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Original Article

Effects of Exercise on the Body Composition and Lipid Profile of Individuals with Obesity: A Systematic Review and Meta-Analysis

Kyoung-Bae Kim[1], Kijin Kim[2], Changsun Kim[3], Suh-Jung Kang[4], Hyo Jeong Kim[5], Seok Yoon[6], Yun-A Shin[7,*]

[1]Department of Physical Education, Korea Military Academy, Seoul; [2]Department of Physical Education, College of Physical Education, Keimyung University, Daegu; [3]Department of Physical Education, Dongduk Women's University, Seoul; [4]Department of Sports and Health Management, Sangmyung University, Seoul; [5]Department of Sport and Healthy Aging, Korea National Sport University, Seoul, Korea; [6]Department of Sport Science, Chowan University, Murfreesboro, NC, USA; [7]Department of Prescription and Rehabilitation of Exercise, College of Sport Science, Dankook University, Cheonan, Korea

Background: Numerous researchers have worked to develop treatments for obesity; however, the prevalence of obesity continues to increase in many countries. Moreover, the effects of physical activity and exercise on obesity remain unclear. Therefore, it is necessary to perform a systematic review and meta-analysis to assess the relationship between exercise and obesity using mediator variables such as the mode of exercise.

Methods: Our review focuses on research tracking the effects of exercise on obesity conducted from 2007 to 2016 and available in any of three databases: Embase, PubMed, and EBSCO Academic Search Premier. The keywords used in the search were "exercise and obesity" and "exercise and obese."

Results: The average size of the effects that exercise interventions have on body mass index (standardized mean difference [SMD], 0.533), waist circumference (SMD, 0.666), total cholesterol (SMD, 0.721), and triglyceride (TG; SMD, 0.603) were medium or larger. Exercise had greater effects on the outward appearance of obesity (body mass index, waist circumference) than on its practical factors (weight, % body fat). The effect of exercise on TG (SMD, 0.603) was larger than that on low-density lipoprotein (SMD, 0.406) and high-density lipoprotein (SMD, –0.222). Exercise duration (weeks of exercise) and intensity correlate better than exercise time (minutes per week) with a large and consistent improvement in adult obesity.

Conclusion: We suggest that individuals with obesity should exercise consistently to achieve significant improvements in their health.

Key words: Obesity, Exercise mode, Body composition, Lipid profile, Meta-analysis

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*Corresponding author
Yun-A Shin

https://orcid.org/0000-0002-8480-3454

Department of Prescription and Rehabilitation of Exercise, College of Sport Science, Dankook University, 119 Dandae-ro, Dongnam-gu, Cheonan 31116, Korea
Tel: +82-41-550-3831
Fax: +82-41-550-3831
E-mail: shinagel@dankook.ac.kr

INTRODUCTION

Obesity is a direct and indirect cause of serious chronic diseases such as hypertension, diabetes, heart disease, and cancer. Many studies during the past few decades have sought solutions to the problem of obesity. Despite those efforts, however, the prevalence of obesity has increased in many countries. In the attempt to fundamentally improve obesity treatment, many new detailed approaches have emerged.

Recent studies have described several interventions for obesity, including diet, physical activity or exercise, behavioral therapy, and medication. Among the various behavioral strategies, exercise interventions can provide effective weight maintenance, weight loss, weight maintenance after loss, and reduction of obesity. However, exercise alone has a limited effect on the body weights of individuals with obesity.[1] Furthermore, the guidelines for how much physical activity and exercise are needed to improve health are widely known to the public as well as researchers, but they are too general to specifically address obesity, and the effects are variable and often inconsistent. Thus, it is necessary to understand the magnitude of the effects that physical activity or exercise interventions have on obesity.

Most reviews that have examined the relationship between exercise and obesity have considered only a partial range of factors. For example, the study of Witham and Avenell[2] included only participants with a mean age ≥ 60 years. The meta-analysis of Türk et al.[3] considered only randomized controlled trials (RCTs) that used high intensity exercise with obese patients aged 18 to 60 years. Furthermore, they did not consider the influence of exercise mode (intensity, time, frequency, duration) in their mediation analysis.

Because a systematic review and meta-analysis can statistically integrate multiple independent study variables by their effect sizes for a particular issue and infer overall conclusions, it is a useful strategy in this situation. If we know the average effect size of exercise intensity, time, frequency, and duration in improving obesity, we will be able to concretely establish how different interventions influence the dependent variables, especially weight, body composition, and lipid profile. Therefore, we here include studies of adult subjects to assess the relationship between exercise and obesity using mediator variables. Our purpose in this study was to examine the effectiveness of exercise in terms of time, duration, intensity, and the exercise itself in adults with obesity.

METHODS

Search strategy and eligibility criteria

We conducted a literature search of three databases: Embase (http://www.embase.com/), PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), and EBSCO Academic Search Premier (http://search.ebscohost.com/), to obtain a comprehensive list of studies from 2007 to 2016 that examined the effects of exercise on obesity. The keywords we used were "exercise and obesity" and "exercise and obese." After the initial online search, we selected only RCTs and removed duplicate studies using the EndNote program (Thomson Reuters Co., Toronto, Canada).

At the screening stage, we used the participants, interventions, comparisons, outcomes, timing of outcome measurement, settings, study design (PICOTS-SD) frame to determine the scope of the literature.[4] Three reviewers (professors with expertise in the area of physical exercise and exercise physiology) screened the titles and abstracts of 4,106 studies based on the inclusion criteria and PICOTS-SD and selected 726 studies. To increase the accuracy of the screening, two other reviewers (professors with expertise in the area of physical exercise and exercise physiology) screened those 726 studies and selected 109 studies. The screening process is summarized in a flowchart (Supplementary Fig. 1): participants: adults with obesity (body mass index [BMI], ≥ 30 kg/m^2; age, 18–65 years); intervention: exercise; comparison: routine care, diet therapy, etc.; outcome: body composition, lipid profile, etc.; time: pre- and post-test studies; study design: RCT.

Full-text articles were then assessed for eligibility. Articles were eliminated if inadequate intervention conditions (e.g., improper control conditions) or insufficient statistical data (e.g., partial or not present) were reported and if weight loss and maintenance for adults with obesity were not the primary focus of the study (e.g., analysis of functional capacity after gastric bypass surgery, breast cancer research). In the end, 64 studies were selected for this systematic review and meta-analysis, and all of them were published in English.

Data extraction and quality assessment

For the meta-analysis of exercise interventions in adults with obesity, we extracted body composition (weight, BMI, % body fat, waist circumference) and lipid profile (total cholesterol [TC], triglycerides [TGs], low-density lipoprotein [LDL], and high-density lipoprotein [HDL]) data in the form of the mean, standard deviation, and sample sizes for both the treatment and control groups at pre- and post-test. In addition, to analyze the moderator variable effects, we extracted diet control (with or without diet), exercise time (from < 60 to 450 minutes per week), duration (from ≤ 4 to 48 weeks), and intensity (low, moderate, vigorous, and high) data about the exercise interventions.

The quality of all studies was assessed using the Physiotherapy Evidence-based Database scale (PEDro) as rated by two authors in this study. The total PEDro score was derived by adding all scale items except for item 1 and specifying the eligibility criteria.[4] The quality of the studies was assessed using four PEDro score categories: excellent (9–10), good (6–8), fair (4–5), and fail (≤ 3).[5] In this study, we considered only studies that scored more than 6 points.

Disagreements were resolved by discussion.

Reviewer agreement

Three reviewers (CK, SK, HJK) independently screened the titles and abstracts for eligibility. Agreement among the reviewers was assessed using the kappa statistic.[4] The three kappa statistics for the three reviewers (K_{A_B}, K_{B_C}, and K_{C_A}) were 0.765 (95% confidence interval [CI], 0.568–0.883), 0.788 (95% CI, 0.644–0.932), and 0.702 (95% CI, 0.531–0.873), respectively. After the secondary screening by two other reviewers (KBK, YAS), another kappa statistic (K_{D_E}) was obtained and determined to be 0.766 (95% CI, 0.557–0.976). According to Landis & Koch's guidelines,[6] all the kappa values indicated substantial agreement, and they were at all acceptable within Fleiss's guidelines.[7]

Statistical analysis

The meta-analysis and meta-analysis of variance (meta-ANOVA) were performed using R version 3.5.2 (http://www.r-project.org). The random effects model for computation of the mean effect size was assumed because we considered heterogeneous effect sizes among the studies, including this systematic review and meta-analysis. The moderator variable effects were analyzed by meta-ANOVA. Consecutive variables of the moderator were converted into categorical variables for the meta-ANOVA.

Publication bias and heterogeneity

Publication bias, often called the file-drawer effect because unpublished results are imagined to be tucked away in researchers' file cabinets, is a potentially severe impediment to combining the statistical results of studies collected from the literature. To consider publication bias, we used Begg's funnel plots and Egger's regression test with a significance level of 0.10.

Heterogeneity was tested using I^2 values, and the extent of heterogeneity was estimated as follows: low (25%), moderate (50%), and high (75%) I^2 values.[8] For the meta-analysis, the standardized mean difference (SMD) was considered as the mean effect size, and the 95% CI and I^2 value were obtained using forest plots. The effect sizes were interpreted using Cohen's criteria: small (0.20), medium (0.50), and large (0.80).[8]

RESULTS

We included 64 articles in this systematic review and meta-analysis study. Twenty-nine articles had only one comparison between the experimental and control groups, and 35 articles had several (2–5) comparisons. Therefore, the total number of cases for comparison was 109. Table 1 presents the characteristics of the studies included in this meta-analysis.[9-72]

Characteristics of the included studies

The characteristics of the 64 included studies are presented in Table 1. Overall, 5,025 subjects were included in these studies, and the groups ranged in size from 5 to 118 subjects. All studies were published between 2007 and 2017, though the search period rep-

Table 1. The characteristics of the studies included in the systematic review and meta-analysis

Author (year)	Group	N	Age (yr)	Exercise type	Frequency (day/wk)	Time (min)	Duration (wk)	Intensity	Diet control
Herring et al. (2017)[9]	EXP	12	44.3±7.9	Aerobic and resistance training	3	60	12, 24	64%–77% MHR, 60% 1RM	○
	CON	12	52.4±8.1						
Marcon et al. (2017)[10]	EXP 1	22	43.4±2.3	Aerobic and stretching exercise	2	25	19	RPE 2–4	×
	EXP 2	17	50.1±2.8	Aerobic and stretching exercise	2	25	19	RPE 2–4	○
	CON	18	42.5±2.7						
Zhang et al. (2017)[11]	EXP 1	73	53.2±7.1	Vigorous/moderate exercise		150/wk	12 mo	Vigorous/moderate	×
	EXP 2	73	54.4±7.4	Moderate exercise		150/wk	12 mo	Moderate	×
	CON	74	54±6.8						×
Ash et al. (2017)[12]	EXP 1	6	39.7±4.9	Aerobic exercise	3	45	8	60% VO_2 peak	×
	EXP 2	5	43.4±5.3	Isometric handgrip	3	8	8	30% MVC	×
	CON	27	40.6±2						

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Table 1. Continued

Author (year)	Group	N	Age (yr)	Exercise type	Frequency (day/wk)	Time (min)	Duration (wk)	Intensity	Diet control
Freitas et al. (2017)[13]	EXP	26	45.9±7.7	Aerobic and resistance training	2		3 mo	50%–75% VO_2 peak	○
	CON	25	48.5±9.6	Stretching and breathing	2		3 mo		○
Baillot et al. (2016)[14]	EXP	8	41.4	Endurance and strength training	3	80	12		○
	CON	20	43.3						○
Nikseresht et al. (2016)[15]	EXP 1	12		Nonlinear resistance training	3	55	12	Very light–very heavy	○
	EXP 2	10		Aerobic interval training	3	4 min x 4 rep	12	90% HRmax, 65% HRmax	○
	CON	11							○
Nunes et al. (2016)[16]	EXP 1	10	62	Low volume resistance training	3		16	70% 1RM/3 sets	○
	EXP 2	11	62	High volume resistance training	3		16	70% 1RM/6 sets	○
	CON	11	60						
Soori et al. (2017)[17]	EXP 1	8		Water-based endurance training	3	45	10	40%–60% HRmax	×
	EXP 2	8		Resistance training	3	10–12 rep	10	40%–60% 1RM/3 sets	×
	EXP 3	8		Combined training	3	44	10	40%–60% HRmax, 40%–60% 1RM	×
	CON	8							×
Cuthbertson et al. (2016)[18]	EXP	30	50	Moderately intense aerobic exercise	3–5	30–45	16	30%–60% HRR	×
	CON	20	52						×
Rafraf et al. (2015)[19]	EXP 1	11	34.8±6.2	Exercise+carnitine	3		8	55%–70% HRmax	×
	EXP 2	10	36.1±7.2	Exercise+placebo	3	30/30×3	8	55%–70% HRmax	×
	CON 1	11	34.4±5.5	Carnitine					×
	CON 2	11	36.5±7.3	Placebo					×
Abdelaal and Mohamad (2015)[20]	EXP 1	20	52.2±3	Circuit weight training	3		12	60%–75% 1RM	×
	EXP 2	20	53±3.5	Aerobic exercise training	3	20–35/40–50	12	60%–75% HRmax/RPE 12–14	×
	CON	19	52±3.3						
Arad et al. (2015)[21]	EXP	9		High intensity interval training	3	24	14	75%–90% HRR	○
	CON	11							○
Kim et al. (2015)[22]	EXP	29	24.9±2.8	Aerobic exercise	4		8	65%–75% VO_2max	×
	CON	10	26.6±2.8						×
Benito et al. (2015)[23]	EXP 1	24		Strength training	3	60	22	50%–60% 1RM	○
	EXP 2	26		Endurance training	3	60	22	50%–60% HRR	○
	EXP 3	24		Strength+endurance training	3	60	22	50%–60% 1RM/50%–60% HRR	○
	CON	22							○
Kordi et al. (2015)[24]	EXP	14	42.2±14.4	Abdominal resistance training	3		12	2 Sets of 8 reps	○
	CON	16	43±15.1						○
Park et al. (2015)[25]	EXP	10	57.2±2.6	Aerobic+resistance exercise	4	30–40	12	40%–75% HRR	×
	CON	10	57.2±1.7						
Ross et al. (2015)[26]	EXP 1	73	52.1±7.4	Low amount, low intensity exercise	5	180–300 kcal	24	50% VO_2 peak	×
	EXP 2	76	50.9±8.6	High amount, low intensity exercise	5	300–600 kcal	24	50% VO_2 peak	×
	EXP 3	76	50.3±8.1	High amount, high intensity exercise	5	360–600 kcal	24	75% VO_2 peak	×
	CON	75	52.2±8.2						
Pugh et al. (2014)[27]	EXP	34	48	Gymnasium	3–5	30–45	12	45%–60% HRR	×
	CON	20	47						
Nikseresht et al. (2014)[28]	EXP 1	12		Nonlinear resistance training	3	40–65	12	Very light–very heavy	×
	EXP 2	12		Aerobic interval training	3	16–20	12	80%–90% HRmax/3 min recovery	×
	CON	10							×
Herring et al. (2014)[29]	EXP 1	11		Resistance exercise	3	60	12	60% 1RM	×
	EXP 2	12		Aerobic exercise	3	60	12	50%–70% HRR	×
	CON	10							×

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Table 1. Continued

Author (year)	Group	N	Age (yr)	Exercise type	Frequency (day/wk)	Time (min)	Duration (wk)	Intensity	Diet control
Irving et al. (2009)[30]	EXP 1	13	49.2±1.8	Low intensity exercise	5	350–400 kcal	16	RPE 10–12	×
	EXP 2	11	49.0±2.9	High intensity exercise	5	350–400 kcal	16	3 Day RPE 15–17/2 day RPE 10–12	×
	CON	10	49.2±4.8						×
Straznicky et al. (2010)[31]	EXP	20	54±1	Bicycle riding	3	40	12	65% MHR	×
	CON 1	20	55±1	Dietary weight loss					○
	CON 2	19	55±1	No treatment					
Ibáñez et al. (2010)[32]	EXP 1	12	51.4±5.5	Caloric restriction of 500 kcal/day	3		16		○
	EXP 2	13			2	45–60	16	50%–80% 1RM	○
	CON	9							×
Christiansen et al. (2010)[33]	EXP 1	25		Aerobic exercise	3	60–75	12		×
	CON	29		600 and 800 kcal/day					○
	EXP 2	25		750–1,000 kcal/day, aerobic exercise	3	60–75	12		○
Sartor et al. (2010)[34]	EXP	10	37±10	High intensity interval training	3	40	2	90% VO_2 peak	×
	CON	9	41±14						×
Plotnikoff et al. (2010)[35]	EXP	27	55±12	Core and assistance exercise	3		16	80% 1RM	×
	CON	21	54±12						×
Yamaguchi et al. (2011)[36]	EXP	11	50.0±3.1	Treadmill walking	Every day	2 rep×30 min	4	Anaerobic threshold	○
	CON	8	50.0±2.7	Low calorie diet of 25 kcal/kg			4		○
Straznicky et al. (2011)[37]	EXP	13	52±1	Bicycle riding	3	40	12	65% MHR	○
	CON 1	13	55±2	Reduction of 600 calories					○
	CON 2	12	56±2						○
Lim et al. (2011)[38]	EXP	99	28.0±0.3	Aerobic, resistance exercise	7	60	12		○
	CON 1	98	28.0±0.3	Metformin, maximum dose of 1,500 mg/day			12		
	CON 2	100	28.0±0.3	Placebo, maximum dose of 1,500 mg/day			12		
Brinkley et al. (2011)[39]	EXP 1	15	57.3±5.7	Treadmill 15–20 min at 45%–50% of HRR during first week/hypocaloric menu/ calcium supplement	3	55	20	45%–50% HRR	○
	EXP 2	8	59.4±4.9	Treadmill 15–20 min at 70%–75% of HRR during first week/hypocaloric menu/ calcium supplement	3	30	20	70%–75% HRR	○
	CON	8	57.6±4.8	Hypocaloric menu lunch & dinner/daily calcium supplement (1,000 mg/day)			20		○
Brinkley et al. (2011)[40]	EXP 1	22	58.5±5.3	Treadmill	3	20–55 min	20	45%–50% HRR	○
	EXP 2	17	57.2±4.3	Treadmill	3	10–30 min	20	70%–75% HRR	○
	CON	22	58.4±6.2	Hypocaloric menu/allowed 2 free days per month/calcium supplement 1,000 mg/day			20		○
Atashak et al. (2011)[41]	EXP 1	8	23.6±4.4	Resistance training protocol	3		10	75%–80% 1RM	○
	EXP 2	8	23.7±3.8	Resistance training protocol	3		10	75%–80% 1RM	○
	CON 1	8	23.6±3.3	4 Capsules of ginger rhizome power	4 times/ day		10		○
	CON 2	8	25.3±2.2	1 g of maltodextrin (placebo)			10		×
Shah et al. (2011)[42]	EXP	21	47.3±10.0	Moderate-intensity aerobic exercise	5		12	60%–70% VO_2max	○
	CON	12	53.9±8.8						○
Castello et al. (2011)[43]	EXP	11	38.4±4.0	Aerobic training on a treadmill	3	61	12	70% HRpeak	×
	CON	10	36±4						×

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Table 1. Continued

Author (year)	Group	N	Age (yr)	Exercise type	Frequency (day/wk)	Time (min)	Duration (wk)	Intensity	Diet control
You et al. (2011)[44]	EXP 1	13	57±2	Treadmill	3	55	20	45%–50% HRR	○
	EXP 2	8	62±2	Treadmill	3	30	20	70%–75% HRR	○
	CON	9	59±2	Hypocaloric menu (RD) & allowed 2 free day/mo & calcium supplement (1,000 mg/day)			20		○
Henagan et al. (2011)[45]	EXP	12	65.2±2.6	Progressive RT	3		12	8RM	○
	CON	11	66.1±3.0						○
Lee et al. (2012)[46]	EXP	8	54.8±2.8	Yoga exercise	3	60	16		×
	CON	8	54.3±2.9						×
Sullivan et al. (2012)[47]	EXP	12	48.6±2.2	Walking on a motor-driven treadmill	5	30–60	16	45%–55% VO_2max	×
	CON	6	47.5±3.1						×
Swift et al. (2012)[48]	EXP 1	68	57.4±5.4	Cycle ergometer	3	20	4	Pedal cadence of 50 RPM	×
	EXP 2	32	55.9±6.0	Cycle ergometer	3	20	8	Pedal cadence of 51 RPM	×
	EXP 3	32	56.3±6.8	Cycle ergometer	3	20	12	Pedal cadence of 52 RPM	×
	CON	23	56.8±5.4						
Foster-Schubert et al. (2012)[49]	EXP 1	117	58.1±5.0	Aerobic exercise	5	45	12 mo	70%–85% HRmax	×
	EXP 2	117	58.0±4.5	Aerobic exercise & caloric restriction	5	45	12 mo	70%–85% HRmax	○
	CON 1	87	57.4±4.4						×
	CON 2	118	58.1±6.0	Caloric deficit of 500–1,000 kcal/day					○
Abd El-Kader et al. (2015)[50]	EXP	39	43.6±6.2	Treadmill aerobic exercise	3	10–30	3 mo	60%–70% HRmax	×
	CON	39	44.1±5.9	No exercise training					×
Wong et al. (2016)[51]	EXP 1	14	58±4	WBVT & intake placebo (4 capsules before breakfast & sleeping)	3	11–60	8	25–40 Hz	×
	EXP 2	13	58±3	WBVT & intake L-Citrulline	3	11–60	8	25–40 Hz	○
	CON	14	58±4	Intake L-Citrulline (4 capsules before breakfast & sleeping)					○
Osama and Shehab (2015)[52]	EXP	50	36.4±5.1	Aerobic training	3	40	36	Moderate	○
	CON	50	37.2±4.3				36		
Franklin et al. (2015)[53]	EXP	10	30.3±5.4	Circuit-based resistance training	1	20	8	10RM	×
	CON	8	30.8±9.0						
Coen et al. (2015)[54]	EXP	66	41.3±9.7	Semi-supervised moderate exercise	3–5	147/ wk	6 mo		×
	CON	62	41.9±10.3	Health education					
Romero Moraleda et al. (2013)[55]	EXP 1	24	36.1±8.7	Strength training	3	50–60	22	50%–60% HRR or 15RM	○
	EXP 2	26	35.8±8.0	Endurance training	3	50–60	22	50%–60% HRR or 15RM	○
	EXP 3	24	36.0±7.3	Strength+endurance training	3	50–60	22	50%–60% HRR or 15RM	○
	CON	22	36.8±8.9	Physical activity	3	50–60	22	50%–60% HRR or 15RM	○
Figueroa et al. (2013)[56]	EXP 1	13	54±1	Low-intensity resistance exercise	3		12		×
	EXP 2	14	54±1	Low-intensity resistance exercise	3		12		○
	CON	14	55±1				12		○
Bhutani et al. (2013)[57]	EXP 1	18	45±5	ADF+exercise	3	35–60	12	60%–75% HRmax	○
	EXP 2	24	42±2		3	35–60	12	60%–75% HRmax	×
	CON 1	25	42±2	Dietary restriction			12	Controlled feeding	○
	CON 2	16	49±2						
Figueroa et al. (2013)[58]	EXP 1	14	54±1	Supervised exercise session	3–4	40	12	18–22 Repetitions	×
	EXP 2	14	54±1	Combination	3–4	40	12	18–22 Repetitions	○
	CON	13	54±1	Commercial weight-loss program			12		○

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Table 1. Continued

Author (year)	Group	N	Age (yr)	Exercise type	Frequency (day/wk)	Time (min)	Duration (wk)	Intensity	Diet control
Trussardi Fayh et al. (2013)[59]	EXP	17	32.4±7	Training program	3	30–45	12	50%–70% HRR	○
	CON	18	30.1±5.5						○
García-Unciti et al. (2012)[60]	EXP	13	48.6±6.4	Resistance training	2		16	50%–80% 1RM	○
	CON 1	12	51.4±5.5				16		○
	CON 2	9	50.2±6.8						○
Tseng et al. (2013)[61]	EXP 1	10	22.2±0.7	3 Day aerobic, 2 day resistance training	5	60	12	50%–60% HRR, 60%–70% HRR, 50%–60% 1RM	○
	EXP 2	10	22.1±1.1	Aerobic training	5	60	12	50%–60% HRR, 60%–70% HRR	○
	EXP 3	10	21.3±0.6	Resistance training	5	60	12	50%–60% 1RM	○
	CON	10	22.3±1.0						○
Fayh et al. (2013)[62]	EXP	17	32.3±6.4	University gymnasium	3	45	65.9 day	70% HRR	×
	CON	18	31.4±5.6	Physical activity					
Kim and Kim (2012)[63]	EXP	15	53.5±2.4	Line dance exercise	3	60	16	HRmax-age%	×
	CON	15	53.5±2.4						
Snel et al. (2012)[64]	EXP	13	53.0±2.5	Very low calorie diet+exercise	1	30	16	70% VO_2max	○
	CON	14	56.1±2.4	Very low calorie diet			16		○
Cakmakçi (2011)[65]	EXP	34	36.2±9.6	Pilates training	4	60	8	60%–70% HRmax	×
	CON	27	39.0±10.0						
Masuo et al. (2012)[66]	EXP 1	30	37±6	Aerobic exercise or gym exercise	2	60	24		○
	EXP 2	30	38±5	Aerobic exercise or gym exercise	2	60	24		○
	CON	30	38±5	Calorie restriction			24		○
Kerksick et al. (2010)[67]	EXP 1	9	43±7	Diet+exercise (high energy diet)	1	30	14	60%–80% HRmax	○
	EXP 2	5	42±2	No diet+exercise	2	30	14	60%–80% HRmax	×
	EXP 3	39	38±8	Very low carbohydrate, high protein diet	1	30	14	60%–80% HRmax	○
	EXP 4	36	40±7	Low carbohydrate, moderate protein diet	1	30	14	60%–80% HRmax	○
	EXP 5	43	38±8	High carbohydrate, low protein diet	1	30	14	60%–80% HRmax	○
	CON	9	32±10	No diet+no exercise	2		14		×
Kadoglou et al. (2010)[68]	EXP 1	22	56.9±7.1	Exercise training	4	60	12 mo	50%–80% VO_2 Peak	×
	EXP 2	23	57.8±7.6	Therapy+exercise training	4	60	12 mo	50%–80% VO_2 Peak	×
	CON	21	60.3±9.3	Maintenance			12 mo		×
	RSG	23	59.0±7.4	Add -on therapy with rosiglitazone	7		12 mo		×
Murakami et al. (2007)[69]	EXP	24	51.0±2.1	Diet+exercise	3	60	12	RPM 12–14	○
	CON	18	48.2±1.9	Diet			12		○
Arslan (2011)[70]	EXP	29	41.6±6.7	Step-aerobic dance	3	60	8	50%–85% VO_2max	×
	CON	20	37.0±9.1						×
Mezghanni et al. (2014)[71]	EXP 1	11	27±4	Moderate intensity training	5	60	12	50% HRR	×
	EXP 2	10	25±5	High intensity training	5	60	12	75% HRR	×
	EXP 3	12	28±5	Alternate intensity training	5	60	12	50%–75% HRR	×
	CON	10	25±4						
Rshikesan and Subramanya (2016)[72]	EXP	37	40.0±8.7	Special yoga training (IAYT)	5	90	14		×
	CON	35	42.2±12.1	Regular physical activities					

Values are presented as mean±standard deviation.
EXP, experimental group; CON, control group; MHR, maximal heart rate; RM, repetition maximum; RPE, rated perceived exertion; VO_2 peak, peak oxygen uptake; MVC, maximum voluntary contraction; rep, repetition; HRmax, maximal heart rate; HRR, heart rate reserve; RD, registered dietitian; RT, resistance training; WBVT, whole-body vibration training; ADF, alternate day fasting; IAYT, integrated approach of yoga therapy.

resented 10 years (2007–2016).

There were 29 studies with diet control and 35 studies without it. The exercise time per week for the interventions ranged from 20 to 450 minutes, with an average time of 153.3 minutes. The exercise duration varied between 2 and 48 weeks, with an average time of 16.5 weeks. The exercise intensity was classified into four categories (low, moderate, vigorous, and high) using the American College of Sports Medicine (ACSM) Guidelines for Exercise Testing and Prescription.[73] The ACSM's Foundations of Strength Training and Conditioning classifies the percent 1 repetition maximum (%1RM) as supramaximal (> 100%), very heavy (95%–100%), heavy (90%–95%), moderately heavy (80%–90%), moderate (70%–80%), light (60%–70%) and very light (< 60%).[74] In this study, we used low (< 70%), moderate (70%– < 80%), vigorous (80%– < 90%), and high (≥ 90%) (Supplementary Table 1). The PEDro scores of all the included studies varied between 6 and 9 points, with an average of 6.52 points (standard deviation, 0.69).

Effects of exercise on body composition and lipid profiles

We used the SMD as the effect size of each study and present the 95% CI of the SMD and I^2 value as a measure of heterogeneity in Table 2. Heterogeneity in the effect of exercise on weight in 89 studies was high (I^2 = 75.9%), with an average SMD of 0.358 in the range from 0.213 to 0.503. Thus, the average effect size was between small and medium. Heterogeneity in the effect of exercise on BMI in 78 studies was high (I^2 = 84.8%), with an average SMD of 0.533 in the range from 0.349 to 0.716. Thus, the average effect size was medium. Heterogeneity in the effect of exercise on % body fat in 47 studies was moderate (I^2 = 44.3%), with an average SMD of 0.379 in the range from 0.246 to 0.512. Thus, the average effect size was between small and medium. Heterogeneity in the effect of exercise on waist circumference in 75 studies was high (I^2 = 84.1%), with an average SMD of 0.666 in the range from 0.478 to 0.854. Thus, the average effect size was between medium and large.

Heterogeneity in the effect of exercise on TC in 35 studies was high (I^2 = 94.5%), with an average SMD of 0.721 in the range from 0.228 to 1.214, for an almost large average effect size. Heterogeneity in the effect of exercise on TG in 56 studies was high (I^2 = 92.2%), with an average SMD of 0.603 in the range from 0.257 to 0.949, for a medium to large average effect size. Heterogeneity in the effect of exercise on LDL in 49 studies was above moderate (I^2 = 65.3%), with an average SMD of 0.406 in the range from 0.238 to 0.573, for a small to medium average effect size. Heterogeneity in the effect of exercise on HDL in 57 studies was high (I^2 = 88.7%), with an average SMD of –0.222 in the range from –0.495 to 0.052, for a small average effect size.

One result (% body fat) from the meta-analysis is presented as a forest plot (Fig. 1) because it was the only result that met both the statistical significance and heterogeneity criteria (I^2 < 50%) (Table 2).

With respect to the Egger's regression test for publication bias, the *P*-value was statistically significant for % body fat (t = 3.11, df = 45, *P* = 0.003), waist circumference (t = 1.95, df = 73, *P* = 0.055), and HDL (t = –4.58, df = 55, *P* = 0.019). The *P*-values for the remaining variables (weight, BMI, TC, TG, and LDL) were not significant. The funnel plot was somewhat asymmetric with respect to % body fat (Supplementary Fig. 2), though the regression model resulting from Egger's regression test for % body fat was satisfactory.

Table 2. Effect size of exercise interventions on body composition and lipid profiles

Factor	Study (n)	Subject (n)	SMD (95% CI)	*P*	I^2 (%)
Weight (kg)	89	3,665	0.358 (0.213 to 0.503)	< 0.001	75.9
BMI (kg/m²)	78	3,682	0.533 (0.349 to 0.716)	< 0.001	84.8
Body fat (%)	47	2,049	0.379 (0.246 to 0.512)	< 0.001	44.3
Waist circumference (cm)	75	3,516	0.666 (0.478 to 0.854)	< 0.001	84.1
TC (mg/dL)	35	906	0.721 (0.228 to 1.214)	0.004	94.5
TG (mg/dL)	56	2,226	0.603 (0.257 to 0.949)	< 0.001	92.2
LDL (mg/dL)	49	1,994	0.406 (0.238 to 0.573)	< 0.001	65.3
HDL (mg/dL)	57	2,270	–0.222 (–0.495 to 0.052)	0.112	88.7

SMD, standardized mean difference; CI, confidence interval; BMI, body mass index; TC, total cholesterol; TG, triglyceride; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

Effects of moderators on exercise and obesity

The meta-ANOVA results showing the effects of the moderators on exercise, obesity, and body composition are shown in Table 3. The average SMD in the studies with diet control was higher than in those with no diet control (except for % body fat). Regardless of diet, the average SMDs for BMI and waist circumference were close to or above medium (0.452–0.761).

The average SMD for minutes of exercise per week did not yield a specific pattern, possibly because the small number of studies caused inconsistent results. The average SMD for an exercise dura-

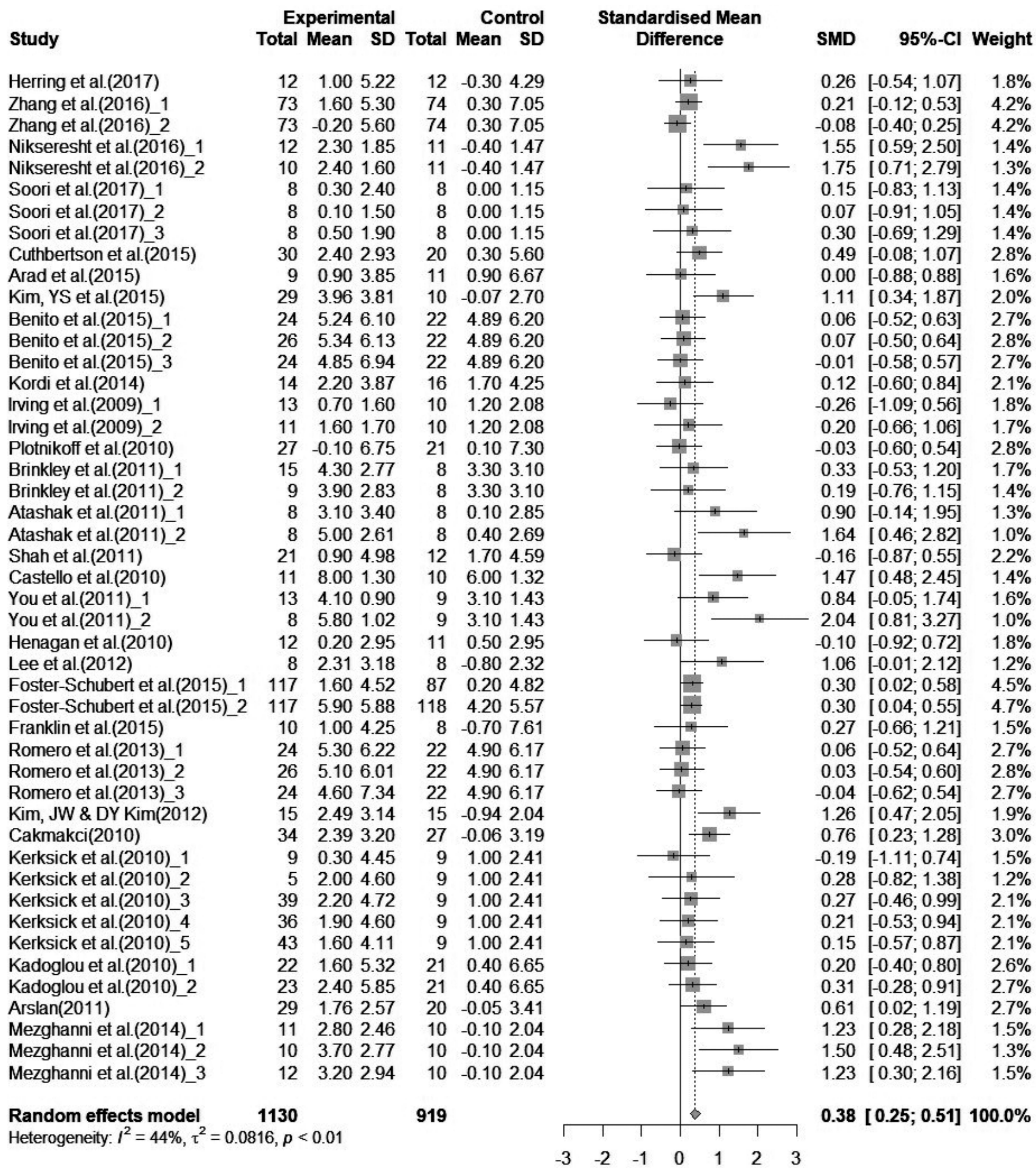

Figure 1. Forest plot of % body fat. The meta-analysis result of % body fat is presented because only % body fat met both the statistical significance and heterogeneity criteria (I^2 <50%). "Total" in the figure indicates the number of subjects. Thirteen articles had several (2-5 pieces) comparisons, and each comparison was presented independently in the plot. SD, standard deviation; SMD, standardized mean difference; CI, confidence interval.

tion of 12 weeks was close to or above medium for all 4 variables (weight, BMI, % body fat, waist circumference). This was especially the case for BMI (0.911) and waist circumference (0.910), which had large average SMDs.

The average SMD for exercise intensity was between 0.043 (% body fat) and 0.609 (BMI) for the low intensity case, 0.346 (weight) and 0.874 (waist circumference) for the moderate intensity case, and 0.293 (weight) and 0.613 (waist circumference) for the vigorous intensity case; no studies used high intensity exercise. The average SMD for the moderate intensity case was higher than that for the low and vigorous cases for BMI, % body fat, and waist circumference. Only with respect to weight was the average SMD higher at low intensity.

The meta-ANOVA results for the effects of the moderators on exercise, obesity, and lipid profile are shown in Table 4. The average SMD for diet treatment was above medium for TC (0.825) and TG (0.772). The average SMD for HDL was smaller than that for the other factors. The average SMD for exercise time per week was

Table 3. Meta-ANOVA results for moderator effects on body composition

Moderator	Weight		BMI		% Body fat		Waist circumference	
	SMD (95% CI)	n	SMD (95% CI)	n	SMD (95% CI)	n	SMD (95% CI)	n
Diet control								
With diet	0.433 (0.205 to 0.661)	47	0.608 (0.294 to 0.922)	38	0.296 (0.106 to 0.485)	204	0.761 (0.465 to 1.056)	39
No diet	0.255 (0.099 to 0.412)	42	0.452 (0.257 to 0.648)	40	0.464 (0.273 to 0.655)	23	0.562 (0.333 to 0.792)	36
Exercise time (min/wk)								
<60	0.899 (0.335 to 1.463)	5	0.075 (–0.855 to 1.005)	1	0.995 (–0.457 to 2.446)	2	0.771 (0.242 to 1.300)	3
60–89	0.002 (–0.255 to 0.258)	5	0.360 (–0.433 to 1.153)	3	0.000 (–0.881 to 0.881)	1	0.089 (–0.179 to 0.358)	4
90–119	0.154 (–0.081 to 0.389)	10	0.391 (0.006 to 0.777)	9	0.193 (–0.763 to 1.148)	1	0.315 (0.034 to 0.595)	7
120–149	0.373 (0.091 to 0.656)	17	0.615 (0.283 to 0.947)	14	0.293 (0.110 to 0.475)	4	0.976 (0.472 to 1.480)	9
150–179	0.052 (–0.194 to 0.298)	7	0.243 (0.075 to 0.411)	8	0.200 (–0.051 to 0.450)	8	0.476 (0.234 to 0.718)	7
180–209	0.208 (–0.045 to 0.460)	13	0.257 (–0.003 to 0.517)	13	0.498 (0.125 to 0.871)	8	0.362 (–0.027 to 0.750)	13
210–239	0.092 (–0.889 to 1.072)	1	0.063 (–0.917 to 1.043)	1	-	-	-	-
240	0.303 (–0.206 to 0.811)	1	0.283 (–0.042 to 0.608)	3	0.450 (0.104 to 0.796)	3	0.331 (–0.178 to 0.840)	1
300	1.237 (0.464 to 2.009)	6	1.643 (0.795 to 2.490)	6	1.309 (0.753 to 1.866)	3	2.290 (1.311 to 3.268)	6
420–450	0.078 (–0.334 to 0.491)	2	0.103 (–0.310 to 0.515)	2	-	-	–0.288 (–0.752 to 0.177)	1
Duration (wk)								
≤4	–0.028 (–0.408 to 0.353)	3	0.017 (–0.893 to 0.928)	1	-	-	0.087 (–0.386 to 0.560)	1
8–11	0.237 (0.032 to 0.441)	12	0.322 (0.104 to 0.540)	13	0.655 (0.390 to 0.921)	9	0.706 (0.226 to 1.186)	7
12–15	0.455 (0.179 to 0.731)	43	0.911 (0.501 to 1.322)	33	0.541 (0.216 to 0.866)	16	0.910 (0.573 to 1.246)	41
16–19	0.576 (0.266 to 0.886)	13	0.431 (0.169 to 0.694)	10	0.411 (–0.041 to 0.864)	6	0.600 (0.242 to 0.959)	11
20–23	0.114 (–0.085 to 0.313)	11	0.150 (–0.047 to 0.348)	10	0.235 (–0.052 to 0.522)	9	0.143 (–0.085 to 0.372)	9
24	0.120 (–0.499 to 0.738)	3	0.096 (–0.556 to 0.748)	3	-	-	0.117 (–0.230 to 0.464)	1
36	-	-	0.642 (0.240 to 1.045)	1	-	-	-	-
48	0.129 (–0.059 to 0.318)	2	0.214 (0.078 to 0.352)	6	0.209 (0.071 to 0.347)	6	0.284 (0.138 to 0.430)	4
Intensity								
Low	0.533 (0.022 to 1.044)	11	0.609 (0.079 to 1.140)	7	0.043 (–0.322 to 0.407)	5	0.558 (–0.446 to 1.562)	4
Moderate	0.346 (0.165 to 0.526)	28	0.627 (0.386 to 0.868)	31	0.457 (0.181 to 0.733)	16	0.874 (0.566 to 1.182)	27
Vigorous	0.293 (0.136 to 0.450)	28	0.370 (0.184 to 0.557)	23	0.345 (0.189 to 0.501)	21	0.613 (0.387 to 0.838)	27

Meta-ANOVA, meta-analysis of variance; BMI, body mass index; SMD, standardized mean difference; CI, confidence interval; n, number of studies.

above medium and ranged from –0.506 (HDL) to 0.709 (TG) for 120 to 149 minutes of exercise per week. Similar to the results for body composition, the average SMD for exercise time per week did not appear to follow a specific pattern as exercise time increased. For this attribute also, the number of studies was small, which might have caused inconsistent results.

The average SMD for the effect of exercise duration on TC and TG increased rapidly from 12 weeks. The average SMD at 36 weeks was very large and ranged from –0.993 (HDL) to 2.585 (TG).

The average SMD for exercise intensity was between –1.675 (HDL) and 1.191 (TG) for the low intensity case, –0.023 (HDL) and 0.506 (LDL) for the moderate intensity case, and –0.285 (HDL) and 0.410 (TG) for the vigorous intensity case. The average SMD for the low intensity case was far greater than that of the other cases. The meta-ANOVA results for one variable (% body fat) are presented in the form of a forest plot (Fig. 2).

DISCUSSION

For this study, we performed a systematic review and meta-ANOVA to examine the effect of exercise on both the body composition and lipid profiles of adults with obesity. According to Table 2, the average effect size of exercise on BMI (SMD, 0.533), waist circumference (SMD, 0.666), TC (SMD, 0.721), and TG (SMD, 0.603) was above medium. The average effect size on weight (SMD, 0.358), % body fat (SMD, 0.379), LDL (SMD, 0.406), and HDL (SMD, –0.222) was below medium. The heterogeneity of most of the dependent variables was high (I^2 = 75.9%–94.5%), except for LDL

Table 4. Meta-ANOVA results for the effect of exercise on lipid profile variables

Moderator	TC		TG		LDL		HDL	
	SMD (95% CI)	n	SMD (95% CI)	n	SMD (95% CI)	n	SMD (95% CI)	n
Diet control								
With diet	0.825 (0.050 to 1.601)	22	0.772 (0.184 to 1.359)	25	0.340 (0.092 to 0.588)	27	–0.116 (–0.549 to 0.317)	29
No diet	0.449 (0.172 to 0.727)	13	0.377 (0.114 to 0.641)	31	0.468 (0.259 to 0.677)	22	–0.318 (–0.611 to –0.024)	28
Time (min/wk)								
<60	–0.019 (–0.949 to 0.911)	1	1.509 (–0.031 to 3.049)	3	0.232 (–0.404 to 0.869)	2	–2..441 (–4.439 to –0.443)	4
60–89	–0.044 (–0.677 to 0.589)	1	–0.281 (–0.918 to 0.355)	1	–0.076 (–0.709 to 0.558)	1	0.220 (–0.415 to 0.855)	1
90–119	0.421 (0.023 to 0.819)	5	–0.131 (–0.468 to 0.206)	5	0.274 (–0.081 to 0.628)	5	0.443 (0.100 to 0.786)	5
120–149	0.656 (0.028 to 1.284)	6	0.709 (0.109 to 1.308)	12	0.578 (0.100 to 1.056)	10	–0.506 (–1.075 to 0.063)	12
150–179	0.040 (–0.215 to 0.294)	5	–0.195 (–0.550 to 0.159)	6	0.028 (–0.215 to 0.271)	6	–0.179 (–0.436 to 0.080)	6
180–209	1.010 (0.641 to 1.558)	3	0.193 (–0.384 to 0.769)	4	0.527 (0.096 to 0.958)	3	–0.359 (–0.667 to –0.050)	5
210–239	1.733 (0.562 to 2.904)	1	0.141 (–0.841 to 1.122)	1	0.406 (–0.586 to 1.397)	1	0.495 (0.502 to 1.492)	1
240	0.575 (0.144 to 1.005)	2	0.634 (0.202 to 1.066)	2	1.164 (0.706 to 1.623)	2	–1.020 (–1.631 to –0.409)	2
300	-	-	0.904 (0.040 to 1.769)	6	0.876 (0.350 to 1.401)	3	0.173 (–0.324 to 0.669)	3
420–450	–0.585 (–1.519 to 0.350)	1	–0.016 (–0.927 to 0.895)	1	–0.548 (–1.480 to 0.383)	1	0.505 (–0.423 to 1.434)	1
Duration (wk)								
≤4	–0.585 (–1.519 to 0.350)	1	0.012 (–0.628 to 0.653)	2	–0.301 (–0.949 to 0.346)	2	0.083 (–0.734 to 0.899)	2
8–11	0.332 (–0.235 to 0.898)	3	0.274 (–0.105 to 0.652)	6	0.484 (0.105 to 0.862)	7	–0.452 (–0.807 to –0.100)	7
12–15	1.165 (–0.116 to 2.447)	13	0.834 (0.161 to 1.507)	26	0.515 (0.249 to 0.780)	20	0.007 (–0.460 to 0.474)	24
16–19	0.837 (0.465 to 1.209)	8	0.643 (0.150 to 1.136)	12	0.292 (0.048 to 0.535)	10	–0.575 (–1.212 to 0.063)	14
20–23	–0.058 (–0.322 to 0.205)	5	–0.276 (–0.541 to –0.011)	5	–0.076 (–0.339 to 0.187)	5	0.154 (–0.110 to 0.417)	5
24	0.096 (–0.251 to 0.443)	1	–0.014 (–0.361 to 0.333)	1	0.079 (–0.268 to 0.426)	1	0.005 (–0.291 to 0.402)	1
36	1.492 (1.047 to 1.937)	1	2.585 (2.049 to 3.121)	1	1.402 (0.963 to 1.842)	1	–0.993 (–1.410 to –0.577)	1
48	0.575 (0.144 to 1.005)	2	0.634 (0.202 to 1.066)	2	1.164 (0.706 to 1.623)	2	–1.020 (–1.631 to –0.409)	2
Intensity								
Low	-	-	1.191 (0.376 to 2.006)	6	0.894 (0.076 to 1.711)	3	–1.675 (–3.175 to –0.175)	6
Moderate	0.505 (0.188 to 0.822)	17	0.294 (–0.159 to 0.747)	20	0.506 (0.225 to 0.787)	20	–0.023 (–.0358 to 0.313)	22
Vigorous	0.124 (–0.081 to 0.330)	13	0.410 (0.171 to 0.649)	22	0.176 (–0.057 to 0.409)	20	–0.285 (–0.513 to –0.057)	21

Meta-ANOVA, meta-analysis of variance; TC, total cholesterol; TG, triglyceride; LDL, low-density lipoprotein; HDL, high-density lipoprotein; SMD, standardized mean difference; CI, confidence interval; n, number of studies.

($I^2 = 65.3\%$) and % body fat ($I^2 = 44.3\%$). The heterogeneity of % body fat was the only variable that was below moderate. These results indicate that the effects of exercise interventions on outward appearance, such as BMI and waist circumference, are larger than the effects on practical factors of obesity such as weight and % body fat. Moreover, the effect of exercise on TG (SMD, 0.603) was larger than that on LDL (SMD, 0.406) and HDL (SMD, –0.222).

The results of the publication bias analysis were statistically significant for % body fat, waist circumference, and HDL. In other words, the studies used in this meta-analysis adequately represent the population only for those three factors. With respect to the effects of the moderators on diet control, the SMDs for the cases with diet treatment were larger than those without diet control, as indicated by the weight, BMI, waist circumference, TC, and TG variables. Conversely, the SMDs with diet treatment were lower than those without diet control with respect to % body fat, LDL, and HDL. In a meta-analysis by Vissers et al.,[75] supervised exercise-only interventions had a greater effect than combined diet and exercise interventions. In a meta-analysis by Wu et al.,[76] a combined diet and exercise program provided greater long-term weight loss than a diet-only program. However, they concluded that both the diet-only and diet and exercise programs were associated with partial weight regain and that future studies should seek strategies to limit weight regain and achieve greater long-term weight loss.

In studies that considered the effects of moderators on exercise time per week, a medium or large SMD emerged for both body composition and lipid profile in programs that used more than 120 minutes of exercise per week. The ACSM's guidelines for exercise

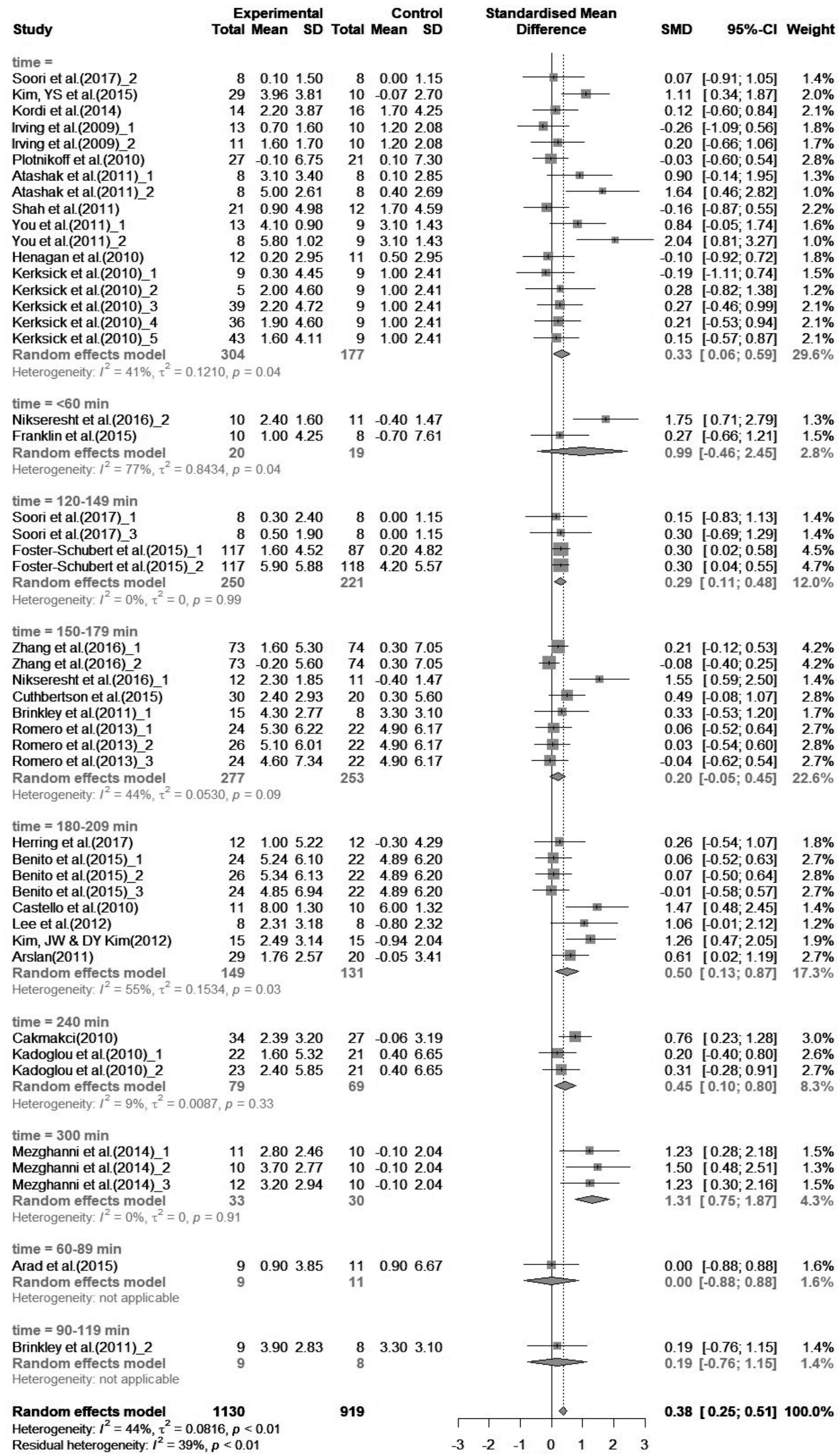

Figure 2. Forest plot of % body fat by exercise time (minutes per week). The average standardized mean difference (SMD) for exercise time per week did not yield a specific pattern as the exercise time increased, possibly because of the small number of studies. "Total" in the figure indicates the number of subjects. Sixteen articles had several (2-5 pieces) comparisons, and each comparison was presented independently in the plot. SD, standard deviation; CI, confidence interval.

testing and prescription recommend a minimum of 150 min·wk^{-1} (30 min·day^{-1}) progressing to 300 min·wk^{-1} (60 min·day^{-1}) of moderate intensity exercise for overweight and obese individuals.[73] Every study we considered here used a different combination of exercise intensity and duration.

An exercise duration of more than 8 weeks produced a medium or large SMD for body composition, as did a duration of 12 or more weeks for lipid profile. The ACSM's guidelines for exercise testing and prescription recommend a minimum reduction in initial body weight of 5%–10% over the course of 3–6 months for overweight and obese individuals.[73] Furthermore, the "2018 Korean Society for the Study of Obesity Guideline for the Management of Obesity in Korea"[74] states, "Physical activity is necessary for weight loss and maintenance. At the start, more than moderate physical activity is recommended. Moderate levels of physical activity include exercising between 30 minutes and 60 minutes five times per week. When including resistance exercise, it is recommended to engage in physical activity twice per week."

In this study, the average SMDs for weight loss by exercise duration were 0.237, 0.455, and 0.576 for 8–11 weeks, 12–15 weeks, and 16–19 weeks, respectively. In other words, the effect size was above medium after exercising for 16 weeks (4 months). Future studies should analyze both the rate of change in body weight and exercise duration together.

By exercise intensity, a medium or large SMD was observed in most cases with low and moderate intensity. Only waist circumference had an SMD above medium for vigorous intensity exercise. In a meta-analysis by Türk et al.,[3] training at high intensity was found to be superior to moderate exercise in reducing % body fat in obese adults. That result is supported by some recent studies, but not by others. For example, a study by Keating et al.[77] showed that high intensity interval training (HIIT) could improve fitness levels with only 50%–60% of the time commitment required by continuous aerobic exercise training (CONT). However, the CONT group showed a reduction in total body fat, whereas the HIIT group did not. In addition, Kemmler et al.[78] found that HIIT provided more weight loss than moderate intensity continuous exercise(MICE) but produced no difference in body fat mass. Auriemma[79] explained that the available studies on HIIT in overweight and obese patients remain limited by their short duration, small number of participants, and variation in the intensity and duration of their "on" intervals. Researchers should also consider the risk of potential injuries, even though more vigorous exercises might provide additional benefits.[73]

In conclusion, our novel finding is that the effect of exercise on obesity is larger in outward appearance (BMI, waist circumference) than in practical factors (weight, % body fat). Moreover, the effect of exercise on TG was larger than that on LDL and HDL. With respect to exercise mode, the effects of exercise duration and intensity are more consistent and larger among obese adults than the effects of exercise time (minutes per week).

The limitations of this study include the generalization of the findings due to the small sample sizes in some of the studies, heterogeneity, and publication bias in the analysis of some variables. Some cases had very large SMDs with very small sample sizes. In future reviews, the number of studies included for each moderator effect analysis must be adequate to satisfy the normality of the statistical inference.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

Study concept and design: KBK; acquisition of data: KK, CK, SJK, and HJK; analysis and interpretation of data: KBK and YAS; drafting of the manuscript: KBK and SY; critical revision of the manuscript: KBK and YAS; statistical analysis: KBK; administrative, technical, or material support: KBK and YAS; and study supervision: KK and YAS.

SUPPLEMENTARY MATERIALS

Supplementary Table 1. Classification of exercise intensity.

Supplementary Figure 1. Flowchart for searching studies.

Supplementary Figure 2. Funnel plot of %body fat.

They can be found via https://doi.org/10.7570/jomes.2019.28.4.278.

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