

Which exercise interventions are more helpful in treating primary obesity in young adults? A systematic review and Bayesian network meta-analysis

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Abstract

Introduction: Network meta-analysis was used to evaluate the effectiveness of different exercise interventions in the treatment of obesity in young people and recommend the most suitable exercise method.

Material and methods: We searched five electronic databases for articles on obesity treatment in the youth population from inception to April 2022. The two researchers independently retrieved and screened the articles, carried out a quality assessment and data extraction, and carried out a network meta-analysis in the Bayesian framework in Stata software.

Results: A total of 32 original studies were included in the study, all randomized controlled trials (RCTs). High-intensity aerobic exercise may be the best way to reduce the weight of obese people; high-intensity aerobic training combined with resistance training may be the best way to reduce BMI and FAT%; moderate-intensity aerobic training combined with resistance training may be the best way to reduce the waistline; high-intensity aerobic exercise may be the best way to boost VO_{2max} .

Conclusions: Exercise interventions such as high-intensity aerobic training combined with resistance training can be considered and promoted as a non-drug treatment for primary obesity in young adults.

Key words: obesity, exercise prescription, young people, network meta-analysis.

Introduction

The prevalence of obesity has tripled in the past 30 years [1], and it is estimated that the side effects of obesity will affect more than 1 billion people by 2030 [2]. The negative impact of obesity is very large. It increases the risk not only of cardiovascular diseases, metabolic diseases and some cancers [3], but also comorbidities with diseases such as type 2 diabetes, dyslipidemia and hypertension [4–6]. Obesity has become a major public health hazard and risk [7].

Articles and data on obesity management show that different exercise interventions play a role in obesity but show different characteristics [8]. The intensity of aerobic exercise will have different effects on weight loss [9, 10], and the load intensity of resistance training will also have different effects on weight loss [11]. Of concern, good effects have also

been reported in studies of the effects of whole body vibration training [12] and hypoxia training on weight loss in young adults. Current health guidelines suggest that weight-loss programs for obese people should prioritize moderate-intensity aerobic exercise [13], but the issue remains controversial in academia and in the practice of weight loss.

In this context, it is difficult to determine the superiority of different types of exercise interventions using only single randomized controlled trials or paired meta-analyses, as these studies often aim to compare one or two types of exercise interventions with those of a control group, and therefore cannot distinguish between the effects of different exercise interventions for the treatment of obesity in young people, which makes it difficult to draw firm conclusions [14].

Network meta-analysis (NMA), also known as mixed treatment comparison or multi-treatment comparison meta-analysis, expands the scope of traditional pairwise analyses by simultaneously analyzing direct and indirect evidence from different studies, allowing the evaluation of relative effectiveness and sequencing of interventions across all interventions [15].

So far, there has been no systematic review of the effects of different exercise methods on weight loss among young obese people. There are only some meta-analyses or network meta-analyses to study and provide the most appropriate exercise prescription for adolescents and children [16], middle-aged and elderly people [17] or adults in the broad sense (only > 18 years old) [18]. For the time being, no studies have focused on obesity and its management. In the case of young people, the general consensus is that they are between the ages of 18 and 50 and have a number of characteristics not shared by other groups: (1) physical and mental development is complete, and different exercise intervention methods have little impact on their potential threats (e.g. resistance training is teenage children use is not recommended, because it might affect their bones [19]); (2) the majority of the working day is spent at work or studying,

leaving little opportunity for longer exercise [20], or (3) an unhealthy lifestyle, such as staying up late, drinking and frequent social activities [21]. These characteristics, to some extent, lead to primary obesity in this group of people. It is not targeted and scientific to only evaluate the effect of different exercise interventions on obese adults in a broad sense (young adults and middle-aged and elderly people).

Therefore, the purpose of this study is to: (1) evaluate the effects of different exercise interventions on weight loss in young obese people, and (2) establish the ranking of the effects of these exercise interventions.

Material and methods

Search strategy

Five electronic databases (PubMed, EMBASE, Cochrane Central Register of Controlled Trials, Web of Science, and CNKI) was searched from inception to April 2022. The search strategy is built around the PICOS tool: (P) Population: young people with obesity; (I) Intervention: movement; (C) Comparator: other exercise intervention or control group without intervention; (O) Outcomes: body composition and cardiopulmonary fitness and (S) Study type: RCTs. The detailed search strategy is shown in the following Table I (taking PubMed as an example).

Inclusion criteria

(1) a study on the treatment of obesity with different exercise styles as an intervention in the experimental group; (2) a control group with or without exercise styles as an intervention; (3) a randomized controlled clinical trial.

Exclusion criteria

(1) age > 45 or < 18; (2) non-obese individuals; (3) who took relevant weight-loss medications one month before and during the intervention; (4) significant baseline differences between each independent study.

Outcomes

The main outcome indicators were: Body composition: weight (kg), body mass index (BMI), body fat percentage (fat %), and waist circumference (WC) [22]. The secondary outcome measure was cardiopulmonary function: maximal oxygen uptake (VO_{2max}) [23].

Study selection

Zotero, the literature management software, was used to screen and eliminate the literature.

Table I. Search strategy on PubMed

#1	Search 'Obesity' [MeSh]
#2	Search (obesity) OR (overweight) OR (obese)
#3	Search #1 OR #2
#4	Search 'exercise therapy' [MeSH Major Topic] OR (physical activity) OR exercise OR aerobic OR resistance OR (strength training) OR (combined training) OR (concurrent training) OR (circuit training) OR (HIIT training) OR (interval training)
#5	Search #3 AND #4

First, two researchers screened the titles of the literature to eliminate duplicate literature, non-randomized controlled trial studies, review papers, conference papers, experimental protocols and correspondence. Later, the two researchers read the abstract of the literature to further determine the inclusion of the literature, excluding from the object non-young and middle-aged population and non-primary obesity literature. Finally, two researchers read the full text of the remaining literature and further determined the literature to be included. In this process, both researchers conducted independent screening, and finally compared the remaining literature. If they were the same, they were finally included; if they were different, the third researcher discussed the difference and resolved it.

Data extraction

A nine-item, standardized and pre-selected data extraction table was used to record the data included in the study under the following headings: (1) author, (2) year of publication, (3) country, (4) study period, (5) sample size, (6) mean age, (7) mean baseline, (8) follow-up weight, BMI, FAT%, WC and VO_2 max, and (9) detailed information on exercise interventions.

Risk of bias of individual studies

Two authors independently assessed the risk of bias (ROB), in accordance with the Cochrane Handbook version 5.1.0 tool for assessing ROB in RCTs [24–26]. The following seven domains were considered: (1) randomized sequence generation, (2) treatment allocation concealment, blinding of (3) participants and (4) personnel, (5) incomplete outcome data, (6) selective reporting and (7) other sources of bias. Trials were categorized into three levels of ROB by the number of components for which high ROB potentially existed: high risk (five or more), moderate risk (three or four) and low risk (two or less). All studies would, by default, be classified as high ROB with respect to the category ‘blinding of participants’ given that it was impossible to blind participants to group assignment in exercise intervention protocols.

Exercise categories

Exercise interventions included in randomized controlled trials were classified using nine categories [27]:

- (1) Aerobic exercise; vigorous intensity (AE-V),
- (2) Aerobic exercise; moderate intensity (AE-M),
- (3) Resistance training; high load (R-HI),
- (4) Resistance training; low-to-moderate load (R-LM),
- (5) Combined high; vigorous intensity aerobic/high-load resistance (COM-HI),

- (6) Combined low-moderate; moderate intensity aerobic/low-to-moderate load resistance (COM-LM),
- (7) Restricting oxygen in AE-M (AE-M-R),
- (8) Whole body vibration training (WBV),
- (9) No exercise (control group).

The nine categories were based on the frequency, intensity, duration, and type of exercise prescription and ACSM estimates of cardiopulmonary endurance and exercise intensity. The detailed explanation is shown in Table II.

Data analysis

Since the units of outcome indicators to be extracted were consistent, MD + SD was used to calculate the five outcome indicators. MD + SD at the end of intervention minus MD + SD at baseline was used to calculate the five outcome indicators [28]. The extracted intervention was immediately after the end of exercise intervention to avoid any potential impact of the cleaning period on the results. For weight, BMI, WC and FAT %, the better the intervention effect was, the smaller was the value at the end of the intervention [22], while for VO_2 max, the higher the value at the end of the intervention was compared to the baseline, the better was the intervention [23]. When baseline was not available, at the end of the intervention, or the difference between the two, the calculation was performed using the formula given in the Cochrane guidelines [26].

We used Stata software (version 15.1) and performed summary analysis in a Bayesian framework according to the PRISMA NMA guidelines.

Stata software is used to present and describe network diagrams of different exercise interventions. In the generated network diagram, each node represents different motion interventions and different control conditions, and the lines connecting nodes represent direct head-to-head comparisons between interventions. The size of each node and the width of the lines are proportional to the number of studies [29, 30].

The heterogeneity and consistency test between each independent study will be calculated by the instructions in Stata software. If $p > 0.05$, the heterogeneity of each NMA is considered low and the consistency test is passed [31].

Intervention hierarchy was summarized and reported as a P score. The P score is considered as a frequentist analogue to surface under the cumulative ranking curve (SUCRA) values and measures the extent of certainty that a treatment is better than another treatment, averaged over all competing treatments. The P score ranges from 0 to 1, where 1 indicates the best treatment with no uncertainty and 0 indicates the worst treatment with no uncertainty. While the P score or

Table II. Detailed classification of different exercise interventions

Type of exercise	Abbreviation	Definition
Aerobic; vigorous intensity	AE-V	Frequency: 3–5 times per week, each session lasting 30–60 min Intensity: > 65% VO ₂ max or > 65% HRR or > 75% HRmax Type: Any mode of aerobic only (e.g., walking, running, cycling and swimming)
Aerobic; moderate intensity	AE-M	Frequency: 3–5 times per week, each session lasting 30–60 min Intensity: 45–65% VO ₂ max or > 50–65% HRR or 65–75% HRmax Type: Any mode of aerobic only (e.g., walking, running, cycling and swimming)
Resistance; high load	R-HI	Frequency: 3 times per week; each session lasting 30–60 min Intensity: Average maximum load > 75% 1RM Type: Any mode of resistance training (e.g., free weights, weight machines and resistance bands)
Resistance; low-moderate load	R-LM	Frequency: 3 times per week; each session lasting 30–60 min Intensity: Average maximum load 50–75% 1RM Type: Any mode of resistance training (e.g., free weights, weights machines and resistance bands)
Combined; high intensity	COM-HI	A combination of aerobic; vigorous intensity and resistance; high load
Combined; low-moderate intensity	COM-LM	A combination of aerobic; moderate intensity and resistance; low-moderate intensity
Restricting oxygen in AE-M	AE-M-R	Frequency: 3–5 times per week, each session lasting 30–60 min Intensity: 45–65% VO ₂ max or > 50–65% HRR or 65–75% HRmax Type: Any mode of aerobic only, in a low oxygen environment (e.g., walking, running, cycling and swimming in hypoxic training room or plateau)
Whole body vibration training	WBV	Whole body vibration training (WBVT) is the vibration of a special shaker placed on the ground (for standing on both feet or one foot, supporting with both hands or sitting) so that the impactive vibrational stimulation it produces is transmitted through the limb to the muscle group
Control	CON	No exercise

SUCRA can be usefully re-expressed as the percentage of effectiveness or acceptability of the exercise interventions, such scores should be interpreted cautiously unless there are actual clinically meaningful differences between interventions. To check for the presence of bias due to small-scale studies, which may lead to publication bias in NMA, a network funnel plot was generated and visually inspected using the criterion of symmetry [32].

Results

Literature selection

A total of 6656 studies were initially identified. Following review by title and abstract, 219 studies progressed to full manuscript review. Of these, 187 were excluded as they did not fulfil our inclusion criteria. The remaining 32 studies were included in this review [33–65]. The detailed process is illustrated in Figure 1.

Characteristics of the included studies

The specific characteristics of the included studies are presented in Table III. Of these, 7 stud-

ies were from North America, 9 from East Asia, 4 from the Middle East, 7 from Europe, 2 from Oceania, 2 from South America, and 1 from Africa. A total of 1401 patients were enrolled in the study.

In terms of exercise interventions, 308 people were in the AE-M group, 187 in the AE-V group, 75 in the R-LM group, 81 in the R-HI group, 95 in the COM-LM group, 25 in the COM-HI group, 63 in the AE-M-R group, There were 75 participants in the WBV group and 492 participants in the CON group.

Intervention duration was 4 weeks in 7 studies, 6 weeks in 2 studies, 8 weeks in 4 studies, 10 weeks in 1 study, 12 weeks in 13 studies, and > 12 weeks in 5 studies.

Results of ROB assessment

Specific ROB details are presented in Supplementary Table SI. Overall, 4 articles were judged to be of low ROB, 16 of moderate ROB and the remaining 12 rated as at high ROB. Eleven of the studies specify measures regarding distribution concealment, while the rest are largely unclear. In 23 studies, subjects dropped because of the subjects themselves (e.g., loss of interest or withdraw-

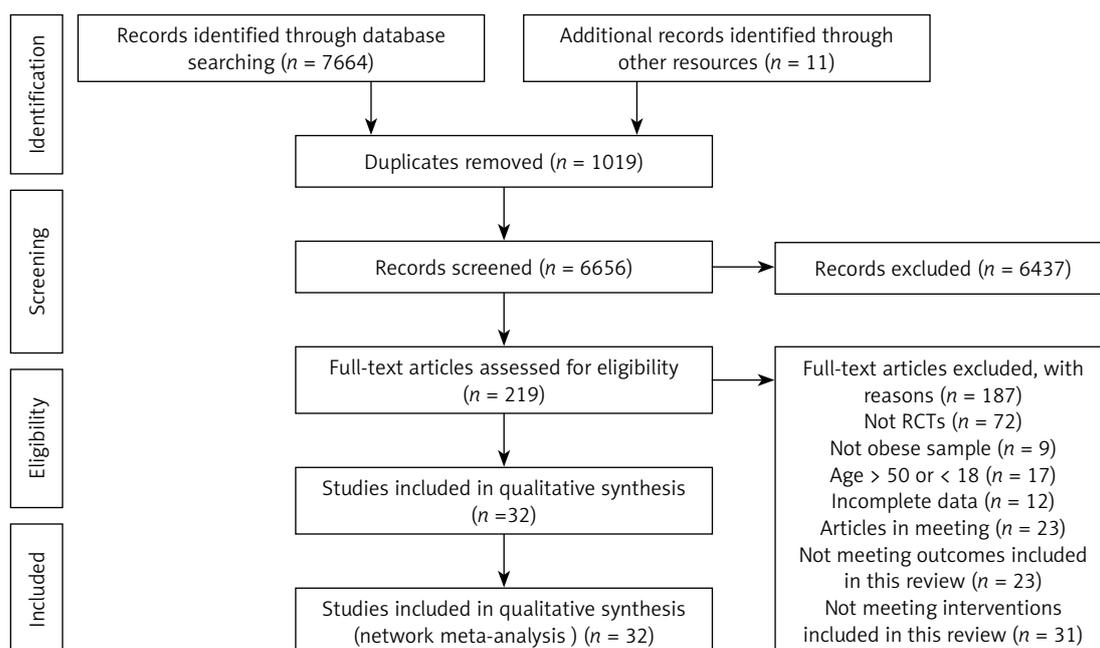


Figure 1. PRISMA flow diagram of RCT selection

al due to time reasons). No studies have reported safety-related results. Eleven studies reported on other factors of bias.

Network meta-analysis

After the heterogeneity test for each substudy, all p -values were > 0.05 (weight: $p = 0.891$; BMI: $p = 0.327$; FAT %: $p = 0.537$; WC: $p = 0.980$ and VO_2 max: $p = 0.916$), which was considered as low heterogeneity. The consistency test between each study was also considered to be passed, as shown in Supplementary Table SII.

Four indicators of body composition, BMI, weight (kg), WC (cm), FAT%, and one indicator of cardiorespiratory fitness, VO_2 max (L min⁻¹), are included in the NMA. Detailed information is presented in Supplementary Table SIII. Figures 2 A–E show the complete NMA diagram, which illustrates the intervention effects of different exercise interventions on BMI, weight, WC, FAT% and VO_2 max. The size of nodes is correlated with the number of participants of different intervention types, and the width of the lines between different interventions is correlated with the number of studies. Table IV lists the complete league chart matrix, and Table V is ranked according to the likelihood of the expected effects of the exercise intervention. SUCRA area is shown in Figures 3 A–E.

Body weight

Twenty-seven studies (8 intervention categories) helped us conduct NMA in terms of body weight. The average ranges from -2.95 to -4.33 . The two exercise measures had significant advan-

tages over the control group in terms of weight reduction, and the difference was statistically significant (AE-V: -4.33 [$-6.91, -1.75$] and COM-LM: -2.95 [$-5.72, -0.18$]). The complete league chart comparison is presented in the table. In NMA comparison, AE-V was the best intervention to reduce body weight (P score = 0.82).

BMI

Twenty-seven studies (8 intervention categories) helped us to conduct NMA in BMI. The average ranges from -1.16 to -1.34 . The five exercise measures had significant advantages in reducing BMI compared with the control group, and the difference was statistically significant (COM-HI: -1.34 [$-2.63, -0.05$]; COM-LM: 1.25 [$1.89, 0.60$]; AE-V: 1.25 [$1.92, 0.57$]; AE-M-R: 1.29 [$2.36, 0.22$] and AE-M: 1.16 [$1.66, 0.66$]). The entire league contrast figure is presented in the table. In NMA comparison, COM-HI was the best intervention to reduce BMI (P score = 0.71).

FAT%

Nineteen studies (8 intervention categories) helped us to conduct NMA in FAT%. The average ranges from -2.78 to -4.07 . The four exercise measures had significant advantages in FAT% reduction compared with the control group, and the difference was statistically significant (COM-LM: -4.07 [$-6.95, -1.19$]; R-LM: 3.49 [$6.76, 0.21$]; AE-V: 3.35 [$5.51, 1.18$]) and AE-M: Com-hi was the best intervention to reduce FAT% in NMA (P score = 0.73). Com-hi was the best intervention to reduce FAT% in NMA (P score = 0.73).

Table III. Detailed information on the included literature

Study	Country	Duration [weeks]	Sample N/F/M	Mean age (SD)	Exercise	Summary description of exercise intervention
Ma, Said <i>et al.</i> 2021	Saudi Arabia	12	15/0/15	NA	CON	No exercise
			15/0/15		AE-M	Continue exercise; 60 min; 50–75% HR _{max} ; 5 days week ⁻¹
			16/0/16	R-LM	3 sets of 10–15 max reps; 60 min; 50–55% 1RM; 5 days week ⁻¹	
			15/0/15	COM-LM	3 sets of 10–15 max reps + Continue exercise; 60 min; 50–55% 1RM + 50–75% HR _{max} ; 5 days week ⁻¹	
Hu, Mingzhu and Kong, Zhaowei 2021	China	12	15/15/0	20.9 ±1.1	CON	No exercise
			15/15/0	20.9 ±1.1	AE-M	Cycling; 60 min; 65–70% HR _{max} ; 4 days week ⁻¹
			15/15/0	21.5 ±1.7	AE-V	Cycling; 30 min; 75–80% HR _{max} ; 4 days week ⁻¹
Tucker <i>et al.</i> 2021	USA	4	9/0/9	28 ±9	CON	No exercise
			9/0/9	29 ±7	AE-M	Cycling; 30–45 min; 50% VO _{2max} ; 5 days week ⁻¹
			10/0/10	30 ±7	AE-V	Cycling; 8–11 × 1 min intervals + 1 min active recovery periods; 90–95% HR _{max} ; 5 days week ⁻¹
Robinson <i>et al.</i> 2020	Spain	12	15/NA/NA	41.2 (7.6)	CON	No exercise
			14/NA/NA	43.6 (7.2)	AE-V	85–95% HR _{max} ; 28 min; 4 days week ⁻¹ ; cycle ergometer
			12/NA/NA	38.7 (6.0)	R-LM	40–80% 1RM; NA; 4 days week ⁻¹
			14/NA/NA	39.2 (6.8)	CON-LM	85–95% HR _{max} + 40–80% 1RM; 4 days week ⁻¹
Ebrahim Skakiba <i>et al.</i> 2019	Iran	12	11/0/11	NA	CON	No exercise
			11/0/11		AE-V	Continue exercise; 3 × 10 min; 80–90%HR _{max} ; 3 days week ⁻¹
			11/0/11	R-HI	4 sets of 8 max reps; NA; 80% 1RM; 3 days week ⁻¹	
			11/0/11	COM-HI	3 × 10 min continue exercise + 4 sets of 8 max reps; NA; 80–90% HR _{max} + 80% 1RM; 3 days week ⁻¹	
Zhao, Jun, Liang, Jinyu 2019	China	12	12/0/12	21.45 (1.02)	CON	No exercise
			12/0/12	21.68 (0.98)	AE-M	Continue exercise; 60 min; 60–70% HR _{max} ; 5 days week ⁻¹
			12/0/12	21.43 (1.14)	COM-LM	30 min Continue exercise + 20 min 3 sets; 60–70% HR _{max} + 70% 1RM; 5 days week ⁻¹
Gram <i>et al.</i> 2018	Denmark	26	18/9/9	35	CON	No exercise
			39/21/18	33	AE-M	320 kcal (f)/425 kcal (m); 5 days week ⁻¹ ; 50% VO ₂ peak
			38/20/18	36	AE-V	320 kcal (f)/425 kcal (m); 5 days week ⁻¹ ; 70% VO ₂ peak
Tong <i>et al.</i> 2018	China	12	18/18/0	21.3 (1)	CON	No exercise
			18/18/0	20.7 (1.5)	AE-V	90% VO _{2max} × 4 min; 3-min recovery (until 400 kJ achieved); 4 days week ⁻¹
Chih-Hui <i>et al.</i> 2017	China	12	12/3/9	20.8 (0.7)	CON	No exercise
			12/3/9	20.9 (0.4)	AE-M	60–70% HHR; 60 min; 3 days week ⁻¹
			12/4/8	20.7	AE-V	70–80% HHR; 60 min; 3 days week ⁻¹
Rustaden <i>et al.</i> 2017	Norway	12	36/36/0	40 (10)	CON	No exercise
			35/35/0	42 (11)	R-HI	80–90% 1RM; 8 global exercises; 45 min; 3 days week ⁻¹
Jabbour <i>et al.</i> 2015	Canada	8	12/7/5	23.1 (3.3)	CON	No exercise
			12/7/5	22.5 (2.3)	AE-V	30–50% of VO _{2max} × 6 s, followed by 2-min recovery × 6 times; total duration = 15 min; 3 days week ⁻¹ ; cycle ergometer

Table III. Cont.

Study	Country	Duration [weeks]	Sample N/F/M	Mean age (SD)	Exercise	Summary description of exercise intervention
Keating <i>et al.</i> 2015	Australia	8	12/9/3	39.1 (2.9)	CON	No exercise
			12/6/6	44.2 (2.8)	AE-V	70% VO ₂ peak; 45 min; 3 days week ⁻¹
			12/7/5	45.5 (2.3)	AE-M	50% VO ₂ peak; 60 min; 4 days week ⁻¹
Sheikholeslami-Vatani <i>et al.</i> 2015	Iran	8	10/0/10	23.2 (1.4)	CON	No exercise
			10/0/10	23.2 (1.4)	COM-HI	80% HR _{max} ; 10 min and 80% 1RM; 6 global exercises; 3 days week ⁻¹
Arad <i>et al.</i> 2015	USA	12	14/14/0 14/14/0	30.2(7) 29.1(4)	CON AE-V	No exercise HITT: 6 min; 50% HRR, 4 intervals (60 s at 80–90% HRR) and 4 recovery minutes (210 s 50% HRR); 24 min; 3 days week ⁻¹
Croymans <i>et al.</i> 2014	USA	12	8/8/0 28/28/0	22.0 (1.5) 21.5 (2.1)	CON R-HI	No exercise 3 days week ⁻¹ ; 60 min; 8 global exercises; 2 sets (15 reps); progressing from 100% 15 rep max to 100% 6 rep max
Donnelly <i>et al.</i> 2013	USA	42	15/15/0	21.8 (2.6)	CON	No exercise
			31/31/0	22.6 (2.9)	AE-V	70–80% HR _{max} ; 48 min; 5 days week ⁻¹ ; treadmill
Tseng <i>et al.</i> 2013	China	12	10/0/10	22 (0.7)	CON	No exercise
			10/0/10	22.2 (1.1)	AE-M	50–70% HR _{max} ; 60 min; 5 days week ⁻¹
			10/0/10	21.3 (0.6)	R-LM	50–80% 1RM; 8 global exercises
			10/0/10	22.3 (1)	COM-LM	3 sets × 12 reps; 5 days week ⁻¹ Aerobic (AE-M) × 3 days and resistance (R-ML) × 2 days
Arslan <i>et al.</i> 2011	Turkey	8	20/20/0	37 (9.1)	CON	No exercise
			29/29/0	41.6 (6.7)	AE-M	Weeks 1–4: 60–70% HR _{max} ; 40 min; 3 days week ⁻¹ and then Weeks 5–8: 80% HR _{max} ; 50 min; 3 days week ⁻¹ (step-aerobics)
Alves <i>et al.</i> 2009	Brazil	26	78/78/0 78/78/0	37 (10.6) 39.4 (11.1)	CON AE-M	No exercise Continuous walking; 40 min; 40–60% HRR; 3 days week ⁻¹
Van Aggel-Leijssen <i>et al.</i> 2001	Netherlands	12	8/8/0 7/7/0	42.5 (6.4) 32.8 (9.6)	CON AE-M	No exercise 40% VO _{2max} ; 57 (6) min (250 kcal); 3 days week ⁻¹ ; cycle ergometer
Kong <i>et al.</i> 2014	China	4	8/3/5	22.3 (1.7)	AE-M	Running; 60–70% HR _{max} ; 60 min; 7 days week ⁻¹
			10/5/5	19.8 (2.2)	AE-M-R	Cycling; 60–70% HR _{max} ; 60 min; AE-M-R for 3 days week ⁻¹ + AE-M for 4 days week ⁻¹
Wang <i>et al.</i> 2012	China	4	7/3/4	22.4 (2.07)	AE-M	Continue exercise; 60–70% HR _{max} ; 60 min × 2; 7 days week ⁻¹
			11/5/6	19.5 (1.64)	AE-M-R	Continue exercise; 60–70% HR _{max} ; 45 min AE-M-R for 3 days week ⁻¹ + 20 min AE-M for 4 days week ⁻¹
Zhao <i>et al.</i> 2016	China	4	9/0/9	18.08 (1.79)	AE-M	Cycling; 60–70%HR _{max} ; 60 min; 5 days week ⁻¹
			9/0/0	18.24 (2.23)	AE-M-R	Cycling; 60–70%HR _{max} ; 60 min; 5 days week ⁻¹
Wiesner <i>et al.</i> 2012	Germany	4	21/13/8	42.2 (1.2)	AE-M	Continue exercise; 65–70% HR _{max} ; 60 min; 7 days week ⁻¹
			24/14/10	42.1 (1.7)	AE-M-R	Continue exercise; 65–70% HR _{max} ; 60 min; AE-M for 4 days week ⁻¹ and AE-M-R for 3 days week ⁻¹

Table III. Cont.

Study	Country	Duration [weeks]	Sample N/F/M	Mean age (SD)	Exercise	Summary description of exercise intervention
Rojo-Tirado <i>et al.</i> 2021	Spain	22	27/NA/NA	18–45	CON	No exercise
			21/NA/NA		COM-LM	Cycling 50–60% HRR + strength exercise 70% 1RM; 51 min; 3 days week ⁻¹
			25/NA/NA		AE-M	Continue exercise; 50–60% HRR; 50 min; 3 days week ⁻¹
			25/NA/NA		R-LM	Strength exercise 70% 1RM; 51 min; 3 days week ⁻¹
Cardoso <i>et al.</i> 2013	Brazil	4	22/22/0 12/12/0	20–40	CON R-LM	No exercise Strength exercise 70% 1RM; NA; 3 days week ⁻¹
Fortuin-de Smidt <i>et al.</i> 2020	South Africa	12	22/22/0 23/23/0	23 (3.5) NA	CON COM-LM	No exercise 75–85% HR _{peak} ; 30–40 min; 4 d/wk; aerobic exercise (dance, running, skipping, stepping) and 60–70% HR _{peak} ; 10–20 min; 4 d/wk; global exercises (squats, lunges, bicep curls, push-ups, and shoulder press) × 3 sets; 10–20 reps
Alvarez-Alvarado <i>et al.</i> 2017	USA	6	13/13/0 25/25/0	21	CON WBVT	No exercise Whole-body vibration training
Milanese <i>et al.</i> 2013	Italy	10	13/13/0 28/28/0	45	CON WBVT	No exercise Whole-body vibration training
Wilms <i>et al.</i> 2012	Switzerland	6	7/7/0 7/7/0	43.1 (3.5)	CON WBVT	No exercise Whole-body vibration training
Kerri Winters-Stone <i>et al.</i> 2020	USA	24	40/NA/NA 15/NA/NA	26.87 (8.48) 27.36 (8.03)	CON WBVT	No exercise Whole-body vibration training
Takuma Morishima <i>et al.</i> 2013	Japan	4	11/0/11	33 (2)	AE-M	Running; 55%VO _{2max} ; A60 min; 3 days week ⁻¹
			9/0/9		AE-M-R	Running; 55%VO _{2max} ; 60 min; 3 days week ⁻¹

WC

Ten studies (seven intervention categories) helped us conduct NMA in WC. The average ranges from -7.14 to -4.61 . The four exercise measures had significant advantages in reducing WC compared with the control group, and the difference was statistically significant (COM-LM: -7.14 [-10.02 , -4.26]; AE-V: -6.98 [-10.39 , -3.58]; AE-M: -6.29 [-8.83 , -3.75] and R-LM: -4.61 [-7.74 , -1.47]). The complete league chart comparison is presented in the table. In comparison of NMA, COM-LM was the best intervention to reduce WC (P score = 0.81).

VO₂max

Eight studies (3 intervention categories) helped us conduct NMA in VO₂max. The average ranges from 0.23 to 0.32. The two exercise measures had significant advantages over the control group in improving VO₂max, and the difference was statistically significant (AE-V: 0.32 [0.23, 0.40] and AE-M: 0.23 [0.14, 0.33]). The complete league chart comparison was presented in the table. In NMA

comparison, AE-V was the best intervention to improve VO₂max (P score = 0.80).

Publication bias test

Stata15.1 was used to test the funnel plot of the research results. The funnel plot of weight had poor symmetry and might have publication bias. The funnel plot of other related indicators is shown in Figures 4 A–E.

Discussion

In this NMA, we compared the effects of different exercise interventions on weight loss in 1401 obese young adults. We pooled the results of 32 RCTs and made direct and indirect comparisons. High-intensity aerobic exercise may be the best way to reduce the weight of obese people; high-intensity aerobic training combined with resistance training may be the best way to reduce BMI and FAT%; moderate-intensity aerobic training combined with resistance training may be the best way to reduce the waistline; high-intensity aerobic exercise may be the best way to boost VO₂max.

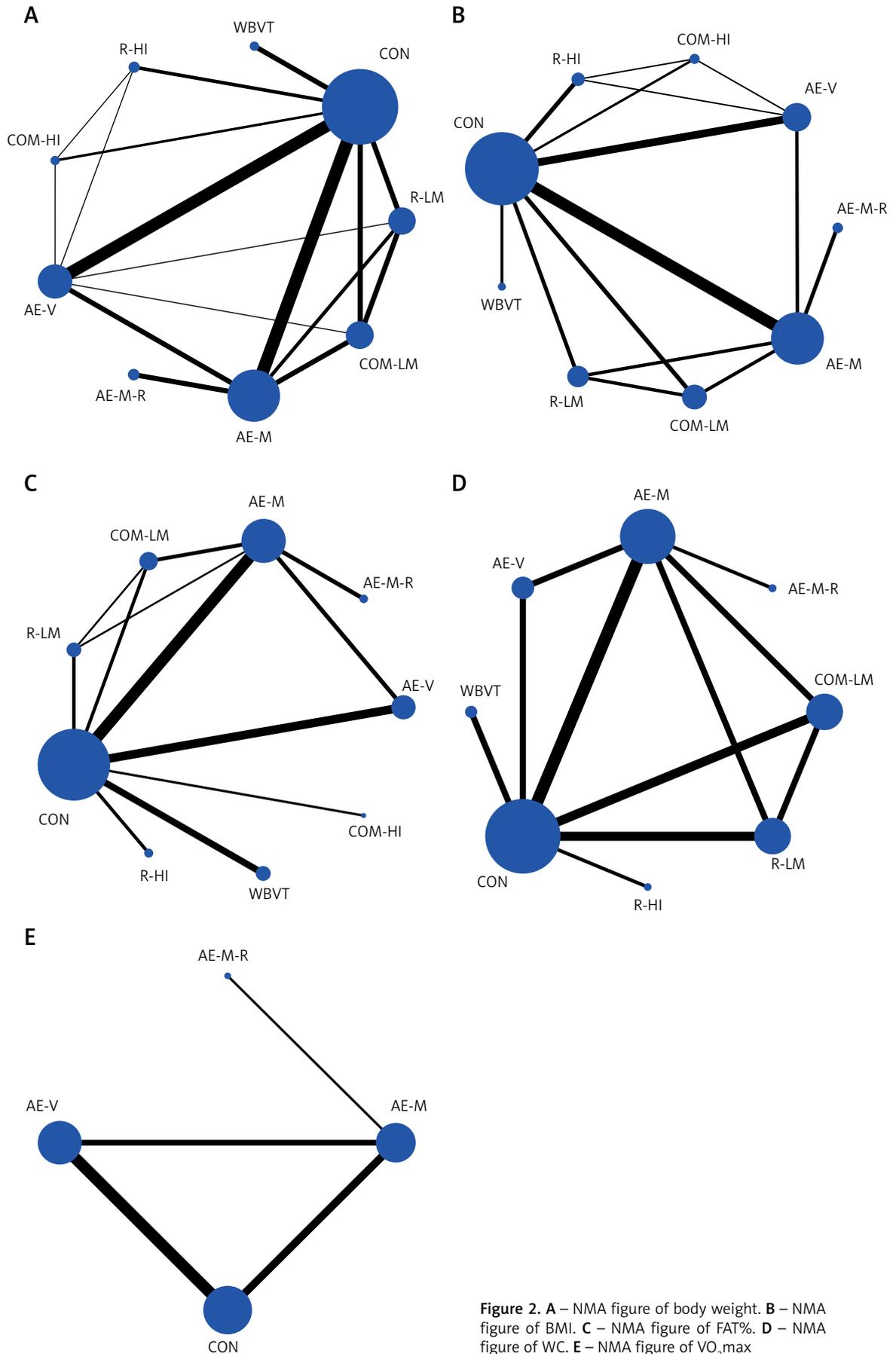


Figure 2. A – NMA figure of body weight. B – NMA figure of BMI. C – NMA figure of FAT%. D – NMA figure of WC. E – NMA figure of VO₂max

Table IV. League charts of direct and indirect comparisons between different interventions

Weight										
AE-V	COM-HI	COM-LM	AE-M-R	R-HI	AE-M	R-LM	WBVT	CON		
AE-V	0.39 (-5.24, 6.03)	1.38 (-2.23, 4.99)	1.46 (-3.41, 6.33)	1.80 (-3.73, 7.34)	2.56 (-0.40, 5.51)	2.83 (-0.81, 6.48)	3.67 (-0.60, 7.94)	4.33 (1.75, 6.91)		
-0.39 (-6.03, 5.24)	COM-HI	0.99 (-4.91, 6.88)	1.06 (-5.72, 7.84)	1.41 (-5.25, 8.07)	2.16 (-3.44, 7.77)	2.44 (-3.48, 8.37)	3.28 (-2.96, 9.51)	3.93 (-1.29, 9.16)		
-1.38 (-4.99, 2.23)	-0.99 (-6.88, 4.91)	COM-LM	0.08 (-4.70, 4.85)	0.42 (-5.42, 6.27)	1.18 (-1.71, 4.07)	1.45 (-1.85, 4.75)	2.29 (-2.10, 6.69)	2.95 (0.18, 5.72)		
-1.46 (-6.33, 3.41)	-1.06 (-7.84, 5.72)	-0.08 (-4.85, 4.70)	AE-M-R	0.35 (-6.40, 7.09)	1.10 (-2.71, 4.91)	1.38 (-3.51, 6.27)	2.21 (-3.33, 7.76)	2.87 (-1.49, 7.24)		
-1.80 (-7.34, 3.73)	-1.41 (-8.07, 5.25)	-0.42 (-6.27, 5.42)	-0.35 (-7.09, 6.40)	R-HI	0.76 (-4.79, 6.30)	1.03 (-4.84, 6.90)	1.87 (-4.32, 8.05)	2.53 (-2.64, 7.69)		
-2.56 (-5.51, 0.40)	-2.16 (-7.77, 3.44)	-1.18 (-4.07, 1.71)	-1.10 (-4.91, 2.71)	-0.76 (-6.30, 4.79)	AE-M	0.28 (-2.79, 3.34)	1.11 (-2.90, 5.13)	1.77 (-0.35, 3.89)		
-2.83 (-6.48, 0.81)	-2.44 (-8.37, 3.48)	-1.45 (-4.75, 1.85)	-1.38 (-6.27, 3.51)	-1.03 (-6.90, 4.84)	-0.28 (-3.34, 2.79)	R-LM	0.84 (-3.60, 5.27)	1.49 (-1.35, 4.33)		
-3.67 (-7.94, 0.60)	-3.28 (-9.51, 2.96)	-2.29 (-6.69, 2.10)	-2.21 (-7.76, 3.33)	-1.87 (-8.05, 4.32)	-1.11 (-5.13, 2.90)	-0.84 (-5.27, 3.60)	WBVT	0.66 (-2.75, 4.07)		
-4.33 (-6.91, -1.75)	-3.93 (-9.16, 1.29)	-2.95 (-5.72, -0.18)	-2.87 (-7.24, 1.49)	-2.53 (-7.69, 2.64)	-1.77 (-3.89, 0.35)	-1.49 (-4.33, 1.35)	-0.66 (-4.07, 2.75)	CON		

BMI

COM-HI	COM-LM	AE-V	AE-M-R	AE-M	R-HI	R-LM	WBVT	CON
COM-HI	0.09 (-1.34, 1.53)	0.09 (-1.30, 1.49)	0.05 (-1.62, 1.72)	0.18 (-1.19, 1.55)	0.54 (-1.12, 2.19)	0.90 (-0.58, 2.38)	0.94 (-0.66, 2.55)	1.34 (0.05, 2.63)
-0.09 (-1.53, 1.34)	COM-LM	0.00 (-0.89, 0.89)	-0.05 (-1.21, 1.12)	0.08 (-0.60, 0.77)	0.44 (-0.92, 1.80)	0.81 (0.00, 1.61)	0.85 (-0.30, 2.00)	1.25 (0.60, 1.89)
-0.09 (-1.49, 1.30)	-0.00 (-0.89, 0.89)	AE-V	-0.05 (-1.24, 1.14)	0.08 (-0.62, 0.79)	0.44 (-0.80, 1.68)	0.81 (-0.14, 1.76)	0.85 (-0.32, 2.02)	1.25 (0.57, 1.92)
-0.05 (-1.72, 1.62)	0.05 (-1.12, 1.21)	0.05 (-1.14, 1.24)	AE-M-R	0.13 (-0.82, 1.08)	0.49 (-1.11, 2.08)	0.85 (-0.36, 2.07)	0.90 (-0.54, 2.33)	1.29 (0.22, 2.36)
-0.18 (-1.55, 1.19)	-0.08 (-0.77, 0.60)	-0.08 (-0.79, 0.62)	-0.13 (-1.08, 0.82)	AE-M	0.36 (-0.92, 1.63)	0.72 (-0.04, 1.49)	0.77 (-0.31, 1.84)	1.16 (0.66, 1.66)
-0.54 (-2.19, 1.12)	-0.44 (-1.80, 0.92)	-0.44 (-1.68, 0.80)	-0.49 (-2.08, 1.11)	-0.36 (-1.63, 0.92)	R-HI	0.37 (-1.03, 1.76)	0.41 (-1.13, 1.95)	0.80 (-0.40, 2.01)
-0.90 (-2.38, 0.58)	-0.81 (-1.61, -0.00)	-0.81 (-1.76, 0.14)	-0.85 (-2.07, 0.36)	-0.72 (-1.49, 0.04)	-0.37 (-1.76, 1.03)	R-LM	0.04 (-1.16, 1.24)	0.44 (-0.29, 1.17)
-0.94 (-2.55, 0.66)	-0.85 (-2.00, 0.30)	-0.85 (-2.02, 0.32)	-0.90 (-2.33, 0.54)	-0.77 (-1.84, 0.31)	-0.41 (-1.95, 1.13)	-0.04 (-1.24, 1.16)	WBVT	0.40 (-0.56, 1.35)
-1.34 (-2.63, -0.05)	-1.25 (-1.89, -0.60)	-1.25 (-1.92, -0.57)	-1.29 (-2.36, -0.22)	-1.16 (-1.66, -0.66)	-0.80 (-2.01, 0.40)	-0.44 (-1.17, 0.29)	-0.40 (-1.35, 0.56)	CON

Table IV. Cont.

FAT%										
COM-HI	COM-LM	AE-M-R	R-LM	AE-V	AE-M	R-HI	WBVT	CON		
COM-HI	0.63 (-5.56, 6.83)	0.72 (-6.31, 7.75)	1.21 (-5.17, 7.60)	1.35 (-4.54, 7.25)	1.92 (-3.90, 7.73)	2.61 (-4.52, 9.74)	4.39 (-1.62, 10.39)	4.70 (-0.78, 10.18)		
-0.63 (-6.83, 5.56)	COM-LM	0.09 (-4.83, 5.01)	0.58 (-3.24, 4.41)	0.72 (-2.75, 4.19)	1.28 (-1.67, 4.23)	1.97 (-3.41, 7.36)	3.75 (-0.02, 7.53)	4.07 (1.19, 6.95)		
-0.72 (-7.75, 6.31)	-0.09 (-5.01, 4.83)	AE-M-R	0.49 (-4.77, 5.76)	0.63 (-4.03, 5.30)	1.20 (-2.74, 5.13)	1.89 (-4.43, 8.21)	3.67 (-1.36, 8.69)	3.98 (-0.41, 8.37)		
-1.21 (-7.60, 5.17)	-0.58 (-4.41, 3.24)	-0.49 (-5.76, 4.77)	R-LM	0.14 (-3.70, 3.97)	0.70 (-2.80, 4.20)	1.39 (-4.21, 7.00)	3.17 (-0.91, 7.26)	3.49 (0.21, 6.76)		
-1.35 (-7.25, 4.54)	-0.72 (-4.19, 2.75)	-0.63 (-5.30, 4.03)	-0.14 (-3.97, 3.70)	AE-V	0.56 (-1.95, 3.08)	1.25 (-3.78, 6.29)	3.03 (-0.23, 6.30)	3.35 (1.18, 5.51)		
-1.92 (-7.73, 3.90)	-1.28 (-4.23, 1.67)	-1.20 (-5.13, 2.74)	-0.70 (-4.20, 2.80)	-0.56 (-3.08, 1.95)	AE-M	0.69 (-4.25, 5.64)	2.47 (-0.65, 5.59)	2.78 (0.85, 4.72)		
-2.61 (-9.74, 4.52)	-1.97 (-7.36, 3.41)	-1.89 (-8.21, 4.43)	-1.39 (-7.00, 4.21)	-1.25 (-6.29, 3.78)	-0.69 (-5.64, 4.25)	R-HI	1.78 (-3.39, 6.95)	2.09 (-2.46, 6.65)		
-4.39 (-10.39, 1.62)	-3.75 (-7.53, 0.02)	-3.67 (-8.69, 1.36)	-3.17 (-7.26, 0.91)	-3.03 (-6.30, 0.23)	-2.47 (-5.59, 0.65)	-1.78 (-6.95, 3.39)	WBVT	0.31 (-2.13, 2.76)		
-4.70 (-10.18, 0.78)	-4.07 (-6.95, -1.19)	-3.98 (-8.37, 0.41)	-3.49 (-6.76, -0.21)	-3.35 (-5.51, -1.18)	-2.78 (-4.72, -0.85)	-2.09 (-6.65, 2.46)	-0.31 (-2.76, 2.13)	CON		

WC

COM-LM	AE-V	AE-M	AE-M-R	R-LM	R-HI	WBVT	CON
COM-LM	0.16 (-4.09, 4.41)	0.85 (-2.48, 4.19)	2.81 (-9.11, 14.74)	2.54 (-1.11, 6.18)	5.04 (-3.29, 13.37)	4.87 (-0.21, 9.95)	7.14 (4.26, 10.02)
-0.16 (-4.41, 4.09)	AE-V	0.70 (-2.72, 4.12)	2.66 (-9.29, 14.61)	2.38 (-2.02, 6.78)	4.88 (-3.64, 13.41)	4.71 (-0.67, 10.10)	6.98 (3.58, 10.39)
-0.85 (-4.19, 2.48)	-0.70 (-4.12, 2.72)	AE-M	1.96 (-9.49, 13.41)	1.68 (-1.79, 5.15)	4.19 (-4.03, 12.41)	4.02 (-0.87, 8.91)	6.29 (3.75, 8.83)
-2.81 (-14.74, 9.11)	-2.66 (-14.61, 9.29)	-1.96 (-13.41, 9.49)	AE-M-R	-0.28 (-12.24, 11.69)	2.23 (-11.87, 16.32)	2.06 (-10.39, 14.51)	4.33 (-7.40, 16.06)
-2.54 (-6.18, 1.11)	-2.38 (-6.78, 2.02)	-1.68 (-5.15, 1.79)	0.28 (-11.69, 12.24)	R-LM	2.51 (-5.92, 10.93)	2.34 (-2.90, 7.57)	4.61 (1.47, 7.74)
-5.04 (-13.37, 3.29)	-4.88 (-13.41, 3.64)	-4.19 (-12.41, 4.03)	-2.23 (-16.32, 11.87)	-2.51 (-10.93, 5.92)	R-HI	-0.17 (-9.04, 8.70)	2.10 (-5.72, 9.92)
-4.87 (-9.95, 0.21)	-4.71 (-10.10, 0.67)	-4.02 (-8.91, 0.87)	-2.06 (-14.51, 10.39)	-2.34 (-7.57, 2.90)	0.17 (-8.70, 9.04)	WBVT	2.27 (-1.93, 6.47)
-7.14 (-10.02, -4.26)	-6.98 (-10.39, -3.58)	-6.29 (-8.83, -3.75)	-4.33 (-16.06, 7.40)	-4.61 (-7.74, -1.47)	-2.10 (-9.92, 5.72)	-2.27 (-6.47, 1.93)	CON

VO_{2max}

AE-V	AE-M-R	AE-M	CON
AE-V	0.12 (-1.15, 1.38)	-0.08 (-0.17, 0.00)	-0.32 (-0.40, -0.23)
-0.12 (-1.38, 1.15)	AE-M-R	-0.20 (-1.46, 1.06)	-0.43 (-1.70, 0.83)
0.08 (-0.00, 0.17)	0.20 (-1.06, 1.46)	AE-M	-0.23 (-0.33, -0.14)
0.32 (0.23, 0.40)	0.43 (-0.83, 1.70)	0.23 (0.14, 0.33)	CON

Table V. P score

Weight loss	P score	BMI	P score	FAT%	P score	Waist circumference	P score	VO _{2max}	P score
AE-V	0.82	COM-HI	0.71	COM-HI	0.73	COM-LM	0.81	AE-V	0.80
COM-HI	0.71	AE-V	0.70	COM-LM	0.71	AE-V	0.78	AE-M-R	0.64
COM-LM	0.63	AE-M-R	0.70	AE-M-R	0.68	AE-M	0.69	AE-M	0.47
AE-M-R	0.59	COM-LM	0.70	AE-V	0.61	AE-M-R	0.50		
R-HI	0.54	AE-M	0.64	R-LM	0.61	R-LM	0.49		
AE-M	42.6	R-HI	0.45	AE-M	0.49	R-HI	0.32		
R-LM	0.37	R-LM	0.25	R-HI	0.41	WBV	0.29		
WBV	0.26	WBV	0.24	WBV	0.15				

Our findings suggest that different intensities of exercise interventions produce different effects on weight and BMI reduction, with high intensity aerobic exercise and high intensity aerobic exercise combined with high intensity resistance training being more effective than low to moderate intensity exercise interventions, possibly because higher intensity exercise causes excess post-exercise oxygen consumption, and the substrate for these energy oxidations is fat, in addition to the fact that during high intensity exercise the body needs to secrete more adrenaline and noradrenaline for muscle control and after exercise the body still maintains a high metabolic level for a longer period of time. All of these effects cause an increase in the resting metabolic level of the body, which further stimulates fat burning [66–68]. In addition, aerobic exercise combined with resistance training is more effective than resistance training alone, which is the same as the results reported in previous studies [69].

At the same time, however, recent research suggests that the percentage of body fat (fat%) may be a more accurate indicator of weight loss than BMI or body weight [70]. A recent meta-analysis showed that exercise as an intervention had a greater impact on fat% change than body weight change, but since the type of exercise intervention reported in this study was a single exercise mode, it is difficult to say which exercise mode had a greater impact on fat% change. In addition, our study shows different results from previous studies due to the inclusion of the COM-HI motion mode. In their study, Pedro *et al.* mentioned that resistance training combined with aerobic training had a –3.8% reduction in fat%, 95% CL: [–4.7, –2.9] [71], and in Mary *et al.*'s study, resistance training had the greatest effect on fat% reduction, –1.4%, 95% CL: [–4.24, 1.44] [72]. However, our study suggested that COM-HI was perhaps the best exercise intervention for reducing fat%: –4.7%.

In addition to the above indicators on the overall changes of the body, abdominal fat volume, as

a local change indicator [73], has gradually been recognized by the academic community as a better indicator for predicting obesity and obesity-related diseases (such as hypertension, coronary heart disease, stroke, etc.). Waist circumference is often used as a simple measure of abdominal fat, and changes in waist circumference can lead to changes in abdominal fat, which in turn can lead to changes in health-related risks [74]. Related studies have reported that larger waist circumference is associated with higher risk of cardiovascular disease and mortality [22]. In our NMA, COM-LM was found to be the best type of exercise in reducing waist circumference, which is consistent with the results reported in a previous study [75]. However, it is worth noting that no study has reported the effect of COM-HI on waist circumference, and in view of the research results of other indicators in this NMA, we maintain a conservative attitude towards the result that COM-LM is the best type of exercise to improve waist circumference. We hope that there will be further studies to support our hypothesis.

In addition, compared with previous studies on the intervention effect of exercise on obese people, our NMA is more prominent in the inclusion of the index of cardiopulmonary fitness (VO_{2max}). Most of the previous studies focus on the changes in body composition of obese people caused by exercise. The American College of Sports Medicine (ACSM) suggests that improving cardiopulmonary fitness can help reduce all-cause mortality and health risks in obese people [23]. In addition, increased cardiopulmonary fitness can improve the autonomic nervous system (ANS) in obese patients. Therefore, we believe that the improvement of cardiopulmonary fitness is an important indicator for obese young people. We observed that aerobic exercise has a good effect on cardiopulmonary fitness of obese young people, especially the category of AE-V.

Both aerobic exercise and resistance training are helpful to the effect of weight loss in obese

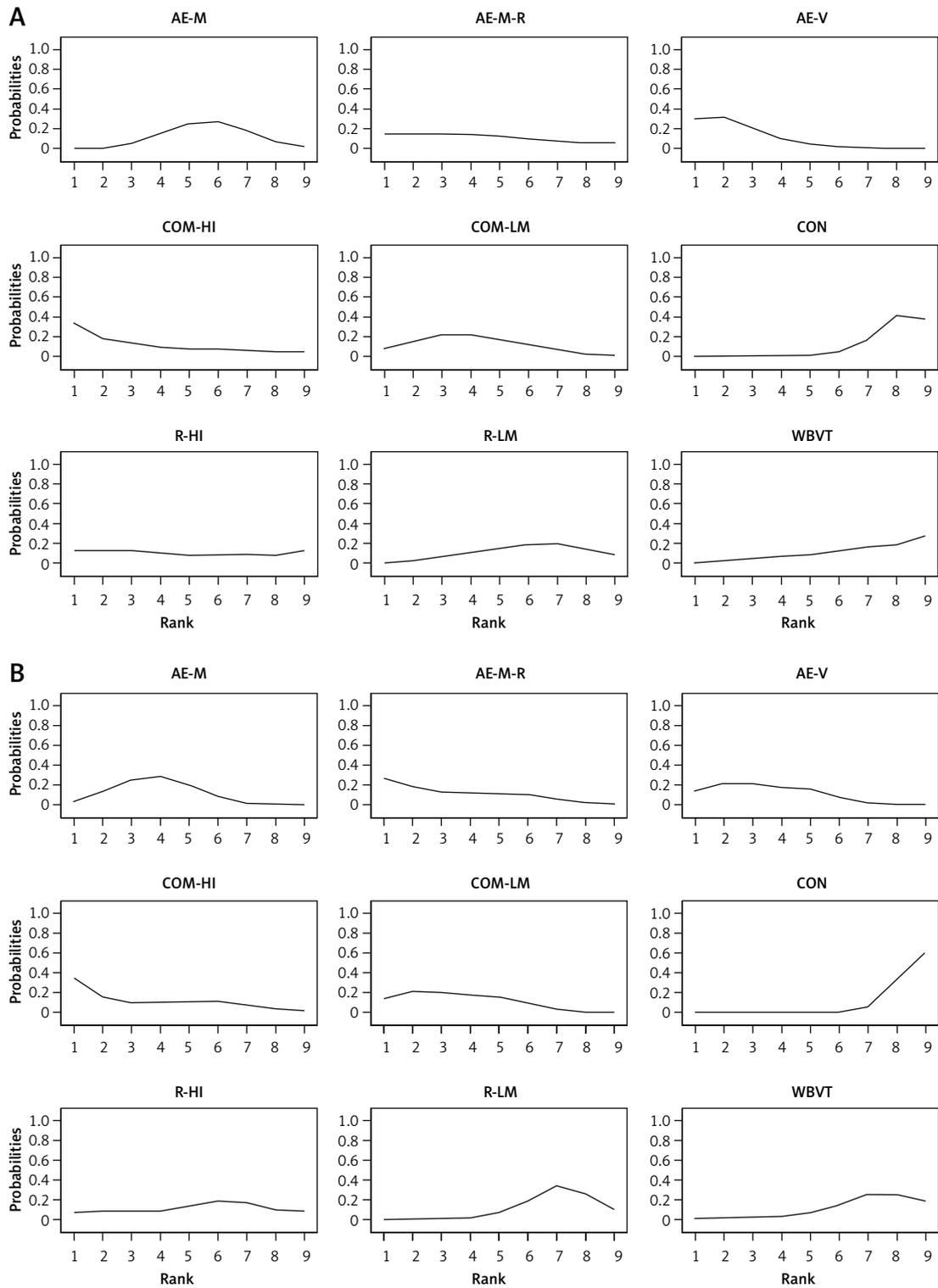


Figure 3. **A** – SUCRA area of body weight. **B** – SUCRA area of BMI

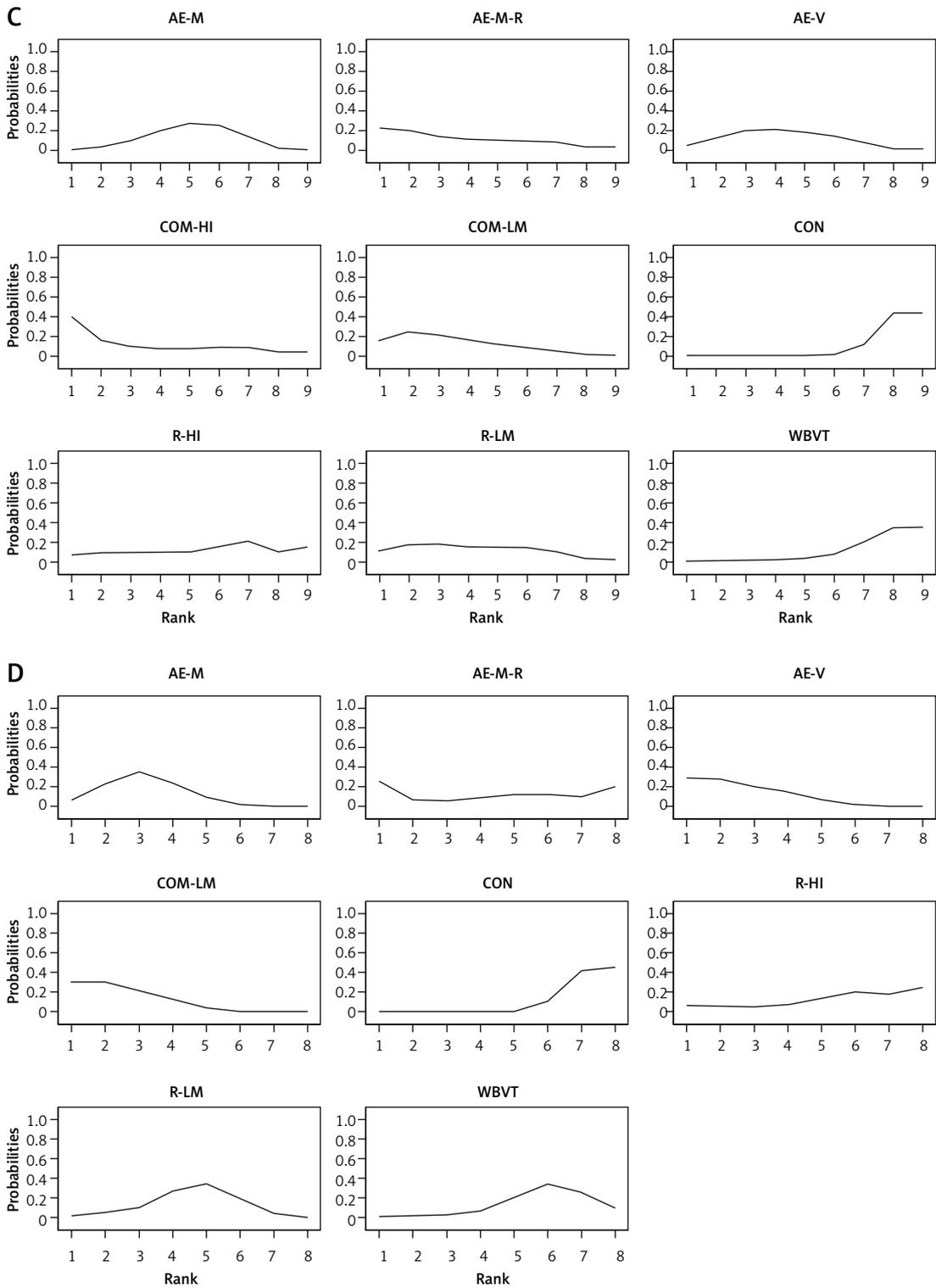


Figure 3. Cont. C – SUCRA area of FAT%. D – SUCRA area of WC

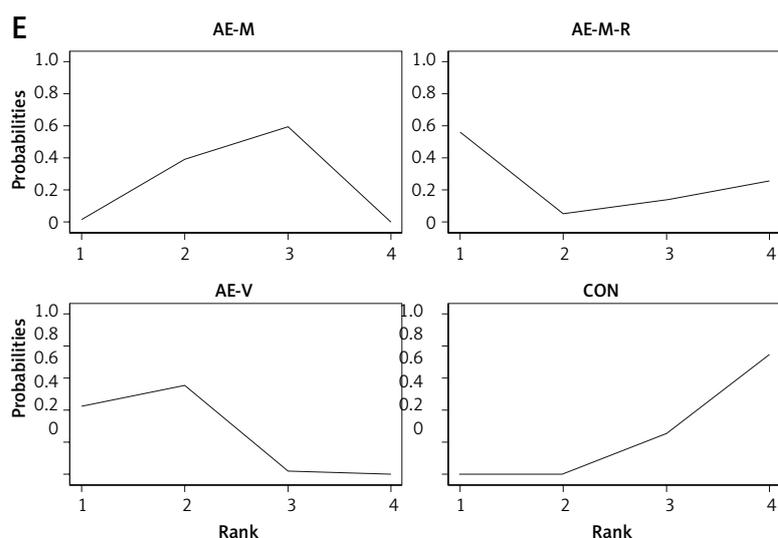


Figure 3. Cont. E – SUCRA area of VO_2 max

young people, but they have their own characteristics. Firstly, aerobic exercise cannot reduce the number of fat cells, but can inhibit the accumulation of fat cells and reduce the volume of fat cells [76]. Secondly, aerobic exercise can improve the reduction of insulin receptor binding and insulin resistance of obese people, and avoid storing a large amount of energy as fat [77]. Thirdly, during aerobic exercise, the sympathetic nerve is activated and the plasma insulin resistance concentration increases, and the decrease of insulin secretion will increase the activity of related enzymes in the process of fat hydrolysis, thus accelerating the hydrolysis of fat [78]. Finally, aerobic exercise also increases growth hormone and adiponectin levels, which play a role in reducing abdominal fat and circulating free fatty acids [79]. In terms of resistance training, it can change the metabolic characteristics of skeletal muscle, strengthen muscle anabolism, increase muscle weight, and increase lean body weight. In addition, resistance strength can also increase resting basal metabolic rate (RMR) [80]. The improvement of RMR has a good effect on the regulation of body weight. An increase in RMR of 1–2% has a great influence on the regulation of body weight. Finally, resistance training can also reduce the exercise-induced oxidative stress response and increase the glycated hemoglobin glycosylated hemoglobin (HbA_{1c}) level [81] in obese people.

Finally, we found that fewer people mentioned before that hypoxic training is a kind of effective exercise intervention, a low oxygen environment is a stimulus for the organism, short and long term low oxygen exposure in the body or hypoxia training will occur after a series of reactions and adaptability to changes, including body oxygen transport, oxygen utilization of the glucose transporter

[82], changes in vasodilation function and related metabolic enzyme activities. Periodic hypoxia training can promote and improve the body health status, and meanwhile, hypoxia has a significant improvement effect on lipid metabolism. Hypoxia training can improve the body composition and lipid level of obese people by affecting the activity of the glycolytic enzyme, increasing serum in the blood and reducing the leptin level [83].

Our NMA has several advantages and disadvantages. First of all, the investigation of the corresponding study was comprehensive, systematic and detailed, including a large sample size of obese young people ($n = 1401$), so the differences in comparison between different groups could be detected. Our study only analyzed RCTs, the gold standard for evaluating the effectiveness of clinical interventions. At the same time, on the basis of conventional exercise interventions, we added new exercise interventions (AE-M-R and WBV) with fewer studies. A meta-analysis also described the effect of intervention duration on exercise effect, and the peak of the exercise effect occurred 8–32 weeks after intervention. In our study, 26 original studies had interventions with duration > 8 weeks (accounting for about 81% of the total included studies).

Admittedly, our study shares some limitations with the research on which it is based. Although we did our best to control for heterogeneity in the inclusion of these original studies, heterogeneity between studies was unavoidable (e.g., study location and ratio of male to female participants). In addition, metabolic outcomes related to obesity (e.g., blood pressure, triglycerides, high-density lipoprotein) were not included in this NMA because there were too few reports of relevant data in the original studies included. However, since exercise is considered

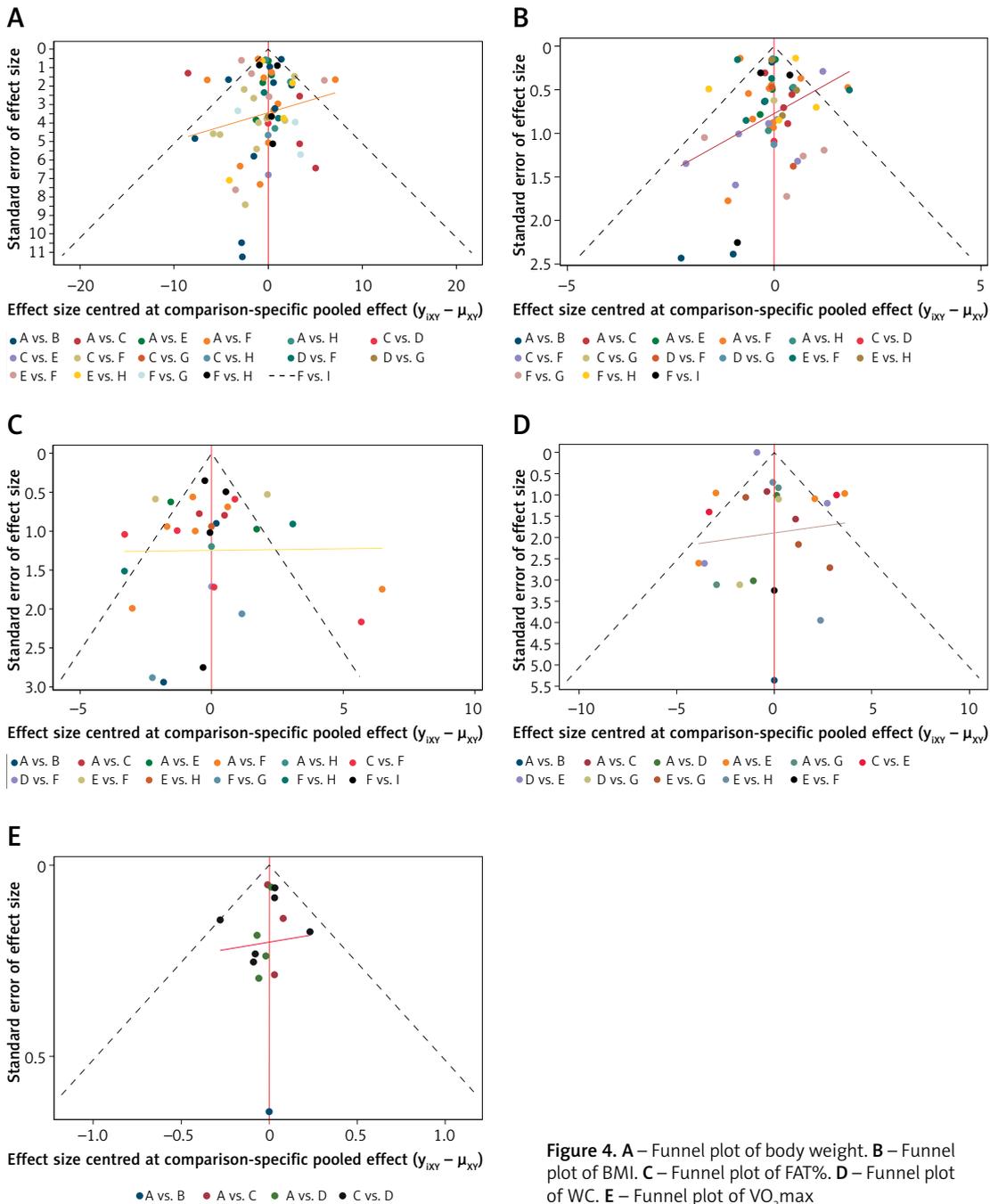


Figure 4. A – Funnel plot of body weight. B – Funnel plot of BMI. C – Funnel plot of FAT%. D – Funnel plot of WC. E – Funnel plot of VO_{2max}

a cornerstone for the prevention and management of metabolic syndrome, we suggest that subsequent RCTs should consider reporting these metabolic markers as an important outcome indicator.

In our study, readers should interpret the results with caution because of the small number of studies and limited evidence for direct head-to-head comparisons of certain interventions. At the same time, it also highlights the necessity and timeliness of further expanding relevant research.

Finally, this article has included in 12 of the 32 study is defined as a high risk, but because for sport as intervention study, implement blinded for

intervention objects, and researchers is not too realistic, before intervention, always by the patients themselves or their relatives signed the informed consent form to ensure safety research.

In conclusion, our study shows that different exercise methods are effective in treating primary obesity in young people, but moderate to high intensity aerobic training combined with resistance training is the most recommended exercise method. However, more studies are needed to expand the results of this study to update the therapeutic effects of different exercise interventions on primary obesity in young adults.

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Conflict of interest

The authors declare no conflict of interest.

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