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SYSTEMATIC REVIEW

Effect of exercise type on men's physical fitness and body composition: a systematic review and meta-analysis

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Abstract

Background: Resistance training (RT), endurance training (ET) and concurrent training (CT) have been extensively researched for their diverse effects, including increases in muscle strength and mass, reductions in body fat, and improvements in cardiorespiratory fitness. This systematic review with meta-analysis aimed to summarize and analyse the effect of exercise type on men's physical fitness and body composition. **Methods**: Extensive searches were conducted in the English biomedical databases PubMed, MEDLINE, Web of Science and CINAHL, as well as the EBSCO database. Cochrane's risk of bias was used to assess the quality and risk of bias of the selected articles. STATA/MP 18 version was used for the meta-analysis. **Results**: A total of 5137 articles were retrieved from five database. 17 randomized controlled trials were selected for the analysis. The CT group exhibited the highest effect size (ES) across all variables. In the leg press, CT (d = 1.65) displayed the largest effect size, with RT (d = 1.65) demonstrating similar trends as CT. In the bench press, CT (d = 2.25) demonstrated the largest effect size, whereas RT (d = 2.21) exhibited a level comparable to that of CT. For maximal oxygen consumption max (VO_{2max},) CT (d = 0.94) displayed the largest ES and ET (d = 0.90) showed an ES similar to that of CT. CT (d = 0.22) and RT (d = 0.20) exhibited low effect sizes in the lean body mass. The CT intervention group (d = −0.43) demonstrated the largest reduction in fat mass. **Conclusions**: CT demonstrated superior effectiveness in preventing muscle loss, obesity and enhancing physical fitness in men. This underscores its potential for practical exercise planning and future research on exercise types. However, further investigation is warranted due to limitations such as the heterogeneity of analyzed studies, differences in exercise intervention methods and variations in subjects' ages. **The PROSPERO Registration**: CRD42024549681, https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024549681.

Keywords

Concurrent training; Endurance training; Resistance training; Physical fitness; Body composition

1. Introduction

Population aging is rapidly progressing worldwide, and a quarter of the world's population is expected to be over 60 years old by 2050 [1]. Sarcopenia occurs in 10–50% of elderly people aged ≥65 years worldwide and is also seen in numerous young adults due to changes in the living conditions and habits [2, 3]. Decreased muscle strength and mass reduces physical ability, causing pain and disease, resulting in sarcopenic obesity due to decreased physical activity [4]. Excessive fat accumulation, the hallmark of obesity, poses significant risks to heart metabolism [5]. In 2022, approximately 16% of adults aged 18 and above were classified as obese globally. Between 1990 and 2022, the global obesity rate more than doubled [6]. This condition is also a major contributor to various metabolic syndromes and cardiovascular diseases [7]. Physical activity is generally effective in preventing and treating musculoskeletal and cardiovascular diseases [8]. With the increase in the proportion of urbanized and sedentary lifestyles in modern society, physical activity and daily exercise levels are decreasing. The combination of aging, over nourishment and of a sedentary lifestyle has contributed to the lack of time for proper physical activity [9]. Therefore, more efficient and effective exercise methods should be developed to prevent sarcopenia and obesity, thus improving quality of life.

Endurance training (ET) effectively reduces body weight and body fat, while also enhancing endothelial function, cardiovascular health and bone density. These improvements positively impact the body and elevate the overall quality of life [10, 11]. The European Society for Observation Research guidelines recommend daily moderate-intensity ET for 30–60 min [12]. However, differences in the exercise type should be considered in all aspects such as energy consumption during exercise, impact on energy consumption during breaks, sex and age [13]. Resistance training (RT) is an effective exercise for improving human body composition and muscle function and has positive effects, such as reducing falls, relieving depression and improving the quality of life [14, 15]. RT can be performed by individuals of all age groups and offers a variety of benefits in terms of functionality, performance and psychology [16, 17].

RT improves muscle strength and mass and increases the density of mitochondria and capillaries [18]. In contrast, ET causes an increase in the mitochondrial protein content and maximum oxygen consumption rate [19]. ET increases the proportion of Type I muscle fibers, and the increase in Type II muscle fibers is relatively small compared with RT [20]. Furthermore, a previous study demonstrated that high-intensity ET may reduce muscle fiber area [21]. However, the body's response to ET varies based on the training intensity, volume and method. When the amount, frequency, intensity and duration of concurrent training (CT) combined with RT and ET are moderate, it can potentially lead to more significant improvements in physical function and body composition compared to RT or ET alone [22, 23]. However, the balance of training stimuli is crucial, as excessive or inadequate CT may hinder neuromuscular adaptation and physical function due to the competing demands on molecular pathways, particularly the mTOR (mammalian target of rapamycin) and AMPK (AMP-activated protein kinase) pathways [24, 25].

The body's response according to exercise varies according to personal characteristics, such as age, sex and race; moreover, exercise type is also a major factor influencing the differences in the bodily response [26, 27]. In particular, physiological differences according to sex have been proven in many previous studies. Given the significant differences in body composition, weight, hormones and energy metabolism between sexes, researchers should focus on either men or women participants in their meta-analysis studies [28, 29]. Considering the physiological differences between sexes and the trends in research, combining results from both men and women in a comprehensive analysis carries the risk of producing ambiguous findings. Therefore, underscoring the need to analyze data separately by sex to obtain accurate and representative results.

ET, RT and CT have attracted considerable attention owing to their training efficacy. However, few studies have been classified and compared according to sex, which greatly affects body adaptation after exercise. Moreover, few studies have compared the three exercise types simultaneously; thus, the results to date are still controversial. Therefore, this systematic review with meta-analysis aimed to summarize and analyse the effect of exercise type on men's physical fitness and body composition.

2. Materials and methods

The systematic review and meta-analysis were performed according to the PRISMA guidelines (**Supplementary Table 1**) and registered in PROSPERO (CRD42024549681) [30].

2.1 Search strategy

We searched the English biomedical databases, PubMed, MEDLINE, Web of Science and CINAHL. In addition, we performed extensive searches of the EBSCO database. Keywords in the search included a combination of the MeSH languages, such as "endurance training", "resistance training", "concurrent training", "muscle strength", "body composition", "cardiorespiratory fitness", "sex characteristics" and "men". Specifically, we searched for the following keywords: (resistance training) (endurance training) or (concurrent training); (muscle strength) or (cardiorespiratory fitness) or (body composition); and men. The language was limited to English, and five databases were searched from inception up to April 2024.

2.2 Inclusion criteria and exclusion criteria of randomized controlled trials

A systematic review was conducted to investigate the changes in the physical fitness and body composition of men according to the exercise type. The PICOS model was used to determine the inclusion criteria [30, 31]. The specific criteria of our search were as follows: P (population): Male; I (intervention): ET, RT and CT; C (comparator): This study necessarily included the CT, ET and RT group, and the pre-post values within each group were compared; O (outcome): mean ± standard deviation data (muscle strength, cardiorespiratory fitness, muscle mass, fat mass); S (study design): This systematic review included only randomized controlled trials (RCT) studies.

The following studies were excluded: (I) research on animals, children, adolescents, obese people, patients and only women. (II) Nonrandomized controlled trials. (III) Studies that included interventions other than the study's purpose. (IV) Studies not including muscle strength, cardiorespiratory fitness, muscle mass or fat mass as outcome indicators. (V) Cohort studies, quasi-experimental studies, qualitative studies, meta-analyses and reviews. (VI) Studies not published in English.

2.3 Quality assessment

The methodological quality of the studies included was evaluated independently by three different authors (KWN, EKS and SP) using the Cochrane Risk of Bias Tool for RCTs [31, 32]. The tool's items were categorized into seven domains. Each study was evaluated for risk of bias as low, high or unclear. Statistical heterogeneity was determined using the I^2 statistic. Each study was assessed and categorized according to quality assessment criteria: (I) the study was considered to have a low risk of bias if all quality criteria were met; (II) the study was deemed to have a moderate risk of bias if one or more quality criteria were partially met or unclear; (III) the study was judged to have a high risk of bias if one or more quality criteria were barely met. Any disagreements were resolved through discussion among the authors.

2.4 Data extraction

The participants included in the meta-analysis were assigned to the ET, RT and CT groups. Data were independently extracted by two reviewers according to a preset data table format. The extracted data included author names, publication dates, journal names and participant demographics. The measurements included muscle strength, cardiorespiratory fitness, lean body mass and fat mass. The three reviewers exchanged data sheets and cross-reviewed the extracted data. Disagreements in the process of extracting the data were resolved after discussion from various perspectives.

2.5 Statistical analyses and meta-analysis

Participant characteristics were summarized with means and standard deviations. The meta-analysis used STATA/MP 18 (Stata Corp, College Station, TX, USA). Changes in dependent variables were quantified by comparing intragroup pre- and post-intervention through standardized mean differences (SMD), participant numbers and SMD standard errors for each study. Given the methodological heterogeneity across the included studies, either a random-effects model ($I^2 \geq 50\%$) or a fixed-effects model ($I^2 < 50\%$) was employed to quantify the pooled SMD of the studies (Cohen, 1988). The SMD was categorized as follows: small effect, SMD = 0.2; medium effect, SMD = 0.5; and large effect, SMD = 0.8 [33].

3. Results

3.1 Literature search results

A comprehensive search of the literature identified 5137 potential articles for inclusion. Out of these, 2253 duplicates were removed. After evaluating the titles and abstracts, 2667 articles were deemed irrelevant and excluded. From the remaining studies that required full-text evaluation, 49 were excluded. Of the 168 articles reviewed in full text, 152 were removed for various reasons: 37 had incomplete data, 88 did not satisfy the inclusion criteria, and 26 were not randomized controlled trials (RCTs). Ultimately, 17 articles were included in the final analysis (Fig. 1).

3.2 Study characteristics

Table 1 (Ref. [34–49]) presents the characteristics of the 17 studies included in this systematic review and meta-analysis. A total of 645 men with an average age of 44.94 years, as a result of combining 17 included studies. Among the 18 studies, the analysis was classified according to the measured dependent variables; six studies measured the leg press [34–39], Five studies measured the bench press [35, 38–41], 12 studies measured cardiorespiratory fitness [34–36, 38–46], seven studies measured the lean body mass [23, 34, 35, 38, 39, 47], and eight studies measured fat mass [23, 34, 35, 38, 39, 42, 48, 49] (Table 1).

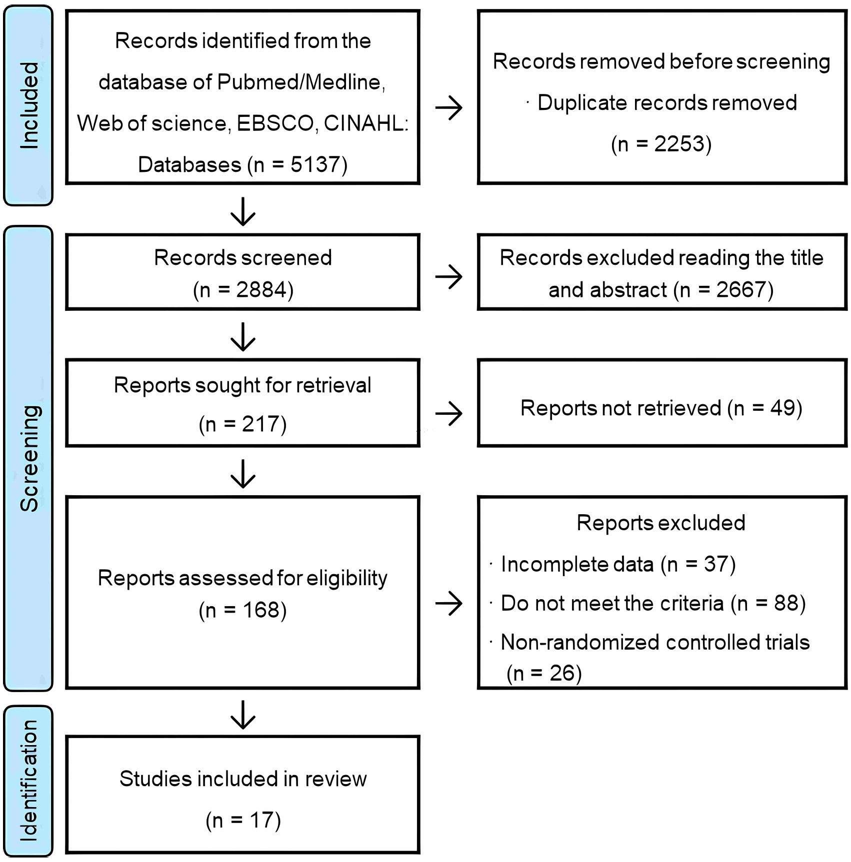


FIGURE 1. Flow chart of the search and study selection process.

TABLE 1. Characteristics of RCTs included in the present meta-analysis.

Study	Study participants	Groups	Age (yr) (mean)	N	Exercise Intervention		Outcome
					Exercise program	Frequency × Duration	
Ahtiainen *et al.* [34], 2009	Middle aged men	ET	58.00	9	A cycle ergometer and HR were used, 45–90 min, progressive overload	2 d/wk × 21 wk	LP, VO_{2max}, LBM, FM
		RT	61.00	10	1RM 40–90%, 6–30 reps/set, progressive overload		
		CT	64.00	7	ET + RT concurrent training	4 d/wk × 21 wk	
Dolezal. *et al.* [35], 1998	Adult men	ET	20.10	10	Used a treadmill, intensity of HRmax 65–85%. Progressive overload	3 d/wk × 10 wk	BP, LP, VO_{2max}, LBM, FM
		RT		10	4–15 reps/set, 3 sets, progressive overload		
		CT		10	1/2 (ET + RT)		
Karavirta, *et al.* [36], 2011	Middle aged men	ET	54.00	25	Used a cycle ergometer and aerobic thresholds (30–60 min)	2 d/wk × 21 wk	LP, VO_{2max}
		RT	56.00	25	1RM 40–85% 5–20 reps/set, 2–4 sets, progressive overload		
		CT	56.00	30	ET + RT concurrent training	4 d/wk × 21 wk	
de Souza, *et al.* [37], 2012	Adult men	ET	24.00	8	Used to high intensity interval training on treadmill, VO_{2max} 80–100%	2 d/wk × 8 wk	LP
		RT	25.90	11	6–12 RM reps/set, lower body muscle		
		CT	22.50	11	ET + RT concurrent training		
Glowacki, *et al.* [38], 2004	Adult men	ET	25.00	12	Used a treadmill, HR reserve 65–80%, progressive overload	2~3 d/wk × 12 wk	LP, BP, VO_{2max}, LBM, FM
		RT	23.00	13	1RM 75–85%, progressive overload		
		CT	22.00	16	RT (3 d/wk) + ET (2 d/wk) × 6 wk, ET (3 d/wk) + RT (2 d/wk) × 6 wk	5 d/wk × 12 wk	
Cadore, *et al.* [40], 2010	Older men	ET	64.40	7	A cycle ergometer was utilized, HRmax 80% 20 min (~10 wk), HRmax 100% 6 sets × 4 min (11–12 wk)	3 d/wk × 12 wk	BP, VO_{2max}
		RT	64.00	8	6–20 RM reps/set, progressive overload		
		CT	66.80	8	ET + RT concurrent training		
Donges, *et al.* [39], 2013	Middle aged men	ET	45.40	13	A cycle ergometer was utilized, HRmax 75–80% (40–60 min)	3 d/wk × 12 wk	LP, BP, VO_{2max}, LBM, FM
		RT	51.70	13	1RM 75–80%, 8–10 reps/set, 3–4 sets		
		CT	46.20	13	Half of ET + RT concurrent training		

TABLE 1. Continued.

Study	Study participants	Groups	Age (yr) (mean)	N	Exercise Intervention		Outcome
					Exercise program	Frequency × Duration	
Bentley, *et al.* [42], 2009	Adult men	ET	24.80	9	HRmax 65%, progressive overload	3 d/wk × 8 wk	VO_{2max}, FM
		RT	25.40	9	1RM 50%, 10 reps, 2 set, progressive overload		
		CT	24.40	9	Half of ET + RT concurrent		
Sillanpää, *et al.* [43], 2009	Middle aged men	ET	52.60	17	Progressive overload by cycling (60–90 min)	2 d/wk × 21 wk	VO_{2max}
		RT	54.10	15	1RM 60–90%, progressive overload		
		CT	56.30	15	ET + RT	4 d/wk × 21 wk	
Karavirta, *et al.* [44], 2009	Middle aged men	ET	54.00	23	Used a bicycle ergometer and heart rate levels, 60–90 min, progressive overload	2 d/wk × 21 wk	VO_{2max}
		RT	56.00	25	1RM 40–85%, progressive overload		
		CT	56.00	29	ET + RT concurrent training	4 d/wk × 21 wk	
Azizbeigi, *et al.* [41], 2018	Adult men	ET	21.10	10	HRmax 50–85%, progressive overload	3 d/wk × 8 wk	BP, VO_{2max}
		RT	21.20	10	1RM 50–85%, progressive overload		
		CT	22.80	10	Alternatively every weeks, first week: RT, second week: HRmax 50–85%, progressive overload		
Mikkola, *et al.* [45], 2011	Adult men	ET	37.00	11	A cycle ergometer was utilized, progressive overload	2 d/wk × 21 wk	VO_{2max}
		RT	37.00	16	1RM 5–15 reps/set, 2–5 sets, progressive overload		
		CT	38.00	11	ET (2 d/wk) + RT (2 d/wk) + concurrent training	4 d/wk × 21 wk	
Izquierdo, *et al.* [23], 2005	Adult men	ET	42.30	10	A cycle ergometer was utilized, HRmax 70–90%, 30–40 min	2 d/wk × 12 wk	LBM, FM
		RT	43.50	11	1RM 50–70%, 10–15 reps/set, 3–4 sets, progressive overload		
		CT	41.80	10	ET (1 d/wk) + RT (1 d/wk)		
Macdonald, *et al.* [47], 2012	Adult men	ET	20.56	9	Plyometric training, 3–7 reps/set 3 sets	2 d/wk × 9 wk	LBM
		RT	22.00	11	Day 1 training volume (1RM 75–90%, 3–6 reps/set, 3 sets) Day 2 training volume (1RM 45–67%, 3–6 reps/set, 3 sets)		
		CT	22.50	10	ET + RT concurrent training		

TABLE 1. Continued.

Study	Study participants	Groups	Age (yr) (mean)	N	Exercise Intervention		Outcome
					Exercise program	Frequency × Duration	
Izquierdo, *et al*. [48], 2004	Older men	ET	68.20	10	A cycle ergometer was utilized, HRmax 55–85%, 30–40 min	2 d/wk × 16 wk	LBM, FM
		RT	64.80	11	1RM 50–70%, 10–15 reps/set, 3–4 sets (~8 wk) 1RM 70–80%, 5–6 reps/set, 3–5 sets (9–16 wk)		
		CT	66.40	10	ET (1 d/wk) + RT (1 d/wk) concurrent training		
Sillanpää, *et al*. [49], 2008	Middle aged men	ET	54.10	14	Used a cycle ergometer, progressive overload (30–90 min)	2 d/wk × 21 wk	FM
		RT	54.60	13	1RM 40–90%, progressive overload		
		CT	56.30	15	ET + RT concurrent training	4 d/wk × 21 wk	
Cadore, *et al*. [46], 2011	Older men	ET	65.50	7	A cycle ergometer was utilized, HRmax 80–100%, progressive overload	3 d/wk × 12 wk	VO_{2max}
		RT		8	18–20 RM reps/set, 12–14 RM reps/set, 6–8 RM reps/set, progressive overload		
		CT		8	ET + RT concurrent training		

ET, endurance training; RT, resistance training; CT, concurrent training; N, number; HR, heart rate; RM, repetition maximum; LP, leg press; BP, bench press; LBM, lean body mass; FM, fat mass; VO_{2max}*, maximal oxygen consumption; rep, repetition; min, minute; d, day or days; wk, week or weeks.*

3.3 Quality of individual studies

Each study was judged as having a low risk of bias, high risk of bias or unclear risk of bias (Figs. 2,3). Our meta-analysis evaluated the included studies as having either a low risk regarding random sequence generation (11/17), allocation concealment (5/17), blinding of participants and personnel (11/17), blinding of outcome assessment (1/17), incomplete outcome data (11/17), selective reporting (6/17) and other sources of bias (7/17).

3.4 Muscle strength by the types of exercise (leg press)

Fig. 4 presents the analysis results regarding the impact of different exercise type on leg press strength in men. The pooled SMD, obtained with the random effects model, was 1.65 (95% confidence interval (CI): 0.74–2.56, $p < 0.001$; $I^2 = 82.7\%$, $p < 0.001$) across 6 CT intervention studies, demonstrating a notable improvement in leg press strength among men following the CT intervention. I^2 indicated statistical heterogeneity. The pooled SMD calculated using the random effect measurement (mean $\pm$ standard deviation (SD)) of the RT intervention study was 1.65 (95% CI: 0.55–2.75, $p = 0.003$; $I^2 = 87.6\%$, $p < 0.001$), similar to the CT intervention group, which significantly increased the leg press muscle strength in men after RT intervention. The pooled SMD calculated leg press measurements from the ET intervention study was 0.84 (95% CI: 0.21–1.47; $p = 0.009$; $I^2 = 68.4\%$, $p = 0.007$), which was less than that of the CT and RT intervention groups, but showed increased leg press muscle strength following ET intervention (Fig. 4).

3.5 Muscle strength based on the types of exercise (bench press)

Fig. 5 presents the analysis results regarding the impact of different exercise type on bench press strength in men. The pooled SMD, calculated using the random effect model, was 2.25 (95% CI: 0.77–3.74, $p = 0.003$; $I^2 = 88.9\%$, $p < 0.001$) based on 5 CT intervention studies, reflecting a considerable enhancement in bench press strength among men following the CT intervention. The pooled SMD calculated using the random effect measurement (mean $\pm$ SD) of the RT intervention study was 2.21 (95% CI: 0.58–3.84, $p = 0.008$; $I^2 = 89.8\%$, $p < 0.001$), similar to the CT intervention group, which significantly increased the bench press muscle strength in men following RT intervention. In the same way, the pooled SMD calculated leg press measurements from the ET intervention study was 0.59 (95% CI: −0.14 to 1.32, $p = 0.115$; $I^2 = 68.5\%$, $p = 0.013$), which was less than that of the CT and RT intervention groups, but showed increased bench press muscle strength following ET intervention (Fig. 5).

3.6 Cardiorespiratory fitness based on the types of exercise (VO_{2max})

Fig. 6 shows the results of the analysis of the effects of the exercise type on cardiorespiratory fitness as measured by maximal oxygen consumption max (VO_{2max}) in men. The pooled SMD, calculated using the random effect model, was 0.94 (95% CI: 0.50–1.39, $p < 0.001$; $I^2 = 69.3\%$, $p < 0.001$) from 12 CT intervention studies, demonstrating a significant improvement in VO_{2max} in men following CT intervention. The pooled SMD calculated using the fixed-effects measurement (mean $\pm$ SD) of the RT intervention study was 0.19 (95% CI: −0.19 to 0.46, $p = 0.186$; $I^2 = 25.0\%$, $p = 0.206$) from 11 RT studies. Compared with CT, RT showed a significantly smaller ES and RT intervention did not appear to have a significant effect on the cardiorespiratory fitness. The pooled SMD calculated using the random effect measurement (mean $\pm$ SD) of the ET intervention study was 0.90 (95% CI: 0.5–1.29, $p < 0.001$; $I^2 = 59.6\%$, $p = 0.004$), similar to the CT intervention group, which significantly increased the VO_{2max} in men following ET intervention (Fig. 6).

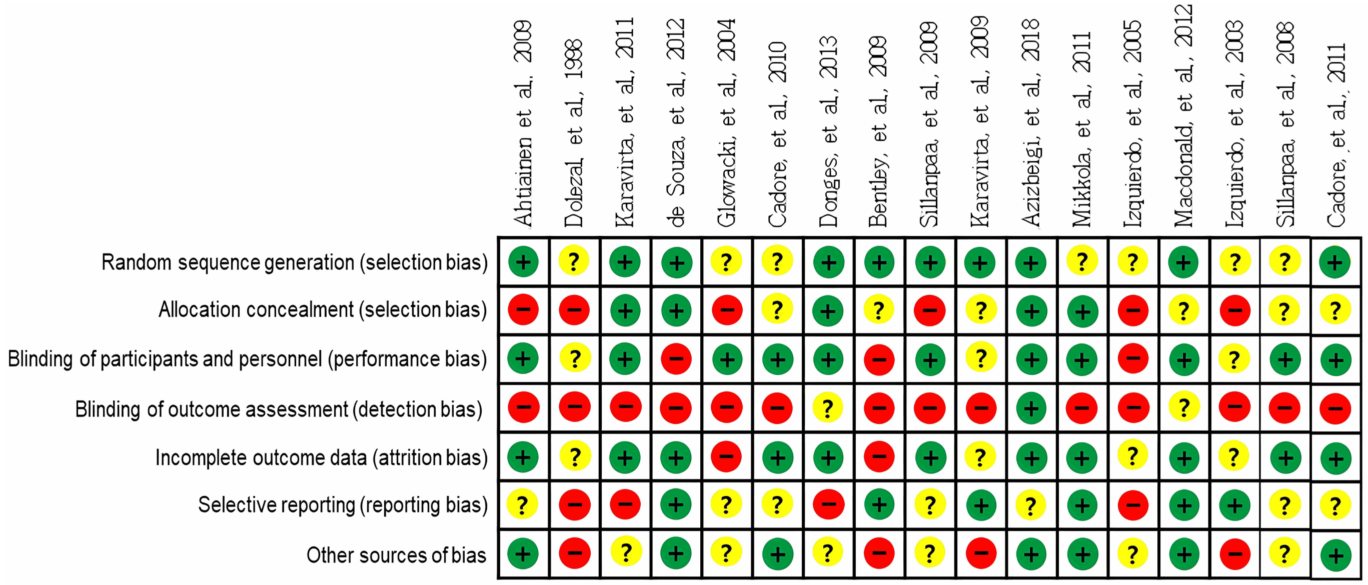


FIGURE 2. Risk of bias summary: assessment about each bias item for each study. +, low risk of bias; ?, unclear risk of bias; −, high risk of bias.

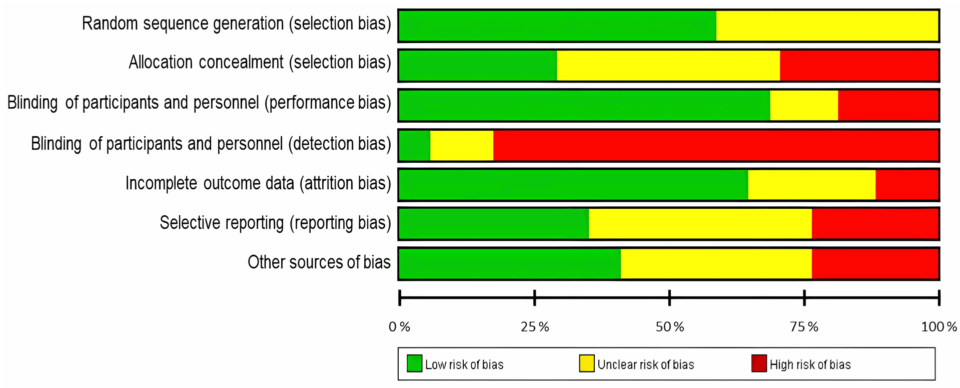
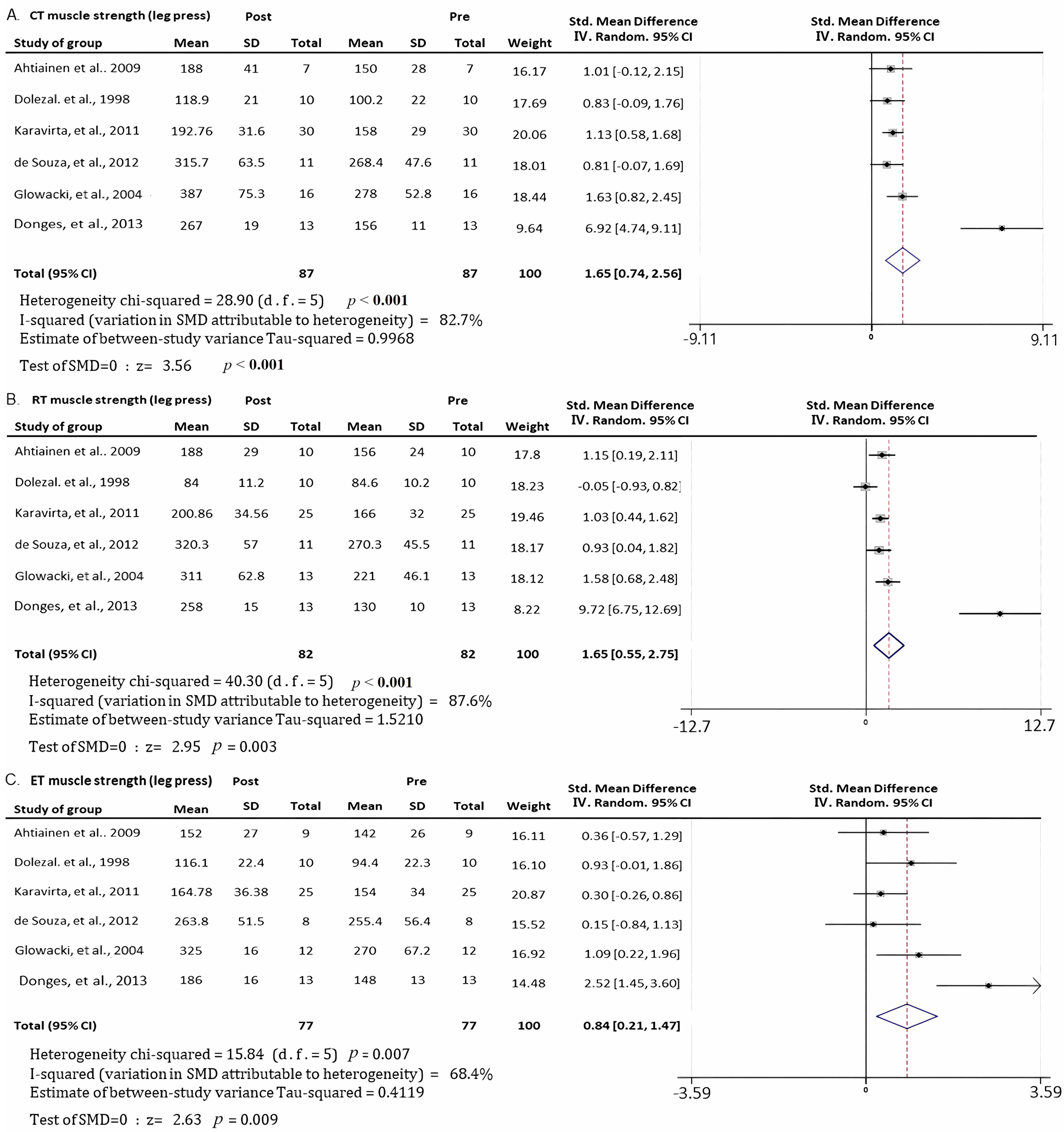


FIGURE 3. Risk of bias graph.



A. CT muscle strength (leg press)

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Ahtiainen et al.. 2009	188	41	7	150	28	7	16.17	1.01 [-0.12, 2.15]
Dolezal. et al., 1998	118.9	21	10	100.2	22	10	17.69	0.83 [-0.09, 1.76]
Karavirta, et al., 2011	192.76	31.6	30	158	29	30	20.06	1.13 [0.58, 1.68]
de Souza, et al., 2012	315.7	63.5	11	268.4	47.6	11	18.01	0.81 [-0.07, 1.69]
Glowacki, et al., 2004	387	75.3	16	278	52.8	16	18.44	1.63 [0.82, 2.45]
Donges, et al., 2013	267	19	13	156	11	13	9.64	6.92 [4.74, 9.11]
Total (95% CI)			**87**			**87**	**100**	**1.65 [0.74, 2.56]**

B. RT muscle strength (leg press)

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Ahtiainen et al.. 2009	188	29	10	156	24	10	17.8	1.15 [0.19, 2.11]
Dolezal. et al., 1998	84	11.2	10	84.6	10.2	10	18.23	-0.05 [-0.93, 0.82]
Karavirta, et al., 2011	200.86	34.56	25	166	32	25	19.46	1.03 [0.44, 1.62]
de Souza, et al., 2012	320.3	57	11	270.3	45.5	11	18.17	0.93 [0.04, 1.82]
Glowacki, et al., 2004	311	62.8	13	221	46.1	13	18.12	1.58 [0.68, 2.48]
Donges, et al., 2013	258	15	13	130	10	13	8.22	9.72 [6.75, 12.69]
Total (95% CI)			**82**			**82**	**100**	**1.65 [0.55, 2.75]**

C. ET muscle strength (leg press)

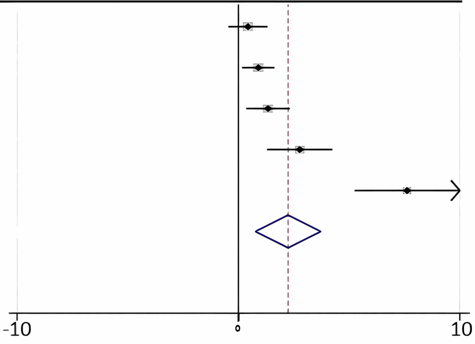
Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Ahtiainen et al.. 2009	152	27	9	142	26	9	16.11	0.36 [-0.57, 1.29]
Dolezal. et al., 1998	116.1	22.4	10	94.4	22.3	10	16.10	0.93 [-0.01, 1.86]
Karavirta, et al., 2011	164.78	36.38	25	154	34	25	20.87	0.30 [-0.26, 0.86]
de Souza, et al., 2012	263.8	51.5	8	255.4	56.4	8	15.52	0.15 [-0.84, 1.13]
Glowacki, et al., 2004	325	16	12	270	67.2	12	16.92	1.09 [0.22, 1.96]
Donges, et al., 2013	186	16	13	148	13	13	14.48	2.52 [1.45, 3.60]
Total (95% CI)			**77**			**77**	**100**	**0.84 [0.21, 1.47]**

FIGURE 4. Forest plot and meta-analysis of leg press muscle strength. (A) Concurrent training (CT) group muscle strength (leg press), (B) Resistance training (RT) group muscle strength (leg press), (C) Endurance training (ET) group muscle strength (leg press). SD, standard deviation; CI, confidence interval; SMD, standardized mean difference.

A. CT muscle strength (Bench press)

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Dolezal. et al., 1998	92.9	21.5	10	83.2	22	10	21.95	0.43 [-0.46, 1.32]
Glowacki, et al., 2004	99.5	17.8	16	82.1	19.9	16	22.52	0.90 [0.17, 1.63]
Karavirta, et al., 2011	39.3	5.5	10	32.5	4.1	10	21.53	1.34 [0.35, 2.34]
Cadore, et al., 2010	57.15	4.65	8	43.1	4.9	8	19.26	2.78 [1.30, 4.26]
Donges, et al., 2013	92	4	13	67	2	13	14.75	7.66 [5.27, 10.04]
Total (95% CI)			**57**			**57**	**100**	**2.25 [0.77, 3.74]**

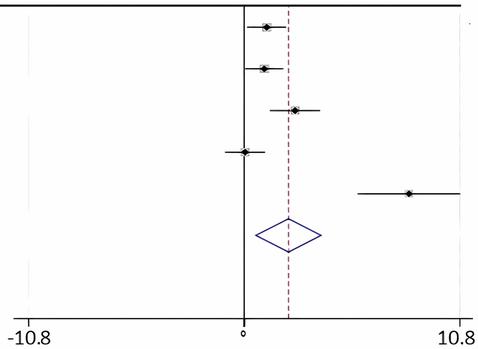
Heterogeneity chi-squared = 35.96 (d.f. = 4) $p < 0.001$
I-squared (variation in SMD attributable to heterogeneity) = 88.9%
Estimate of between-study variance Tau-squared = 2.4112
Test of SMD=0 : z= 2.97 $p = 0.003$



B. RT muscle strength (Bench press)

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Dolezal. et al., 1998	94.3	15.3	10	76.1	15.7	10	21.55	1.12 [0.17, 2.08]
Glowacki, et al., 2004	86.5	18.6	10	66.3	20	10	21.61	1.00 [0.06, 1.94]
Karavirta, et al., 2011	44.2	4.2	10	33.7	3.7	10	20.52	2.54 [1.30, 3.78]
Cadore, et al., 2010	51.21	3.1	8	38.3	408	8	21.48	0.04 [-0.94, 1.02]
Donges, et al., 2013	87	4	13	53	4	13	14.84	8.23 [5.68, 10.78]
Total (95% CI)			**51**			**51**	**100**	**2.21 [0.58, 3.84]**

Heterogeneity chi-squared = 39.11 (d.f. = 4) $p < 0.001$
I-squared (variation in SMD attributable to heterogeneity) = 89.8%
Estimate of between-study variance Tau-squared = 2.9707
Test of SMD=0 : z= 2.66 $p = 0.008$



C. ET muscle strength (Bench press)

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Dolezal. et al., 1998	66.8	12	10	67.1	11.8	10	20.62	-0.02 [-0.90, 0.85]
Glowacki, et al., 2004	99.5	19.1	12	78.8	22.1	12	20.93	0.97 [0.11, 1.82]
Karavirta, et al., 2011	30.8	6.2	10	30.8	6.2	10	20.62	0.00 [-0.88, 0.88]
Cadore, et al., 2010	39.2	15.4	7	37.8	14.6	7	18.29	0.09 [-0.96, 1.14]
Donges, et al., 2013	73	4	13	66	3	13	19.54	1.92 [0.96, 2.87]
Total (95% CI)			**52**			**52**	**100**	**0.59 [-0.14, 1.32]**

Heterogeneity chi-squared = 12.69 (d.f. = 4) $p = 0.013$
I-squared (variation in SMD attributable to heterogeneity) = 68.5%
Estimate of between-study variance Tau-squared = 0.4751
Test of SMD=0 : z= 1.58 $p = 0.115$

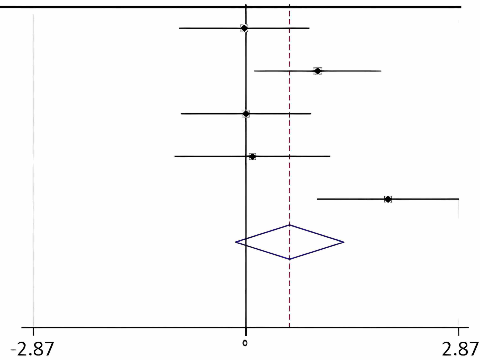


FIGURE 5. Forest plot and meta-analysis of bench press muscle strength. (A) Concurrent training (CT) group muscle strength (bench press), (B) Resistance training (RT) group muscle strength (bench press), (C) Endurance training (ET) group muscle strength (bench press). SD, standard deviation; CI, confidence interval; SMD, standardized mean difference.

3.7 Lean body mass based on the types of exercise

Fig. 7 presents the analysis results regarding the impact of different exercise type on lean body mass in men. The pooled SMD, calculated using the fixed-effects model, was 0.22 (95% CI: −0.10 to 0.54, $p = 0.174$; $I^2 = 0.0\%$, $p = 0.935$) from 7 CT intervention studies. CT intervention demonstrated a small ES on the increase in the lean body mass in men. The pooled SMD calculated using the fixed-effects model measurement (mean ± SD) of the RT intervention study was 0.20 (95% CI: −0.12 to 0.52, $p = 0.217$; $I^2 = 0.0\%$, $p = 0.948$). The RT intervention group showed a low ES for increasing the lean body mass, similar to the results of the CT intervention group. The pooled SMD calculated in the ET intervention study was −0.12 (95% CI: −0.45 to 0.2, $p = 0.465$; $I^2 = 0.0\%$, $p = 0.997$), which contradicted the findings of the CT and RT intervention groups. Based on ES and confidence intervals, it also appeared that the other types of exercise did not affect lean mass in men (Fig. 7).

3.8 Fat mass based on the types of exercise

Fig. 8 presents the analysis results regarding the impact of different exercise type on fat mass in men. The pooled SMD, calculated using the fixed-effects model, was −0.43 (95% CI: −0.72 to −0.13, $p = 0.005$; $I^2 = 0\%$, $p = 0.727$) from eight

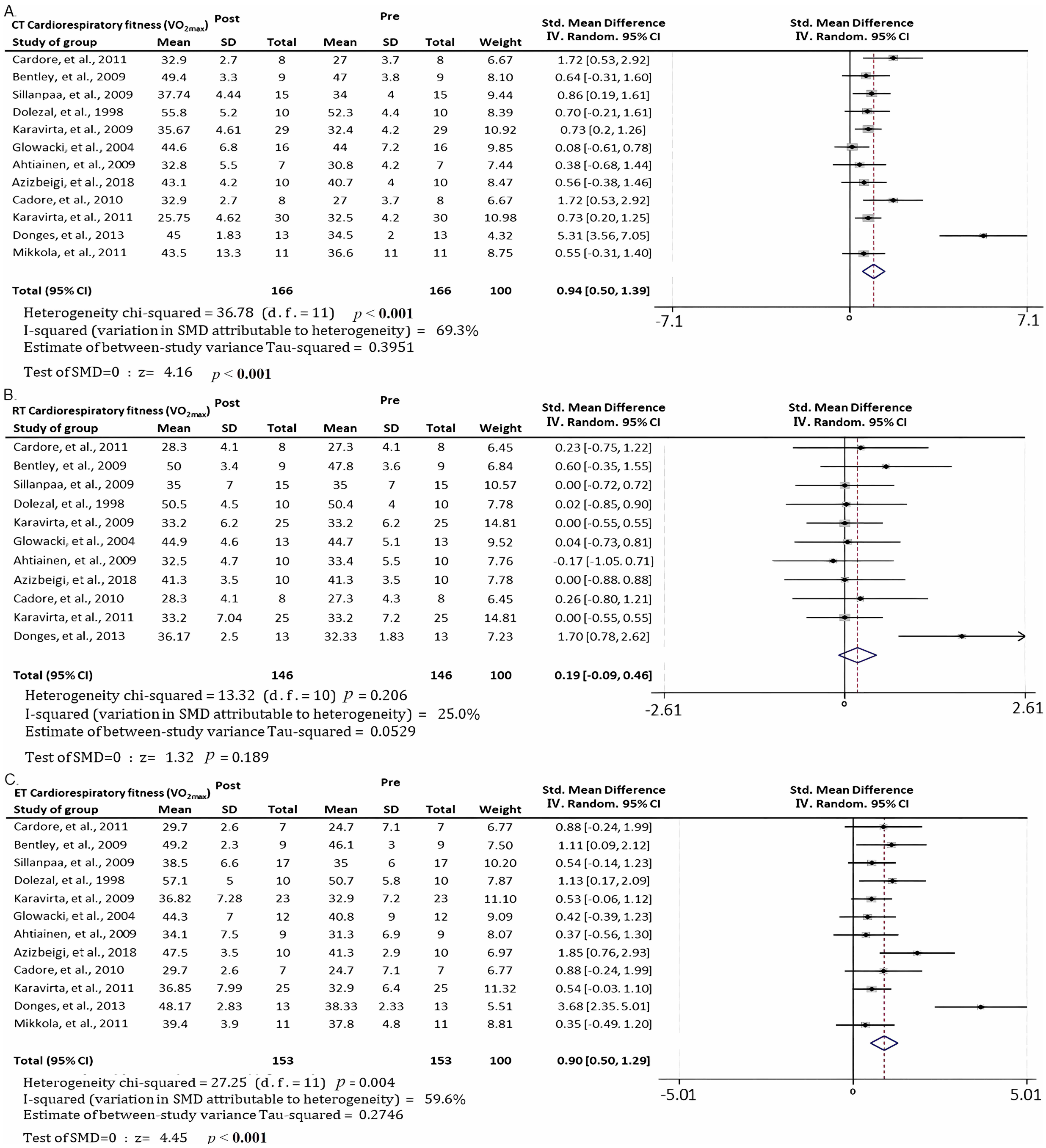


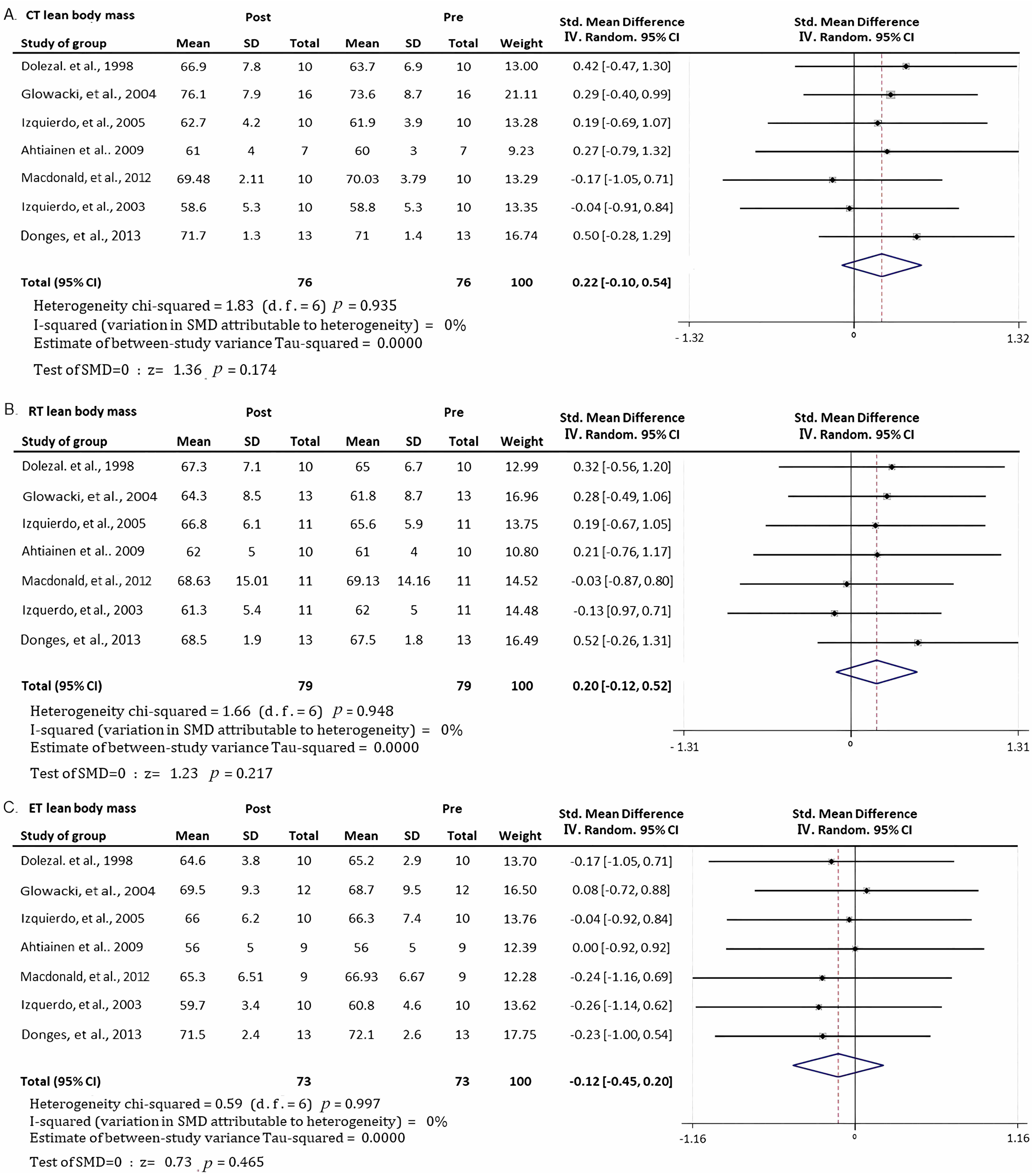
FIGURE 6. Forest plot and meta-analysis of VO_{2max} cardiorespiratory fitness. (A) Concurrent training (CT) group cardiorespiratory fitness (VO_{2max}), (B) Resistance training (RT) group cardiorespiratory fitness (VO_{2max}), (C) Endurance training (ET) group cardiorespiratory fitness (VO_{2max}). SD, standard deviation; CI, confidence interval; SMD, standardized mean difference.

CT intervention studies. The CT intervention had a moderate effect on the reduction of fat mass in men. The pooled SMD of the RT intervention studies was −0.30 (95% CI: −0.60 to 0.00, $p = 0.047$; $I^2 = 0.0\%$, $p = 0.986$). The RT intervention group exhibited a smaller ES for decreased fat mass. The pooled SMD calculated using the fixed-effects measurement (mean ± SD) of the ET intervention study was −0.39 (95% CI: −0.70 to −0.09, $p = 0.011$; $I^2 = 0.0\%$, $p = 0.807$), similar to the CT intervention group, which significantly decreased the fat mass in men following ET intervention (Fig. 8).

4. Discussion

Through a systematic review of the literature, 17 randomized controlled trials (RCTs) were selected to assess the impacts of ET, RT and CT interventions on various outcomes including muscle strength, cardiopulmonary fitness, lean body mass and fat mass in men. Meta-analysis of the 17 extracted articles confirmed the effect of exercise type on men's physical fitness and body composition.

Among the 17 papers included in the meta-analysis, VO_{2max}, lean body mass and fat mass were found to be homogeneous among each study. The leg press and bench



A. CT lean body mass

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Dolezal. et al., 1998	66.9	7.8	10	63.7	6.9	10	13.00	0.42 [-0.47, 1.30]
Glowacki, et al., 2004	76.1	7.9	16	73.6	8.7	16	21.11	0.29 [-0.40, 0.99]
Izquierdo, et al., 2005	62.7	4.2	10	61.9	3.9	10	13.28	0.19 [-0.69, 1.07]
Ahtiainen et al.. 2009	61	4	7	60	3	7	9.23	0.27 [-0.79, 1.32]
Macdonald, et al., 2012	69.48	2.11	10	70.03	3.79	10	13.29	-0.17 [-1.05, 0.71]
Izquierdo, et al., 2003	58.6	5.3	10	58.8	5.3	10	13.35	-0.04 [-0.91, 0.84]
Donges, et al., 2013	71.7	1.3	13	71	1.4	13	16.74	0.50 [-0.28, 1.29]
Total (95% CI)			**76**			**76**	**100**	**0.22 [-0.10, 0.54]**

Heterogeneity chi-squared = 1.83 (d.f. = 6) p = 0.935
I-squared (variation in SMD attributable to heterogeneity) = 0%
Estimate of between-study variance Tau-squared = 0.0000
Test of SMD=0 : z= 1.36 p = 0.174

B. RT lean body mass

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Dolezal. et al., 1998	67.3	7.1	10	65	6.7	10	12.99	0.32 [-0.56, 1.20]
Glowacki, et al., 2004	64.3	8.5	13	61.8	8.7	13	16.96	0.28 [-0.49, 1.06]
Izquierdo, et al., 2005	66.8	6.1	11	65.6	5.9	11	13.75	0.19 [-0.67, 1.05]
Ahtiainen et al.. 2009	62	5	10	61	4	10	10.80	0.21 [-0.76, 1.17]
Macdonald, et al., 2012	68.63	15.01	11	69.13	14.16	11	14.52	-0.03 [-0.87, 0.80]
Izquerdo, et al., 2003	61.3	5.4	11	62	5	11	14.48	-0.13 [0.97, 0.71]
Donges, et al., 2013	68.5	1.9	13	67.5	1.8	13	16.49	0.52 [-0.26, 1.31]
Total (95% CI)			**79**			**79**	**100**	**0.20 [-0.12, 0.52]**

Heterogeneity chi-squared = 1.66 (d.f. = 6) p = 0.948
I-squared (variation in SMD attributable to heterogeneity) = 0%
Estimate of between-study variance Tau-squared = 0.0000
Test of SMD=0 : z= 1.23 p = 0.217

C. ET lean body mass

Study of group	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV. Random. 95% CI
Dolezal. et al., 1998	64.6	3.8	10	65.2	2.9	10	13.70	-0.17 [-1.05, 0.71]
Glowacki, et al., 2004	69.5	9.3	12	68.7	9.5	12	16.50	0.08 [-0.72, 0.88]
Izquierdo, et al., 2005	66	6.2	10	66.3	7.4	10	13.76	-0.04 [-0.92, 0.84]
Ahtiainen et al.. 2009	56	5	9	56	5	9	12.39	0.00 [-0.92, 0.92]
Macdonald, et al., 2012	65.3	6.51	9	66.93	6.67	9	12.28	-0.24 [-1.16, 0.69]
Izquerdo, et al., 2003	59.7	3.4	10	60.8	4.6	10	13.62	-0.26 [-1.14, 0.62]
Donges, et al., 2013	71.5	2.4	13	72.1	2.6	13	17.75	-0.23 [-1.00, 0.54]
Total (95% CI)			**73**			**73**	**100**	**-0.12 [-0.45, 0.20]**

Heterogeneity chi-squared = 0.59 (d.f. = 6) p = 0.997
I-squared (variation in SMD attributable to heterogeneity) = 0%
Estimate of between-study variance Tau-squared = 0.0000
Test of SMD=0 : z= 0.73 p = 0.465

FIGURE 7. Forest plot and meta-analysis of the lean body mass. (A) Concurrent training (CT) group lean body mass, (B) Resistance training (RT) group lean body mass, (C) Endurance training (ET) group lean body mass. SD, standard deviation; CI, confidence interval; SMD, standardized mean difference.

press, both measurement variables of muscle strength, exhibited heterogeneity across studies. However, they were analyzed using a random effects model and an overall effective effect was observed. Furthermore, one study exhibited a notably large individual effect, which appears to have significantly contributed to the observed heterogeneity [40]. Except for studies showing specific individual effects, most studies show similar effect sizes. As a result of analyzing six studies that measured lower body muscle strength, the CT and RT intervention groups exhibited a high ES of 1.65. The ET intervention group showed a significant ES of 0.84, although it was lower than CR and RT. The main result of this investigation was that CT resulted in a large increase in maximal muscle strength. This study results contradict previous studies indicating that CT may impose limitations on neuromuscular adaptation [50], and corroborate findings from earlier studies where CT demonstrated comparable or even greater muscle strength gains compared to RT [22]. If CT is not balanced, the AMPK pathway's activation may inhibit the mTOR pathway, causing a metabolic conflict that hampers protein synthesis and muscle growth. Therefore, optimizing CT to balance both pathways is essential to harness the full

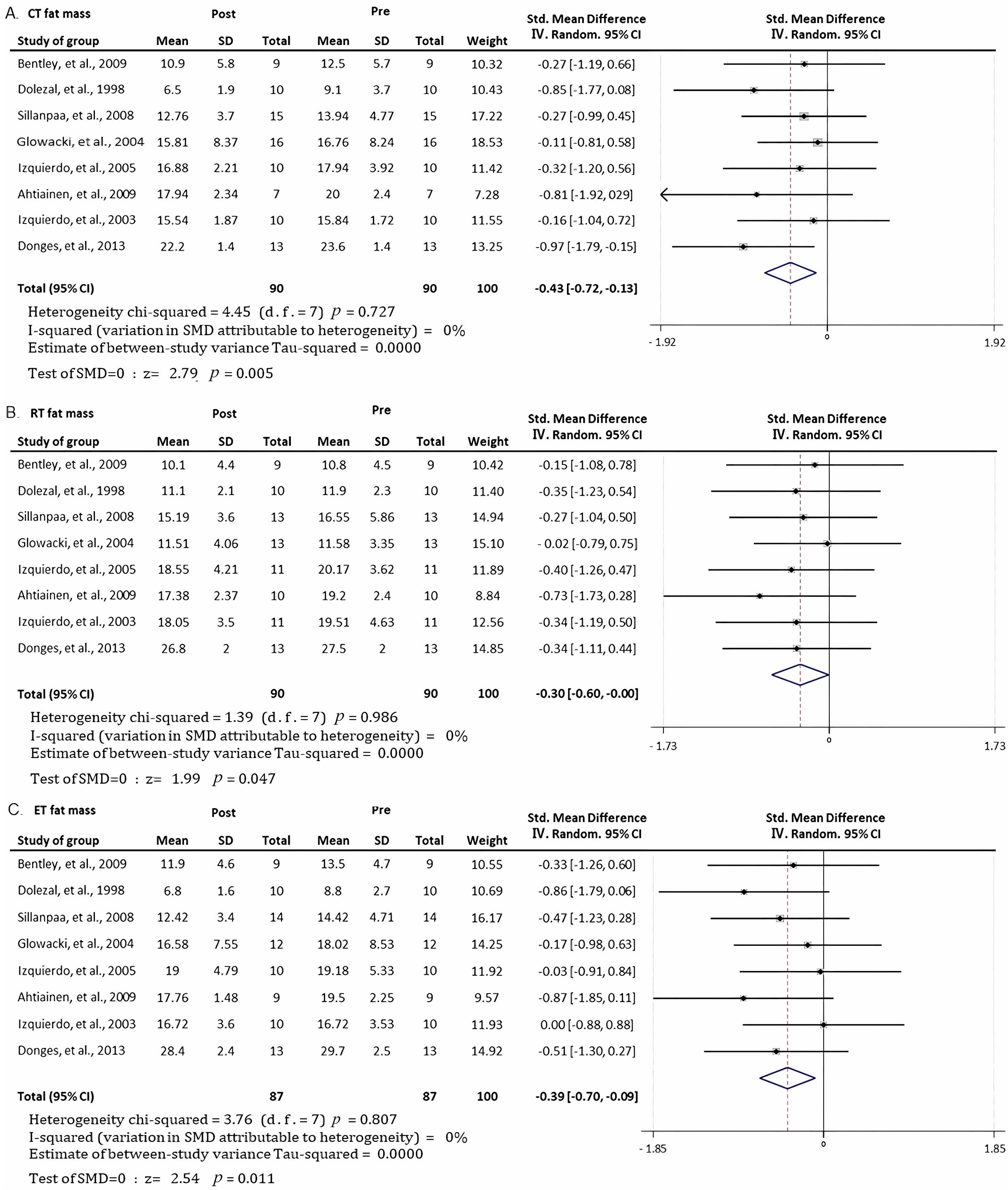


FIGURE 8. Forest plot and meta-analysis of fat mass. (A) Concurrent training (CT) group fat mass, (B) Resistance training (RT) group fat mass, (C) Endurance training (ET) group fat mass. SD, standard deviation; CI, confidence interval; SMD, standardized mean difference.

benefits of RT and ET while minimizing interference [24, 25]. The high ES observed in the increase of lower body muscle strength with ET may be considered an unexpected result. These results appear to be due to the fact that the ET exercise method of the leg press measurement study included in this study used a cyclometer [34, 35, 39]. According to the results of previous studies, cycle ergometer showed neuromuscular adaptation similar to strength training [51]. However, in increasing lower limb muscle strength in men, CT and RT can be considered more effective than ET.

In the bench press, which measures upper body muscle strength, the difference between the CT and RT groups and the ET intervention group was more pronounced. An evaluation of 5 studies that assessed upper body strength through the bench press revealed a high pooled effect size (ES) of 2.25 for the CT intervention group, whereas the RT group demonstrated a similar ES of 2.21. The ET intervention group demonstrated a moderate ES of 0.59, indicating a relatively lower ES compared to the CT and RT groups. This suggests that CT is the most effective in increasing upper body muscle strength in men. CT stimulates the secretion of hormones such as testosterone, growth hormone, epinephrine and norepinephrine. The combined effects of these hormones substantially boost strength improvements and overall physical fitness. Additionally, CT targets both type I and type II muscle fibers, thereby fostering the growth of various muscle fiber types. This comprehensive stimulation leads to improvements not only in muscular strength but also in muscular endurance and power [52, 53]. The reason for the difference in changes in upper and lower body muscle strength according to the type of exercise is thought to be due to the exercise method of ET. Given that the majority of the included studies utilized a cycle ergometer or treadmill for the ET intervention method, it appears that there is a much greater emphasis on lower body exercise compared to upper body when focusing on muscle strength comparison [34–40]. Therefore, it appears that further research on ET including exercise programs other than lower limb-focused ET is needed. When comprehensively comparing upper and lower body muscle strength, the exercise type that demonstrated the highest efficacy in men's strength was CT. This could provide important information for optimizing exercise programs to maximize enhancements in physical fitness, prevent muscle loss, and increase muscle strength.

After analyzing 12 studies measuring cardiopulmonary capacity, the CT group exhibited a high ES of 0.94, indicating the most significant efficacy among exercise types in improving cardiorespiratory fitness. The ET group demonstrated a high ES of 0.90, showing a similar degree of improvement in cardiorespiratory fitness as CT. However, the RT group exhibited an ES of 0.19, indicating that it did not have a significant impact on improving cardiorespiratory fitness. In summary, significant improvements in VO_{2max} were observed in both CT and ET groups, while there was almost no change observed in the RT group. These findings are consistent with previous studies that investigated changes in maximal strength and aerobic endurance across RT, interval training and CT groups [54]. Furthermore, in previous studies observing changes in VO_{2max} between CT and ET groups, the CT group showed a 17% increase, the ET group showed a 16% increase. RT, on the other hand, has been shown to have effects on muscle fiber surface area but does not affect capillary density, thus it appears to not directly improve VO_{2max} [55]. However, ET increases capillary density, CT increases muscle fiber surface area and simultaneously increases capillary density, which suggests an improvement in VO_{2max} [55]. ET enhances the oxygen-carrying capacity of red blood cells and increases mitochondrial efficiency, thereby enabling more effective energy production [56]. RT strengthens both muscles and the heart, while CT simultaneously enhances muscle strength and oxygen-carrying capacity. This combination optimizes energy metabolism and can further improve cardiovascular endurance beyond the effects of ET alone [57]. Synthesizing data from 8 studies revealed that the difference in ES between CT and ET was not significant, although CT appeared as the most effective exercise type in improving cardiorespiratory fitness in men.

As a result of meta-analysis of seven papers measuring lean body mass in this study, the ES of the CT group was the largest, but it showed a low ES of 0.22. The RT group showed a low ES of 0.2 similar to the CT group. It is concluded that CT and RT do not significantly increase lean body mass in men. On the contrary, ET showed a negative ES of −0.012, indicating a tendency to decrease lean body mass in men. However, since the ES of −0.12 is very small, it is difficult to say that ET significantly reduces the lean body mass in men. In their 2022 study, Aagaard *et al*. [57] reported that while 14 weeks of resistance training did not result in increased lean mass, there was a notable enhancement in muscle strength. Similarly, in the results of this study, the ES of RT and CT interventions on lean body mass was not high, but the ES was high in muscle strength increase. This appears to be the result of neural adaptation, explaining the improvement in muscle strength in the absence of an increase in lean body mass [58]. In addition, in order to accurately compare muscle function and muscle mass improvement, it seems necessary to study the muscle mass rather than the lean body mass. This is because muscle mass is an important measure of evaluating sarcopenia, metabolic disease risk, cardiovascular disease and cancer, and is a very important factor in improving and maintaining quality of life [59, 60]. However, among the studies that measured muscle mass according to the type of exercise, there are few studies that can be compared equally [34, 61, 62].

As a result of meta-analysis of eight papers measuring fat mass in this study, the CT group was found to be −0.43, which is a moderate ES. Therefore, it may be seen that CT has a significant effect on the decrease in the fat mass in men (p = 0.005). Although the RT group was lower than the CT group, it showed an ES of −0.30 and was found to be effective in reducing fat mass (p = 0.047). This contradicts the findings of some previous studies on RT interventions [63, 64]. According to the analysis results of this study, it can be seen that the intervention of RT provides an advantage for body composition changes in positive directions such as body fat reduction. The ET group appears to be −0.39, a moderate ES similar to CT, and has been shown to have a significant effect on the reduction of fat mass (p = 0.011). The more significant reduction in fat mass in CT compared to ET may be considered an unexpected result. These results can be attributed to CT intervention improving insulin resistance and promoted natriuresis [65]. CT is considered to exhibit the most significant reduction in body fat mass among the three exercise types due to its ability to increase insulin sensitivity, thereby suppressing fat accumulation and simultaneously activating fat energy metabolism [66]. Moreover, the duration of exercise intervention among the 17 studies analyzed ranges from 8 to 21 weeks. Since changes in fat mass may vary depending on the duration of exercise, further research examining the effects of exercise type and duration seems necessary. The meta-analysis revealed that CT had the highest ES across all variables, including leg press, bench press, VO_{2max}, lean body mass and fat mass. Based on these results, CT is considered the most effective exercise type for preventing sarcopenia and obesity, as well as improving physical fitness in men. This could be important information for planning practical exercise routines or for future research on exercise types.

Due to significant differences in body composition, weight, hormones and energy metabolism between sexes, researchers should consider focusing their meta-analysis studies on either male or female participants [30, 31]. Combining results from both sex in a comprehensive analysis may lead to ambiguous findings given these physiological differences and research trends. Therefore, emphasizing the importance of separate sex-specific analyses is crucial for obtaining accurate and representative results. This approach minimizes statistical ambiguity and enhances result precision tailored to the specific group under study. Traditionally, exercise physiology research has predominantly centered on male participants, reflecting historical biases in military and sports research participant demographics [67, 68]. Considering these research findings and trends, further studies are warranted to conduct experimental research and comprehensive analyses focusing on women.

Despite these findings, our analysis had several limitations. Firstly, although all included studies were RCTs, there were limitations in the heterogeneity and quality of the analyzed studies. Secondly, while the included studies analyzed CT, RT and ET intervention groups, it is challenging to consider that all studies intervened with similar exercise methods. There appears to be a need for a standardized exercise intervention method agreed upon for exercise intensity, volume, frequency and intensity. In particular, among the studies included in the meta-analysis, there was a tendency for CT to involve higher exercise volumes compared to ET or RT alone. Therefore, there is a question as to whether the higher effect sizes observed for CT in muscle strength, hypertrophy and fat reduction compared to other exercise types might be attributed to its greater exercise volume. Thirdly, since this study exclusively targeted adult males, generalizing the results is challenging. To enhance the applicability of these findings, future research integrating studies focused on specific groups such as women, adolescents and older adults appears necessary. Given the superior effectiveness of CT observed in this study, future research should explore its application across diverse populations, including women, adolescents and older adults. This could provide comprehensive insights into the broader applicability and potential benefits of CT-based interventions. Finally, the age of the subjects who participated in the 17 studies included in the analysis ranged from 20.1 to 68.2 years old, and it seems that additional research is needed because it is unclear what difference the body's response will make depending on the age and the intervention.

5. Conclusions

This study targeted randomized controlled trials RCTs published between 1994 and 2024, focusing on studies involving male participants and interventions of endurance training (ET), resistance training (RT) and combined training (CT). In summary, CT exhibited the highest effect sizes across all variables, leading to the conclusion that CT is the most effective type for preventing muscle loss, obesity, and enhancing physical fitness in men. This could be valuable information for planning practical exercises or for future research on exercise types. The findings underscore the efficacy of CT in enhancing muscle strength, reducing fat mass, and improving physical fitness among male participants. Further investigations are needed to assess the efficacy of CT in various demographic groups, such as women, adolescents and older adults, to evaluate its broader applicability and potential benefits. Although this study highlights the benefits of CT, additional research is crucial to examine methodological differences and demographic variables that could impact exercise results. This encompasses examining how various exercise protocols and participant characteristics influence the observed outcomes.

AVAILABILITY OF DATA AND MATERIALS

Data available in a publicly accessible repository that does not issue DOIs for publicly available datasets were analyzed in this study. This data can be found here: accessed on 19 May 2024. More information at: https://figshare.com/articles/figure/Effects_of_Exercise_Types_on_Men_s_Physical_Fitness_and_Body_Composition_A_Systematic_Review_and_Meta_analysis/25855924.

AUTHOR CONTRIBUTIONS

KWN and SP—Conceptualization; methodology; project administration supervision; writing-original draft. KWN and EKS—Data curation; formal analysis; visualization. KWN—Funding acquisition. EKS—Writing-review and editing. All authors have read and agreed to the published version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

ACKNOWLEDGMENT

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jomh.org/files/article/1882622567503544320/attachment/Supplementary%20material.docx.

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