Effects of 2 Types of Resistance Training Models on Obese Adolescents' Body Composition, Cardiometabolic Risk, and Physical Fitness

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Abstract

Magnani Branco, BH, Carvalho, IZ, Garcia de Oliveira, H, Fanhani, AP, Machado dos Santos, MC, Pestillo de Oliveira, L, Macente, SB, and Nelson, NJ. Effects of 2 types of resistance training models on obese adolescents' body composition, cardiometabolic risk, and physical fitness. *J Strength Cond Res* XX(X): 000–000, 2018—The main objective of this study was to investigate the effects of 2 types of resistance training (RT) models in conjunction with interdisciplinary interventions by other health professionals to reduce the body fat and cardiometabolic risk of obese adolescents while improving their general health-related physical fitness. The 12-week analyses involved 18 male adolescents who were split into 2 groups (weightlifting: $n = 9$ and functional: $n = 9$), with equalization according to the primary muscle group (whenever possible), the effort:pause ratio, and intensity. The results showed reductions in fat mass and body fat, as well as in waist and hip circumferences ($p < 0.05$) after the intervention period. However, no significant differences were observed in terms of the body mass, body mass index, neck circumference, systolic and diastolic blood pressures, and for lean mass ($p > 0.05$) after the respective period. Maximal isometric strength, abdominal strength resistance, flexibility, and maximal oxygen consumption all produced significant increases after the interventions ($p < 0.05$). There were reductions in low-density lipoproteins and triglyceride levels after the intervention period ($p < 0.05$). For fasting glycemia, high-density lipoproteins, and alanine aminotransferase, no differences were observed ($p > 0.05$). In addition, no differences were observed in rating of perceived recovery, internal training load, or caloric intake ($p > 0.05$). With the results presented, it is concluded that both RT methods were effective at reducing both fat mass and body fat, thus improving health-related physical fitness components and decreasing cardiometabolic risk.

Key Words body mass, adolescent health, interdisciplinary research, biomarkers

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Introduction

Epidemiological research has shown that in recent years, obesity and its associated comorbidities have grown exponentially across different age groups and socioeconomic levels in Brazil (5,6,29,36). However, strategies and dynamics to improve health are still incipient, and involve studying organized sports, active lifestyle changes, government investments, community involvement, and educational proposals for health promotion in the general population and, especially, for children and adolescents (25,31). On the other hand, scientific studies conducted with adolescents have shown that interdisciplinary programs for obesity treatment bring beneficial responses to health promotion, in addition to having a positive impact on reducing body mass and cardiometabolic risk, encouraging the adoption of an active, healthy lifestyle, and promoting dietary re-education while enhancing biopsychosocial parameters in this vulnerable age group (4,5,20,25,29).

For the success of this program, behavioral changes are vital to change bad habits that lead to harmful behaviors and relapses. Human movement planning during interdisciplinary interventions for children and adolescents involves participation in recreational activities, games, sports, physical exercises with body masses, daily life tasks, water games, theoretical and practical nutrition classes, and cognitive-behavioral therapy in a group setting (3,25,29). Similarly, there is evidence that resistance exercises using resistance training (RT) at the gym have also been effective to treat obesity and its associated comorbidities in adolescents (25).

In addition, among the several comparisons made in their study, Carnier et al. (8) found that aerobic training can reduce adiposity in adolescents. The combination of aerobic training and RT, in addition to reducing fat mass and body fat, tends to increase lean body mass in obese adolescents (8). In the same perspective, a meta-analysis recently published by García-Hermoso et al. (15) found that high-intensity interval training (HIIT) completed between 4 and 12 weeks can increase maximal oxygen consumption ($\dot{V}O_2max$) and reduce blood pressure in overweight or obese adolescents. Similarly, Machado et al. (26) pointed out that the HIIT completed with body mass can be beneficial to health. Thus, it is believed that training with body mass can be an alternative means to minimize the impact caused by being overweight or obese.

Nevertheless, a study by García-Hermoso et al. (15) did not observe differences in variables related to the lipid profile, body composition, fasting glycemia, and insulin after HIIT in obese adolescents. Specifically, the absence of differences in body composition (lean mass and fat mass), as well as biochemical variables, is presumably related to the inexistence of proposals/programs for dietary re-education and behavioral changes in the adolescents studied. Another method that has been used is high-intensity interval RT (HIRT) during training sessions. The use of HIRT in adults has shown higher values for resting energy than traditional RT (35). In this way, Hoor et al. (19) suggested that RT can be a valuable tool for the treatment of obesity in adolescents.

In view of this, as far as the authors know, there are no interdisciplinary interventions for obesity treatment that have compared 2 different models of RT: body mass (commonly called "functional training") and weightlifting (performed with machines, bars, and dumbbells) using a structured periodization equalized by the muscle groups involved and the volume and intensity in obese adolescents. Thus, the main objective of this study was to investigate the effects of 2 types of RT models in conjunction with interdisciplinary interventions by other health professionals to reduce body fat and cardiometabolic risk, as well as to improve health-related physical fitness in obese adolescents. Consequently, similar responses are expected between the 2 different experimental groups for reduced fat mass, body fat, circumference, and cardiometabolic risk. They also promote muscle hypertrophy and improved parameters associated with health-related physical fitness. The similarity of responses is expected because both methods were equalized by the primary muscle groups (whenever possible) and by the volume and intensity of the efforts.

Methods

Experimental Approach to the Problem

This study is characterized by presenting an experimental design. The intervention aimed to compare the effects of 2 types of RT models, together with physiotherapeutic practices, food education activities (with a focus on dietary re-education), and behavioral changes, through cognitive-behavioral therapy over 12 weeks.

Subjects

Forty male adolescents were enrolled to participate in this study. However, at the initial meeting with the parents, 19 of them dropped out before conducting the assessments because they indicated that they would not have time to perform the proposed activities. This study was approved by the State University of Maringa, Parana, Brazil, and research committee under number 915.526/2014 and registered in the Brazilian clinical trials registry (RBR 45ywtg). All specifications set forth by resolution number 466/2012 of Brazil's Ministry of Health and the Declaration of Helsinki were followed. All the adolescents' parents or guardians and adolescents were duly informed about the purposes of the research and signed the informed consent form (the age of the adolescents is described in Table 1). Figure 1 shows a flow chart of this study.

Procedures

The 21 remaining adolescents were randomized into 2 RT groups: weightlifting group (WG) and functional group (FG). However, 3 adolescents dropped out of the study during the first week of intervention. On the first day, a medical consultation was done (including measurement of blood pressure, pulmonary, and cardiac auscultation). Anamnesis and biochemical tests were also completed. On the second day, the blood samples were taken, completing the international physical activity

Table 1. Training periodization used throughout the 12 weeks of interdisciplinary interventions for the obesity treatment.

Weeks	Time (s)	Effort:pause ratio	Intensity
1st–3rd	30″ per 30″	1:1	Moderate interval resistance exercise
4th–6th	40″ per 20″	2:1	Moderate interval resistance exercise
7th–9th	30″ per 30″	1:1	High-intensity interval resistance exercise
10th–12th	40″ per 20″	2:1	High-intensity interval resistance exercise

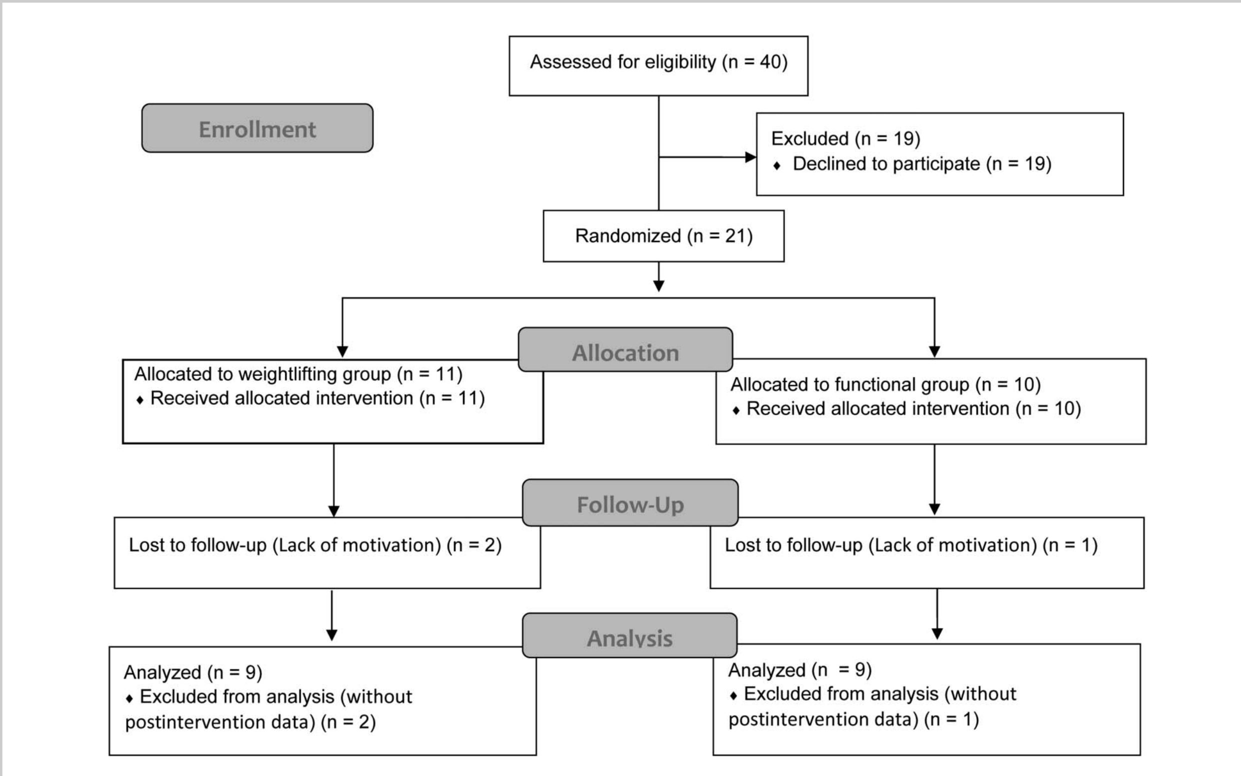

Figure 1. Flowchart of the study.

questionnaire (IPAQ), body composition, circumferences, and delivery of the food record. On the third and last day, physical evaluations were performed. Each visit was interspersed by 24 hours. Therefore, the final analyses included (n = 9) adolescents in the WG and (n = 9) in the FG. Physiotherapeutic, nutritional, and cognitive-behavioral interventions were the same for both groups. The 2 physical exercise models (WG and FG) were equalized by the effort:pause ratio, the muscle groups involved, and the rating of perceived exertion (RPE). Body composition and anthropometric measures, as well as blood pressure, physical fitness, nutritional questionnaire, and biochemical variables were assessed before and after those 12 weeks. The rating of perceived recovery (RPR) and RPE were measured in each physical exercise session. In addition, the RPR and RPE were exposed in the training center and before each physical exercise session, and the adolescents were instructed regarding the descriptor values. Physical education and physiotherapy interventions happened 3 times a week, while the nutritional team assisted the adolescents twice a week, and the psychology team assisted them once a week. As inclusion criteria, adolescents with the following characteristics were accepted: (a) being aged between 15 and 17 years old, (b) being overweight or obese within the cutoff ranges proposed by Cole and Lobstein (11), and (c) being available to participate in the interventions during the treatment period. Exclusion criteria were (a) the use of glucocorticoid and psychotropic medications that could regulate appetite, (b) an attendance of lower than 75% of the interdisciplinary interventions, and (c) joint and musculoskeletal limitations that could hinder their ability to take part in the physical exercises. It should be noted that the adolescents were encouraged to be more physically active on a day-to-day basis (in the environment outside the interventions). However, if any adolescent chose to participate in another regular and systematized training program or decided to start a dietary program (hypocaloric, low carbohydrate, or low fat), he or she would not be included in the analyses (for both experimental groups).

Physical Exercise. From the first to the sixth week, moderate intensity resistance exercises (MIREs) were performed, with RPE between 12 and 14 u.a. During the first 6 weeks, MIREs were used to provide the anatomical adaptation phase to sedentary adolescents, who had no previous experience with RT. This phase was used to minimize possible risks of injuries associated with physical exercise. In turn, from the 7th to the 12th week, high-intensity resistance exercises (HIREs) were used in an "*all-out*" mode; that is, *do it as hard as you can.* The interventions happened 3 times a week,

Table 2. First and second mesocycles of weightlifting and functional training of obese adolescents.*

Weightlifting training		Functional training	
Training A	Training B	Training A	Training B
1) 5-min warm-up	1) 5-min warm-up	1) 5-min warm-up	1) 5-min warm-up
2) Chest press	2) Lever close grip pull-down	2) Push-ups	2) Row on TRX with supinated grip
3) Hack squat	3) Leg curl	3) Squat with Swiss-ball on the back	3) Hip lift with knee flexion on Swiss-ball
4) Aerobics	4) Aerobics	4) Aerobics	4) Aerobics
5) Shoulder press	5) Incline row	5) Medicine ball vertical throw	5) Tire pulling with naval rope
6) Leg extension	6) Calf raise machine	6) Go up and down a plinth	6) Standing calf exercise
7) Aerobics	7) Aerobics	7) Aerobics	7) Aerobics
8) Triceps pulley	8) Scott curl machine	8) Triceps bench dips	8) Biceps curl on TRX
9) Abdominal crunch machine	9) Oblique abdominal machine	9) Straight sit-ups on ball	9) Oblique sit-ups on Swiss-ball
10) Aerobics	10) Aerobics	10) Aerobics	10) Aerobics

*For both training models, the total time for each training session was 46 minutes (5 minutes of warm-up, 3 sets of moderate intensity exercises, each set comprising 9 minutes, plus 3 minutes of passive rest per set, lasting 36 minutes, and finally 5 minutes of back-to-calm = 5 + 36 + 5 minutes).

alternating in trainings A and B, in the form of a circuit, with the execution of 3 sets per session and a passive rest interval between the sets. Table 1 shows the periodization used during the 12 weeks of MIRE and HIRE.

The only difference in relation to the physical exercise protocols was the method used; that is, one group was subjected to an intervention by means of activities that involved body mass and accessories, i.e., TRX (Total-body Resistance Exercise), elastics, medicine balls, and Swiss-balls. This type of training is traditionally known as "functional training." In turn, the other group executed the interventions on machines, bars, and dumbbells (weightlifting). However, all exercises were equalized by the primary muscle groups involved in each session (whenever possible). The only distinction was how the adolescents performed the physical exercise interventions. In this training method, repetitions were not counted; that is, in MIREs, the adolescents performed the exercises at (1:1 concentric and eccentric phase), whereas HIREs were executed in *all-out* mode. Table 2 shows how the 2 groups were divided in first and second mesocycles.

Table 3 shows how the 2 groups were divided in third and fourth mesocycles.

Physical Activity Level Questionnaire. Before and at the end of the study, the IPAQ, adapted for adolescents (16), was applied. Data were tabulated and compared to identify possible differences between physical activity levels before and after interdisciplinary interventions and to assess activities other than the physical exercises within the protocols.

Rating of Perceived Recovery Measurement. To infer considerations about recovery in the 2 different training groups (WG and FG), RPR, which reflects the state of recovery, was used before each training session, with values ranging from 0 u.a. (very poorly recovered/extremely tired) to 10 u.a. (very well recovered/highly recovered) (22).

Rating of Perceived Exertion Measurement. The RPE for each session was reported 30 minutes after the sessions, as indicated by Foster et al. (2001). The scale by Foster et al. (14) comprises values from 0 u.a. (extremely light effort) to 10 u.a. (extremely heavy effort).

Internal Training Load. With the RPE values presented for each training session, the internal load was calculated by multiplying the RPE value vs. time spent on physical exercise (30).

Physical Fitness Tests. Maximal isometric strength tests were performed to assess the maximal handgrip strength, maximal lumbar traction strength and maximal lower limb traction strength, abdominal strength resistance, flexibility, and maximal oxygen consumption, in accordance with the standardization proposed by Lopera et al. (25), before and after the intervention period.

TABLE 3. Third and fourth mesocycles of weightlifting and functional training of obese adolescents.*

Weightlifting training		Functional training	
Training A	Training B	Training A	Training B
1) 5-min warm-up	1) 5-min warm-up	1) 5-min warm-up	1) 5-min warm-up
2) Bench press	2) Lever seated high row	2) Push-ups	2) Sled pull
3) 45° leg press	3) Leg curl	3) Bodyweight squat	3) Single-leg deadlift with medicine ball
4) Aerobics	4) Aerobics	4) Aerobics	4) Aerobics
5) Incline dumbbell fly	5) Lever seated row	5) TRX push-up	5) Row on TRX with pronated grip
6) Leg extension	6) Hip abductor machine	6) Bodyweight lunge	6) Standing resistance-band hip abduction
7) Aerobics	7) Aerobics	7) Aerobics	7) Aerobics
8) Shoulder press	8) Reverse fly	8) Medicine ball vertical throw	8) Trapezius on TRX
9) Hip adductor machine	9) Seated calf machine	9) Sumo squat with medicine ball	9) Standing calf exercise
10) Aerobics	10) Aerobics	10) Aerobics	10) Aerobics
11) Rope high pulley triceps extension	11) Biceps curl	11) Triceps on TRX	11) Biceps curl on TRX
12) Abdominal crunch machine	12) Oblique abdominal machine	12) Standard plank on the floor	12) Side planking

*For both training models, the total time for each training session was 52 minutes (5 minutes of warm-up, 3 sets of high-intensity exercises, each set comprising 11 minutes, plus 3 minutes of passive rest per set, lasting 42 minutes, and finally 5 minutes of back-to-calm = 5 + 42 + 5 minutes).

Body Composition Measurement. Body composition analyses were performed using the bioimpedanciometry method with a tetrapolar multifrequency electric bioimpedance device, the InBody 520 model, as per a standardization protocol proposed by Heyward (17).

Anthropometric Assessment. Body mass, stature, and the following circumferences were measured: waist, hip, and neck, in accordance with the study of Heyward (17).

Blood Pressure Measurement. Blood pressure measurements were conducted following recommendations proposed by the VII Brazilian Guidelines on Hypertension (37).

Physiotherapeutic Care. Physiotherapeutic interventions included kinesiotherapy with core strengthening exercises, posture correction, and body proprioception. Klapp and some isometry exercises were executed by means of the Mackenzie method. All activities were completed 3 times a week, with approximately 30 minutes of duration and individual instructions.

Nutritional Service. The main objective of the nutritional interventions was to instruct the adolescents as to various nutritional aspects, such as (a) the food pyramid, (b) the energy density of foods, (c) the importance of macronutrient and micronutrient and their correlation with health, (d) the nutritional composition of foods, (e) the differences between diet and light foods, (f) the importance of dietary re-education; (g) the ways to prepare healthy foods, and (h) the differences between natural, minimally processed, processed, and ultraprocessed foods. The interventions happened through dialogue-based, expository classes, and practices in the technical and dietetic laboratory. Meetings were held twice a week, with an average duration of 1 hour. In addition, dietary recording was applied on 2 nonconsecutive weekdays, as well as on a weekend day, before and after the intervention period (13,43). The adolescents were instructed to write down, on specific sheets, all foods and beverages consumed throughout the days, including the size of the consumed portions, the name of the preparations, the ingredients, and how they are made. They were also instructed to include details, such as the addition of salt, sugar, oil, and sauces, and whether the food or drink consumed was regular, diet, or light. For the best estimation of portion size, the adolescents used home-based measures (40). The foods were recorded at the time of consumption. Subsequently, responses resulting from the dietary records were analyzed using the software Avanutri 2004 (Avanutri Equipamentos de Avaliação Ltda, Três Rios, Brazil). Comparative analysis used the mean values of the 3 days of dietary records. Individual values of 2 days of records and 1 weekend day of caloric intake were used ($Kcal \cdot d^{-1}$).

Table 4. Body composition, anthropometry, and blood pressure before and after 12 weeks of interdisciplinary interventions for the obesity treatment.*†

	FG		WG	
Variables	Pre	Post	Pre	Post
Age (y)	16 ± 1	16 ± 1	16 ± 1	16 ± 1
Body mass (kg)	99.0 ± 20.5	98.3 ± 18.9	97.8 ± 24.2	96.8 ± 24.4
Stature (cm)	169.7 ± 11.5	169.7 ± 11.5	169.6 ± 7.9	169.6 ± 7.9
BMI ($kg \cdot m^{-2}$)	34.7 ± 3.8	33.9 ± 3.2	33.2 ± 8.3	32.7 ± 8.6
Lean mass (kg)	52.2 ± 11.1	54.8 ± 13.0	54.9 ± 8.8	55.3 ± 8.6
Bone mass (kg)	3.4 ± 0.7	3.6 ± 0.9	3.5 ± 0.5	3.5 ± 0.4
Body fat (%)‡	43.9 ± 4.0	40.9 ± 5.2	38.7 ± 9.2	37.5 ± 11.0
Fat mass (kg)‡	43.5 ± 10.3	39.9 ± 8.0	39.4 ± 18.1	38.1 ± 19.3
Hip circumference (cm)‡	101.6 ± 4.4	98.8 ± 4.2	93.2 ± 13.8	91.0 ± 14.6
Waist circumference (cm)‡	108.6 ± 9.3	105.0 ± 8.1	103.7 ± 13.1	101.1 ± 12.6
Neck circumference (cm)	38.1 ± 2.2	37.7 ± 2.0	36.5 ± 3.9	36.4 ± 3.2
Systolic blood pressure (mm Hg)	133 ± 11	126 ± 17	126 ± 7	124 ± 17
Diastolic blood pressure (mm Hg)	81 ± 8	81 ± 11	75 ± 11	78 ± 10

*FG = functional group; WG = weightlifting group; BMI = body mass index.
†Data are presented by mean and *SD*.
‡Time effect, different from preintervention for the same experimental groups ($p < 0.05$).

Cognitive-Behavioral Therapy. The interventions provided several discussions among the participants regarding the central themes of the project: such as anxiety control, self-esteem development, positive perceptions of body self-image and, above all, a process of behavioral change. The psychological aspects involved in the behavioral change process of an individual focus on his or her beliefs, skills, past experiences, motivation, and self-concept (27). The activities were performed once a week and had an average duration of 1 hour.

Biochemical Dosages. Blood was collected in the morning, after fasting for approximately 10 hours, before and after the interventions. The following biochemical parameters were determined: fasting glycemia, by means of venous blood stored in Vacutainer-type tubes containing sodium fluoride, with analysis using fluorinated plasma. For aspartate aminotransferase (AST), alanine aminotransferase (ALT), triglycerides, high-density lipoproteins (HDL-c), and low-density lipoproteins (LDL-c), Vacutainer-type tubes containing stacking gel were used, with the analysis conducted using the serum. The samples were centrifuged at 3,600 rpm for 11 minutes at room temperature to separate serum and plasma, and then frozen at −80° C and analyzed together at the end of the study (before and after the intervention) by 2 blindfolded researchers (with no access to the physical exercise interventions). Siemens Advia 1800 Chemistry Analyzer was used for analysis of the biochemical variables. For all blood tests, Siemens kits (Frimley, Camberley, Great Britain) were used. The analyses complied with the standardizations specified by the kits' manufacturer.

Statistical Analyses

Data are presented as themean and ±*SD*. Initially, the Levene test was used to identify data homogeneity. After confirmation, a 2-way analysis of variance (ANOVA) was performed (*group* × *time*), and, when a difference was detected, Bonferroni's post hoc was applied. Sphericity was tested using the Mauchly test, and the Greenhouse-Geisser correction was applied when necessary. For the ANOVA results, effect sizes were calculated by (*partial eta square*, ηp^2) in accordance with Cohen (10): 0.01 until <0.06 (*small effect*); ≥0.06 until <0.14 (*medium effect*), and ≥0.14 (*large effect*). For preintervention and postintervention comparisons of the weekly mean of kilocalories (Kcal) for the same experimental group (dietary record), the *t*-paired test was used. For comparison between the 2 nonconsecutive weekdays and 1 weekend day, a 2-way ANOVA for repeated measures was used. In addition, considering that 4 training mesocycles were used for both experimental groups, the choice was to subdivide RPR, RPE, and internal training load (ITL) analyses in agreement with the respective periodization phases. A significance level of 5% was adopted for all variables. Statistical analyses were performed through the program Statistica, version 12.0 (Statsoft, USA).

Results

Table 4 presents the body composition, anthropometry, and blood pressure variables before and after 12 weeks of interdisciplinary interventions for obesity treatment in adolescents.

For body fat (%), there was only a time effect ($F = 10.97$; $p = 0.004$, $\eta p^2 = 0.39$, *large effect*), with lower values after the intervention period ($p = 0.004$).

Table 5. Neuromuscular tests and aerobic fitness before and after 12 weeks of interdisciplinary interventions for the obesity treatment.*†

Variables	FG		WG	
	Pre	Post	Pre	Pre
Sum of maximal handgrip strength (kgf)‡	65.2 ± 16.2	69.5 ± 19.2	68.4 ± 20.9	73.7 ± 16.6
Maximal lumbar traction strength (kgf)§	81.7 ± 32.3	86.6 ± 25.3	81.1 ± 34.6	94.4 ± 25.9
Maximal lower-body traction strength (kgf)‡	81.0 ± 29.2	89.0 ± 29.9	81.0 ± 32.9	92.0 ± 20.6
Abdominal strength/endurance (reps)‡	21 ± 6	27 ± 6	23 ± 5	25 ± 6
Flexibility (cm)‡	29.6 ± 7.4	35.2 ± 6.3	27.7 ± 7.3	34.8 ± 3.9
$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)‡	33.8 ± 3.1	35.7 ± 3.9	34.8 ± 2.3	36.4 ± 3.5

*FG = functional group; WG = weightlifting group.
†Data are presented by mean and *SD*.
‡Time effect, different from preintervention for the same experimental groups ($p < 0.05$).
§Tendency to difference after the intervention period for both groups ($p = 0.06$).

For the fat mass (kg), only a time effect was detected ($F = 6.51$; $p = 0.02$, $\eta p^2 = 0.28$, *large effect*), with lower values after the intervention period ($p = 0.02$).

For the waist circumference, only a time effect was identified ($F = 8.54$; $p = 0.009$, $\eta p^2 = 0.33$, *large effect*), with lower values after the intervention period ($p = 0.009$).

For hip circumference, there was only a time effect ($F = 9.44$; $p = 0.006$, $\eta p^2 = 0.36$, *large effect*), with lower values seen after the intervention period ($p = 0.007$).

For the body mass, stature, body mass index (BMI), lean mass, bone mass, neck circumference, and blood pressure, there was no difference between groups, in either time or interaction ($p > 0.05$).

Table 4 shows the results of neuromuscular and aerobic fitness tests before and after 12 weeks of interdisciplinary interventions for obesity treatment in adolescents.

For the sum of maximal grip strength, only a time effect was identified ($F = 10.74$; $p = 0.005$, $\eta p^2 = 0.42$, *large effect*), with higher values after the intervention period ($p = 0.005$).

For maximal lumbar traction strength, only a time effect was detected ($F = 4.34$; $p = 0.054$, $\eta p^2 = 0.22$, *large effect*), with higher values after the intervention period ($p = 0.06$).

For maximal lower limb traction strength, a time effect was observed ($F = 5.16$; $p = 0.038$, $\eta p^2 = 0.26$, *large effect*), with higher values after the intervention period ($p = 0.04$).

For abdominal strength resistance, there was also a time effect ($F = 23.4$; $p < 0.001$, $\eta p^2 = 0.61$, *large effect*), with higher values noted after the intervention period ($p < 0.001$).

Table 6. Biochemical variables after and before 12 weeks of interdisciplinary intervention for the obesity treatment.*†

Biochemical variables	Functional intervention		Weightlifting intervention	
	Pre	Post	Pre	Post
Fasting glycemia ($mg \cdot dl^{-1}$)	87.7 ± 9.5	82.4 ± 6.3	88.1 ± 12.9	81.3 ± 8.3
HDL-c ($mg \cdot dl^{-1}$)	43.7 ± 10.6	45.8 ± 12.2	44.0 ± 15.8	46.1 ± 17.4
LDL-c ($mg \cdot dl^{-1}$)‡	172.9 ± 28.0	143.0 ± 14.5	170.1 ± 58.9	141.2 ± 32.3
Triglycerides ($mg \cdot dl^{-1}$)‡	81.3 ± 14.1	62.5 ± 11.0	80.9 ± 37.4	60.2 ± 18.9
AST ($U \cdot L^{-1}$)§	34.1 ± 35.2	18.7 ± 4.5	36.8 ± 30.7	18.9 ± 5.8
ALT ($U \cdot L^{-1}$)	19.9 ± 13.9	13.9 ± 5.1	18.3 ± 6.7	13.4 ± 5.0

*HDL-c = high-density lipoprotein; LDL-c = lower-density lipoprotein; AST = aspartate aminotransferase; ALT = alanine aminotransferase.
†The data are presented by mean and ±*SD*.
‡Difference between the moments for both experimental groups with lower values after the intervention period ($p < 0.05$).
§There was a tendency with lower values for both experimental groups after the intervention period ($p = 0.051$).

For flexibility, a time effect was verified ($F = 6.67$; $p = 0.020$, $\eta p^2 = 0.30$, *large effect*), with higher values after the intervention period ($p = 0.019$).

For $\dot{V}O_2max$, a time effect was identified ($F = 6.12$; $p = 0.024$, $\eta p^2 = 0.26$, *large effect*), with higher values after the intervention period ($p = 0.024$).

Table 5 presents biochemical variables after and before 12 weeks of interdisciplinary intervention for weight loss in Brazilian adolescents.

For LDL-c, there was a difference between the times ($F = 14.5$; $p = 0.001$, $\eta p^2 = 0.47$, *large effect*), with lower values after the intervention period ($p = 0.001$).

For triglycerides, there was also a difference between the times ($F = 11.4$; $p = 0.003$, $\eta p^2 = 0.41$, *large effect*), with lower values after the intervention period ($p = 0.003$) (Table 6).

For AST, there was a difference in tendency between the times ($F = 4.5$; $p = 0.05$, $\eta p^2 = 0.21$, *large effect*), with lower values after the intervention period ($p = 0.051$).

For fasting glycemia, HDL-c and ALT, no difference was observed ($p > 0.05$).

International Physical Activity Questionnaire Responses, Rating of Perceived Recovery, Rating of Perceived Exertion, Internal Training Load, and Dietary Records

For IPAQ responses, no significant differences were observed in the level of physical activity completed over the 12 weeks of interventions ($p > 0.05$). The only difference reported and expected was an increase in the level of weekly physical activity due to the physical exercises performed 3 times a week over the 12 weeks of interventions.

For RPR, RPE, and ITL, no significant differences were observed in the same microcycle and mesocycle periods, respectively ($p > 0.05$).

For mean weekly kcal values, no differences were identified before or after the interventions (intragroup and intergroup comparisons) ($p > 0.05$). Similarly, no differences were found between the dietary records on 2 weekdays and 1 weekend day ($p > 0.05$).

Discussion

The main results of this study show the following differences for both RT groups: (a) reduced fat mass (kg) and body fat (%), (b) reduced waist and hip circumferences, (c) improved health-related physical fitness components (maximal handgrip isometric strength, maximal lower limb isometric strength, abdominal strength resistance, flexibility, and $\dot{V}O_2max$), and (d) reduced LDL-c and triglyceride levels. By contrast, no differences were detected for RPR and ITL in the 4 training mesocycles over the 12 weeks of the intervention protocol. The absence of differences suggests that the proposed equalization was homogeneous between the 2 RT experimental groups. On the other hand, no significant differences were identified in terms of lean mass, HDL-c, AST (tendency), and ALT, as well as for caloric intake per day. Consequently, the study's hypothesis was partially confirmed.

When the RT protocols are somehow equalized, the training responses tend to be similar (1). Such responses have been highlighted in previous studies, by identifying significant improvements in various physical tests performed with elderly people (24). On the other hand, De Vreede et al. (12) observed more effective improvements in functional task performance in an elderly woman after functional task exercises than with traditional RT. However, a factor that must be considered in the aforementioned study is the specificity principle, both in the choice of physical tests and the RT exercise protocols, to perform equivalent comparisons. From this perspective, Angleri et al. (2) identified similar improvements in the parameters evaluated during different methods of RT as equalized by the total volume of training. Such responses corroborate this study. The main limitation of studies attempting to compare different methods of RT is the lack of equalization seen between the protocols.

A previous study that incorporated dietary re-education strategies, cognitive-behavioral therapy, and physical exercise identified reductions in body fat, fat mass, and circumferences (waist and hip) after 16 weeks of physical exercises in obese adolescents (25). On the other hand, a meta-analysis published by García-Hermoso et al. (15), with HIIT in children and adolescents, pointed out that interventions between 4 and 12 weeks are not effective at reducing waist and hip circumferences, fat mass, body fat percentage, triglycerides, and LDL-c. The findings of the aforementioned study showed only increases in $\dot{V}O_2max$ and decreases in systolic blood pressure after the HIIT protocols.

Nevertheless, not all studies included in the meta-analysis by García-Hermoso et al. (15) promoted practices for dietary re-education in adolescents concomitantly with HIIT. As a result, the absence of differences for fat mass, body fat, waist and hip circumferences, triglycerides, and LDL-c may be linked to the absence of dietary re-education programs performed in conjunction with physical exercises. It should be noted that the LDL-c and triglycerides presented by the adolescents were higher than the established cutoff ranges (33). Therefore, to decrease the cardiometabolic risk, it is vital to increase HDL-c levels, as well as to reduce LDL-c and triglycerides. Lifestyle changes are also recommended, such as regular physical activity and the incorporation of healthy eating habits (9).

This study identified no elevations in HDL-c concentrations after 12 weeks of interdisciplinary interventions. Higher HDL-c concentrations are believed to be beneficial in reducing cardiometabolic risk because they are protective factors against cardiovascular conditions (41). The absence of differences in HDL-c concentrations may be associated with the "western" dietary pattern, which has some extremely worrying results leading toward senescence and increasing cardiometabolic risk in adolescents (39).

On the other hand, Wang and Xu (41) wrote that aerobic training executed between 60 and 80% of $\dot{V}O_2$max and 70–85% of HRmax is effective at increasing HDL-c concentrations. From the same perspective, LeMura et al. (23) identified that continuous aerobic training alone increased HDL-c concentrations after 16 weeks of intervention. Resistance training and cross-training groups, as the authors call the combination of aerobic and resistance exercises, did not increase the HDL-c concentrations. Therefore, given the evidence presented about HDL-c concentrations, it is believed that the maintenance of these values is related to the time of exposure to physical exercise (12 weeks). Thus, longer intervention periods for significant improvement of HDL-c levels are suggested. However, Campbell et al. (7) emphasized that the HDL_2-C subfraction presents a greater sensitivity to physical effort. Thus, the use of the HDL_2-C subfraction is recommended in further studies involving physical exercise.

Earlier studies with interdisciplinary approaches (25,28,32) identified muscle hypertrophy after 16 weeks of physical exercise in overweight or obese adolescents. However, the protocol used in this study comprised 12 weeks of RT, with 6 weeks of moderate intensity and 6 weeks of high-intensity training. As a result, it is believed that gains in lean mass through resistance exercises for sedentary overweight or obese adolescents are linked to longer intervention periods. Such responses are corroborated by the findings of Watts et al. (42), which indicated that a pronounced increase of fat-free mass has been associated with longer protocols, between 4 and 5 months of resistance exercises.

Regarding the AST and ALT enzymes, there was a tendency toward lower AST values after the intervention period for both experimental groups. These responses are positive, as AST and ALT enzymes are used for diagnosis and assessment of liver diseases, including for nonalcoholic hepatic steatosis (21). In nonalcoholic hepatic steatosis, ALT and AST concentrations, to a greater and a lesser extent, respectively, were increased drastically, which is a public health issue in the United States (21). Antunes et al. (3) observed reductions in the prevalence of nonalcoholic hepatic steatosis in obese adolescents aged between 12 and 15 years, after 20 weeks of concurrent training (assessment done through ultrasound). However, unlike the aforementioned study, the present research did not perform upper abdomen ultrasound measurements to analyze the thickness of either the right and left lobes of the liver or of the intra-abdominal and visceral fat. For this reason, the absence of such an analysis can be listed as a limitation. Despite this, there is evidence that moderate and HIRT in conjunction with dietary re-education programs can be effective at reducing fat accumulation in the liver.

For caloric intake, no significant differences were identified before or after the intervention period. The literature notes that 3 months of interventions are sufficient to promote behavioral changes in adolescents (20). Nonetheless, the same authors stress that parental support is critical for the promotion of behavioral changes and the selection of healthy foods (20). In this context, behavioral change requires an understanding of the surrounding context; that is, in this process, family members also have the responsibility of complying with the treatment (34). However, the interventions were performed with adolescents, without the participation of their parents, although the latter were periodically informed about the process of their children's treatment. Thus, future studies should investigate the effects of cognitive-behavioral therapy, dietary re-education, and physical exercise to fight obesity in both parents and children, performing the interventions in the 2 groups in conjunction.

Another important point that merits discussion is the equalization of physical exercise variables. In this scenario, it is reasonable to believe that the equalization of the executed training was effective at controlling variables that could generate information biases and result in interpretation biases. Therefore, it is possible to affirm that one physical exercise model overlaps the other without the rigid standardization of muscle groups involved, effort:pause ratio, as well as volume and intensity of sessions. In this context, RPR, RPE, and ITL were used as instruments of recovery and intensity control, respectively.

The novelty brought in this research lies in the execution of 2 different models of RT (functional training and weightlifting training) within an interdisciplinary conjuncture for obesity treatment in adolescents. Empirically, physical education professionals believe that the so-called functional training is typically more effective than conventional (machine-based) training for fat mass loss and body fat reduction. However, when training is equalized, the responses are identical following both methods used. The term "functional training" has been used by researchers in the field. The term "functional" refers to the functionality aspect; that is, it indicates that the training must therefore meet the needs of the target audience, regardless of the exercise choice and the use of instruments (38).

Based on the findings of this study, we conclude that the 2 RT models were effective at reducing fat mass, body fat, waist and hip circumferences, LDL-c, and triglycerides, and improving health-related physical fitness components such as muscle strength and resistance, flexibility, and cardiorespiratory capacity. Given this, when the 2 different RT models are equalized through the muscle groups involved according to the session and the effort:pause ratio of stimuli and intensity, the benefits deriving from the intervention will be identical, even following different means of execution.

Finally, as a limitation, the use of perceptual scales to measure the training load may underestimate or overestimate the descriptors. However, as discussed in a systematic review by Haddad et al. (18), there is a good reliability in the use of RPE for the monitoring of the training load in adolescents. Therefore, it is believed that familiarization with the use of RPE must be incorporated to minimize possible measurement errors, as was performed in this study. Complementarily, considering that this study was the first to perform the comparisons made in adolescents, the discussion was based, fundamentally, on studies with other age groups. Therefore, new studies with this characteristic (and other means and methods) should be conducted with adolescents to delineate effective strategies for improving components related to body composition, health-related physical fitness, and the reduction of cardiometabolic risk.

Practical Applications

It is implied that the human body does not respond in a divergent way to the overload caused by machine apparatus or by one's own body mass, with the aid of "functional" equipment. From this perspective, the overload can be assimilated, regardless of the means used. In view of this, there is an alternative for the realization of RT with body mass, which can be considered a low-cost strategy and can be incorporated into different places (schools, basic health units, community centers, and squares, among others). Thus, for the success of any given weight loss program, the pleasure of performing the proposed activities must be substantial, especially if there is a lack of motivation, lack of family support, and, consequently, a strong urge to drop out of the intervention. It is worth highlighting that the choice of the applied means or method of physical training will depend on the availability of materials/infrastructure, compliance with type of exercise, pleasure, satisfaction, and maintenance of the activity by the adolescents. Finally, it should be emphasized that body mass and BMI should be analyzed with caution in a weight loss program. Changes in body composition (reduction of fat mass and body fat, as well as improve lean mass) and improvements in physical fitness parameters related to health and the reduction of cardiometabolic risk are more important outcomes.

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