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SUPPLEMENT ARTICLE

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# Effect of different types of regular exercise on physical fitness in adults with overweight or obesity: Systematic review and meta-analyses

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## Summary

This systematic review examined the effect of exercise training interventions on physical fitness in adults with overweight or obesity and compared the effectiveness of different types of exercise training. Four electronic databases were searched. Articles were included if they described randomized controlled trials of exercise training interventions and their effect on maximal oxygen consumption or muscle strength in adults with overweight or obesity. Changes in outcome parameters were analyzed using random effects meta-analyses for different training types (aerobic, resistance, combined aerobic plus resistance, and high-intensity interval training). Eighty-eight articles satisfied the inclusion criteria of which 66 (3964 participants) could be included in the

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meta-analyses. All training types increased $VO_{2max}$ (mean difference 3.82 ml/min/kg (95% CI 3.17, 4.48), $P < 0.00001$; $I^2 = 48\%$). In direct comparisons, resistance training was less effective in improving $VO_{2max}$ than aerobic training, HIIT was slightly more effective than aerobic training, and no difference between aerobic and combined aerobic plus resistance training was found. For muscle strength benefits, incorporation of resistance exercise in the training program is indicated. Exercise training increases $VO_{2max}$ and muscle strength in adults with overweight or obesity. Differences between training types should be weighed with other needs and preferences when health professionals advise on exercise training to improve physical fitness.

**KEYWORDS**
exercise modality, maximal oxygen uptake, muscle strength

## 1 | INTRODUCTION

In the general population, regular exercise is well-known to have beneficial effects on physical fitness, such as an increase in aerobic capacity and increased muscle strength, which are important for the ability to lead a physically active life and for health.[1] In order to define the role of regular exercise in the management of adults with overweight or obesity, it is important to know what the effects on physical fitness are in this specific group of individuals. In general, physical fitness (per kg body weight) is lower in individuals with than in those without overweight or obesity.[2,3] We therefore started with a literature search of systematic reviews on this topic that were published over the last 10 years (2009–2019). This resulted in six reviews.[4–9]

Miller et al.[4] reviewed the effects of different modalities of exercise training during diet-induced weight loss interventions in adults with obesity. Fourteen randomized controlled trials (RCT's) were included. The authors concluded that exercise training during energy restriction improved strength and cardiovascular fitness. No clear conclusion about the differences between training modalities was drawn. The review by Baker et al.[5] addressed the effects of physical activity interventions specifically in postmenopausal women with overweight or obesity. The review included five large RCT's (with multiple publications) with long duration (≥12 months). The inclusion criteria of the review were not very strict (some normal-weight women were included; intervention and control groups differed not only for physical activity). The authors concluded that physical activity interventions have a positive impact on physical capacity. Different types of exercise were included, but differences were not evaluated. Batacan et al.[6] focused on the effects of high intensity interval training (HIIT). Sixty-five studies with different study designs in populations with normal weight and overweight were included. The inclusion criteria were not strict: in many studies categorized as studies in individuals with overweight or obesity, this was not mentioned as one of the inclusion criteria in the original study. The authors concluded that short (<12 weeks) and long-term (≥12 weeks) HIIT improve $VO_{2max}$ in individuals with overweight or obesity as well as in individuals in the non-overweight group.

Türk et al.[8] compared the effects of high intensity (continuous and interval) exercise and lower intensity endurance exercise or no exercise on $VO_{2max}$. Fifteen studies were included. The conclusion of the authors was that high intensity exercise was superior to improve cardiopulmonary fitness in comparison with lower intensity or no exercise in adults with obesity. Su et al.[9] compared the effects of HIIT with those of moderate intensity continuous training (MICT). Sixteen studies were included. Overall HIIT was equally effective as MICT in improving $VO_{2max}$, but HIIT training with longer (≥2 min) intervals appeared to be more effective than MICT. Hita-Contreras et al.[7] reviewed the effects of exercise interventions on muscle strength and gait speed in sarcopenic obesity. Five RCT's were included, two of which used electrostimulation as exercise intervention. The authors concluded that exercise increases grip strength and gait speed in people with sarcopenic obesity. The effects of different types of training were not analyzed.

Because of the limited information available from these systematic reviews, which mostly focused on specific groups, did not distinguish between types of training or studied the combination with a weight loss diet, we decided to do a systematic review and meta-analyses on the topic in the context of the EASO Physical Activity Working Group guidelines development. The aim of this systematic review was to examine the impact of various types of exercise interventions (aerobic training, resistance training, combined aerobic and resistance training, and high-intensity interval training) on physical fitness, with a focus on cardiorespiratory fitness and muscle strength, in adults with overweight or obesity and compare their effectiveness. A secondary aim was to compare the effectiveness in adults with normal weight and those with overweight or obesity.

## 2 | METHODS

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and is registered in the PROSPERO database (registration number CRD42019157823).

## 2.1 | Search strategy

Four electronic databases (PubMed, Web of Science, Cochrane Library, and EMBASE) were searched for original RCTs published up to December 2019. The specific key words used for the search are listed in Table S1. Reference lists from the resulting articles were screened to identify additional articles.

## 2.2 | Study selection, inclusion, and exclusion

Articles were included if the RCT involved adults (>18 years, no maximum age) with overweight (BMI $\geq$ 25 kg/m$^2$) or obesity (BMI $\geq$ 30 kg/m$^2$) participating in physical activity interventions, that is, exercise training programs, or interventions promoting increases in physical activity. Studies focusing on the primary prevention of weight gain/obesity were not included. The presence of obesity comorbidities, such as type 2 diabetes, hypertension, dyslipidemia, metabolic syndrome, liver disease (NAFLD/NASH), and osteoarthritis, was not an exclusion criterion. Exercise training programs included regular sessions with one or more types of exercise (aerobic and/or resistance and/or high-intensity interval training). Exercise sessions could be supervised, partially supervised or non-supervised. Exercise interventions in combination with other interventions (e.g., diet) were excluded. Comparators included no intervention, another form of exercise or sham exercise (e.g., stretching).

Abstracts and full texts were assessed for eligibility independently by two authors (M. A. v. B. and A. P.) with uncertainty regarding eligibility discussed among authors.

## 2.3 | Data extraction

Data were extracted by two authors using standardized forms. The following characteristics were extracted: reference, study design, number of participants included in intervention and control groups, population characteristics (age, BMI, %female, comorbidities for intervention, and control groups), description of intervention (program duration, number of sessions per week, type of training/topic, and supervision/delivery) and comparison, and outcomes. Additional data were obtained from six authors.[10–15]

The findings pertaining to cardiorespiratory fitness (measured or estimated $VO_{2max}$), muscle strength, and any other parameter of physical function of each included article are reported.

## 2.4 | Data synthesis and statistical analysis

To calculate the effect size of each study, we used the mean change (post- to pre-intervention) and SD of the variable of interest over the experimental period in the control and intervention groups. If these values were not reported, we calculated the mean difference as the difference in mean pre and post intervention and its SD using the formula: SD = square root $((SD_{pretreatment})^2 + (SD_{posttreatment})^2) - (2r \times SD_{pretreatment} \times SD_{posttreatment})$). Because the pretest–posttest correlation coefficients ($r$) were not reported in the studies, a conservative $r$ value of 0.5 was assumed throughout. If an exact p value for the within group intervention effect was reported, we used this value together with the subject number ($N$) to estimate the SD of the effect.

The meta-analysis of included studies was conducted using the Cochrane Review Manager 5.3 software.[16] If a study included more than two experimental groups, which were compared with one control group, the number of subjects in the control group was divided by the number of comparisons. The effect size was expressed as mean difference (MD) or standardized mean difference (SMD) when not all studies reported the outcome in the same units. Most studies reported data from a completers analysis. In a limited number of studies intention-to-treat analysis was performed and, if available, these results were included in the meta-analyses.

Random-effects models were used for the statistical analysis. The effect size is reported as the (standardized) mean difference with its 95% confidence interval (95% CI). Effect sizes were considered large, medium, small and negligible when SMD was >0.8, between 0.5 and 0.8, between 0.2 and 0.5 and below 0.2, respectively.[17] Heterogeneity was measured using the $I^2$ test.[18] Heterogeneity was considered low, moderate, and high when $I^2$ was <50%, between 50 and 75% and ≥75%.[19]

## 2.5 | Quality assessment

Study quality was assessed with a standardized tool including 14 criteria, as previously described.[20] Study quality was defined as good, fair, or poor when 0, 1, or ≥2 criteria defined as "fatal flaws" (randomization, dropout <20%, intention-to-treat analysis) were not fulfilled. Quality assessment was conducted independently by two reviewers (M. A. v. B. and A. P.) using this standardized tool. Any disagreement between the reviewers was resolved through discussion.

## 2.6 | Risk of bias assessment

Publication bias was assessed by visual inspection of the funnel plots. When the funnel plot showed signs of asymmetry and the number of included studies was >10, Egger's test was performed.

# 3 | RESULTS

The database search yielded 3068 articles, 2831 of which were eliminated based on titles and abstracts alone. Twenty-five studies were added from additional sources. Full texts were retrieved from 162 articles and 88 satisfied the inclusion criteria (Figure S1). Of these, 66 could be included in the various meta-analyses. The 66 studies included 3954 participants, sample size ranged from 12 to 464 (median 43), training duration ranged from 2 to 70 weeks (median 12 weeks),

% females participating in the studies ranged from 0 to 100% (median 82%), mean age in study groups ranged between 20 and 75 years (median 46 y), mean baseline BMI ranged between 26.4 and 37.2 kg/m$^2$ (median 30.9) and mean baseline $VO_{2max}$ ranged between 14.9 and 39.7 ml/min/kg (median 28.4). The quality assessment yielded 21 studies that were of good quality, 28 of fair and 17 of poor quality, mainly due to high dropout rates and lack of an intention-to-treat analysis (Table S2). Table 1 summarizes the effects of different types of exercise training on selected physical fitness parameters in adults with overweight or obesity.

## 3.1 | Effect of exercise training on cardiorespiratory fitness

For the meta-analyses on cardiorespiratory fitness the outcome was maximal or peak oxygen consumption ($VO_{2max}$). Only studies which expressed $VO_{2max}$ in ml/min/kg were included to take the effect of potential weight changes during the intervention period into account.

### 3.1.1 | Effect of aerobic exercise training on cardiorespiratory fitness

The characteristics of the 24 included RCTs[10,11,14,21–41] with 1802 participants are presented in Table S3. The meta-analysis had 41 study arms with 995 individuals in the experimental groups and 447 in the control groups. It showed that aerobic exercise training significantly improved $VO_{2max}$ (mean difference (MD) 4.08 ml/min/kg (95% CI 3.22, 4.95), $P < 0.00001$). The heterogeneity was moderate ($I^2 = 61\%$). The effect size was medium (standardized mean difference (SMD) 0.70 (95% CI 0.58, 0.82)). Figure S2 shows the forest plot. One of the factors that may have influenced the heterogeneity among studies was the duration of the intervention. Studies were subdivided in three groups according to intervention duration: <12 weeks (eight studies, $N = 244$), 12 weeks (11 studies, $N = 268$) and >12 weeks (seven studies, $N = 932$). In the subgroup with study duration <12 weeks the MD was 3.31 ml/min/kg (95% CI 1.78, 4.83), $P < 0.0001$, $I^2 = 0\%$. In the subgroup with an intervention duration of 12 weeks the MD was 5.41 ml/min/kg (95% CI 3.88, 6.93), $P < 0.00001$, $I^2 = 39\%$. When study duration was >12 weeks the MD was 3.34 ml/min/kg (95% CI 2.30, 4.39), $P < 0.00001$, $I^2 = 62\%$. The heterogeneity remained high in the studies with a duration >12 weeks (13 weeks to 16 months), which may be suggestive for problems with adherence with longer intervention durations. Quality assessment of the studies included in the meta-analysis showed that 15 of the studies had fair or good quality,[10,14,21–24,27,29,31,32,35,37,39–41] whereas nine were of poor quality[11,25,26,28,30,33,34,36,38] (Table S2). Removing the poor-quality studies from the meta-analysis slightly reduced the MD in $VO_{2max}$ change to 3.89 ml/min/kg (95% CI 2.79, 5.00), $P < 0.00001$, $I^2 = 65\%$ ($N = 999$). The effect size was medium (SMD 0.66 (95% CI 0.51, 0.80).

The funnel plot looked asymmetric, which was confirmed by Egger's test ($P = 0.001$) (Figure S3). When the study by Church et al.[24] was excluded, Egger's test was no longer significant ($P = 0.084$). The study by Church et al. had by far the largest number of subjects, had a relatively long duration of 6 months and reported a relatively small effect on $VO_{2max}$ compared to most of the other studies. The participants exercised three times per week 20, 40, or 60 min at 50% $VO_{2peak}$.

**TABLE 1** Summary of meta-analyses on the effects of different types of exercise training (aerobic, resistance, combined aerobic plus resistance, and high-intensity interval training) on $VO_{2max}$, muscle strength and other fitness parameters in adults with overweight or obesity

| | | | | | | 95% CI | | | |
|---|---|---|---|---|---|---|---|---|---|
| Outcome | Intervention | N | Comparator | N | (S)md | min | max | $I^2$ (%) | *P* value |
| $VO_{2max}$ | Aerobic | 995 | No exercise | 447 | 4.08 | 3.22 | 4.95 | 61 | 0.00001 |
| | Resistance | 75 | No exercise | 84 | 4.52 | 1.76 | 7.28 | 59 | 0.001 |
| | Aerobic + Resistance | 165 | No exercise | 153 | 4.57 | 2.14 | 7.00 | 74 | 0.0002 |
| | HIIT | 183 | No exercise | 123 | 4.31 | 2.81 | 5.80 | 51 | <0.00001 |
| | Resistance | 143 | Aerobic | 137 | −1.40 | −2.41 | −0.38 | 11 | 0.007 |
| | Aerobic + Resistance | 96 | Aerobic | 97 | 0.38 | −0.63 | 1.38 | 0 | 0.46 |
| | HIIT | 300 | Aerobic | 221 | 0.99 | 0.25 | 1.73 | 0 | 0.008 |
| Muscle strength | Aerobic | 78 | No exercise | 76 | 0.26 | −0.06 | 0.58 | 0 | 0.12 |
| | Resistance | 291 | No exercise | 206 | 0.74 | 0.54 | 0.93 | 0 | <0.00001 |
| | Aerobic + Resistance | 74 | No exercise | 71 | 0.62 | 0.27 | 0.96 | 0 | 0.004 |
| | Resistance | 96 | Aerobic | 95 | 0.49 | 0.19 | 0.78 | 0 | 0.001 |
| Physical fitness (flexibility, balance, walking speed, and global physical capacity score) | Resistance or Aerobic + Resistance | 131 | No exercise | 98 | 0.66 | 0.37 | 0.95 | 0 | <0.00001 |

*Note*: For muscle strength, no studies on the effects of HIIT were found.
Abbreviations: CI, confidence interval; HIIT, high-intensity interval training; $I^2$, heterogeneity; MD, mean difference; *N*, number of participants; SMD, standardized mean difference; $VO_{2max}$, maximum oxygen consumption.

Despite its size, the study seemed well-controlled, and no serious compliance issues were reported. This might suggest a small study effect, that is, smaller studies with no significant effect may not have been published. On the other hand, the baseline $VO_{2peak}$ was the lowest of all studies included, which may suggest that it was underestimated, and thus, training intensity was also lower than suggested.

### 3.1.2 | Effect of resistance exercise training on cardiorespiratory fitness

The characteristics of the six included RCTs[14,21,29,33,42,43] with a total sample size of 195 are presented in Table S4. The meta-analysis had six study arms with 75 individuals in the experimental groups and 84 in the control groups. It showed that resistance training significantly improved $VO_{2max}$ (MD 4.52 ml/min/kg (95% CI 1.56, 7.28), $P$ = 0.001). The heterogeneity was moderate ($I^2$ = 59%) (Figure S4). The effect size was large (SMD 0.81 (95% CI 0.22, 1.41)). Quality assessment of the studies included in this meta-analysis showed that all studies except one[33] were of fair or good quality (Table S2). Removing this study from the meta-analysis resulted in an MD of 4.33 ml/min/kg (95% CI 1.11, 7.56), $P$ = 0.008, $I^2$ = 67%. The funnel plot (Figure S5) showed no evidence of asymmetry.

### 3.1.3 | Effect of combined aerobic plus resistance exercise training on cardiorespiratory fitness

The characteristics of the seven included RCTs[12,14,29,44–47] with 377 participants are presented in Table S5. Seven study arms were included with 165 individuals in the experimental groups and 153 in the control groups. The meta-analysis showed that combined aerobic plus resistance training significantly improved $VO_{2max}$ (MD 4.57 ml/min/kg (95% CI 2.14, 7.00), $P$ = 0.0002). The effect size was medium (SMD 0.78 (95% CI 0.40, 1.16)). The heterogeneity was also large ($I^2$ = 74%), which was due to the study by Hara et al.[45] When this study was excluded the MD was reduced to 2.95 ml/min/kg (95% CI 2.05, 3.85), $P$ < 0.00001, $I^2$ = 0%. The forest plot is shown in Figure S6. The majority of the studies included in this meta-analysis was of fair-to-good quality, only one had poor quality[47] (Table S2). Excluding this poor-quality study resulted in an MD of 4.98 ml/min/kg (95% CI 2.07, 7.88), $P$ = 0.0008, $I^2$ = 78%. The funnel plot looked asymmetric due to the study by Hara et al.[45] (Figure S7). No Egger's test was performed due to the small number of studies. Removing the study by Hara et al.[45] diminished the visual asymmetry.

### 3.1.4 | Effect of high intensity interval training (HIIT) on cardiorespiratory fitness

The characteristics of the 10 included RCTs[11,28,31,41,44,48–52] with a total of 402 participants are presented in Table S6. Sixteen study arms were included with 183 individuals in the experimental groups and 123 in the control groups. The meta-analysis showed that HIIT significantly improved $VO_{2max}$ (MD 4.31 ml/min/kg (95% CI 2.81, 5.80), $P$ < 0.00001). The heterogeneity was moderate ($I^2$ = 51%). The effect size was large (SMD 0.84 (95% CI 0.57, 1.11)). The forest plot is shown in Figure S8. Two studies[50,52] had a very short intervention duration of 3–4 weeks. If these studies were excluded from the meta-analysis the MD in $VO_{2max}$ increased to 5.29 ml/min/kg (95% CI 3.67, 6.91) ($P$ < 0.00001). $I^2$ was 30%. The effect size was large (SMD 0.86 (95% CI 0.53, 1.19). Quality assessment of the studies showed that seven of the studies had fair or good quality, whereas three were of poor quality[11,28,48] (Table S2). When the poor-quality studies and studies with duration ≤4 weeks were excluded, the MD was 4.82 ml/min/kg (95% CI 2.89, 6.75), $P$ < 0.00001, $I^2$ = 0%. Visual inspection of the funnel plot (Figure S9) showed some evidence of asymmetry, but Egger's test was not significant ($P$ = 0.222).

### 3.1.5 | Comparison of the effect of different types of training on cardiorespiratory fitness

We also analyzed whether a certain training type(s) should be preferred as training regimen for the improvement of $VO_{2max}$ in adult with overweight or obesity. The number of studies that compared certain types of training is limited. We were able to analyze the comparison of aerobic endurance type training with resistance training, with combined aerobic and resistance training and with HIIT.

*Aerobic training versus resistance training*

The characteristics of the eight included RCTs[13–15,21,29,33,53,54] with a total of 322 participants are presented in Table S7. Eight study arms were included with 143 individuals in the resistance training groups and 137 in the aerobic training groups. The meta-analysis showed that aerobic training improved $VO_{2max}$ more than resistance training (MD −1.40 ml/min/kg (95% CI −2.41, −0.38, $P$ = 0.007) (Figure S10). The effect size was small (SMD −0.37 (95% CI −0.63, −0.12)). The heterogeneity was low ($I^2$ = 11%). Quality assessment of the studies showed that five of the studies had fair or good quality, whereas three were of poor quality[15,33,53] (Table S2). After removing the poor-quality studies from the meta-analysis the difference in $VO_{2max}$ change was no longer significant (MD −0.65 ml/min/kg (95% CI −2.18, 0.89), $P$ = 0.41, $I^2$ = 7% ($N$ = 133)). The SMD was −0.21 (95% CI −0.55, 0.13) ($P$ = 0.23). Visual inspection of the funnel plot (Figure S11) showed some evidence of asymmetry, but the number of studies was too small to perform Egger's test. Leaving out the study by Schroeder et al.[14] on the bottom left of the funnel plot hardly affected the effect size (MD = −1.45 ml/min/kg (95% CI −2.32, −0.57), $P$ = 0.001, $I^2$ = 0%).

*Aerobic training versus combined aerobic plus resistance training*

Only four studies were available for this comparison. The characteristics of the four included RCTs[14,15,29,55] with a total of 221 participants

are presented in Table S8. Four study arms were included with 96 individuals in the aerobic plus resistance training groups and 97 in the aerobic training groups. The meta-analysis showed that there was no statistically significant difference in effect between the two types of training (MD 0.38 ml/min/kg (95% CI −0.63, 1.38), $P$ = 0.46) (Figure S12). The SMD was 0.07 (95% CI −0.22, 0.35)). The heterogeneity was low ($I^2$ = 0%). Quality assessment of the studies included in the meta-analysis showed that three of the studies had fair or good quality, whereas one was of poor quality[15] (Table S2). Removing the poor-quality study from the meta-analysis hardly changed the results (MD 0.33 (95% CI −1.38, 2.04), $P$ = 0.71, $I^2$ = 0%, $N$ = 104). Because of the small number of studies, the funnel plot (Figure S13) was not informative.

*Aerobic training versus high-intensity interval training*

The characteristics of the 18 included RCTs[11,13,28,31,56–67] with a total of 623 participants are presented in Table S9. Twenty-six study arms were included with 300 individuals in the HIIT groups and 221 in the aerobic training groups. The meta-analysis showed a small, but statistically significant, difference in effect between the two types of training in favour of HIIT (MD 0.99 ml/min/kg (95% CI 0.25, 1.73), $P$ = 0.008). The heterogeneity was low ($I^2$ = 0%) (Figure S14). The effect size was small, SMD = 0.20 (95% CI 0.02, 0.38) ($P$ = 0.03). When studies with a duration <6 weeks were excluded from the analysis,[58,61,66] the MD was 1.19 (95% CI 0.41, 1.97), $P$ = 0.003, $I^2$ = 0%. Quality assessment of the studies included in the meta-analysis showed that three of the studies had poor quality[11,28,63] (Table S2). Removing the poor-quality studies from the meta-analysis resulted in an MD of 1.02 ml/min/kg (95% CI 0.12, 1.91), $P$ = 0.03, $I^2$ = 7%, $N$ = 407). The funnel plot (Figure S15) showed no evidence of asymmetry (Egger's test $P$ = 0.489).

*Effect of exercise training on $VO_{2max}$ in individuals with or without overweight or obesity*

One of the questions we tried to address was whether the effects of training on $VO_{2max}$ are comparable in individuals with or without overweight or obesity. The literature search yielded only two studies,[68,69] in which a direct comparison between groups with normal weight and with overweight/obesity were made. In the study by Blake et al.[68] the effects of a 14-week aerobic training intervention were compared in women with or without overweight or obesity ($N$ = 89). The increase in $VO_{2max}$ was comparable in the two groups. In the study by Gondim et al.[69] the effects of a 12-month aerobic training intervention were compared in men and women with normal weight, overweight, or obesity ($N$ = 143). $VO_{2max}$ (estimated from a 12-min walk/jog test) was increased compared to baseline at 12 months in the group with normal weight and at 6 months in the group with overweight. No significant $VO_{2max}$ changes were found in the group with obesity. However, the changes over time were not compared among the groups. Clearly more studies are needed to answer the question whether training effects on $VO_{2max}$ are comparable in individuals in different BMI categories.

## 3.2 | Effect of exercise training on muscle strength

For the meta-analyses on muscle strength various outcomes were used, including static or dynamic muscle strength of different muscle groups. When available, strength parameters expressed per kg body weight or muscle mass were included to take the effect of potential weight changes during the intervention period into account. The outcomes of the meta-analyses are reported as standardized mean differences (SMD), because study outcomes (strength measurements and units of measurement) differed across studies.

### 3.2.1 | Effect of aerobic exercise training on muscle strength

The characteristics of the six included RCTs[14,23,33,37,70,71] with a total of 206 participants are presented in Table S10. Twelve study arms were included with 78 individuals in the aerobic exercise groups and 76 in the no exercise control groups. The meta-analysis showed no significant difference in effect (SMD 0.26 (95% CI −0.06, 0.58), $P$ = 0.12). The heterogeneity was low ($I^2$ = 0%) (Figure S16). Quality assessment of the studies included in the meta-analysis showed that two of the six studies had poor quality[33,70] (Table S2). Removing the poor-quality studies from the meta-analysis resulted in a SMD of 0.08 (95% CI −0.41, 0.57), $P$ = 0.75, $I^2$ = 0%, $N$ = 66). Visual inspection of the funnel plot (Figure S17) did not suggest asymmetry.

### 3.2.2 | Effect of resistance exercise training on muscle strength

The characteristics of the 12 included RCTs[14,33,42,70–78] with 612 participants are presented in Table S11. Thirty-two study arms were included with 291 individuals in the resistance exercise groups and 206 in the no exercise control groups. The meta-analysis showed a significant difference in effect in favor of resistance training (SMD 0.74 (95% CI 0.54, 0.93), $P$ < 0.00001). The heterogeneity was low ($I^2$ = 0%) (Figure S18). Quality assessment of the studies included in the meta-analysis showed that four of the 12 studies had poor quality[33,70,71,77] (Table S2). Removing the poor-quality studies from the meta-analysis resulted in a SMD of 0.76 (95% CI 0.53, 0.98), $P$ < 0.00001, $I^2$ = 0%, $N$ = 379). The funnel plot (Figure S19) showed no evidence of asymmetry (Egger's test $P$ = 0.698).

### 3.2.3 | Effect of combined aerobic and resistance exercise training on muscle strength

The characteristics of the six included RCTs[14,46,47,70,79,80] with a total of 218 participants are presented in Table S12. Thirteen study arms were included with 74 individuals in the aerobic plus resistance exercise groups and 71 in the no exercise control groups. The meta-analysis also showed a significant difference in effect (standardized

mean difference (SMD) 0.62 (95% CI 0.27, 0.96), $P = 0.0004$). The heterogeneity was low ($I^2 = 0\%$) (Figure S20). Quality assessment of the studies included in the meta-analysis showed that two of the six studies had poor quality[47,70] (Table S2). Removing the poor-quality studies from the meta-analysis resulted in a SMD of 0.67 (95% CI 0.24, 1.10), $P = 0.002$, $I^2 = 0\%$, $N = 93$). Visual inspection of the funnel plot did not suggest serious asymmetry (Figure S21).

### 3.2.4 | Effect of high-intensity interval training on muscle strength

There were no studies that investigated the effect of HIIT on muscle strength in comparison to no exercise training.

### 3.2.5 | Comparison of the effect of different types of training on muscle strength

*Resistance training versus aerobic training*

The characteristics of the seven included RCTs[13,33,53,70,71,81] with 251 participants are presented in Table S13. Fourteen study arms were included with 96 individuals in the resistance exercise groups and 95 in the aerobic exercise groups. The meta-analysis showed a significant difference in effect in favour of resistance training (SMD 0.49 (95% CI 0.19, 0.78), $P = 0.001$). The heterogeneity was low ($I^2 = 0\%$) (Figure S22). Quality assessment of the studies included in the meta-analysis showed that four of the seven studies had poor quality[33,53,70,71] (Table S2). Removing the poor-quality studies from the meta-analysis resulted in a SMD of 0.46 (95% CI −0.01, 0.92), $P = 0.06$, $I^2 = 0\%$, $N = 74$). The funnel plot (Figure S23) showed some evidence of asymmetry with studies missing at the right-hand side of the plot, but due to the small number of studies Egger's test was not performed.

*Resistance training versus combined aerobic plus resistance training*

Three studies additionally compared the effects of combined aerobic plus resistance training with aerobic training[14,15,70] (data not shown). No significant difference was found: SMD 0.50 (95% CI −0.21, 1.21), $P = 0.16$, $I^2 = 70\%$. The study by Slentz et al.[15] was a clear outlier. Removing this study resulted in a SMD 0.17 (95% CI −0.33, 0.67), $P = 0.50$, $I^2 = 0\%$.

*Resistance training versus HIIT*

No studies.

### 3.2.6 | Effect of exercise training on muscle strength in individuals with or without overweight or obesity

Four studies[68,77,82,83] were found that directly compared the effects of exercise training on muscle strength in individuals with normal weight and with overweight or obesity. Pescatello et al.[82] and Vincent et al.[77] studied the effects of resistance training and found no difference in the strength response between the group with normal weight and that with overweight or obesity. On the other hand, no differences in the strength or flexibility response to combined aerobic and resistance exercise training were found by Blake et al.[68] Gondim et al.[69] reported an increase in muscle strength in the group with obesity, but not in the group with normal weight, however whether there was a significant difference between the groups was not reported.

## 3.3 | Exercise training and other physical fitness parameters

Six studies[46,72,73,76,79,80] reporting the effect of resistance or combined aerobic and resistance exercise training on muscle strength also provided data on the effects on other parameters of physical fitness, such as flexibility, balance, global physical capacity score, walking speed.

The meta-analysis (Figure S24) showed that resistance training and combined aerobic plus resistance exercise training had a positive effect on these parameters (SMD 0.66 (95% CI 0.37, 0.95), $P < 0.00001$). Heterogeneity was low ($I^2 = 0\%$). Visual inspection of the funnel plot (Figure S25) did not suggest asymmetry.

Three studies[23,37,38] reported on the effect of aerobic training on flexibility. Two[23,37] found an improvement, one no effect.[38] Manini et al.[83] compared the effect of a combination of different training modalities (aerobic, resistance, and flexibility) on gait speed and Short Physical Performance Battery (SPPB) in individuals with normal weight and with obesity. The responses were less pronounced in the group with obesity.

# 4 | DISCUSSION

In this systematic review and series of meta-analyses we tried to determine the effect of different training modalities on cardiorespiratory fitness and muscle strength in individuals with overweight or obesity. Additionally, we investigated the effects on other parameters of physical fitness (e.g., overall score, flexibility, balance, walking speed). We also tried to evaluate whether the responses were similar in groups with normal weight and groups with overweight or obesity. Our main findings are that all included training modalities (aerobic, resistance, combined aerobic and resistance and forms of high-intensity interval training) improve cardiorespiratory fitness, as measured by maximal oxygen uptake per kg body weight. In direct comparisons, resistance training was less effective than aerobic training and there was no difference between combined aerobic plus resistance training and aerobic training alone. HIIT had a slightly larger effect on $VO_{2max}$ than aerobic training. With respect to muscle strength, resistance training and combined aerobic and resistance training increased muscle strength, whereas aerobic training did not.

No data were available for HIIT. In a direct comparison, resistance training was more effective in improving muscle strength than aerobic training. Other comparisons could not be made because of lack of data. Limited evidence was found that resistance and combined aerobic plus resistance training also improve other aspects of physical fitness such as flexibility, balance, walking speed, and overall physical fitness score.

Physical fitness is important for the tasks of everyday life and health and this review shows that individuals with overweight or obesity can increase aspects of their physical fitness by participating in exercise training programs without focus on weight loss, with effect sizes ranging from medium to large. The question whether the responses are similar in individuals with normal weight and those with overweight or obesity could not be answered based on the studies included in this systematic review.

In general, this systematic review and the included meta-analyses confirm the results of previous ones examining the effects of exercise training on physical fitness in (subgroups of) adults with overweight or obesity,[4–9] but extends these by using more strict inclusion criteria and a more detailed comparison among training modalities. Aerobic training, as expected, increased $VO_{2max}$ as did combined aerobic plus resistance training. Whether resistance training also improves $VO_{2max}$ is a topic of discussion in the literature.[84,85] We found that resistance training was also effective, although less than aerobic training, in increasing $VO_{2max}$, which may be related to the relatively low level of baseline $VO_{2max}$ in the population with overweight or obesity.[84]

The majority of studies in this review were in line with general recommendations for aerobic and resistance exercise for the improvement or maintenance of physical fitness (e.g., that of the American College of Sports Medicine[86]), although the combination of the two, which is recommended in most guidelines, was studied less frequently. We found that combined aerobic and resistance exercise was equally effective as aerobic training in improving $VO_{2max}$, whereas aerobic plus resistance training was equally effective as resistance training for muscle strength, although this latter conclusion was based on only three studies.

Studies included males and females with a wide range of mean ages (18–75 years), BMIs (26.4–40.5 kg/m$^2$) and initial fitness levels ($VO_{2max}$ 14.9–39.5 ml/min/kg) and therefore appear to cover the overall adult population with overweight or obesity, except for the morbid obesity category. Nevertheless, not all training modalities were studied in the same populations. For instance, participants in the high-intensity training studies were generally younger, whereas those participating in training studies where muscle strength was the outcome were on average older and had lower BMIs.

Intervention durations ranged between 2 and 70 weeks. There was some evidence that very short (2–4 weeks) and very long durations (>26 weeks) were associated with less pronounced training effects, which may be related with the time course of obtaining the optimal training effect: in short studies the optimal effect may not have been attained yet, whereas in longer duration interventions reduced compliance may play a role in diminishing the training effect.

In conclusion, in individuals with overweight or obesity all training modalities included in this review (aerobic, resistance, combined aerobic and resistance and high-intensity interval training) increased $VO_{2max}$. HIIT and exercise programs that included aerobic training were the most effective. For muscle strength benefits, incorporation of resistance exercise in the training program is required. Health professionals should weigh these differences with the needs and preferences of the individual with overweight or obesity when advising on exercise.

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## CONFLICT OF INTEREST

No conflict of interest statement.

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## REFERENCES

1. Sui X, LaMonte MJ, Laditka JN, et al. Cardiorespiratory fitness and adiposity as mortality predictors in older adults. *JAMA*. 2007;298(21):2507-2516.
2. Tomlinson DJ, Erskine RM, Morse CI, Winwood K, Onambélé-Pearson G. The impact of obesity on skeletal muscle strength and structure through adolescence to old age. *Biogerontology*. 2016;17(3):467-483.
3. Wang CY, Haskell WL, Farrell SW, et al. Cardiorespiratory fitness levels among US adults 20-49 years of age: findings from the 1999-2004 National Health and Nutrition Examination Survey. *Am J Epidemiol*. 2010;171(4):426-435.
4. Miller CT, Fraser SF, Levinger I, et al. The effects of exercise training in addition to energy restriction on functional capacities and body composition in obese adults during weight loss: a systematic review. *PLoS One*. 2013;8(11):e81692.
5. Baker A, Sirois-Leclerc H, Tulloch H. The Impact of Long-Term Physical Activity Interventions for Overweight/Obese Postmenopausal Women on Adiposity Indicators, Physical Capacity, and Mental Health Outcomes: A Systematic Review. *J Obes*. 2016;2016:6169890.
6. Batacan RB Jr, Duncan MJ, Dalbo VJ, Tucker PS, Fenning AS. Effects of high-intensity interval training on cardiometabolic health: a systematic review and meta-analysis of intervention studies. *Br J Sports Med*. 2017;51(6):494-503.
7. Hita-Contreras F, Bueno-Notivol J, Martinez-Amat A, et al. Effect of exercise alone or combined with dietary supplements on anthropometric and physical performance measures in community-dwelling elderly people with sarcopenic obesity: A meta-analysis of randomized controlled trials. *Maturitas*. 2018;116:24-35.

8. Turk Y, Theel W, Kasteleyn MJ, et al. High intensity training in obesity: a Meta-analysis. *Obes Sci Pract*. 2017;3(3):258-271.
9. Su L, Fu J, Sun S, et al. Effects of HIIT and MICT on cardiovascular risk factors in adults with overweight and/or obesity: A meta-analysis. *PLoS One*. 2019;14(1):e0210644.
10. Blond MB, Rosenkilde M, Gram AS, et al. How does 6 months of active bike commuting or leisure-time exercise affect insulin sensitivity, cardiorespiratory fitness and intra-abdominal fat? A randomised controlled trial in individuals with overweight and obesity. *Br J Sports Med*. 2019;53(18):1183-1192.
11. Chin EC, Yu AP, Lai CW, et al. Low-Frequency HIIT Improves Body Composition and Aerobic Capacity in Overweight Men. *Med Sci Sports Exerc*. 2020;52(1):56-66.
12. Irwin ML, Yasui Y, Ulrich CM, et al. Effect of exercise on total and intra-abdominal body fat in postmenopausal women: a randomized controlled trial. *JAMA*. 2003;289(3):323-330.
13. Schjerve IE, Tyldum GA, Tjonna AE, et al. Both aerobic endurance and strength training programmes improve cardiovascular health in obese adults. *Clin Sci (Lond)*. 2008;115(9):283-293.
14. Schroeder EC, Franke WD, Sharp RL, Lee DC. Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: A randomized controlled trial. *PLoS One*. 2019;14(1):e0210292.
15. Slentz CA, Bateman LA, Willis LH, et al. Effects of aerobic vs. resistance training on visceral and liver fat stores, liver enzymes, and insulin resistance by HOMA in overweight adults from STRRIDE AT/RT. *Am J Physiol Endocrinol Metab*. 2011;301(5):E1033-E1039.
16. Review Manager (RevMan). Version 5.3. In: Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration; 2014.
17. Cohen J. *Statistical power analysis for the behavioral sciences*. USA: Lawrence Erlbaum Associates; 1988.
18. Higgins JPT, Green S. Cochrane Handbook for systematic reviews of interventions. In: version 5.1.0. 2011.
19. Patsopoulos NA, Evangelou E, Ioannidis JP. Sensitivity of between-study heterogeneity in meta-analysis: proposed metrics and empirical evaluation. *Int J Epidemiol*. 2008;37(5):1148-1157.
20. Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *Circulation*. 2014;129(25 suppl 2):S102-S138.
21. Ahmadizad S, Haghighi AH, Hamedinia MR. Effects of resistance versus endurance training on serum adiponectin and insulin resistance index. *Eur J Endocrinol*. 2007;157(5):625-631.
22. Brooker PG, Gomersall SR, King NA, Leveritt MD. The feasibility and acceptability of morning versus evening exercise for overweight and obese adults: A randomized controlled trial. *Contemp Clin Trials Commun*. 2019;14:100320.
23. Cao L, Jiang Y, Li Q, Wang J, Tan S. Exercise Training at Maximal Fat Oxidation Intensity for Overweight or Obese Older Women: A Randomized Study. *J Sports Sci Med*. 2019;18(3):413-418.
24. Church TS, Earnest CP, Skinner JS, Blair SN. Effects of different doses of physical activity on cardiorespiratory fitness among sedentary, overweight or obese postmenopausal women with elevated blood pressure: a randomized controlled trial. *JAMA*. 2007;297(19):2081-2091.
25. Donnelly JE, Honas JJ, Smith BK, et al. Aerobic exercise alone results in clinically significant weight loss for men and women: midwest exercise trial 2. *Obesity (Silver Spring)*. 2013;21(3):E219-E228.
26. Duscha BD, Slentz CA, Johnson JL, et al. Effects of exercise training amount and intensity on peak oxygen consumption in middle-age men and women at risk for cardiovascular disease. *Chest*. 2005;128(4):2788-2793.
27. Emerenziani GP, Gallotta MC, Meucci M, et al. Effects of Aerobic Exercise Based upon Heart Rate at Aerobic Threshold in Obese Elderly Subjects with Type 2 Diabetes. *Int J Endocrinol*. 2015;2015:695297.
28. Gerosa-Neto J, Panissa VLG, Monteiro PA, et al. High- or moderate-intensity training promotes change in cardiorespiratory fitness, but not visceral fat, in obese men: A randomised trial of equal energy expenditure exercise. *Respir Physiol Neurobiol*. 2019;266:150-155.
29. Ho SS, Dhaliwal SS, Hills AP, Pal S. The effect of 12 weeks of aerobic, resistance or combination exercise training on cardiovascular risk factors in the overweight and obese in a randomized trial. *BMC Public Health*. 2012;12(1):704.
30. Irving BA, Davis CK, Brock DW, et al. Effect of exercise training intensity on abdominal visceral fat and body composition. *Med Sci Sports Exerc*. 2008;40(11):1863-1872.
31. Jurio-Iriarte B, Maldonado-Martin S. Effects of Different Exercise Training Programs on Cardiorespiratory Fitness in Overweight/Obese Adults With Hypertension: A Pilot Study. *Health Promot Pract*. 2019;20(3):390-400.
32. Keating SE, Hackett DA, Parker HM, et al. Effect of aerobic exercise training dose on liver fat and visceral adiposity. *J Hepatol*. 2015;63(1):174-182.
33. Kim HJ, Lee HJ, So B, Son JS, Yoon D, Song W. Effect of aerobic training and resistance training on circulating irisin level and their association with change of body composition in overweight/obese adults: a pilot study. *Physiol Res*. 2016;65(2):271-279.
34. Kirk EP, Jacobsen DJ, Gibson C, Hill JO, Donnelly JE. Time course for changes in aerobic capacity and body composition in overweight men and women in response to long-term exercise: the Midwest Exercise Trial (MET). *Int J Obes Relat Metab Disord*. 2003;27(8):912-919.
35. Moghadasi M, Mohebbi H, Rahmani-Nia F, Hassan-Nia S, Noroozi H, Pirooznia N. High-intensity endurance training improves adiponectin mRNA and plasma concentrations. *Eur J Appl Physiol*. 2012;112(4):1207-1214.
36. Nader S, Shahram S, Elham Y. The effect of endurance training on adiponectin and insulin resistance in overweight female university students. *Acta Medica Mediterra*. 2016;32:1007-1010.
37. Ramos RM, Coelho-Junior HJ, Asano RY, et al. Impact of Moderate Aerobic Training on Physical Capacities of Hypertensive Obese Elderly. *Gerontol Geriatr Med*. 2019;5:2333721419859691.
38. Rayes ABR, de Lira CAB, Viana RB, et al. The effects of Pilates vs. aerobic training on cardiorespiratory fitness, isokinetic muscular strength, body composition, and functional tasks outcomes for individuals who are overweight/obese: a clinical trial. *PeerJ*. 2019;7:e6022.
39. Reichkendler MH, Rosenkilde M, Auerbach PL, et al. Only minor additional metabolic health benefits of high as opposed to moderate dose physical exercise in young, moderately overweight men. *Obesity (Silver Spring)*. 2014;22(5):1220-1232.
40. Utter AC, Nieman DC, Shannonhouse EM, Butterworth DE, Nieman CN. Influence of diet and/or exercise on body composition and cardiorespiratory fitness in obese women. *Int J Sport Nutr*. 1998;8(3):213-222.
41. Zhang H, Tong TK, Qiu W, et al. Comparable Effects of High-Intensity Interval Training and Prolonged Continuous Exercise Training on Abdominal Visceral Fat Reduction in Obese Young Women. *J Diabetes Res*. 2017;2017:5071740.
42. Batrakoulis A, Jamurtas AZ, Georgakouli K, et al. High intensity, circuit-type integrated neuromuscular training alters energy balance and reduces body mass and fat in obese women: A 10-month training-detraining randomized controlled trial. *PLoS One*. 2018;13(8):e0202390.

43. Keating SE, Hackett DA, Parker HM, et al. Effect of resistance training on liver fat and visceral adiposity in adults with obesity: A randomized controlled trial. *Hepatol Res*. 2017;47(7):622-631.
44. Banitalebi E, Kazemi A, Faramarzi M, Nasiri S, Haghighi MM. Effects of sprint interval or combined aerobic and resistance training on myokines in overweight women with type 2 diabetes: A randomized controlled trial. *Life Sci*. 2019;217:101-109.
45. Hara T, Fujiwara H, Nakao H, Mimura T, Yoshikawa T, Fujimoto S. Body composition is related to increase in plasma adiponectin levels rather than training in young obese men. *Eur J Appl Physiol*. 2005;94(5-6):520-526.
46. Park SM, Kwak YS, Ji JG. The Effects of Combined Exercise on Health-Related Fitness, Endotoxin, and Immune Function of Postmenopausal Women with Abdominal Obesity. *J Immunol Res*. 2015;2015:830567.
47. Bonfante IL, Chacon-Mikahil MP, Brunelli DT, et al. Combined training, FNDC5/irisin levels and metabolic markers in obese men: A randomised controlled trial. *Eur J Sport Sci*. 2017;17(5):629-637.
48. Arad AD, DiMenna FJ, Thomas N, et al. High-intensity interval training without weight loss improves exercise but not basal or insulin-induced metabolism in overweight/obese African American women. *J Appl Physiol (1985)*. 2015;119:352-362.
49. Jabbour G, Iancu HD, Paulin A. Effects of High-Intensity Training on Anaerobic and Aerobic Contributions to Total Energy Release During Repeated Supramaximal Exercise in Obese Adults. *Sports Med Open*. 2015;1(1):36.
50. Smith-Ryan AE, Trexler ET, Wingfield HL, Blue MN. Effects of high-intensity interval training on cardiometabolic risk factors in overweight/obese women. *J Sports Sci*. 2016;34(21):2038-2046.
51. Tong TK, Zhang H, Shi H, et al. Comparing Time Efficiency of Sprint vs. High-Intensity Interval Training in Reducing Abdominal Visceral Fat in Obese Young Women: A Randomized, Controlled Trial. *Front Physiol*. 2018;9:1048.
52. Trilk JL, Singhal A, Bigelman KA, Cureton KJ. Effect of sprint interval training on circulatory function during exercise in sedentary, overweight/obese women. *Eur J Appl Physiol*. 2011;111(8):1591-1597.
53. Kim B, Kim S. Influences of Resistance versus Aerobic Exercise on Physiological and Physical Fitness Changes in Previously Inactive Men with Obesity: A Prospective, Single-Blinded Randomized Controlled Trial. *Diabetes Metab Syndr Obes*. 2020;13:267-276.
54. Sawczyn S, Mishchenko V, Moska W, et al. Strength and aerobic training in overweight females in Gdansk, Poland. *Open Med (Wars)*. 2015;10(1):152-162.
55. Skrypnik D, Bogdanski P, Madry E, et al. Effects of Endurance and Endurance Strength Training on Body Composition and Physical Capacity in Women with Abdominal Obesity. *Obes Facts*. 2015;8(3):175-187.
56. Baekkerud FH, Solberg F, Leinan IM, et al. Comparison of Three Popular Exercise Modalities on VO2max in Overweight and Obese. *Med Sci Sports Exerc*. 2016;48:491-498.
57. Cheema BS, Davies TB, Stewart M, Papalia S, Atlantis E. The feasibility and effectiveness of high-intensity boxing training versus moderate-intensity brisk walking in adults with abdominal obesity: a pilot study. *BMC Sports Sci Med Rehabil*. 2015;7(1):3.
58. Cocks M, Shaw CS, Shepherd SO, et al. Sprint interval and moderate-intensity continuous training have equal benefits on aerobic capacity, insulin sensitivity, muscle capillarisation and endothelial eNOS/NAD(P)Hoxidase protein ratio in obese men. *J Physiol*. 2016;594(8):2307-2321.
59. De Strijcker D, Lapauw B, Ouwens DM, et al. High intensity interval training is associated with greater impact on physical fitness, insulin sensitivity and muscle mitochondrial content in males with overweight/obesity, as opposed to continuous endurance training: a randomized controlled trial. *J Musculoskelet Neuronal Interact*. 2018;18(2):215-226.
60. Fisher G, Brown AW, Bohan Brown MM, et al. High Intensity Interval- vs Moderate Intensity- Training for Improving Cardiometabolic Health in Overweight or Obese Males: A Randomized Controlled Trial. *PLoS One*. 2015;10(10):e0138853.
61. Kong Z, Sun S, Liu M, Shi Q. Short-Term High-Intensity Interval Training on Body Composition and Blood Glucose in Overweight and Obese Young Women. *J Diabetes Res*. 2016;2016:4073618.
62. Lunt H, Draper N, Marshall HC, et al. High intensity interval training in a real world setting: a randomized controlled feasibility study in overweight inactive adults, measuring change in maximal oxygen uptake. *PLoS One*. 2014;9(1):e83256.
63. Martins C, Kazakova I, Ludviksen M, et al. High-Intensity Interval Training and Isocaloric Moderate-Intensity Continuous Training Result in Similar Improvements in Body Composition and Fitness in Obese Individuals. *Int J Sport Nutr Exerc Metab*. 2016;26(3):197-204.
64. Sun S, Zhang H, Kong Z, Shi Q, Tong TK, Nie J. Twelve weeks of low volume sprint interval training improves cardio-metabolic health outcomes in overweight females. *J Sports Sci*. 2019;37(11):1257-1264.
65. Higgins S, Fedewa MV, Hathaway ED, Schmidt MD, Evans EM. Sprint interval and moderate-intensity cycling training differentially affect adiposity and aerobic capacity in overweight young-adult women. *Appl Physiol Nutr Metab*. 2016;41(11):1177-1183.
66. Robinson E, Durrer C, Simtchouk S, et al. Short-term high-intensity interval and moderate-intensity continuous training reduce leukocyte TLR4 in inactive adults at elevated risk of type 2 diabetes. *J Appl Physiol (1985)*. 2015;119:508-516.
67. Vella CA, Taylor K, Drummer D. High-intensity interval and moderate-intensity continuous training elicit similar enjoyment and adherence levels in overweight and obese adults. *Eur J Sport Sci*. 2017;17(9):1203-1211.
68. Blake A, Miller WC, Brown DA. Adiposity does not hinder the fitness response to exercise training in obese women. *J Sports Med Phys Fitness*. 2000;40(2):170-177.
69. Gondim OS, de Camargo VT, Gutierrez FA, et al. Benefits of Regular Exercise on Inflammatory and Cardiovascular Risk Markers in Normal Weight. *Overweight and Obese Adults PLoS One*. 2015;10:e0140596.
70. Chen HT, Chung YC, Chen YJ, Ho SY, Wu HJ. Effects of Different Types of Exercise on Body Composition, Muscle Strength, and IGF-1 in the Elderly with Sarcopenic Obesity. *J am Geriatr Soc*. 2017;65(4):827-832.
71. Sarsan A, Ardic F, Ozgen M, et al. The effects of aerobic and resistance exercises in obese women. *Clin Rehabil*. 2006;20(9):773-782.
72. Fritz NB, Juesas A, Gargallo P, et al. Positive Effects of a Short-Term Intense Elastic Resistance Training Program on Body Composition and Physical Functioning in Overweight Older Women. *Biol Res Nurs*. 2018;20(3):321-334.
73. Liao CD, Tsauo JY, Huang SW, Ku JW, Hsiao DJ, Liou TH. Effects of elastic band exercise on lean mass and physical capacity in older women with sarcopenic obesity: A randomized controlled trial. *Sci Rep*. 2018;8(1):2317.
74. Plotnikoff RC, Eves N, Jung M, Sigal RJ, Padwal R, Karunamuni N. Multicomponent, home-based resistance training for obese adults with type 2 diabetes: a randomized controlled trial. *Int J Obes (Lond)*. 2010;34(12):1733-1741.
75. Rustaden AM, Haakstad LAH, Paulsen G, Bo K. Effects of BodyPump and resistance training with and without a personal trainer on muscle strength and body composition in overweight and obese women-A randomised controlled trial. *Obes Res Clin Pract*. 2017;11(6):728-739.
76. Vasconcelos KS, Dias JM, Araujo MC, et al. Effects of a progressive resistance exercise program with high-speed component on the physical function of older women with sarcopenic obesity: a randomized controlled trial. *Braz J Phys Ther*. 2016;20(5):432-440.
77. Vincent KR, Braith RW, Vincent HK. Influence of resistance exercise on lumbar strength in older, overweight adults. *Arch Phys Med Rehabil*. 2006;87(3):383-389.

78. Wong A, Figueroa A. The Effects of Low Intensity Resistance Exercise on Cardiac Autonomic Function and Muscle Strength in Obese Postmenopausal Women. *J Aging Phys Act*. 2019;27(6):855-860.
79. Kang H, Lee Y, Park D, Kang D. Effects of 12-week circuit weight training and aerobic exercise on body composition, physical fitness, and pulse wave velocity in obese collegiate women. *Soft Computing*. 2012;16(3):403-410.
80. Park J, Kwon Y, Park H. Effects of 24-Week Aerobic and Resistance Training on Carotid Artery Intima-Media Thickness and Flow Velocity in Elderly Women with Sarcopenic Obesity. *J Atheroscler Thromb*. 2017;24(11):1117-1124.
81. Zemkova E, Kyselovicova O, Jelen M, et al. Upper and Lower Body Muscle Power Increases After 3-Month Resistance Training in Overweight and Obese Men. *Am J Mens Health*. 2017;11(6):1728-1738.
82. Pescatello LS, Kelsey BK, Price TB, et al. The muscle strength and size response to upper arm, unilateral resistance training among adults who are overweight and obese. *J Strength Cond Res*. 2007;21(2):307-313.
83. Manini TM, Newman AB, Fielding R, et al. Effects of exercise on mobility in obese and nonobese older adults. *Obesity (Silver Spring)*. 2010;18(6):1168-1175.
84. Ozaki H, Loenneke JP, Thiebaud RS, Abe T. Resistance training induced increase in VO2max in young and older subjects. *Eur Rev Aging Phys Act*. 2013;10(2):107-116.
85. Zouhal H, Ben Abderrahman A, Khodamoradi A, et al. Effects of physical training on anthropometrics, physical and physiological capacities in individuals with obesity: A systematic review. *Obes Rev*. 2020;21:e13039.
86. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011;43(7):1334-1359.

## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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