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# Concurrent aerobic plus resistance exercise versus aerobic exercise alone to improve health outcomes in paediatric obesity: a systematic review and meta-analysis

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## ABSTRACT

**Objective** To determine if the combination of aerobic and resistance exercise is superior to aerobic exercise alone for the health of obese children and adolescents.

**Design** Systematic review with meta-analysis.

**Data sources** Computerised search of 3 databases (MEDLINE, EMBASE, and Cochrane Controlled Trials Registry).

**Eligibility criteria for selecting studies** Studies that compared the effect of supervised concurrent exercise versus aerobic exercise interventions, with anthropometric and metabolic outcomes in paediatric obesity (6–18 years old). The mean differences (MD) of the parameters from preintervention to postintervention between groups were pooled using a random-effects model.

**Results** 12 trials with 555 youths were included in the meta-analysis. Compared with aerobic exercise alone, concurrent exercise resulted in greater reductions in body mass (MD=−2.28 kg), fat mass (MD=−3.49%; and MD=−4.34 kg) and low-density lipoprotein cholesterol (MD=−10.20 mg/dL); as well as greater increases in lean body mass (MD=2.20 kg) and adiponectin level (MD=2.59 µg/mL). Differences were larger for longer term programmes (>24 weeks).

**Summary** Concurrent aerobic plus resistance exercise improves body composition, metabolic profiles, and inflammatory state in the obese paediatric population.

**Trial registration number** CRD42016039807.

## INTRODUCTION

The prevalence of obesity in paediatric populations has increased over the past two decades.<sup>1</sup> The WHO has recommended lifestyle interventions to reduce 5–10% of body weight as the primary preventive and management strategy for overweight and obesity.<sup>2</sup> Excess fat mass, particularly in the visceral depot, results in more detrimental obesity-related health effects than just excess body weight.<sup>3</sup> Reducing visceral adipose tissue improves cardiovascular and metabolic risk.<sup>4</sup>

Organisations such as the US Office of Disease Prevention and Health Promotion have sanctioned Physical Activity Guidelines for Americans, which recommend 60 min or more of moderate-intensity aerobic physical activity each day for children and adolescents.<sup>5</sup> In addition, this organisation encourages engagement in regular bone-strengthening and muscle-strengthening activities on at least 3 days of the week.<sup>6,7</sup> In the obese paediatric population, both aerobic exercise

training (AT) and resistance exercise training (RT) improve low-density lipoprotein (LDL-C) and triglycerides (TG) concentrations,<sup>8</sup> systolic blood pressure (SBP),<sup>9</sup> flow-mediated dilation,<sup>10</sup> fasting insulin and glucose,<sup>11</sup> and body composition.<sup>12</sup>

Although the benefits of AT and RT alone are well documented, research examining concurrent exercise (ie, the simultaneous integration of RT and AT into a periodised training regimen) in the paediatric population has been limited. Among adults, two recent meta-analysis in obese and patients with type 2 diabetes suggested that concurrent exercise is the most efficacious means to improve anthropometric indicators of adiposity,<sup>13</sup> glycaemic control, and blood lipids,<sup>14</sup> as compared with AT or RT alone. It is unclear whether these benefits would be similar for treating paediatric obesity. In a recent randomised controlled trial (RCT), adding sprint intervals to a concurrent exercise programme provided greater benefits than only RT in young obese women.<sup>15</sup> Likewise, a recent systematic review and meta-analysis on 2247 overweight and/or obese children and adolescents<sup>12</sup> observed significant improvements in lipid profiles and body composition after long-term (ie, 6–52 weeks) interventions that combined RT and AT. However, despite the rising prevalence of obesity, and the multiple position stands promoting exercise for the treatment of obesity and cardiometabolic health, a meta-analytic approach has not previously been used to examine the effects of concurrent exercise compared with AT alone in the obese paediatric population.<sup>16</sup> Therefore, the purpose of this systematic review and meta-analysis was to investigate the effect of concurrent exercise versus AT alone on anthropometric and metabolic outcomes in obese children and adolescents.

## METHODS

This review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (identifier CRD42016039807). However, no study protocol was published before the initiation of the meta-analysis. The study was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.<sup>17</sup>

## Literature search

Queries of the literature were performed using the electronic databases Cochrane Central Register of

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Controlled Trials (CENTRAL), EMBASE, and MEDLINE (all: until 27 May 2016). The search strategy used included a combination of the following Medical Subject Headings (MeSH) terms: obesity AND exercise AND youth AND adolescent AND health. Keyword iterations related to these terms were also used (online supplementary file 1). Also, the reference lists of the included studies were examined as an additional check for potential studies that could be used in this review.

### Eligibility criteria

The a priori inclusion criteria for study inclusion were as follows: (1) children and/or adolescents classified as overweight or obese; (2) RCT and non-RCT (quasi-experimental trials); (3) supervised exercise interventions (ie, not home-based exercise) without hypocaloric diet intervention; (4) comparison of concurrent exercise versus AT; and (5) an assessment of at least one of the following parameters: body composition, lipid profiles, glucose homeostasis, blood pressure, adipokines, and cardiorespiratory fitness. We utilised the following exclusion criteria: studies describing lifestyle interventions not including a well-defined concurrent physical exercise component, studies including patients older than 18 years and younger than 6 years old, studies comparing only the impact of intervention duration, and studies not providing an adequate control group for comparison. All abstracts and full text were assessed for eligibility independently by two authors (AG-H and RR-V). If necessary, a third researcher (RR-C) was consulted. Finally, non-English studies were not explored.

### Data extraction

Two investigators (AG-H and RR-V) independently abstracted all data. For each study, data were extracted regarding the first author's last name, year of publication, characteristics of participants, exercise programmes (type, frequency, duration, and intensity), assessments, sample size, and differences in the means of two time points or postintervention mean values with corresponding SDs. By protocol, we did not restrict inclusion to a specific primary or secondary outcome. The outcome measures were: body mass, body mass index (BMI), waist circumference, fat mass percentage, absolute fat mass, lean body mass (LBM), visceral fat, subcutaneous fat, total cholesterol, high-density lipoprotein (HDL), LDL, TG, fasting glucose, fasting insulin, homeostatic model assessment (HOMA)-IR index, blood pressure, SBP, adiponectin, and leptin (table 1). When there was insufficient information, the respective corresponding author was contacted.

### Risk of bias

Full copies of the studies were independently assessed by two authors (AG-H and RR-V) for methodological quality using the Delphi list, as described by Verhagen *et al.*<sup>18</sup> This assessment includes eight questions with three response options 'yes', 'no', or 'do not know' depending on the compliance with key methodological components, and produces a quality score that provides an overall estimate of the studies' quality. Finally, we did not use risk of bias to inform pooling of data.

### Meta-analysis calculation

All analyses were carried out using Comprehensive Meta-analysis Software (2nd version, Biostat, Englewood, New Jersey, USA) to calculate the standardised mean difference (SMD) and the mean difference or difference in means (MD), a standard statistic that measures the absolute difference between the mean values in two groups in a clinical trial.<sup>19</sup> The SMD and MD of the health parameters (table 1) from preintervention to

**Table 1** List of outcome measures and other data extracted from included studies

Data	Type	Units
Body mass	Outcome	kg
Body mass index	Outcome	kg/m <sup>2</sup>
Waist circumference	Outcome	cm
Fat mass	Outcome	%
Fat mass	Outcome	kg
Lean body mass	Outcome	kg
Visceral fat	Outcome	cm
Subcutaneous fat	Outcome	cm
Total cholesterol	Outcome	mg/dL
HDL	Outcome	mg/dL
LDL	Outcome	mg/dL
Triglycerides	Outcome	mg/dL
Fasting glucose	Outcome	mg/dL
Fasting insulin	Outcome	μU/mL
HOMA-IR	Outcome	
Systolic blood pressure	Outcome	mm Hg
Adiponectin	Outcome	μg/mL
Leptin	Outcome	μg/mL
Session duration	Covariate	Minutes
Programme duration	Covariate	Weeks
Session frequency	Covariate	Sessions per week
Exercise modality	Covariate	Type of activity
Year	Year of publication	Year

HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment; LDL, low-density lipoprotein.

postintervention, between groups (concurrent exercise vs AT)<sup>20</sup> in each study, were calculated and pooled using the random-effects model (DerSimonian-Laird approach). The underlying assumption of the random-effects model is that samples are drawn from populations with different effect sizes, and that true effects differ between studies (interventions, duration, etc). Data were pooled if outcomes were reported by at least three studies.

Heterogeneity between trial results was tested with a Cochran's Q test<sup>21</sup> and I<sup>2</sup> statistic. I<sup>2</sup> values of <25%, 25–50%, and >50% are considered to represent small, medium, and large amounts of inconsistency.<sup>22</sup>

Each study was deleted from the model once in order to analyse the influence of each study on the overall results. Egger regression tests were performed to detect small study effects<sup>23</sup> and possible publication bias.

In addition, a stratified exploratory analysis was performed using the same procedures as the main analysis, comparing the design type (RCT and non-RCT) and short-term (≤24 weeks) versus long-term (>24 weeks) interventions.

## RESULTS

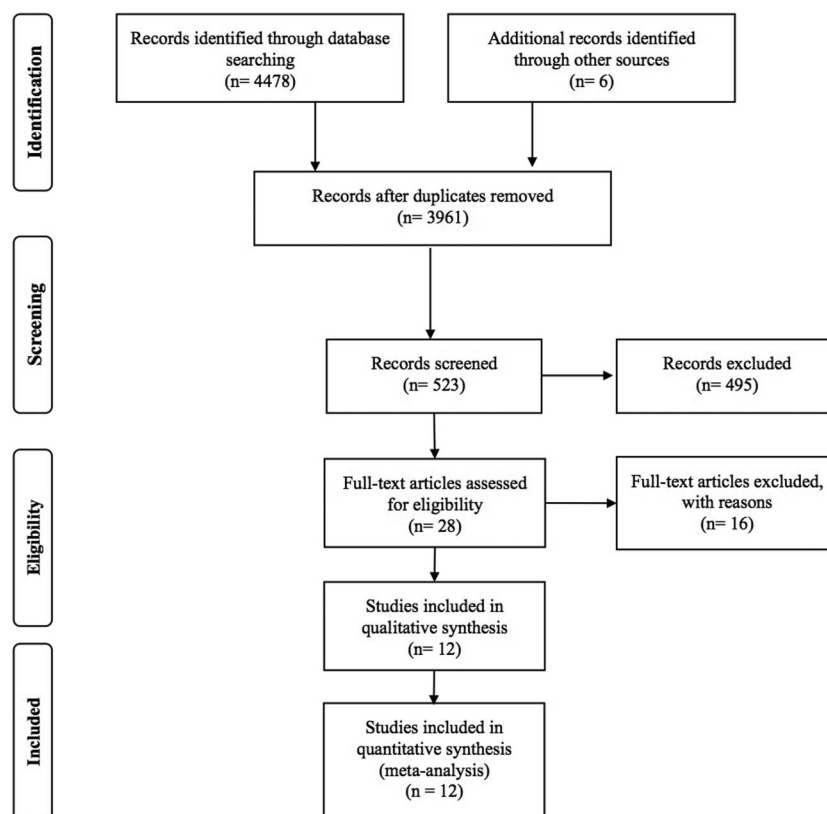
### Study selection

Our search strategy and exclusion criteria resulted in a total of 12 studies, extracted from 4484 articles that met the objectives, and were included in the systematic review and meta-analysis.<sup>24–35</sup> The detailed steps of the article selection process for the meta-analysis are described as a flow diagram in figure 1. Exclusion criteria and the list of excluded articles are in online supplementary file 2.

### Description of included studies

Table 2 summarises the study characteristics. The final analysis included a total of 555 youth (283 and 272 in concurrent

**Figure 1** Flow chart for identification of trials for inclusion in the meta-analysis.



exercise and AT group, respectively). Three studies included the same population, but analysed different parameters.<sup>25 26 35</sup> Nine studies recruited obese youth exclusively;<sup>24 27–34</sup> whereas, the rest targeted both overweight and obese children.<sup>25 26 35</sup> Most studies (n=8) included adolescents (aged 13–18 years),<sup>24–32 35</sup> one included only children,<sup>33</sup> and one enrolled both children and adolescents.<sup>34</sup> All studies included boys and girls. Sample sizes across studies ranged from 30 to 150, with a mean of 55 participants.

The primary mode of the AT programmes were based on treadmills and cycle ergometers,<sup>24 27–32</sup> elliptical trainers,<sup>25 26 35</sup> walking and running programmes,<sup>34</sup> and sports participation.<sup>33</sup> The exercise intensity was monitored using either maximum heart rate,<sup>24–33 35</sup> or peak oxygen uptake.<sup>34</sup>

For resistance exercise, studies used body weight exercise,<sup>34</sup> free weights,<sup>24 27–32</sup> selectorised machines,<sup>25 26 35</sup> or circuit training.<sup>33</sup>

Interventions duration varied from 10 to 48 weeks, with a mean of 30 weeks.

### Risk of bias

Among the included studies, all satisfied the quality criteria for inclusion. Baseline group comparison, point estimate and variability can be seen in the supplementary file 3. Eight studies were allocation randomised,<sup>24–26 29 31 32 34 35</sup> five used blind assessors,<sup>25 26 29 31 35</sup> and four used intention-to-treat analysis.<sup>25 26 34 35</sup>

### Meta-analysis

The results of meta-analysis showed that concurrent exercise was superior to AT in terms of reducing body mass (MD=−2.28 kg, 95% CI −4.56 to −0.01; p=0.049; I<sup>2</sup>=0%; SMD=−0.16), fat mass percentage (MD=−3.49%, 95% CI −5.75 to −1.24; p=0.002; I<sup>2</sup>=67.9%; SMD=−0.47) and

absolute fat mass (MD=−4.34 kg, 95% CI −7.15 to −1.53; p=0.002; I<sup>2</sup>=58.2%; SMD=−0.43), and LDL cholesterol (MD=−10.20 mg/dL, 95% CI −17.97 to −2.43; p=0.01; I<sup>2</sup>=30.8%; SMD=−0.35). Also, compared with AT, concurrent exercise programmes were associated with greater increases in LBM (MD=2.20 kg, 95% CI 0.20 to 4.19; p=0.03; I<sup>2</sup>=48.2%; SMD=0.27) and adiponectin levels (MD=2.59 µg/mL, 95% CI 1.81 to 3.32; p<0.001; I<sup>2</sup>=0%; SMD=0.79) (table 3). The forest-plots are in supplementary file 4.

Subgroup analyses are shown in supplementary file 5. Regarding design of the trials, results remained significant on analysing only RCTs: concurrent exercise was superior to AT for reducing BMI (MD=−1.01 kg/m<sup>2</sup>, 95% CI −1.85 to −0.18; p=0.02; SMD=−0.23), fat mass percentage (MD=−3.54%, 95% CI −6.05 to −1.02; p=0.01; SMD=−0.49) and absolute fat mass (MD=−4.41 kg, 95% CI −7.21 to −1.62; p=0.002; SMD=−0.46), LDL cholesterol (MD=−9.63 mg/dL, 95% CI −16.67 to −2.58; p=0.01; SMD=−0.31), insulin (MD=−2.43 µU/mL, 95% CI −4.55 to −0.32; p=0.02; SMD=−0.31), HOMA-IR (MD=−0.68, 95% CI −1.33 to −0.02; p=0.04; SMD=−0.40), and increasing LBM (MD=2.81 kg, 95% CI 0.57 to 5.04; p=0.01; SMD=0.27) and adiponectin (MD=2.50 µg/mL, 95% CI 1.70 to 3.30; p<0.001; SMD=0.76).

Also, compared with AT, long-term concurrent exercise programmes generated greater improvements than short-term programmes for: body mass (MD=−3.13 kg, 95% CI −6.01 to −0.24; p=0.03; SMD=−0.23), BMI (MD=−1.34 kg/m<sup>2</sup>, 95% CI −2.35 to −0.33; p=0.01; SMD=−0.29), fat mass percentage (MD=−4.68%, 95% CI −6.85 to −2.51; p<0.001; SMD=−0.58) and absolute fat mass (MD=−5.58 kg, 95% CI −9.08 to −2.12; p=0.002; SMD=−0.43), subcutaneous fat (MD=−0.36 cm, 95% CI −0.63 to −0.09; p=0.01; SMD=−0.36), total cholesterol (MD=−27.16 mg/dL, 95% CI −51.12 to −3.21; p=0.03; SMD=−0.80), LDL cholesterol

**Table 2** Characteristics of the studies included in the meta-analysis

Study	Participants (n)/BMI (kg/m <sup>2</sup> or percentile)	Groups	Groups size	Modality	Intervention duration (weeks)	Frequency (days/week)	Session (minutes)	Outcomes
Ackel-D'Elia <i>et al.</i> <sup>25</sup> 2014	48 (16 boys, 32 girls, 15–18 years of age)/ ≥p95	CE AT	24 24	Treadmill+free weights Treadmill	24	3	60	BM, BMI, BF (% and kg), LBM (% and kg), glucose, insulin, HOMA-IR, and leptin
Alberga <i>et al.</i> <sup>26</sup> 2015	150 (44 boys, 106 girls, 14–18 years of age)/ ≥p85	CE AT	75 75	Treadmill, cycle ergometer or elliptical +free weights and machines	22	2	20–40	VO2max CRP, VAT, and SAT
Alberga <i>et al.</i> <sup>27</sup> 2016				Treadmill, cycle ergometer or elliptical				BM, BMI, BF (% and kg), LBM (kg), WC, TC, HDL, LDL, TG, glucose, insulin, SBP, DBP
Sigal <i>et al.</i> <sup>35</sup> 2014								
Campos <i>et al.</i> <sup>28</sup> 2014	42 (28 boys, 14 girls, 14–18 years of age)/ ≥p95	CE AT	21 21	Treadmill+free weights Treadmill	48	3	60	BM, BMI, BF (% and kg), LBM (kg), VAT, SAT, glucose, insulin, HOMA-IR, and leptin
Carnier <i>et al.</i> <sup>29</sup> 2013	26 (10 boys, 16 girls, 14–18 years of age)/ ≥p95	CE AT	13 13	Treadmill+free weights and machines Treadmill	48	3	60	BM, BMI, BF (kg), and LBM (kg)
Dâmaso <i>et al.</i> <sup>30</sup> 2014	116 (57 boys, 82 girls, 14–18 years of age)/ ≥p95	CE AT	61 55	Treadmill+free weights Treadmill	48	3	60	BM, BMI, BF (% and kg), LBM (% and kg), VAT, SAT, TC, HDL, LDL, TG, glucose, insulin, HOMA-IR, leptin, and adiponectin
de Mello <i>et al.</i> <sup>31</sup> 2011	30 (20 boys, 10 girls, 14–18 years of age)/ ≥p95	CE AT	15 15	Treadmill+free weights Treadmill	48	3	60	BM, BMI, BF (% and kg), LBM (kg), VAT, SAT, WC, TC, HDL, LDL, TG, glucose, insulin, HOMA-IR, SBP, DBP, and adiponectin
de Piano <i>et al.</i> <sup>32</sup> 2012	30 (20 boys, 10 girls, 14–18 years of age)/ ≥p95	CE AT	15 15	Treadmill+free weights Treadmill	48	3	60	BM, BMI, BF (% and kg), LBM (kg), VAT, SAT, TC, HDL, LDL, TG, glucose, insulin, HOMA-IR, leptin, and adiponectin
Inoue <i>et al.</i> <sup>18</sup> 2015	45 (17 boys, 28 girls, 14–18 years of age)/ ≥p95	CE CE AT	13 12 20	Treadmill+free weights* Treadmill+free weights* Treadmill	48	3	60	BM, BMI, BF (% and kg), LBM (kg), VAT, TC, HDL, LDL, TG, glucose, insulin, HOMA-IR, and adiponectin
Lee <i>et al.</i> <sup>33</sup> 2010	36 (12–14 years of age)/ ≥p95	CE AT	20 16	Circuit weight training Sports	10	2	60	BMI, WC, TC, HDL, LDL, TG, glucose, CRP, and VO2max
Monteiro <i>et al.</i> <sup>34</sup> 2015	32 (19 boys, 13 girls, 11–17 years of age)/ sex and-age BMI-IOTF	CE AT	14 18	Walking and running +own body weight Walking and running	20	3	50	BM, BMI, BF (% and kg), LBM (kg), VAT, SAT, WC, HDL, LDL, and TG

\*Applied different periodisation.

AE, aerobic training; BF, body fat; BM, body mass; BMI, body mass index; CE, concurrent exercise; CRP, C reactive protein; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment; IOTF, International Obesity Task Force; LBM, lean body mass; LDL, low-density lipoprotein; SAT, subcutaneous fat; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; VAT, visceral fat; VO2max, maximal oxygen consumption; WC, waist circumference.

(MD=−20.61 mg/dL, 95% CI −31.25 to −9.96;  $p<0.001$ ; SMD=−0.69), and greater increases than short-term programmes in LBM (MD=3.07 kg, 95% CI 0.09 to 6.05;  $p=0.04$ ; SMD=0.32). In contrast, long-term AT programmes were more effective in reducing TG (MD=15.26 mg/dL, 95% CI 4.66 to 25.87;  $p=0.01$ ; SMD=0.35) than concurrent exercise.

### Publication bias and sensitivity analysis

Egger's linear regression tests provided evidence for a potential publication bias for two outcomes: percentage of fat mass ( $p=0.014$ ) and TG ( $p<0.001$ ). In the sensitivity analysis, with each study deleted from the model once, the results remained consistent across all deletions, except for glucose, insulin and HOMA-IR, showing significant reductions after deleting the study by Campos *et al.*<sup>27</sup>

### DISCUSSION

We found that long-term (>24 weeks) concurrent exercise interventions provided greater health benefits than AT alone for

improving anthropometric indicators of adiposity (ie, body mass, percentage and kilograms of fat mass, lean mass) and metabolic characteristics (ie, LDL cholesterol, adiponectin) in obese children and adolescents.

### Effects on body composition

Current physical activity guidelines recommend a combination of AT and RT to optimise health and general cardiovascular benefits.<sup>36</sup> Recently, the American College of Sports Medicine confirmed that there is a lack of evidence to indicate that RT, without AT or dietary control, is sufficient to promote weight loss, and therefore its utilisation in combination with aerobic activities is recommended.<sup>37</sup> Our meta-analysis suggested concurrent exercise is indeed more efficient for anthropometric parameters, reducing BMI, and fat mass (in percentage and kilograms) as well as for increasing LBM, when compared with AT alone, with low-to-medium effect (SMD=−0.16 to −0.47).<sup>38</sup> According to another systematic review in obese youth, concurrent exercise promotes better results in body composition when



**Table 3** Effects of concurrent exercise compared with AT on body composition, lipid profile, glucose homeostasis, blood pressure and adipokines in paediatric population

	Study (n)	Participants (n)	MD (95% CI)	p Value	I <sup>2</sup> (%)	Egger test
<b>Body composition</b>						
Body mass, kg	9	487	−2.282 (−4.557 to −0.007)	0.049	0	0.430
Body mass index, kg/m <sup>2</sup>	10	540	−0.690 (−1.425 to 0.045)	0.066	7.1	0.231
Waist circumference, cm	4	247	−3.389 (−7.870 to 1.029)	0.133	63.8	0.140
Fat mass, %	8	493	−3.491 (−5.747 to −1.235)	0.002	67.9	0.014
Fat mass, kg	9	519	−4.337 (−7.147 to −1.528)	0.002	58.2	0.179
Lean body mass, kg	9	519	2.195 (0.204 to 4.186)	0.031	48.2	0.051
Visceral fat, cm	7	443	−0.051 (−0.402 to 0.299)	0.774	35.8	0.468
Subcutaneous fat, cm	6	378	−0.175 (−0.370 to 0.021)	0.081	6.9	0.129
<b>Lipids and lipoprotein</b>						
Total cholesterol, mg/dL	6	406	−17.59 (−39.95 to 4.767)	0.123	91.4	0.346
HDL, mg/dL	6	393	1.053 (−0.894 to 3.000)	0.289	0	0.470
LDL, mg/dL	7	438	−10.20 (−17.97 to −2.433)	0.010	30.8	0.066
Triglycerides, mg/dL	7	438	10.26 (−0.985 to 21.51)*	0.074	46.3	<0.001
<b>Insulin resistance</b>						
Fasting glucose, mg/dL	7	451	−0.422 (−1.119 to 0.275)	0.236	87.4	0.100
Fasting insulin, $\mu$ U/mL	6	416	−1.656 (−3.993 to 0.680)	0.165	53.4	0.404
HOMA-index	5	266	−0.403 (−1.151 to 0.346)	0.292	63.1	0.389
<b>Blood pressure</b>						
Systolic blood pressure, mm Hg	3	215	−2.907 (−12.12 to 6.311)	0.537	79.5	0.173
<b>Adipokines</b>						
Adiponectin, $\mu$ g/mL	5	263	2.591 (1.860 to 3.322)	<0.001	0	0.055
Leptin, $\mu$ g/mL	4	236	−6.810 (−13.73 to 0.107)	0.054	54.9	0.091

\*Positive MD indicates values that favour AT group; all other values indicate results that favour concurrent exercise group.  
AE, aerobic training programs; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MD, mean difference.

compared with RT and AT alone.<sup>12</sup> Similar results were reported in overweight and obese adults, again indicating that concurrent exercise is the most efficacious means to reduce obesity.<sup>13</sup> Also, studies in obese boys<sup>39, 40</sup> and girls<sup>40, 41</sup> separately showed that combined training (12–20 weeks) favour a reduction of ~3% in body adiposity, results are consistent with ours. A recent meta-analysis reported similar, but less reduction in adiposity among obese youth for exercise versus non-exercise controls (1.93% in the fat mass percentage).<sup>42</sup> Therefore, concurrent exercise training, especially over longer interventions, could be the optimal prescription to maximise the benefits of both modalities and counteract the potential decrease in muscle mass associated with AT-driven weight loss.<sup>29, 35</sup> Our results suggest that regular concurrent exercise training could produce greater reductions in cardiometabolic risk over the long-term, through reductions in the deep abdominal fat depot among overweight and obese youth.

### Effects on lipids and lipoprotein

While clinical exercise intervention trials support the efficacy of AT and RT in reducing the prevalence of metabolic risk, less is known about a combined approach in overweight and obese youth. Our meta-analysis indicates that concurrent exercise is more effective in reducing LDL cholesterol than AT programmes, with medium effect (SMD=−0.35).<sup>38</sup> Evidence suggests that intensity of effort may drive the positive effect of concurrent exercise training.<sup>40</sup> Although lipids are the principle fuel for sustaining activities of moderate intensity, activities of lower intensity are important for controlling fasting serum lipids and should be encouraged in sedentary obese adolescents.<sup>43</sup> The reduction in LDL cholesterol may be directly related to the reduction in body mass and fat mass in the visceral region,

owing to decreases in free fatty acids and the formation of different lipoprotein molecules.<sup>44</sup> Also, our subgroup analysis revealed that long-term concurrent exercise programmes generate larger improvements in LDL cholesterol (as well as in total cholesterol). These findings suggest that this population requires longer concurrent exercise interventions for significant changes to occur in lipid variables<sup>45</sup> in comparison with shorter, AT-only interventions. Interestingly, AT was more efficient in reducing TG levels than concurrent exercise during longer interventions. A previous meta-analysis in obese children showed significant reductions in TG with AT exercise, but not with concurrent exercise, which supports our study.<sup>8</sup>

### Effects on adipokines

Obesity has been associated with a subclinical inflammatory state in response to an imbalance between the proinflammatory and anti-inflammatory adipokines produced and secreted by adipose tissue.<sup>46</sup> Our findings showed that concurrent exercise was more effective to increase adiponectin concentration compared with AT-only protocols, suggesting an important large effect (SMD=0.79)<sup>38</sup> in the control of obesity-related inflammatory processes. Given that adiponectin can attenuate the atherogenic process through multiple actions on macrophages, vascular endothelial cells and systemic inflammation,<sup>47</sup> these results have important clinical relevance. Greater reduction of fat mass could explain the increased adiponectin levels.<sup>47</sup> Therefore, our results reinforce the findings from previous studies suggesting that a combined exercise approach can decrease cardiovascular risks and obesity-related inflammatory processes.

These data underline the importance of a multidisciplinary approach aiming at promoting concurrent exercise programmes

in obese youth. The research agenda in this field remains crowded with open questions, including understanding the molecular effects of concurrent exercise versus AT alone for changes in body composition, metabolic profiles, and inflammatory state, as well as clinical studies focusing on the duration, intensity, and frequency of supervise exercise in all the aforementioned scenarios. In addition, practitioners/clinicians working with obese youth should promote concurrent exercise longer than 24 weeks in order to improve outcomes in cardiovascular health.

### Effect of the health benefit compared with nutritional intervention

There is lack of intervention studies comparing the effect of diet-only versus exercise-only. Diet-only interventions seem to lead to greater reductions in BMI, but changes in BMI may reflect a reduction in LBM rather than fat mass, particularly in children engaged in physical activity interventions.<sup>48</sup> A recent meta-analysis reported that diet-only interventions resulted in greater BMI reductions than exercise-only interventions, among obese children and adolescents. However, without information on changes in lean mass it is not possible to compare the effectiveness of these interventions, since we do not know whether this is because the exercise group was gaining lean mass, the diet-only group was losing lean mass, or both.<sup>49</sup> Furthermore, this systematic review concluded that it remains unclear which type of intervention was more effective on reducing adiposity and metabolic risk in the paediatric population. Finally, because evidence suggests that exercise-induced changes in energy balance may stimulate compensatory adjustments that alter daily food intake,<sup>50</sup> the control of diet during physical activity interventions is necessary.

### Limitations

We report several limitations. First, a high degree of clinical and statistical heterogeneity existed among the included studies. Potential sources of heterogeneity include variations in the youth population (eg, obesity criteria), as well as the intensity, type, and duration of interventions. Second, we included non-RCTs, which introduced some risk of bias. Despite advances in exercise science in recent years, there remains a paucity of RCTs to evaluate concurrent exercise programmes in this population. However, subgroup analyses confirmed the overall results when we analysed only the RCTs. Finally, we observed publication bias in percentage of fat mass and TG; therefore, it is possible that small studies with negative results have not been as readily published (ie, risk of file drawer phenomenon).

### CONCLUSIONS

Physical activity is a safe and beneficial method to control/improve body composition, metabolic profiles and inflammatory state in the overweight and obese paediatric population. We recommend exercise programmes that involve aerobic and resistance exercise at least three sessions per week and 24 weeks in length. Our study extends the current knowledge base by reporting the superior improvement in anthropometric indicators of adiposity (ie, body mass, percentage and kilograms of fat mass, lean mass) and metabolic characteristics (ie, LDL cholesterol, adiponectin) accompanying concurrent exercise programmes in comparison with AT-only interventions. The magnitude of the standardised differences on these parameters was small-to-moderate.

### What are the findings?

- ▶ Obese children and adolescents should participate in activities that strengthen muscle in addition to aerobic modalities.
- ▶ Aerobic and resistance exercise improve body composition and cardiometabolic health.

### How might it impact on clinical practice in the future?

- ▶ Concurrent aerobic and resistance exercise is a more effective strategy than aerobic exercise alone to control body composition, metabolic profiles, and inflammatory state in the overweight and obese paediatric population.
- ▶ The advantages of concurrent exercise versus aerobic exercise were greater for longer term exercise programmes (>24 weeks).
- ▶ Clinicians and exercise professionals should inform obese paediatric patients and their parents of the benefits of long-term concurrent aerobic and resistance exercise.

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