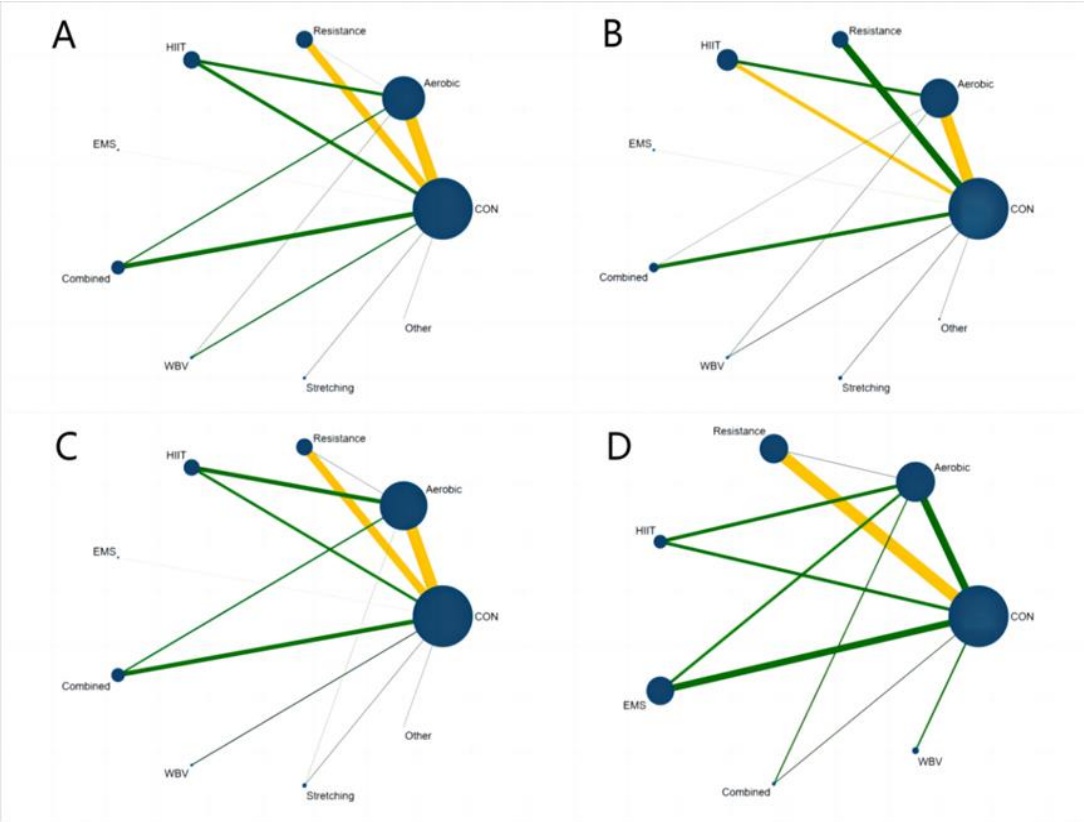


Figure 2: Net graphs for (A) Weight; (B) Body Fat Percentage; (C) Body Mass Index; (D) Fat Free Mass.

3.5 Body Fat Percentage

Figure 2B displays the NMA figure. The network meta-analysis results demonstrated that the no-training control group was not as successful in reducing percentage body fat as the resistance training [MD = -0.67, 95% CI = (-1.00, -0.34)], HIIT [MD = -0.66, 95% CI = (-1.01, -0.31)], combined training [MD = -0.62, 95% CI = (-1.06, -0.18)], and aerobic training [MD = -0.61, 95% CI = (-0.85, -0.37)] in comparison to the conventional measures in the control group. According to SUCRA's probability rankings, resistance training rated highest among the various exercise treatments in terms of the percentage decrease of body fat (SUCRA: 71.8%).

3.6 Body Mass Index (BMI) and Fat Free Mass (FFM)

Figure 2C displays the NMA figure. The network meta-analysis's findings demonstrated that, in terms of improving BMI, resistance training (MD= -0.34, 95% CI = (-0.59, -0.09)] and aerobic training (MD= -0.39, 95% CI = (-0.58, -0.21)) outperformed no training. Other training was ranked first in SUCRA in terms of the probability of improving BMI by different exercise interventions

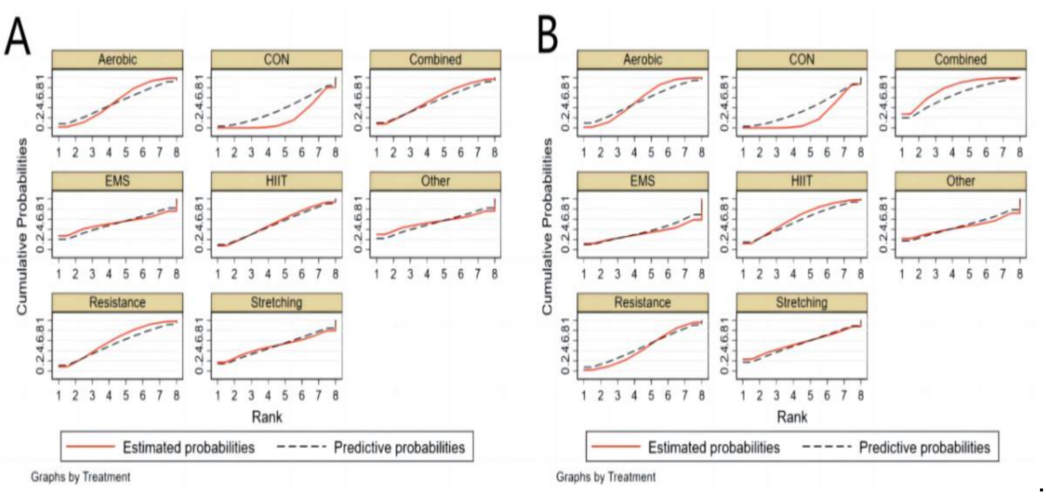
(SUCRA: 77.6%). Figure 2D displays the NMA figure. The network meta-analysis's findings demonstrated that resistance training outperformed no training in terms of enhancing FFM (MD = 0.45, 95% CI = (0.12,0.78)). Moreover, resistance training outperformed aerobic training in terms of enhancing FFM [MD=0.53, 95% CI = (0.08,0.97)]. The ranking of different exercise interventions in improving FFM placed Resistance training first in SUCRA (SUCRA: 86.9%).

3.7 Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP)

The network meta-analysis's findings demonstrated that WBV training [MD= -1.44, 95% CI = (-2.19, -0.70)], resistance training [MD= -0.64, 95% CI = (-1.02, -0.26)], aerobic training [MD= -0.46, 95% CI = (-0.69, -0.22)], and HIIT [MD= -0.38, 95% CI = (-0.73, -0.04)] were all more effective at lowering Systolic Blood Pressure (SBP) than the no-training control group. WBV training was the most effective exercise strategy in lowering SBP in SUCRA (SUCRA: 99.1%). The network meta-analysis's findings showed that aerobic training outperformed the no-training control group in terms of improving diastolic blood pressure (DBP) when compared to traditional measurements in the control group (MD= -0.55, 95% CI = (-1.03, -0.07)). WBV training was the most effective exercise strategy in lowering DBP in SUCRA (SUCRA: 83.1%).

3.8 High Density Lipoprotein (HDL) and Low-Density Lipoprotein (LDL)

Table 3A displays the LDL League table. The network meta-analysis's findings showed that resistance training was the most likely exercise intervention to reduce LDL, with an SUCRA score of 60.4%. Specific comparisons are shown in Figure 3A. Table 3B displays the LDL League table. The network meta-analysis's findings demonstrated that combined training outperformed the no-training control group in terms of HDL improvement (MD = 0.63, 95% CI = (0.08,1.18)). In the meanwhile, when it came to the likelihood of various exercise treatments raising HDL, combined training came out on top in SUCRA (78.5%). Figure 3B displays specific comparisons.



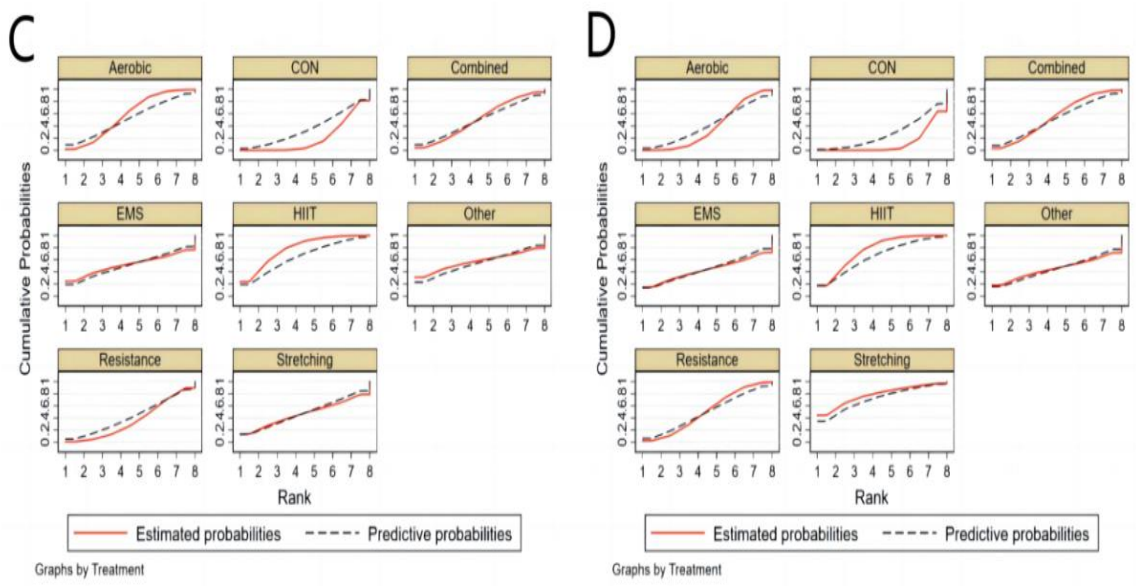


Figure 3: SUCRA plot for (A) Low Density Lipoprotein; (B) High Density Lipoprotein; (C) Total Cholesterol; (D) Triglycerides

Table 3A: League table on LDL

RESISTANCE	COMBINED	OTHER	AEROBIC	EMS	HIIT	STRETCHING	CON
RESISTANCE	0.05 (-0.79,0.88)	0.01 (-2.19,2.21)	0.10 (-0.58,0.78)	0.04 (-2.09,2.17)	0.08 (-0.80,0.96)	0.10 (-1.47,1.68)	0.43 (-0.10,0.97)
-0.05 (-0.88,0.79)	Combined	-0.04 (-2.26,2.19)	0.05 (-0.64,0.74)	-0.01 (-2.17,2.16)	0.04 (-0.88,0.95)	0.05 (-1.54,1.65)	0.39 (-0.26,1.03)
-0.01 (-2.21,2.19)	0.04 (-2.19,2.26)	Other	0.08 (-2.09,2.26)	0.03 (-2.93,3.00)	0.07 (-2.17,2.32)	0.09 (-2.51,2.69)	0.42 (-1.71,2.55)
-0.10 (-0.78,0.58)	-0.05 (-0.74,0.64)	-0.08 (-2.26,2.09)	Aerobic	-0.05 (-2.17,2.06)	-0.01 (-0.72,0.69)	0.01 (-1.48,1.49)	0.34 (-0.11,0.79)
-0.04 (-2.17,2.09)	0.01 (-2.16,2.17)	-0.03 (-3.00,2.93)	0.05 (-2.06,2.17)	EMS	0.04 (-2.14,2.22)	0.06 (-2.48,2.60)	0.39 (-1.67,2.45)
-0.08 (-0.96,0.80)	-0.04 (-0.95,0.88)	-0.07 (-2.32,2.17)	0.01 (-0.69,0.72)	-0.04 (-2.22,2.14)	HIIT	0.02 (-1.59,1.63)	0.35 (-0.36,1.06)
-0.10 (-1.68,1.47)	-0.05 (-1.65,1.54)	-0.09 (-2.69,2.51)	-0.01 (-1.49,1.48)	-0.06 (-2.60,2.48)	-0.02 (-1.63,1.59)	Stretching	0.33 (-1.16,1.82)
-0.43 (-0.97,0.10)	-0.39 (-1.03,0.26)	-0.42 (-2.55,1.71)	-0.34 (-0.79,0.11)	-0.39 (-2.45,1.67)	-0.35 (-1.06,0.36)	-0.33 (-1.82,1.16)	CON

Table 3B: League table on HDL

COMBINED	HIIT	STRETCHING	AEROBIC	RESISTANCE	OTHER	CON	EMS
COMBINED	-0.19 (-1.00,0.61)	-0.26 (-1.62,1.10)	-0.29 (-0.87,0.30)	-0.40 (-1.11,0.31)	-0.48 (-2.39,1.43)	-0.63 (-1.18,-0.08)	-0.79 (-2.62,1.05)
0.19 (-0.61,1.00)	HIIT	-0.06 (-1.45,1.32)	-0.09 (-0.73,0.54)	-0.21 (-0.97,0.56)	-0.29 (-2.22,1.64)	-0.43 (-1.06,0.19)	-0.59 (-2.45,1.27)
0.26 (-1.10,1.62)	0.06 (-1.32,1.45)	Stretching	-0.03 (-1.29,1.23)	-0.14 (-1.49,1.20)	-0.22 (-2.45,2.00)	-0.37 (-1.64,0.89)	-0.53 (-2.69,1.63)
0.29 (-0.30,0.87)	0.09 (-0.54,0.73)	0.03 (-1.23,1.29)	Aerobic	-0.12 (-0.69,0.46)	-0.20 (-2.06,1.67)	-0.34 (-0.72,0.04)	-0.50 (-2.29,1.29)
0.40 (-0.31,1.11)	0.21 (-0.56,0.97)	0.14 (-1.20,1.49)	0.12 (-0.46,0.69)	Resistance	-0.08 (-1.96,1.80)	-0.23 (-0.68,0.23)	-0.38 (-2.19,1.43)
0.48 (-1.43,2.39)	0.29 (-1.64,2.22)	0.22 (-2.00,2.45)	0.20 (-1.67,2.06)	0.08 (-1.80,1.96)	Other	-0.15 (-1.98,1.68)	-0.31 (-2.84,2.23)
0.63 (0.08,1.18)	0.43 (-0.19,1.06)	0.37 (-0.89,1.64)	0.34 (-0.04,0.72)	0.23 (-0.23,0.68)	0.15 (-1.68,1.98)	CON	-0.16 (-1.91,1.59)
0.79 (-1.05,2.62)	0.59 (-1.27,2.45)	0.53 (-1.63,2.69)	0.50 (-1.29,2.29)	0.38 (-1.43,2.19)	0.31 (-2.23,2.84)	0.16 (-1.59,1.91)	EMS

3.9 Total Cholesterol (TC) and Triglycerides

The network meta-analysis's findings demonstrated that, when compared to traditional measures in the control group, HIIT [MD = -0.67, 95% CI = (-1.23, -0.11)] outperformed the no-training control group in terms of TC reduction. HIIT was the top workout intervention in SUCRA (SUCRA: 78.2%) when it came to the likelihood of lowering TC. Specific comparisons are shown in Figure 3C. In addition, the network meta-analysis's findings revealed that HIIT [MD = -0.56, 95% CI = (-0.92, -0.21)] outperformed the no-training control group in terms of Triglycerides reduction. In the ranking of probability of reducing Triglycerides, stretching training ranked first in SUCRA (SUCRA: 77.9%). Specific comparisons are shown in Figure 3D..

3.10 Blood Glucose and Insulin

The network meta-analysis's findings revealed that, relative to conventional measures in the control group, Combined training [MD=-0.77, 95% CI = (-1.49, -0.06)], Aerobic training [MD=-0.75, 95% CI = (-1.16, -0.33)], and Resistance training [MD = -0.69, 95% CI = (-1.24, -0.15)] were superior to the no-training control group in improving Blood Glucose. Combined training ranked first in SUCRA for improving Blood Glucose (SUCRA: 74.4%). Network meta-analysis findings revealed that Combined training ranked first in SUCRA for the probability of improving insulin (SUCRA: 87.2%).

3.11 Maximal Oxygen Uptake

Network meta-analysis findings revealed that Combined training [MD = 1.48, 95% CI = (0.81,2.15)], HIIT [MD = 0.98, 95% CI = (0.37,1.59)], and Aerobic training [MD = 0.91, 95% CI = (0.44,1.38)] were superior to the no-training control group in improving maximal oxygen uptake. In the probability ranking, Combined training ranked first in SUCRA (SUCRA: 92.0%).

3.12 Interleukin 6(IL-6) and C-reactive Protein(CRP)

Network meta-analysis findings revealed that Resistance training was ranked first in SUCRA in the probability ranking of mediating CRP (SUCRA: 77.7%). For IL-6, the network meta-analysis showed that Aerobic training [MD= -0.58, 95% CI = (-0.96, -0.20)] outperformed the no-training control group in reducing IL-6 relative to conventional measures in the control group. In addition, Aerobic training [MD= -0.85, 95% CI = (-1.43, -0.27)] outperformed Resistance training in lowering IL-6. In the probability ranking, Combined training was ranked first in SUCRA (SUCRA: 73.6%).

3.13 Homeostasis Model Assessment-Insulin Resistance (HOMA-IR) and Hemoglobin A1c(HbA1c)

The network meta-analysis's findings revealed that, relative to conventional measures in the control group, Resistance training [MD= -2.15, 95% CI = (-3.02, -1.29)], Combined training [MD= -0.93, 95% CI = (-1.83, -0.02)], and Aerobic training [MD= -0.57, 95% CI = (-1.00, -0.13)] were superior to the no-training control group in reducing HOMA-IR. In the probability ranking, Resistance training ranked first in SUCRA (SUCRA: 98.9%). The results of the network meta-analysis of HbA1c demonstrated that Resistance training ranked first in SUCRA in the probability ranking (SUCRA: 68.1%).

3.14 Publication Bias Test

For every outcome marker, we constructed a different funnel plot to take publication bias into consideration. A visual analysis of the funnel plots revealed no indications of publishing bias(Wallace et al., 2009). Figure 4 shows the funnel plot for some of the indicators.

4. Discussion

In this investigation, we examined the efficacy of various exercise interventions on improving intermediate metabolic health markers in obese patients. A total of 119 studies were included, encompassing nine distinct exercise programs and involving 5,573 obese patients—a sizable sample. In our current Network Meta-Analysis (NMA), these nine exercise interventions, which included aerobic exercise, resistance training, combined exercise, HIIT, WBV, EMS, stretching exercises, and others, were ranked based on their impact on physiological outcome indicators.

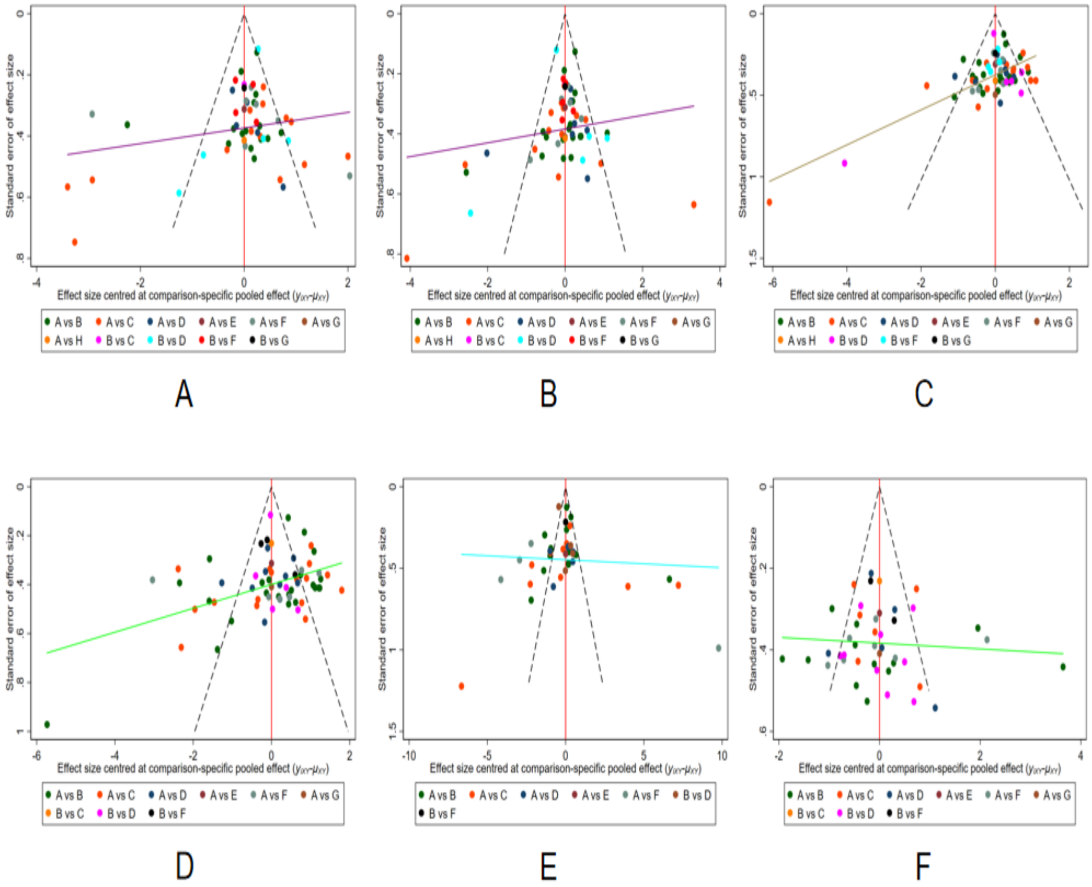


Figure 4: Funnel plot on publication bias. 5AL: LDL; 5B: TC; 5C: Triglycerides; 5D: Blood Glucose; 5E: Insulin; 5F: Maximal Oxygen Uptake.

Obesity is a multifactorial disease with increasing prevalence and burden. It can be managed through behavioral changes involving daily energy intake and expenditure (Petridou et al., 2019). Compelling evidence supports the role of regular exercise in weight and fat reduction, weight maintenance, and improved metabolic health related to obesity (Jurado-Castro et al., 2022). Among the nine exercise interventions investigated in this article, combined aerobic and resistance training had the highest SUCRA value for weight reduction. A 2020 meta-analysis concerning exercise prescription for improving body composition in obese adults similarly reported combined aerobic and resistance training as the most promising intervention for weight loss (O'Donoghue et al., 2021). Some research suggests that fat distribution beyond overall weight is a key determinant of cardiovascular disease risk(Koenen et al., 2021). Being more sensitive to exercise than body weight, body fat percentage may provide a more meaningful measure of health changes resulting from exercise interventions(Millstein, 2014). The results of our NMA showed that the most successful intervention for lowering body fat percentage and FFM was resistance training alone. However, a systematic review and meta-analysis in 2011 highlighted that aerobic exercise alone was more effective in reducing visceral fat in obese patients than resistance training alone. The observed disparity might be attributed to the inclusion mainly of female obese participants in the meta-analysis. Moreover, both sole aerobic and resistance training ranked highly in improving BMI, with stretching training being the least effective. In terms of blood pressure reduction, WBV proved most effective for both SBP and DBP, while EMS and stretching exercises were the least effective for SBP and DBP respectively. A network meta-analysis in 2022 involving 81 studies and 4,331 participants revealed combined training as the most effective in improving cardiac metabolic markers among mixed training, combined aerobic and resistance training, resistance training, interval training and endurance training (Batrakoulis et al., 2022). We observed similar findings in our study. The best type of exercise for elevating HDL cholesterol was combined aerobic and resistance training, with HIIT also showing significant results. In the SUCRA ranking for reducing LDL cholesterol, combined training ranked second, preceded only by resistance training. However, for improving TC, sole resistance training ranked the lowest, with HIIT being the most effective. Notably, HIIT ranked second in reducing triglycerides, aligning with previous experimental findings advocating HIIT as an effective strategy for lipid profile improvement(Fisher et al., 2015). Interestingly, stretching exercises emerged as the most effective for improving triglycerides, with aerobic exercise being the least. In our analysis, the best exercise type for improving blood sugar belonged to combined aerobic and resistance training, followed by aerobic exercise, with EMS training being the least effective. Regarding the HOMA-IR marker for blood sugar control, previous research indicated that exercise training could significantly lower HOMA-IR(Battista et al., 2021). Our findings identified resistance training as the optimal method for improving both HOMA-IR and HbA1c, with HIIT being the least effective for both. Additionally, this study evaluated the nine exercise interventions' impact on insulin, maximum oxygen intake, CRP, and IL6 in obese patients. Our NMA results are consistent with previous intervention trial conclusions, even though most of these trials did not investigate all intermediate disease biomarkers. Our data analysis revealed that combined training and HIIT are effective methods to enhance maximum oxygen intake, which is consistent with previous research concluding the same about HIIT (Atakan et al., 2021). Concurrently, for improving insulin and IL6, combined training ranked the best in SUCRA. Past research on the influence of exercise on inflammatory biomarkers remains controversial. Experimental studies comparing resistance training and aerobic training against a non-training control group found no differences in inflammatory biomarkers between the two exercise groups(Libardi et al., 2011). However, a 2018 study asserted the anti-inflammatory effects of resistance training on CRP, with a trend towards reducing IL-6 as well(Sardeli et al., 2018). In our NMA, resistance training was the least effective in improving IL6 but was the best for CRP. Our study analyzed

119 research articles, comprising data from 5,573 obese patients. This systematic review and meta-analysis of a robust sample facilitated the identification of statistically significant mean differences. Randomized Controlled Trials (RCTs) included every study that was included, and we rigorously assessed potential bias and the overall quality of evidence. Beyond evaluating the effects of daily activities, aerobic, resistance, and combined training on obesity-related disease markers, we also considered five other intervention modalities: High-Intensity Interval Training (HIIT), Whole Body Vibration (WBV), Electrical Muscle Stimulation (EMS), stretching exercises, and other training approaches. By doing so, we provided a comprehensive comparison and evidence-based insights into the efficacy of these interventions. However, our study, while comprehensive, is not without limitations. Despite our meticulous approach in assimilating the studies, certain inherent heterogeneities, such as differences in regional representation or gender ratios, could not be entirely mitigated. Furthermore, due to a paucity of studies on certain interventions, evidence for direct comparisons between specific interventions remains limited. Thus, while our findings are instructive, they should be interpreted with caution, highlighting the imperative for further in-depth studies in this domain. This systematic review elucidates the impact of diverse training modalities on anthropometric outcomes, such as Fat-Free Mass, body fat percentage and body weight, as well as intermediate disease biomarkers including HDL, LDL, TG, DBP, SBP, FG, and HbA1c. In essence, compared to control groups adhering to routine activities, our findings strongly advocate for obese individuals to engage in combined training, encompassing both aerobic and resistance exercises. Such a regimen demonstrates notable efficacy in decreasing body weight and body fat percentage and in enhancing HDL, blood glucose levels, maximal oxygen uptake, and IL-6 levels. For the improvement of HOMA-IR, HbA1c, CRP, LDL, and the increase of FFM, resistance training emerges as preferable. Moreover, High-Intensity Interval Training (HIIT) is identified as particularly effective in diminishing total cholesterol and augmenting maximal oxygen uptake. Additionally, our data suggest that Whole Body Vibration (WBV) training significantly improves both systolic and diastolic blood pressure metrics.

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Registration

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to perform and report the present results. Trial Registration: the registration was made for the protocol of this network meta-analysis in PROSPERO with ID CRD42023462274.

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