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Effects of aerobic exercise combined with resistance training on health-related physical fitness in adolescents: A randomized controlled trial



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ABSTRACT

Background: /Objective: This study aimed to compare the effects of two combined training methods on health-related physical fitness components in adolescents.

Methods: Seventy-six adolescents (16.1 ± 1.1 years, $n = 44$ female) were randomized into groups of moderate-intensity continuous training combined with resistance training (MICT + RT), high-intensity interval training combined with resistance training (HIIT + RT), or Control. The training sessions were performed twice weekly for 12 weeks. The health-related physical fitness components evaluated were: body composition, muscular and cardiorespiratory fitness.

Results: The intervention groups had a significant reduction in body fat percentage and improvement in abdominal repetitions and VO_{2peak} after 12 weeks of combined exercise program ($p < 0.001$). Intervention effects were found to significantly reduce body fat percentage for the MICT + RT and HIIT + RT groups compared to the control group (mean difference: -3.8 ; 95% CI: -6.2 ; -1.0 ; mean difference: -4.7 ; 95% CI: -7.1 ; -2.3 , respectively). For muscle fitness, significant effects of the intervention were found in increasing the number of abdominal repetitions favoring the MICT + RT group compared to the control group (mean difference: 9.5 ; 95% CI: 4.4 ; 14.7) and HIIT + RT compared to the control group (mean difference: 14.1 ; 95% CI: 9 ; 19.3). For cardiorespiratory fitness, significant effects of the intervention on improving VO_{2peak} were found in the experimental groups (MICT + RT vs Control group: mean difference: 4.4 ; 95% CI: 2.2 ; 6.6 ; and HIIT + RT vs. Control group: mean difference: 5.5 , 95% CI: 3.3 ; 7.7).

Conclusion: The results suggest that 12 weeks of training using MICT + RT or HIIT + RT showed a similar effect for health-related physical fitness components in adolescents.

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1. Introduction

Physical fitness can be defined as the capacity to perform daily activities with vigor and energy, and is primarily determined by

genetics and training.¹ The physical fitness is an important health marker in childhood and adolescence,² as well as a predictor of cardiovascular (CVD) risk factors in adulthood.³ Health-related physical fitness (HRPF) consists of five domains; however, body

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composition, cardiorespiratory fitness, and muscular fitness are three domains that tend to have an independent association with morbidity and mortality rates.^{4,5}

Evidence from systematic reviews and meta-analysis of observational studies indicate a relationship between muscular fitness in childhood and adolescence and future health levels, such as lower body mass index, skinfold thickness, homeostasis model assessment estimated insulin resistance, triglycerides, cardiovascular disease risk score, and higher bone mineral density.^{6,7} Studies also have shown that higher body fat is a predictor for insulin resistance^{8,9} and high blood pressure during childhood and adolescence.^{10,11} Regarding cardiorespiratory fitness (CRF), Mintjens et al.¹² reported an association between higher CRF in childhood and adolescence and lower body mass index (BMI), body fatness, and metabolic syndrome incidence.

Given the importance of HRPF as an indicator of health in adolescence, it is necessary to promote the improvement of physical fitness components in adolescents. In this context, international organizations such as the American College of Sports and Medicine¹³ and the World Health Organization¹⁴ recommend the promotion of aerobic and muscle-strengthening activities (moderate-to-vigorous and/or high-intensity) as part of the physical activity guidelines for children and adolescents.

There are many kinds of exercise training (aerobic, resistance, and a combination of these) to improve the HRPF components.^{15,16} Resistance training is a specialized method of conditioning that involves the use of different modes of training with a wide range of resistive loads, from body weight to barbells, that is designed to enhance muscular fitness.¹⁷ In addition, there is evidence that resistance exercises have a positive effect on bone mineral density, lean body mass, as well as reductions in body fat mass.¹⁸

Aerobic training has been associated with reductions in body fat mass,^{19,20} improvements in the cardiometabolic profile, and mental health in adolescents.^{21–23} Moderate-intensity continuous training (MICT) is the more traditional method of aerobic exercise with long-duration sessions.²⁴ Recently, high-intensity aerobic interval training (HIIT) has been considered a viable alternative due to the short session durations.^{24,25} HIIT is defined as the repetition of high-intensity exercise bouts separated by short passive recovery periods or low-intensity exercise.²⁶

Previous meta-analyses^{24,27} showed that HIIT and MICT interventions had similar effects on body composition, blood pressure, and cardiorespiratory fitness. However, meta-analyses conducted by Liu, Zhu and Su²⁴, and Cao et al.²⁸ also found that HIIT had a greater effect on VO_{2peak} than MICT in adolescents with overweight and obesity.

Aerobic and resistance training in the same session, the so-called combined training (CT) is recommended for adolescents.²⁹ Studies have shown that the greatest improvements in overall strength and fitness were demonstrated by CT (aerobic plus resistance exercise) in comparison with any exercise modality performed alone.^{19,30} A systematic review conducted by Gäbler et al.³¹ reported that the majority of the combined training interventions in young people were developed in a sport context, with a lack of evidence about the impact of CT on components of HRPF.³²

Among the types of CT, MICT combined with RT is a training method that has been used in the prescription of exercises for adolescents.³³ On the other hand, few studies have analyzed the effects of the HIIT + RT in the pediatric population.^{34,35} Furthermore, no research has compared the effects of two methods of combined training (MICT + RT and HIIT + RT) on HRPF components of adolescents.

Therefore, based on previous literature evidence, the study hypothesis is that both combined exercise interventions would improve health-related physical fitness in adolescents, with higher

intervention effects for HIIT + RT. Thus, the current study aimed was to analyze, through a randomized controlled trial, the effects of two combined training methods (MICT + RT and HIIT + RT) on health-related physical fitness components in adolescents.

2. Methods

2.1. Study design

The present investigation adopted a 12-week randomized controlled trial (RCT) design, following CONSORT recommendations (clinical trial registry: RBR-7js6r9). This research was approved by the Human Research Ethics Committee in compliance with the Helsinki Declaration.

Sample size analysis was performed using Gpower 3.1 software. Based on a priori analysis, a power of Beta = 0.80, $\alpha = 0.05$, degrees of freedom = 2, and an effect size F = 0.40 were adopted.³⁴ Considering an estimated 15% dropout at follow-up, the minimum estimated sample was 75 adolescents. The adolescents were stratified by sex and BMI status by a researcher.³⁶ Subsequently, participants were randomly assigned to one of three distinct groups: group 1 – Control; group 2 – MICT + RT; group 3 – HIIT + RT by an independent researcher not involved in the project following baseline assessments. Only after, a researcher sent the allocation for the participant via a *smartphone* application.

The research team consisted of: trained assistants, who were blinded to group allocation and conducted assessments; physical education professionals who delivered the training sessions; and researchers who prescribed/supervised the training sessions, and analyzed the results. Data were collected at two-time points (baseline [July–August 2018] and post-test [December 2018]). The post-intervention assessment was collected 72 h after the last training session.

2.2. Participants

Participants were recruited from public schools in Santo Antonio da Platina, Brazil. Eligible participants were adolescents of both sexes age 13–19 years who had not participated in an exercise program for at least 12 weeks before the intervention period of the present study and did not have an injury or illness that would preclude participation in the practice of exercises. Excluded participants were adolescents that declined to continue participating in the intervention after baseline assessment, or who did have an injury or illness that precluded participation in the training program. The adolescents interested in participating, as well as their parents/guardians, were provided with information about the aims of the investigation and gave informed written consent.

Eighty-four adolescents were recruited and agreed to participate in the study. At the initial screening, four dropped out and four could not be included because they did not meet the established criteria. In total, 76 adolescents of both sexes (age = 16.1 ± 1.1 yr) underwent baseline assessments. During the intervention period, 13 participants (7 boys) withdrew from the study for personal reasons related to work (CONSORT flow diagram as shown in Fig. 1).

2.3. Intervention

The participants of intervention groups performed combined training twice a week, during 12 weeks at a private gym. Each training session had a minimum interval of 72 h of recovery. The combined training combines both aerobic MICT or HIIT and RT at the same session. The RT took place immediately following the MICT or HIIT sessions. To avoid any intra-individual circadian variations, all the sessions were carried out at the same time of day

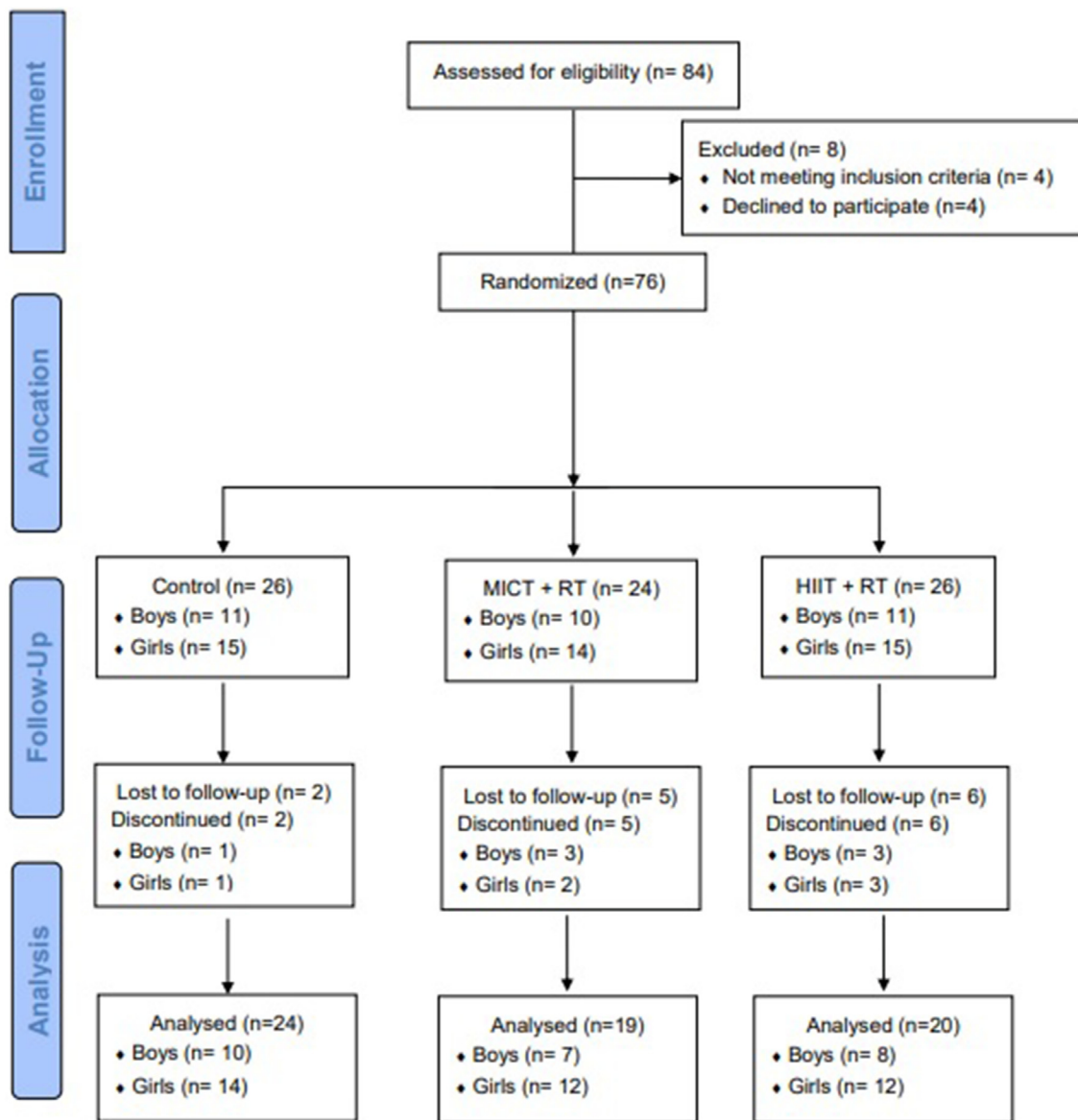


Fig. 1. Flow diagram throughout the course of the study HIIT + TR indicates high intensity interval training combined with resistance training; MCT + TR Moderate intensity continuous training combined with resistance training.

(2:30 p.m. and 6:00 p.m., after school hours). During the training sessions, the adolescents were supervised by physical education professionals and by the researchers who prescribed/supervised the training sessions. Adherence was calculated as the total number of exercise sessions the participant attended divided by the total number of sessions prescribed from baseline to the end of the intervention.

The period of intervention (12 weeks) consisted of three mesocycles, an individualized ramp test was conducted on the treadmill at the beginning of each mesocycle, to adjust the maximal treadmill velocity (v_{max}) equivalent intensities in the aerobic training prescriptions.³⁷ The average v_{max} reached in the individualized ramp test on mesocycles 1, 2, and 3 were 9.2 ± 2.2 km/h, 10.8 ± 2.0 km/h, and 11.1 ± 2.1 km/h, respectively.

2.3.1. Combined training protocol

The RT consisted of 8 exercises in total, covering the main muscle groups (pectoralis, latissimus dorsi, biceps, triceps,

quadriceps, and hamstrings), and 2 sets for each exercise, with a 60-s interval between sets and exercises.³⁷ The order of the resistance exercises was alternated by segment, and the repetitions were adjusted as follows: 15 to 20 maximum repetitions (weeks 1–4), 10 to 12 maximum repetitions (weeks 5–8), and 8 to 10 maximum repetitions (weeks 9–12). The workloads were adjusted every 2 weeks.³⁷ [Supplementary Table 1](#) describes the training prescription in detail.

The MICT began with 5 min of warm-up on the treadmill, at an intensity of 50% of v_{max} . After the warm-up, participants performed at an intensity equivalent to 55%–65% v_{max} (determined by individual results from the abovementioned ramp test) on the treadmill. Participants then performed 15 min (weeks 1–4), 17.5 min (weeks 5–8), and 20 min (weeks 9–12) of walking/running.

The HIIT was designed and prescribed by findings from previous systematic reviews.²⁷ Participants began with 5 min of warm-up on the treadmill, at an intensity of 50% of v_{max} . They then performed running on the treadmill between one and 2 min in the active phase

(>90% of v_{\max}), followed by two to 3 min in the recovery phase (40–50% of v_{\max}). Specific break downs of the active and recovery phase periods for each of the mesocycles were (active: recovery): three sets of 1:3 min (weeks 1–4), three sets of 1.5:2.5 min (weeks 5–8), and three sets of 2:2 min (weeks 9–12).

2.3.2. Exercise session

MICT + RT: This group performed the full exercise programs described in the MICT and RT protocols during each session a total of 2 times per week for a maximum of 50–60 min per session.

HIIT + RT: This group performed the full exercise programs described in the HIIT and RT protocols during each session a total of 2 times per week for a maximum of 50 min per session.

Control group: The adolescents allocated to the control group continued with their usual lifestyle.

The aerobic training intensity was monitored in every session by v_{\max} . Furthermore, blood lactate concentration analysis was performed 1 min after the end of exercise³⁸ in the final week of each mesocycle to monitor the intensity of MICT and HIIT sessions, more detail is given in the study by Faria et al.³³

2.4. Somatic maturation

Somatic maturation was estimated by determining the distance in years of the individual from the baseline peak height velocity (PHV) using mathematical models.³⁹

2.5. Anthropometry and body composition

Body height was measured without shoes to the nearest 0.1 cm with a transportable stadiometer (Ottoboni HM-210D; Ottoboni). Body weight was measured to the nearest 0.1 kg with a calibrated beam balance scale (Toledo 2096 PP; Toledo). Body mass index (BMI) was calculated using the standard equation ($\text{weight [kg]} / \text{height [m]}^2$) and it was classified according to World Health Organization.³⁶ Estimation of body composition was performed using tetrapolar bioelectrical impedance analysis (BIA), at a single frequency of 50 kHz (Quantum II, USA). The body fat percentage was calculated using a recommended equation for children and adolescents aged 10–19 years.^{40,41}

2.6. Muscular fitness

The muscular fitness (MF) was measured by a hand-grip dynamometer (Jamar) and abdominal endurance test. The participant held the dynamometer with the hand and positioned the arm at right angles and the elbow on the side of the body. When ready the subject squeezed the dynamometer with maximum isometric effort, which was maintained for about 5 s.⁴² The average of the best scores of each hand was adopted as a muscular fitness indicator. The hand-grip test is a valid measure of upper body maximal strength among youth and has acceptable test-retest reliability among adolescents (ICC [95% CI] = 0.98 [0.97 to 0.99]).⁴²

The abdominal endurance test^{43,44} evaluates the strength/endurance of the body's abdominal muscles. This test was performed with the individual in a supine position, with the legs flexed. The subject was required to perform the greatest number of complete trunk flexions towards the flexed legs in 1 min. This test is a valid has acceptable test-retest reliability among adolescents (ICC [95% CI] = 0.82 [0.79 to 0.86]).⁴³

2.7. Cardiorespiratory fitness

To estimate cardiorespiratory fitness, the *Progressive Aerobic Cardiovascular Endurance Run* (PACER), which is the most widely

accepted field-based measure of CRF, demonstrates high reliability and validity.⁴⁵ The test was applied, which involves running with changes of direction at progressive intensity.⁴⁴ The test was ended when the adolescent fail to complete two consecutive laps before the beep sounds, or on volitional failure. The test result was registered through the number of complete laps, for later determination of the peak oxygen consumption ($VO_{2\text{peak}}$) which was estimated by the formula proposed by Saint-Maurice et al.⁴⁶: $VO_{2\text{peak}} = 0.353(\text{number of laps}) - 1.121(\text{age}) + 45.619$. The number of completed laps was moderately correlated with the final treadmill speed ($R^2 = 0.51$) and $VO_{2\text{peak}}$ ($R^2 = 0.49$).⁴⁴

2.8. Statistical analysis

The general characteristics of the participants are presented as means and standard deviations. Student t-test was employed to compare the general characteristics at baseline and post-intervention. ANOVA for repeated measures was used to compare the blood lactate values in the experimental groups in each mesocycle. The effects of experimental interventions on the HRRPF outcomes were analyzed by ANOVA for repeated measures. When Mauchly's sphericity test was violated, the Greenhouse–Geisser correction was assumed. ANCOVA and adjustment for the covariates PHV, BMI, and baseline values were employed to compare the effects of experimental interventions on the HRRPF outcomes between the groups investigated at the post-intervention moment. When the F test identified an effect and/or interaction, the Bonferroni post hoc was applied to locate the differences between the means. Effect sizes between groups were calculated using Cohen's d. The thresholds considered were: insignificant (<0.19); small (0.20; 0.49); moderate (0.50; 0.79); and large (>0.80).⁴⁷ The analyses were processed using the SPSS 20.0 program, except for effect size calculations (Cohen's d), which were processed using the GPower 3.1 program. The significance alpha levels are set at $p < 0.05$.

3. Results

Eighty-four adolescents of both sexes were recruited, with seventy-six participants (mean age = 16.1 ± 1.1 yr) assessed at baseline, representing a recruitment rate of 90%. From baseline to 12 weeks (24 training sessions), there were no significant differences in adherence rates between exercise training groups. The median exercise training adherences were 87.5% (interquartile range, 83.3% to 94.1%) in HIIT + RT, 100% (interquartile range, 88%–100%) in MICT + RT.

Blood lactate values after finishing each mesocycle were significantly higher in the HIIT + RT group than the MICT + RT group in the three mesocycles ($F = 3.294$; $p < 0.05$): (Mesocycle 1 = 6.2 mmol [95%CI 5.5; 6.8] vs 2.7 mmol [95%CI 2.1; 3.4]); (Mesocycle 2 = 6.9 mmol [95%CI 6.3; 7.6] vs 3.1 mmol [95%CI 2.3; 3.7]); and (Mesocycle 3 = 7.4 mmol [95%CI 6.7; 8.2] vs 2.9 mmol [95%CI 2.1; 3.6]).

Baseline and post-intervention characteristics of the study sample are presented in Table 1. We observed a significant increase in fat-free mass (FFM) and a reduction in fat mass (FM) in both experimental groups. No significant difference was found for FFM and FM in the control group.

4. Intra-group comparison for the health-related physical fitness components

The intra-group comparison for the health-related physical fitness components is present in Table 2. The intervention groups presented a significant reduction in body fat percentage after 12

Table 1
Participant characteristics at the baseline and after 12 weeks of intervention.

	Control (n = 24)			MICT + RT (n = 19)			HIIT + RT (n = 20)		
	Mean (DP) Baseline	Mean (DP) 12 weeks	Δ%	Mean (DP) Baseline	Mean (DP) 12 weeks	Δ%	Mean (DP) Baseline	Mean (DP) 12 weeks	Δ%
Age (years)	16.6 (1.0)	16.8 (1.0)*	1.4	15.9 (1.0)	16.1 (1.0)*	1.5	15.5 (1.0)	15.8 (1.0)*	1.5
Height (m)	1.64 (0.09)	1.64 (0.09)*	0.15	1.66 (0.07)	1.66 (0.07)*	0.12	1.64 (0.08)	1.64 (0.08)	0.12
Weight (kg)	63.0 (16)	63.4 (16.8)	0.52	70.4 (20.7)	71.0 (20.3)	1.0	69.3 (18.4)	69.6 (17.6)	0.62
FFM (kg)	45.8 (8.39)	46.2 (9.1)	0.83	48.7 (11)	51.7 (11.3)*	6.3	48.3 (10.6)	51.7 (11.9)*	7.1
FM (kg)	17.2 (9.3)	17.2 (9.7)	-1.2	21.7 (11.9)	19.3 (11.6)*	-11.9	21.0 (10.5)	17.8 (9.4)*	-16.8
BMI (kg/m²)	23.2 (5)	23.3 (5.3)	0.22	25.3 (6.9)	25.4 (6.7)	0.76	25.5 (5.6)	25.5 (6.3)	0.38

MICT + RT moderate-intensity of continuous training + Resistance training; HIIT + RT: high-intensity interval training + Resistance training; FFM: Fat-free mass; FM: Fat mass; BMI: Body Mass Index.

Data are presented as mean and standard deviation. *significant difference to baseline in $p < 0,05$.

Table 2
Intra-group comparisons of health-related physical fitness components between the baseline and after 12 weeks of intervention.

	Control (n = 24)	MICT + RT (n = 19)	HIIT + RT (n = 20)
	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
Body Fat (%)			
Baseline	25.9 (22.3; 29.5)	29.2 (25.1; 33.2)	29.2 (25.2; 33.2)
12 weeks	25.6 (21.8; 29.4)	25.6 (21.3; 29.9)	24.7 (20.5; 28.8)
p	0.632	<0.001	<0.001
Handgrip (kg)			
Baseline	26.7 (23.2; 30.3)	29 (25.5; 32.4)	30.3 (26.7; 33.9)
12 weeks	25.4 (21.6; 29.3)	27.8 (24.1; 31.6)	31.2 (27.3; 35)
p	0.218	0.276	0.399
Abdominal (reps)			
Baseline	23.6 (19.2; 28.1)	20.3 (15.2; 25.3)	22.6 (17.8; 27.3)
12 weeks	23.6 (18.6; 28.7)	28.8 (24.1; 35.5)	36 (30.6; 41.4)
p	1.000	<0.001	<0.001
PACER (laps)			
Baseline	31.5 (27.4; 38.3)	25.4 (17.7; 33)	26.4 (18.9; 33.8)
12 weeks	29 (21.2; 38.8)	33.2 (24.4; 41.9)	37.4 (28.8; 45.9)
p	0.119	<0.001	<0.001
VO_{2peak} (mL/kg/min)			
Baseline	38.1 (35.7; 40.5)	36.1 (33.4; 38.8)	37.4 (34.8; 40.1)
12 weeks	37.2 (34.4; 40)	39.0 (35.8; 42.1)	41.3 (38.3; 44.4)
p	0.117	<0.001	<0.001

MICT + RT. Moderate-intensity continuous training combined + Resistance training; HIIT + RT: high-intensity interval training + Resistance training; VO_{2peak}: peak oxygen consumption; 95%CI: 95% confidence interval; Data are presented as mean and 95% confidence interval.

weeks of combined exercise program (MICT + RT: mean difference: -3.5; 95%CI: -4.9; -2.2; HIIT + RT: mean difference: -4.5; 95%CI: -5.8; -3.2). The control group showed no significant difference in body fat percentage after 12 weeks (mean difference: -0.283; 95%CI: -1.4; 0.89).

For muscular fitness, significant increases in the number of repetitions in the abdominal test were found in the experimental groups (MICT + RT: mean difference: 9.5; 95%CI: 6.5; 12.5; HIIT + RT: mean difference: 13.4; 95%CI: 10.6; 16.2). However, no significant differences were observed in the handgrip test (MICT + RT: -1.1; 95%CI: -3.1; 0.91; HIIT + RT: mean difference: 0.88; 95%CI: -1.2; 2.9). The control group showed no significant difference after 12 weeks in the number of abdominal repetitions (mean difference: 0.00; 95%CI: -2.6; 2.6) and in the handgrip test (mean difference: -1.2; 95%CI: -3.3; 0.79).

For cardiorespiratory fitness, significant increases in the number of laps in the PACER test were found in the experimental groups (MICT + RT: mean difference: 7.7; 95%CI: 4.1; 11.3; HIIT + RT: mean difference: 11; 95%CI: 7.4; 14.5). Likewise, significant increases in VO_{2peak} were found in the experimental groups (MICT + RT: mean difference: 2.8; 95%CI: 1.6; 4.1; HIIT + RT: mean difference: 3.8; 95%CI: 2.6; 5.1). The control group showed no significant difference after 12 weeks in the number of laps in the PACER test (mean difference: -2.5; 95%CI: -5.7; 0.66) and VO_{2peak} (mean difference: -0.89; 95%CI: -2; 0.23).

5. Intervention effects for the health-related physical fitness components between the groups

Analyzing the components of health-related physical fitness between groups (Table 3), intervention effects were found to significantly reduce body fat percentage for the MICT + RT and HIIT + RT groups compared to the control group (mean difference: -3.8, 95%CI: -6.2; -1.3, $p = 0.001$, in MICT + RT vs Control group; mean difference: -4.7, 95%CI: -7.1; -2.3, $p < 0.001$, in HIIT + RT vs Control group). There were no significant intervention effects observed between the experimental groups.

For muscular fitness, the effects of the intervention significantly increased the number of abdominal repetitions favoring the intervention groups compared to the control group (mean difference: 9.5, 95%CI: 4.4; 14.7, $p < 0.001$, in MICT + RT vs Control group; mean difference: 14.1, 95%CI: 9; 19.3, $p < 0.001$, in HIIT + RT vs Control group). No significant differences were observed in the handgrip test between the experimental and control groups.

For cardiorespiratory fitness, significant effects of the intervention on increasing PACER (laps) were found in the experimental groups compared to the control group (mean difference: 12.2, 95%CI: 6; 18.3, $p < 0.001$, in MICT + RT vs Control group; mean difference: 15.6, 95%CI: 9.5; 21.7, $p < 0.001$, in HIIT + RT vs Control group). Likewise, significant effects of the intervention on improving VO_{2peak} were found in the experimental groups

Table 3
Intergroup comparison of the health-related physical fitness components after 12-week intervention.

	MICT + RT (n = 19) vs Control (n = 24)		HIIT + RT (n = 20) vs Control (n = 24)		MICT + RT (n = 19) vs HIIT + RT (n = 20)	
	Mean Difference (95%CI)	Cohen (d)	Mean Difference (95%CI)	Cohen (d)	Mean Difference (95%CI)	Cohen (d)
Body Fat (%)	-3.8 (-6.2; -1.3) p = 0.001	0.60	-4.7 (-7.1; -2.3) p < 0.001	0.44	0.9 (-1.3; 3.3) p = 0.956	0.09
Handgrip (kg)	0.5 (-3.6; 4.8) p = 1.000	0.02	2.6 (-1.6; 6.9) p = 0.407	0.09	-2.0 (-5.8; 1.7) p = 0.567	0.08
Abdominal (reps)	9.5 (4.4; 14.7) p < 0.001	0.23	14.1 (9; 19.3) p < 0.001	0.40	-4.6 (-9.6; 0.31) p = 0.080	0.08
Pacer (laps)	12.2 (6; 18.3) p < 0.001	0.18	15.6 (9.5; 21.7) p < 0.001	0.20	-3.4 (-9.3; 2.5) p = 0.485	0.05
VO_{2peak} (mL/kg/min)	4.4 (2.2; 6.6) p < 0.001	0.53	5.5 (3.3; 7.7) p < 0.001	0.56	-1.0 (-3.2; 1.0) p = 0.624	0.14

MICT + RT: Moderate-intensity continuous training combined + Resistance training; HIIT + RT: high-intensity interval training + Resistance training; VO_{2peak}: peak oxygen consumption; 95%CI: confidence interval 95%; Data are presented as mean difference, 95% confidence interval and p value.

compared to the control group (mean difference: 4.4, 95%CI: 2.2; 6.6, p < 0.001, in MICT + RT vs Control group; mean difference: 5.5, 95%CI: 3.3; 7.7, p < 0.001, in HIIT + RT vs Control group). There were no significant intervention effects in the comparison between the experimental groups.

6. Discussion

A key finding of the current RCT was that there were no significant differences in the effects of MICT + RT or HIIT + RT on HRRP in adolescents. This observed fact can be explained by the fact that both experimental groups were composed of untrained individuals. Despite different protocols with fitness cardiorespiratory, both groups tend to improve the component with the protocols administered.⁴⁸ Furthermore, both groups share a similar training protocol regarding RT. We also observed that both experimental groups significantly reduced the body fat percentage, increased muscular (abdominal endurance) and cardiorespiratory fitness (VO_{2peak} and Pacer laps).

As expected, both interventions led to significant BF% reductions. Our findings found improvements in BF% MICT + RT group ($\Delta = -12.9\%$) and HIIT + RT group ($\Delta = -17.4\%$) from baseline to post-intervention. By our results, a study with obese adolescents observed a reduction in fat mass percentage in the HIIT group ($\Delta = -4.7\%$) and MICT ($\Delta = -2.8\%$).⁴⁹

There was a moderate intervention effect for BF% in both training groups vs control group (Table 3). These findings have clinical implications because the excess fat body has been associated with increased cardiovascular risk factors, reinforcing the crucial need maintaining body fat at adequate levels.⁵⁰ However, no significant differences were observed in the BF% between the HIIT + RT and MICT + RT interventions. Such evidence may be explained by the fact that in the present study, both training methods included resistance training (RT) since RT interventions have shown beneficial effects on body fat (%) in youth.⁵¹ Therefore, our results confirmed that both HIIT and MICT improved body fat to a similar extent in these adolescents. These findings were consistent with previous studies, have demonstrated a reduction in BF% after combined⁵² and interval⁵³ training programs in adolescents.

In addition to reducing body fat percentage, the current study observed a significant increase of FFM in both intervention groups, by results from Lopes et al.⁵⁴ The increase in fat-free mass promoted by resistance training directly influences the reduction of body fat due to the increase in the basal metabolic rate and lipid oxidation.^{54,55}

Regarding cardiorespiratory fitness, the present study found a moderate intervention effect for MICT + RT and HIIT + RT group compared to the control group. The previous meta-analysis⁵⁶ demonstrated that HIIT is more effective in improving CRF (VO_{2max} mL·kg⁻¹ min⁻¹) of adolescents when compared to MICT. Dias et al.⁵⁷ also observed that HIIT showed significantly greater

improvements in relative VO_{2peak} in comparison MICT (EMD 3.6 mL/kg/min, 95% CI 1.1–6.0, P = 0.004). This difference between groups demonstrated by Dias et al.,⁵⁷ could be due, in part, to differences in methodology (CRF assessed by treadmill ramp protocol with respiratory gas analysis; heart rate was used to control for exercise intensity, and total session time of 40 min (HIIT) and 44 min (MICT). Regarding session time, previous meta-analysis²⁴ showed that long-interval HIIT programs seemed to more effectively improve VO_{2peak} (SMD = 0.691, 95% CI: 0.290 to 1.092, p = 0.006) than short-interval HIIT programs. In this context, HIIT has been shown to improve CRF for health pediatric populations.^{58,59}

Our finding, however, found a significant percentage change in estimate VO_{2peak} of 9.8% (HIIT + RT) and 7.7% (MICT + RT) after 12 weeks of training. In addition, PACER tests (laps), another indicator of cardiorespiratory fitness, also improved significantly in 7.7 and 11 laps for MICT + RT and HIIT + RT groups, respectively. By our findings, researchers have observed that both training methods (HIIT and MICT) have been effective in improving cardiorespiratory fitness.^{48,60}

A relevant component of our study with exercise intensity is that combined training with the “HIIT protocol” (~12 min) was sufficient to improve VO_{2peak} in adolescents. This training method has a practical significance because, in summary, we considered that HIIT + RT shows promise as a time-efficient training method, yielding similar improvements to MICT + RT in CRF.

Importantly, the increase in CRF observed in the intervention groups is promising to produce clinically meaningful effects for metabolic outcomes. The previous studies^{61,62} have shown that low CRF in childhood and adolescence predicts cardiovascular health later in life, with a risk of metabolic syndrome, arterial stiffness, and myocardial infarction.⁶¹ Likewise, higher levels of CRF are related to decreased adiposity and improved glucose uptake by muscle tissue, further contributing to the imbalance between absorption and oxidation of fatty acids in skeletal muscle, and thus promoting cardiometabolic health benefits.⁶²

Regarding muscular fitness, we observed significant changes in abdominal muscular endurance after 12 weeks of intervention in both training groups. Lopes et al.⁵⁴ showed significant increases in muscular strength of adolescents through the one-repetition maximum test on bench press and leg press exercises after 3-months of combined training. Improvements in muscular strength have been observed in previous studies¹⁹ evaluating adolescents undergoing combined aerobic and resistance exercise training.

Conversely, the results of the hand-grip test did not change following 12 weeks of exercise training in any group. Although RT employed whole body exercises designed to improve upper and lower body strength, no specific exercises were prescribed to improve upper member isometric strength. The different results may be partially explained by the test used to assess MF in the

current study, which is not specific to the trained muscle group, and then, it may not have been able of detecting change.

These positive results with to the improvement of muscular endurance in response to RT have important implications because MF (power, strength, and endurance) has been inversely associated with clustered cardiometabolic risk,⁶³ adiposity, and positive association with bone health and self-esteem (including physical self-concept, perceived physical appearance, and perceived sports competence) in adolescents.⁶ Therefore, we suggest that engaging adolescents in resistance or combined training is essential to the maintenance and/or improving MF.

In summary, the results found in the present study allow us to infer that both MICT + RT and HIIT + RT training methods were effective for improving health-related physical fitness in adolescents. However, some limitations should be mentioned, such as lack of equivalence of metabolic demand (calories/session) between MICT + RT and HIIT + RT; lack of control of the session by heart rate; lack of control over habitual behaviors related to physical activity and food consumption during the intervention period. Strengths of this study include the design and delivery of appropriate combinations of HIIT + RT and MICT + RT to be performed by adolescents, regardless of sex and BMI status. Further studies should be conducted to prove the applications of combined training methods in the health-related components in adolescents.

Moreover, research is needed to evaluate means to deliver the combined training stimulus within the school setting, such as integrating it within PE class, or before/after school. Offsite programs such as the ones evaluated in the current study involved substantial space and equipment requirements, making scalability questionable.

In conclusion, twelve weeks of HIIT + RT and MICT + RT were effective for increasing muscular and cardiorespiratory fitness and reducing body fat percentage in adolescents. No significant differences were observed between the two training methods for any HRPF components.

6.1. Practical applications

Twice sessions a week of the combined exercise (Aerobic + RT) has the potential to improve adolescents' health-related physical fitness, regardless of the protocol (MICT + RT or HIIT + RT).

CRediT authorship contribution statement

Filipe Rodrigues Mendonça: Conceptualization, Methodology, Writing – original draft. **Wayne Ferreira de Faria:** Conceptualization, Methodology. **Jadson Marcio da Silva:** Methodology, Writing – original draft. **Ricardo Busquim Massuto:** Conceptualization, Writing – original draft. **Géssika Castilho dos Santos:** Methodology, Writing – original draft, Visualization. **Renan Camargo Correa:** Methodology, Formal analysis. **Claudinei Ferreira dos Santos:** Formal analysis, Visualization. **Jeffer Eidi Sasaki:** Investigation, Writing – review & editing. **Antonio Stabelini Neto:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jesf.2022.03.002>.

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