Effects of a Combination of Aerobic and Resistance Training and Dietary Intervention on Body Composition, Lipid Profile, Inflammation, and Cardiorespiratory Fitness in Obese Adolescents

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ABSTRACT

Albuquerque Filho NJB, Matos VAF, Felipe TR, Pinto EF, Rebouças GM, Oliveira Segundo VH, Knackfuss MI, Medeiros HJ. Effects of a Combination of Aerobic and Resistance Training and Dietary Intervention on Body Composition, Lipid Profile, Inflammation, and Cardiorespiratory Fitness in Obese Adolescents. JEPonline 2016;19(5):1-14. The aim of this study was to determine the effects of a combination of aerobic and resistance training plus dietary intervention on body composition, lipid profile, inflammation, and cardiorespiratory fitness in obese adolescents. Twenty-three obese adolescents were divided into two groups: Intervention Group (IG) that performed a combined exercise program plus nutritional intervention for 16 wks and a Control Group (CG) that did not performed any intervention. Body weight, height, body mass index, waist circumference, sum of triceps and subscapular skinfold thickness, fasting blood glucose, triglycerides, LDL-C, HDL-C, total cholesterol, hs-CRP, strength by one-maximum repetition, and VO₂peak were measured. Across intervention period, effects were tested using analysis of variance for repeated measures with post
hoc pairwise comparisons. There were significant improvements in body composition, lipid profile, hs-CRP, upper and lower body strength, and cardiorespiratory fitness in the IG when compared with the CG. There were no effects for fasting glucose, despite a slight decrease in the IG and a significant increase in the CG after 16 wks. The findings indicate that the combination of aerobic and resistance training plus dietary intervention resulted in an improvement in body composition, lipid profile, hs-CRP, and cardiorespiratory fitness in obese adolescents.

**Key Words**: Obesity, Strength Training, Aerobic Training, Blood Markers, Inflammation, Nutrition

**INTRODUCTION**

Childhood obesity is considered a growing global health problem. It is associated with several comorbidities, such as metabolic syndrome, cardiovascular, hepatic, orthopedic, psychological, and pulmonary diseases that may result in high costs to health in the future (29, 30). These downstream health effects represent a substantial challenge for the long-term health and well-being of children.

Obesity rates have skyrocketed over the last 30 yrs in both developing and developed countries, which suggests that interventions and public policies must be established to reduce or reverse this increase (14). In Brazil, the overweight also showed an increase in their levels. Between 1979 and 2009 there has been an observed increase of 19.3% in adolescents (5).

Calcaterra et al. (6) indicate that compared to normal individuals, children and adolescents who are overweight or obese are subject to health risks resulting from elevated cardiometabolic values of lipoproteins, fasting glucose, triglycerides, and inflammatory markers. Behavior factors, such as a sedentary lifestyle and a diet high in fat and sugar contribute strongly to cardiovascular disease, diabetes, osteoarthritis, and chronic kidney disease. In agreement, Hardy and colleagues (17) indicate that sedentary activities, particularly watching TV and computer use, and serum lipid levels during childhood and adolescents are associated with metabolic and atherosclerotic disease.

Fortunately, the prevalence of overweight or obese children and adolescents can be treated by regular exercise, which reduces body fat while improving physical fitness, lipid profile, inflammatory markers, thus mitigating the comorbidities associated with a sedentary lifestyle (2, 39). The combination of both aerobic training and resistance training, known as combined training, has been proposed as an interesting training strategy for maintaining and/or improving health and well-being (11).

In fact, this point is in agreement with the findings of Pienaar et al. (28). They demonstrated that the effects of physical activity, diet, and behavior modification resulted in positive changes in body composition and health-related physical fitness parameters in 37 overweight or obese subjects. Specifically, there were significant decreases in body mass, waist circumference, BMI, and body fat percentage after participation in the intervention (28).

Thus, the purpose of this study was to determine the effects of a combination of aerobic and resistance training plus dietary intervention on body composition, lipid profile, inflammation, and cardiorespiratory fitness in obese adolescents.
METHODS

Subjects
Initially, this study consisted of 45 pubertal adolescents (P3 and P4) (35). There were 25 males and 20 females who were classified as overweight with a body mass index (BMI) >85th percentile (25) with an age range from 12 to 15 yrs old. They were recruited from general population from August 2012 to July 2013 from Mossoró city, RN, Brazil. The selection criteria required the subjects to be overweight with no previous experience with resistance exercise (bodybuilding) or with a systematic program of aerobic exercise. Subjects were excluded from the study if it was confirmed that they used tobacco or alcohol, refused to make any assessment (that showed limitations preventing the execution of some exercise), pregnancy, or had a 15% absence in the training sessions.

Study Design
The Research Ethics Committee under the process nº 240.550 approved the study design. It met all the ethical requirements of Resolution No. 466/2012 on research involving human subjects from the National Board of Health of the Ministry of Health.

Anthropometric data (body weight, height, body mass index, waist circumference, and sum of triceps and subscapular skinfold thickness) and fasting glucose, triglycerides, LDL-C, HDL-C, total cholesterol, hs-CRP, strength by one-maximum repetition, and VO\textsubscript{2}peak were measured in 23 obese adolescents. The subjects were randomly divided into two groups: (a) the Intervention Group (IG) that followed a 30-min combination of resistance training on weight machines and free weights plus 33 min of aerobic exercise on a cycle ergometer 3 times·wk\textsuperscript{-1} during 16 wks in addition to a dietary prescription; and (b) the Control Group (CG) that did not performed any intervention.

The training program, dietary prescriptions, body composition, strength, and cardiovascular evaluations were performed at the Support Center for Obesity Control Jansen Jefferson Diogenes e Medeiros, Mossoró, RN, Brazil, while blood tests were carried out in the Center for Clinical and Immunologic Analysis from Mossoró, (CCIAM) RN, Brazil. All measurements were performed at baseline, after 8 wks, and 16 wks.

Anthropometry and Body Composition
Anthropometric measurements were performed according to the guidelines of International Standards for Anthropometric Assessment (ISAK) (22). Body mass (kg) was determined by a portable electronic digital scale TANITA® (Ironman BC 553, Tokyo, Japan) with an accuracy of 0.100 kg. Height was measured using a SANNY® (Personal Portable Caprice, Brazil) stadiometer with an accuracy of 0.1 cm. Body mass index calculation (BMI) was determined by the ratio of body mass by the square of height (kg·m\textsuperscript{-2}) with the cutoff points being the indexes proposed by the World Health Organization (25). Waist circumference was measured at the midpoint between the last arc rib and the iliac by an anthropometric SANNY® tape measure with an accuracy of 0.1 cm. Body fat percentage (BF%) was determined from the sum of triceps and subscapular skinfolds measured by a SANNY® scientific adipometer with an accuracy of 0.1 mm (34).
Biochemical Markers Analysis
Blood samples (5 mL) were collected at ~7:00 a.m. after a 12-hr fast. Glucose, triglycerides (TG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), and total cholesterol (TC) were determined using the enzymatic colorimetric method in accordance with the manufacturers’ specifications in automated equipment Roche (Hitachi 917 automated, Switzerland). LDL-C was calculated using the Friedewald formula (LDL-C = TC - HDL-C - TG / 5), which is valid for triglycerides values less than 400 mg·dL\(^{-1}\) (15). The measurement of high sensitive c-reactive protein (mg·dL\(^{-1}\)) (hs-CRP) was performed through ultrasensitive ELISA (Diagnostic Systems Laboratories, Inc. Webster, Texas, USA).

Strength and Cardiorrespiratory Assessment
Upper and lower body strength were assessed by one repetition maximum (1RM) in bench press and leg press, respectively, using established procedures (13). Cardiorespiratory fitness was assessed by means of a progressive intensity test (VO\(_{2}\)peak) and maximum heart rate (HRmax) conducted with a spirometer Flow Met (Micromed, Brazil) on a cycle ergometer Szobakerékpár (Ergo Bike Cardio Pro, Hungary) and a heart rate monitor Polar® (Model RS800CX, Finland), respectively, before the start of the training sessions.

The progressive intensity test followed the maximum load protocol (1). With a minimum work load of 25 watts, each stage lasted 3 min with an ongoing increase in work load up to 25 watts maximum or the subject’s appearance of limiting symptoms. The highest heart rate during the test was used as a reference to denote the intensity of aerobic exercise.

Dietary
Three 24-hr recalls (R24) on alternate days (including a weekend day) were used to determine the subjects' weekly average consumption of calories, fats, and fibers. The assessment of food consumption and dietary prescription was performed at the beginning of the program (baseline) and at ~8 wks. The recommendations of the energy distribution of macronutrients were 15 to 20% protein, 50 to 55% carbohydrates, and 30% fat, which were individually adapted to reduce the energy consumption by approximately 250 kcal (26).

Exercise Program
The endurance training “Interval” occurred prior to resistance training in one session. Then, it was reversed in the subsequent session, which consisted of four periods of 3 min at 90 to 95% HR max with 2 min of an active gap at 70 to 80% HR max between each period of 3 min. At the end of the last stage of high intensity, the subjects remained for 5 min in a cool down period amounting to 23 min (36).

The resistance training protocol followed a system divided into two phases. The first phase consisted of 2 wks of adaptation and learning how to use the equipment, weights, and dumbbells in the weight room. This stage consisted of a frequency of 3 times·wk\(^{-1}\) (on non-consecutive days), two sets of 15 to 20 repetitions, performing 8 to 10 exercises per session, with intervals between sets of a minute.

After the adaptation period, the load was adjusted by increasing weight and intensity with a decrease in the maximum number of repetitions to 8 to 12 repetitions and an increase in a series, totalling three. There was also an increase in the rest interval, where the subjects were given 1 to 2 min between sets (13). The load intensity was determined by perceived
exertion after each subject’s last repetition (8 to 10), and it was adjusted weekly (31). If a subject could not perform the minimum number of repetitions, the load was maintained and the readjustment would occur the following week. In order for the resistance training not to have had duration much higher than the endurance training (taking into account the number of sets, exercises, and rest interval), the total number of exercises was reduced to 5, lasting ~30 min·session⁻¹.

Regardless of the type of training (endurance or resistance) that started the session, the subjects’ warmed-up for 10 min on a cycle ergometer at a HR max ≤70%. Thus, together the 10-min warm-up plus the 23 min of endurance training and ~30 min of resistance exercise, the exercise session lasted <63 min and not more than 65 min. The resistance training sessions consisted of Model A and Model B, which were performed on different days. Both Models had 5 workouts each. Model A was made up of the following exercises (frontal pull, bench press, leg extension, leg curl, and plantar flexion) while Model B was composed of leg press, squat, biceps curl, triceps extension, and side elevation (shoulder abduction).

Statistical Analyses
The statistical analysis was carried out using SPSS (Statistical Package for Social Science, 20.0 Inc. Chicago, IL, USA) and GraphPad Prism® (6.05, San Diego, CA, USA). The normality of the data was verified by the Shapiro-Wilk test. The parametric variables were expressed by the mean and the standard deviation, while the non-parametric variables were expressed by the median, minimum, and maximum values. Comparison of the parametric variables scores between the three moments was done using an analysis of the variance for repeated measures with the use of multiple comparisons of Bonferroni. The Friedman test, followed by the Mann-Whitney U test, was used for the non-parametric variables. For the comparison between the IG and the CG on the three moments at the same time, Mann-Whitney’s t and U test were used, along with the Spearman’s coefficient of correlation (ρ) to evaluate potential associations between the variables. A level of significance of P≤0.05 was used.

RESULTS

Of the adolescents initially included in the program, 23 (52.2% female) completed more than 85% of the treatment sessions during the 16 wks and were not absent in any evaluation. Of the 22 subjects who did not finalize the study, 15 were from the IG while 7 were from the CG. The general characteristics of subjects are presented on Table 1. The comparative analysis of all initial parameters showed that there were no significant differences between genders at baseline.

After 8 wks, there was significant improvement in body weight (P=0.034), BMI (P=0.009), waist circumference (P=0.001), ∑SFT (P=0.001), triglycerides (P=0.003), LDL-C (P=0.012), HDL-C (P=0.003), total cholesterol (P=0.003), upper body strength (P=0.002), lower body strength (P=0.002), and cardiorespiratory fitness (P=0.002) in the IG. On the other hand, subjects’ body weight (P=0.003), BMI (P=0.002), waist circumference (P=0.004), ∑SFT (P=0.001), triglycerides (P=0.005), LDL-C (P=0.003), total cholesterol (P=0.006), and hs-CRP (P=0.043) in the CG got worse (Figure 1).
After 16 wks, the IG obtained significant improvements in the body weight (P=0.002), BMI (P=0.001), waist circumference (P=0.001), \( \Sigma \text{SFT} \) (P=0.001), triglycerides (P=0.008), LDL-C (P=0.002), HDL-C (P=0.003), total cholesterol (P=0.019), hs-CRP (P=0.015), upper body strength (P=0.003), lower body strength (P=0.002), and cardiorespiratory fitness (P=0.002). In the CG, a significant increase was observed in body weight (P=0.002), BMI (P=0.001), waist circumference (P=0.001), \( \Sigma \text{SFT} \) (P=0.001), fasting glucose (P=0.02), triglycerides (P=0.004), LDL-C (P=0.002), total cholesterol (P=0.003), hs-CRP (P=0.045), upper body strength (P=0.013), and lower body strength (P=0.013) along with a decreased in HDL-C (P=0.002) (Figure 1).

Table 1. General Characteristics at Baseline.

<table>
<thead>
<tr>
<th>Variables</th>
<th>干预组</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>(N = 6)</td>
<td>(N = 6)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>13.5 ± 1.4</td>
<td>11.9 ± 1.4</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td>82.1 (55.9 - 125.6)</td>
<td>67.8 (63.9 - 79.3)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.0 ± 12.7</td>
<td>154.6 ± 4.0</td>
</tr>
<tr>
<td>BMI (kg·m(^{-2}))</td>
<td>32.0 ± 5.3</td>
<td>29.4 ± 2.8</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>103.8 ± 12.0</td>
<td>93.4 ± 5.3</td>
</tr>
<tr>
<td>( \Sigma \text{SFT} ) (mm)</td>
<td>65.1 ± 9.9</td>
<td>69.1 ± 4.9</td>
</tr>
<tr>
<td>Fast Glucose (mg·dL(^{-1}))</td>
<td>80.5 (68 - 97)</td>
<td>88.8 (83 - 96)</td>
</tr>
<tr>
<td>Triglycerides (mg·dL(^{-1}))</td>
<td>110 (68 - 232)</td>
<td>114 (78 - 227)</td>
</tr>
<tr>
<td>LDL-C (mg·dL(^{-1}))</td>
<td>98.5 (67 - 124)</td>
<td>90.0 (67 - 119)</td>
</tr>
<tr>
<td>HDL-C (mg·dL(^{-1}))</td>
<td>38.5 (29 - 49)</td>
<td>48.0 (37 - 61)</td>
</tr>
<tr>
<td>TC (mg·dL(^{-1}))</td>
<td>161.8 ± 34.8</td>
<td>169.3 ± 20.8</td>
</tr>
<tr>
<td>hs-CRP (mg·dL(^{-1}))</td>
<td>4.7 ± 2.1</td>
<td>6.1 ± 3.3</td>
</tr>
<tr>
<td>Bench Press (kg)</td>
<td>15.0 (12 - 46)</td>
<td>12.0 (12 - 20)</td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>140.0 (94 - 330)</td>
<td>137.5 (115 - 180)</td>
</tr>
<tr>
<td>( \text{VO}_{2}\text{peak} ) (mL·kg(^{-1})·min(^{-1}))</td>
<td>23.6 (16.9 - 37.4)</td>
<td>22.8 (20.6 - 26.8)</td>
</tr>
</tbody>
</table>

BMI = body mass index; WC = waist circumference; \( \Sigma \text{SFT} \) = sum of skinfold thickness; LDL-C = low-density lipoprotein cholesterol; HDL-C = high-density lipoprotein cholesterol; TC = total cholesterol; hs-CRP = high sensitive c-reactive
Strong and significant correlations were found for body weight with BMI and $\sum$SFT; between triglycerides and fasting glucose; between LDL-C and waist circumference; and between total cholesterol with triglycerides. In addition, the following moderate correlations were found for subjects in the IG: waist circumference and hs-CRP; between total cholesterol with fasting glucose; and a negative correlation between LDL-C and HDL-C. In the CG, strong and significant correlation were found for body mass and BMI; hs-CRP and waist circumference, as well as moderate correlations between triglycerides and fasting glucose; waist circumference and LDL-C; and a negative correlation between LDL-C and HDL-C (Table 2).

Table 2. Correlation Coefficient Among Changes in Variables after 16 Weeks.

<table>
<thead>
<tr>
<th></th>
<th>BMI</th>
<th>$\sum$SFT</th>
<th>GLU</th>
<th>TRI</th>
<th>LDL-C</th>
<th>HDL-C</th>
<th>TC</th>
<th>hs-CRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Weight (IG)</td>
<td>0.776**</td>
<td>0.713**</td>
<td>0.074</td>
<td>0.316</td>
<td>0.165</td>
<td>-0.068</td>
<td>0.139</td>
<td>0.031</td>
</tr>
<tr>
<td>Body Weight (CG)</td>
<td>0.891**</td>
<td>0.427</td>
<td>-0.508</td>
<td>-0.097</td>
<td>0.103</td>
<td>0.424</td>
<td>0.206</td>
<td>0.202</td>
</tr>
<tr>
<td>WC (IG)</td>
<td>-0.006</td>
<td>0.357</td>
<td>0.110</td>
<td>-0.237</td>
<td>0.824**</td>
<td>0.140</td>
<td>-0.276</td>
<td>0.694*</td>
</tr>
<tr>
<td>WC (CG)</td>
<td>0.221</td>
<td>-0.055</td>
<td>0.043</td>
<td>0.018</td>
<td>0.691*</td>
<td>0.067</td>
<td>0.008</td>
<td>0.835**</td>
</tr>
<tr>
<td>$\sum$STF (IG)</td>
<td>0.650*</td>
<td>-0.007</td>
<td>0.168</td>
<td>-0.252</td>
<td>0.112</td>
<td>-0.196</td>
<td>-0.091</td>
<td></td>
</tr>
<tr>
<td>$\sum$STF (CG)</td>
<td>-0.109</td>
<td>-0.318</td>
<td>-0.491</td>
<td>0.027</td>
<td>-0.447</td>
<td>0.427</td>
<td>-0.573</td>
<td></td>
</tr>
<tr>
<td>GLU (IG)</td>
<td>-0.199</td>
<td>0.007</td>
<td>-</td>
<td>0.829**</td>
<td>-0.304</td>
<td>0.565</td>
<td>0.668*</td>
<td>-0.151</td>
</tr>
<tr>
<td>GLU (CG)</td>
<td>-0.215</td>
<td>0.340</td>
<td>-</td>
<td>0.697*</td>
<td>0.191</td>
<td>-0.230</td>
<td>0.312</td>
<td>-0.169</td>
</tr>
<tr>
<td>TC (IG)</td>
<td>-0.042</td>
<td>0.168</td>
<td>0.829**</td>
<td>-</td>
<td>0.064</td>
<td>0.407</td>
<td>0.719**</td>
<td>-0.077</td>
</tr>
<tr>
<td>TC (CG)</td>
<td>-0.049</td>
<td>-0.491</td>
<td>0.697*</td>
<td>-</td>
<td>-0.313</td>
<td>0.682</td>
<td>0.003</td>
<td>-0.203</td>
</tr>
<tr>
<td>HDL-C (IG)</td>
<td>-0.391</td>
<td>0.112</td>
<td>0.565</td>
<td>0.407</td>
<td>-0.086</td>
<td>-</td>
<td>-0.619*</td>
<td>0.158</td>
</tr>
<tr>
<td>HDL-C (CG)</td>
<td>0.198</td>
<td>-0.445</td>
<td>-0.230</td>
<td>0.463</td>
<td>-0.645*</td>
<td>-</td>
<td>0.109</td>
<td>0.057</td>
</tr>
</tbody>
</table>

IG = intervention group; CG = control group; BMI = body mass index; WC = waist circumference; $\sum$STF = sum of skinfold thickness; hs-CRP = high sensitive c-reactive protein; GLU = fasting glucose; TRI = triglycerides; LDL-C = low-density lipoprotein cholesterol; HDL-C = high-density lipoprotein cholesterol; TC = total cholesterol. *P≤0.005; **P≤0.001

Compared to baseline, there was no significant difference in hs-CRP after 8 wks in the IG. There was a significant decrease after 16 wks compared to baseline and 8 wks (Figure 1). In the CG, there were significant increases in hs-CRP from baseline to 8 wks and 16 wks as well as from 8 wks to 16 wks (Figure 1).
Figure 1. General Parameters of Obese Adolescents at Baseline, After 8 Weeks and After 16 Weeks. BMI = body mass index; WC = waist circumference; ∑SFT = sum of skinfold thickness; hs-CRP = high sensitive c-reactive protein; GLU = fasting glucose; TRI = triglycerides; LDL-C = low-density lipoprotein cholesterol; HDL-C = high-density lipoprotein cholesterol; TC = total cholesterol.
DISCUSSION

The benefits of combined aerobic and resistance training plus dietary intervention are clearly evident in the present study. The obese adolescents in the IG showed a significant decrease in body fat and central obesity. They also improved their lipid profile markers, inflammation, strength, and cardiorespiratory fitness. In agreement, Ho et al. (19) and Voulgari et al. (37) point out that intervention in behavior, both in physical exercise and dietary, represent an important non-pharmacological means to decreasing the risk of cardiometabolic diseases. Regular exercise and healthy dietary considerations also help to regulate body weight by decreasing body fat and blood glucose, and improves lipid profile and inflammatory markers.

Similarly, according to Dave et al. (10) and Donnelly et al. (11), the combination of aerobic exercise and resistance training provides more effective results than when either exercise program is done alone. The beneficial effects of this type of training are evident in both overweight and obese adolescents and adults (27,33). In particular, Ho et al. (20) reported that the effects of 12 wks of aerobic, resistance, or a combination of both types of exercise training in a randomized trial of overweight and obese adults decreased body weight, adiposity, and improved cardiorespiratory fitness in a short period when compared to individuals who participated in either a resistance training or aerobic training program (20).

In young subjects, the combination of resistance and aerobic exercises seems to have the same beneficial effects in reducing cardiovascular risk. Davis and colleagues’ (9) findings regarding overweight adolescents who received concurrent training and nutritional guidance showed positive results in adiposity measures despite not having a significant effect on the subjects’ fasting glucose as was the case in the present study.

Mello and colleagues (23) compared two training methods, concurrent (both resistance and aerobic exercises) and aerobic exercise, for 1 yr in two groups of 15 obese adolescents with metabolic syndrome. The results showed a reduction in all cases of metabolic syndrome in the group that engaged in concurrent training against 80% of the group that underwent isolated aerobic exercise. In addition, as to the short-term comparisons (e.g., 6 months), the findings indicate that the concurrent training group significantly improved body weight, BMI, body fat, visceral fat, and inflammation. Interestingly, their findings are in agreement with the data at 16 wks in the present study.

Monteiro et al. (24) evaluated the effects of 16 wks of concurrent training (30 min of strength training and 30 min of endurance training 3 session·wk⁻¹) on risk factors for the accumulation of hepatic fat in 38 obese children and adolescents of both sexes between 12 and 15 yrs of age. They reported significant improvements in the percentage of total fat and fat in the trunk region, significant reductions in total cholesterol, triglycerides, and lipoproteins density, but not for high-density. Hence, their findings that concurrent training was effective in combating some risk factors associated with the accumulation of fat in the liver in young obese subjects are consistent with the expectation of improvement in health and fitness in the present study.

Escalante et al. (12) published a systematic review of the effectiveness of different programs of aerobic training and combined training on blood markers in overweight youth. They
reported that a combination of training programs resulted in significant improvements in the serum concentration of HDL-C, which corroborates our findings. This is important in that low levels of HDL-C are more associated with increased cardiovascular risk when the serum concentration of LDL-C is reduced to levels considered normal (3).

In the present study, the 8-wk intervention played an important role in the improvement of the subjects’ body weight, BMI, waist circumference, body fat percentage, blood lipids, strength, and cardiorespiratory fitness. Fasting glucose and hs-CRP were not statistically significant, which was probably due to the short duration of the intervention. Similar results were found by Lee et al. (21) in a study with 54 obese Koreans adolescents who were divided into three groups of which one group was administered a concurrent exercise program for 10 wks. After this period, while there were significant decreases in blood pressure, waist circumference, and LDL-C as well as a significant increase in HDL-C, there were no significant changes in the subjects’ fasting glucose and hs-CRP.

However, after 16 wks of intervention, there was a significant decrease in the inflammatory marker hs-CRP in the IG. Studies by Christodoulos et al. (7) and Church et al. (8) show that the increase in physical activity and cardiorespiratory fitness that is associated with the decrease in body mass, body fat, and central obesity contribute significantly to the decrease in hs-CRP. The decrease in hs-CRP the IG and the increase in hs-CRP in the CG are linked to the subject’s improvement in body fat and central obesity (i.e., waist circumference).

Gleeson and colleagues (16) reported that a healthy diet and regular exercise reduce the risk of chronic metabolic and cardiorespiratory diseases, in part because exercise exerts an anti-inflammatory effect. This reduction may be mediated via reducing the subjects’ visceral fat mass that favors the suppression of pro-inflammatory cytokines (adipokines), leading to an increase in the anti-inflammatory cytokines with each exercise session.

Moreover, our exercise protocol included high intensity interval training (HIIT) that promotes fat loss. The increase in fat loss is a result of increase fat oxidation during and after exercise, which reduces post-exercise appetite (4). The mechanisms responsible for altering appetite regulating hormones remains unclear and several mechanisms may be involved, such as: redistribution of blood flow; sympathetic nervous system (SNS) activity; gastrointestinal motility; inteleukin-6; free fatty acids; blood glucose and insulin; lactate production; and body temperature (32). Of these mechanisms, blood redistribution during exercise may be important for suppressing ghrelin (hunger hormone), while other mechanisms involving cytokine release, changes in plasma glucose and insulin concentrations, SNS activity, and muscle metabolism likely mediate changes in anorexigenic signals (18).

Limitations of this Study

We can highlight as limitations of our study: (a) the lack of control of the menstrual period in the female subjects that somehow can influence body composition; (b) the analysis of individuals of the same sex in groups; (c) the quantification of enjoyment in performing physical activity, which is an important influence on adherence; (d) the limited sample size; and (e) the lack of control of other physical activities the subjects may be engaged in before, during, and at end of the intervention period in both groups.
CONCLUSIONS

The findings of this study confirm the hypothesis that the proposed intervention program can produce beneficial changes in body composition, lipid profile, inflammation, strength, and cardiorespiratory fitness. In particular, the reduction in body fat after 16 wks of intervention contributed to an improvement in the subjects’ lipid profile and a decrease in CRP levels. As health professionals, we must continue to help change the pattern of physical inactivity and its relationship to obesity and chronic diseases by helping the population to become more active and thus healthier.

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