Linear and undulating periodized strength plus aerobic training promote similar benefits and lead to improvement of insulin resistance on obese adolescents

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A B S T R A C T

The present study compares the effectiveness of three types of physical training for obesity control in adolescents submitted to a long-term interdisciplinary therapy. Forty-five post-puberty obese adolescents (15–18yo) were randomly placed in three different groups of physical trainings: aerobic training (AT n = 20), aerobic plus strength training with linear periodization (LP n = 13) and aerobic plus strength training with daily undulating periodization (DUP n = 12). The body composition was evaluated by air-displacement plethysmography; the rest metabolic rate was measured by indirect calorimetry; serum analysis was collected after an overnight fasting. The most important finding of this study was that both LP and DUP groups improved lipid profile, insulin sensitivity and adiponectin concentration (p < 0.01). The linear regression showed a negative association between delta (%) adiponectin and delta (%) insulin (p < 0.05). Each group presented a significant reduction in body mass, body mass index and fat mass (kg) after short and long-term intervention (p < 0.01). However, the AT group reduced the fat-free mass after short-term intervention (p < 0.01) and enhanced protein oxidation (p < 0.01), whereas only LP group was able to increase the fat-free mass and maintain the rest metabolic rate (RMR). There was a negative correlation between percentage of protein oxidation and RMR (r = −0.75) in all groups. The interdisciplinary therapy models that included aerobic plus strength training were more effective than only aerobic training to improve lipid profile and insulin sensitivity, as well as the inflammatory state by increasing adiponectin. In all groups were observed an improvement on anthropometrical profile.

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1. Introduction

Obesity is a chronic multifactorial disease that presents a pro-inflammatory state and a number of metabolic and hormonal disturbances. Together, these factors may lead to cardiovascular problems; metabolic syndrome risks; psychosocial factors; sleep apnea; asthma; and others co-morbidities. Childhood obesity is one of the main predictor factors of adult obesity. Thus, the prevention and treatment in early ages is fundamental to epidemic control (Elloumi et al., 2009; Sinha & Kling, 2009).

In fact, physical training is an important tool on obesity treatment and its co-morbidities. Traditionally, aerobic exercise is recognized as the most suitable form of training (Cauza et al., 2005; Lazzer et al., 2010) by providing positive metabolic effects on lipids and glucose profiles; and reducing body fat (de Mello et al., 2011; Lazzer et al., 2010). Currently, the practice of strength exercise has received greater attention in many publications due the improvement of strength and muscle mass that this type of exercise promotes. Some effects of the strength training are similar to aerobic training in contributing to the improvement of the metabolic profile (Cauza et al., 2005; Hills et al., 2010).
Usually, in strength training there are different types of periodization, including the linear and undulating periodization. The linear is a classical form of periodization that divides a typical strength training program into different cycles gradually, increasing the training intensity while decrease training volume, within and between cycles. However, the undulating periodization was adapted to daily undulating periodization where the intensity and volume are modified daily. Some studies compared both types of periodization and showed that daily undulating periodization is more efficient to improve strength (Poliquin, 1988; Prestes et al., 2009; Rhea, Ball, Phillips, & Burkett, 2002).

The first study that compared the effectiveness of the periodization models in obese adolescents showed that daily undulating periodization was more efficient than linear periodization to reduce insulin-resistance after short-term interdisciplinary intervention (Foschini et al., 2010). However, the effectiveness of periodization models and duration of the therapy on adiponectin concentration, and anthropometric and metabolic profile remains to be clarified.

The initial hypothesis of the present study was that strength training plus aerobic training could promote improvement on insulin resistance, as well as in the metabolic profile. Thus, the aim of this study was to compare the effectiveness of three physical trainings on insulin resistance, and on anthropometric and metabolic profile in obese adolescents submitted to a long-term interdisciplinary therapy.

2. Methods

2.1. Subjects

A total of 80 post-puberty (Tanner & Whitehouse, 1976) obese adolescents ([BMI = 95th percentile on the Centers for Disease Control and Prevention reference growth charts) (Center for Disease Control & Prevention, 1999) were enrolled in the program (AT n = 40; LP n = 20; and DUP n = 20). However, only 45 adolescents, aged 15 to 18 years (16.28 ± 1.34), including 28 girls and 17 boys, completed the whole year of therapy and were included in this study (Table 1). Exclusion criteria were as follows: other metabolic or endocrine androgenic steroids or psychotropic which may affect appetite regulation; and pregnancy. The adolescents and their parents' assent to participate as volunteers in a long-term (1-year) interdisciplinary weight loss program were obtained.

The study was conducted in accordance with the guidelines present in the Declaration of Helsinki and was formally approved by the Ethical Committee of the Federal University of São Paulo (number 0135/04).

2.2. Anthropometric measurements

Subjects were weighted while wearing light clothing and no shoes on a Filizola high sensitive scale that measures the nearest of 0.1 kg. Height was measured by a wall-fixed stadiometer that measures the nearest of 0.5 cm (Sanny, model ES 2030), and body mass index (BMI) was calculated. Body composition was measured by air-displacement plethysmography in a BOD POD body composition system (version 1.69; Life Measurement Instruments, Concord, CA) (Fields & Goran, 2000; Fields, Hunter, & Goran, 2000).

2.3. Visceral adiposity measurements

All abdominal ultrasonography (US) procedures and measurements of visceral fat were performed by the same technique and imaging specialist using a 3.5-MHz multifrequency transducer (broad band). The intra-examination coefficient of variation for the US was 0.8%. Ultrasonography measurements of intra-abdominal (visceral) were taken. Ultrasonography-determined visceral fat was defined as the distance between the internal face of the same muscle and the aorta anterior wall as previously described by Ribeiro-Filho, Faria, Azjen, Zanella, and Ferreira (2003).

The ultrasound measures were positively correlated to accurate methods such as magnetic resonance imaging (MRI) measures of visceral and subcutaneous fat (Cong et al., 2007; De Lucia et al., 2010, 2011).

2.4. Serum analysis

Blood samples were collected at the outpatient clinic at around 8 a.m. after an overnight fasting and centrifuged for 10 min at 5,000 r.p.m. and stored at −70 °C for future analyses. The materials used for collection

Table 1

<table>
<thead>
<tr>
<th>Comparison of anthropometric, biochemical, and physiological variables for AT, LP and DUP groups baseline between completers and non-completers.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic training (N = 40)</td>
</tr>
<tr>
<td>Completers (N = 20)</td>
</tr>
<tr>
<td>BM (kg)</td>
</tr>
<tr>
<td>BMI (wt/ht²)</td>
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<tr>
<td>% Fat</td>
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<tr>
<td>Fat mass (Kg)</td>
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<td>FFM (Kg)</td>
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<td>Visceral fat (cm)</td>
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<td>Glucose</td>
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<tr>
<td>Insulin</td>
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<td>HOME</td>
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<tr>
<td>TC (mg/dL)</td>
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<tr>
<td>LDL</td>
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<tr>
<td>Adiponectin (µg/mL)</td>
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</tbody>
</table>

Values were expressed by mean ± standard error. BM = body mass; BMI = body mass index; FFM = fat free mass; TG = triglycerides (33–129 mg/dL); TC = total cholesterol (<170 mg/dL); LDL = low density lipoprotein (<130 mg/dL); adiponectin = 5–30 µg/mL.

* Completers vs. non-completers in the same group.

** AT completers vs. LP completers.

*** AT completers vs. LP non-completers.

† AT non-completers vs. LP completers.

‡ AT non-completers vs. LP non-completers.

‡‡ AT completers vs. DUP completers.

‡‡‡ AT completers vs. DUP non-completers.

# AT non-completers vs. DUP completers.

$ AT non-completers vs. DUP non-completers

*p ≤ 0.05 (ANOVA one way and Tukey HSD post-hoc).
were disposable, adequately labeled, and of recognized quality. Blood was collected by a skilled and qualified technician. Total cholesterol, triglyceride (TG), low-density lipoprotein (LDL-c) and glucose were analyzed by using a commercial kit (CELM, Barueri, Brazil). Serum level of insulin and adiponectin were detected by using commercial enzyme-linked immunosorbent assay kits (EZHI-14 K, Millipore, Merck KGaA, Darmstadt, Germany; Phoenix Pharmaceuticals (Belmont, CA, respectively)) according to the manufacturer's instruction. The HOMA-IR and serum lipids data were analyzed according to Schwimmer et al. (2003). Insulin resistance was assessed by the homeostatic model assessment of insulin resistance index (HOMA-IR). HOMA-IR was calculated as the product of blood glucose (fasting blood glucose) and immunoreactive insulin (I): (fasting blood glucose (mg/dl) × 1 (mU/L)/405).

2.5. Maximal oxygen consumption (VO₂max) tests

The VO₂max was determined by using an incremental exercise test on a Life Fitness® motor-driven treadmill (Model TR 9700HR) or cycle ergometer (Model 9500HR) where the ergometers utilized were in accordance to the specificity of the aerobic exercise training. The modified Bruce protocol was used for this test (Kraemer et al., 1997). During each stage of the test, heart rate was monitored continuously with a cardiometer (Polar® - Model FS1 dark blue). Continuous respiratory gas analysis, volume measurements, oxygen uptake (VO₂), and carbon dioxide production (VCO₂) were performed breath by breath with a ventilated hood system (Model Quark PFT Ergo - COSMED® – Rome). Ventilatory threshold was determined by the Wasserman (1999) method.

2.6. Resting metabolic rate (RMR)

The RMR was measured by indirect calorimetry with a ventilated hood system (Model Quark PFT Ergo - COSMED® – Rome). RMR was measured as previously described by Haugen, Melanson, Tran, Kearney, and Hill (2003). Oxygen consumption as well as carbon dioxide production in the exhaled air was measured as suggested by Compher, Frankenfield, Keim, and Roth-Yousey (2006). RMR was estimated according to equations proposed by Weir (1949). The substrate oxidation analysis of the respiratory quotient (QR) made possible to distinguish the substrate metabolism and individuate the percentage of fat, carbohydrates, and protein (Weir, 1949).

3. Research design

The aim of the interdisciplinary program consists in promoting changes in their sedentary lifestyle and nutritional habits through clinical therapy (once a month), physical exercise (three times a week), nutritional and psychological counseling (once a week). The interdisciplinary intervention has been suggested by the World Health Organization (1999). All measurements were performed at the baseline, after short-term (6 months), and after long-term (1 year) of therapy.

3.1. Exercise protocols

The subjects were randomized in three groups (Table 1). The exercises were performed three times a week, under the supervision of a sport professional. The aerobic training in all groups was done at the cardiac frequency intensity of the Ventilatory Threshold I (VTI) (± 4 bpm) on a motor-driven treadmill (Life Fitness® – Model TR 9700HR) or a cycle ergometer (Life Fitness® – Model 9500HR). The predominant aerobic training group (AT) was initiated with 14 weeks performing 60 minutes of aerobic exercises only. From 14 to 26 weeks the adolescents performed 30 minutes of aerobic plus 30 minutes of strength training non-periodized with (in addition to) sub-maximal repetitions (SR: load = about 25% less of RM). Linear periodization group (LP) was divided in three mesocycles lasting eight weeks. In the first mesocycle the participants performed 30 minutes of aerobic plus strength training of three sets of 15–20 maximal repetition (RM). In the second, there is 30 minutes of aerobic plus strength training of three sets of 10–12 RM. In the third, there is 30 minutes of aerobic plus strength training of three sets of 6–8RM (Table 2).

Daily undulating periodization group (DUP) performed three different loads in the same week. On Mondays, the participants trained 30 minutes of aerobic plus strength training with three sets of 15–20 RM; on Wednesdays, 30 minutes of aerobic plus strength training with three sets of 10–12RM; and on Fridays, 30 minutes of aerobic plus strength training with three sets of 6–8RM on all of the intervention period (Table 2).

The first 2 weeks of strength training allowed the participants to adapt to the training and learn the movements required for each exercise [three sets of 15–20 sub-maximum repetition (SR)]. In the LP and DUP, the total volume was equalized. In this context, the disparity between groups was the time and sequence of the load applied. At each training session, the LP and DUP groups were instructed to reverse the beginning order between aerobic and resistance training exercises. The strength training followed the protocol proposed by Foschini et al. (2010). All subjects performed ten exercises: bench press; leg press, sit-ups, lat pull-down, hamstring curls, lower back, military press, calf raises, arm curls and triceps pushdown. The resting intervals between series and exercises were: 15–20 RM = 45 s; 10–12 RM = 1 minute and 6–8 RM = 1.5 minutes. The periodization models applied were based on our previous studies (Foschini et al., 2010) and other published literature (Kraemer et al., 1997; Rhea et al., 2003). The training loads were adjusted in each training session.

3.2. Nutritional therapy

Energy intake was set at recommended levels for subjects, of same age and gender with low levels of physical activity, by following a balanced diet. No drugs or antioxidants were recommended. Once a week, adolescents received dietetic lessons. All patients received individual nutritional orientation during the intervention program. At the beginning of the study and at the 12th month of the program, a 3-day dietary record was collected (de Piano et al., 2007).

3.3. Psychological therapy

The psychological therapy treatment plan was established based on validated questionnaires, taking into account some of the psychological problems caused by obesity as described in the literature (Lofrano-Prado et al., 2009). Interdisciplinary therapy consisted in weekly one-hour group session. Individualized psychological therapy was recommended when weight problems or poor dietary habits were found.

3.4. Clinical therapy

To address the health and clinical parameters, obese adolescents visited the endocrinologist once each month. Medical follow-ups and treatment were based on previous patient-and-family history, physical examination, and intervention in any health problems that had developed over the course of the therapy.

4. Statistical analysis

All statistical analyses were conducted using Statistica® 7.0 and SPSS® 15.0 with significance level set at p < 0.05. The data were tested through normal distribution using Kolmogorov–Smirnov test, and nonparametric methods were performed when appropriate. Variables with normal distribution were BMI, BMI, fat percentage, fat...
mass, fat-free mass (FFM), visceral fat, fat oxidation, carbohydrate oxidation, protein oxidation (%PRO), QR, RMR, glucosuc insulin, HOMA-IR, TG, total cholesterol, LDL-c and adiponectin. It used the Mauchly sphericity test to apply the two-way ANOVA with repeated measurements and to determine the main effects of the groups, the time, and the interaction. ANCOVA was applied to adjust the short and long term of the adiponectin basal values. The eta squared was presented to demonstrate the effect size of the variables per group. It performed the Newman Keuls post hoc test when a significant interaction occurred between group and time. Levene’s test was used to apply the one-way ANOVA to determine main effects of the groups, and Tukey post hoc test was performed when a significant interaction occurred between groups. The Pearson’s Correlation was used to compare RMR, protein oxidation (%), adiponectin, insulin, visceral fat, and HOMA-IR. The linear regression was applied on %Δ adiponectin and %Δ insulin values.

5. Results

The AT group was able to improve only the TG (p < 0.01) and significantly decrease the FFM after short-term and the %PRO and RMR after long-term intervention (Table 3). The LP group was able to maintain the RMR values (p < 0.01) and to enhance the FFM (p < 0.01), whereas the RMR was diminished in DUP (p < 0.01) group. In both LP and DUP groups, the %PRO presented no significant difference on baseline values. Moreover, LP and DUP promoted a significant improvement in the total cholesterol and LDL-c (p < 0.05), and a significant increase on adiponectin concentration (Table 3).

The effects of the therapy on metabolic profile of the obese adolescents are presented on Fig. 1. The glucose values, as well as the HOMA-IR and the insulin, were reduced significantly in LP and DUP (p < 0.01) after the long-term intervention.

A negative correlation (r = −0.75, p < 0.01) between RMR and %PRO variables was observed at the baseline in all groups. On the other hand, a negative correlation was found only in DUP group between %Δ adiponectin and %Δ visceral fat (r = −0.68, p < 0.05), and %Δ insulin plasma (r = −0.7, p < 0.05) and %Δ HOMA-IR (r = −0.72, p < 0.05). The linear regression showed a negative association between %Δ adiponectin and %Δ insulin (β = −0.45; t = −2.6; p < 0.028).

The Table 4 presents relative effects (%Δ) of the three training models. It was shown that both LP and DUP groups were more effective than AT on increasing FFM, reducing insulin, HOMA-IR and LDL-c, and enhancing adiponectin (p < 0.01). Indeed, DUP was more effective than AT in reducing fat percentage, fat mass, and total cholesterol over the time (p < 0.01).

6. Discussion

The most important finding in the present investigation was the result obtained from LP and DUP that demonstrated being a more effective treatment for obesity than AT, when observed baseline vs. long-term post-training values, because of the improving of insulin resistance (IR), increasing adiponectin, and reducing total cholesterol and LDL-c. Together, the results suggest a protective effect of this kind of training on atherosclerotic and on the development of type 2 diabetes (Ahima, Qi, Singhal, Jackson, & Scherer, 2006). Elloumi et al. (2009) showed that aerobic training, when combined with energy restriction, improved adiponectin concentration in obese adolescents. Moreover, Fatouros et al. (2005) showed that moderate and high intensity strength training could increase adiponectin concentration in elderly. The mechanism attributed to the enhancement of insulin sensitivity is related to the increase of fat oxidation, which reduces fatty acid concentration and intracellular triglycerides in the liver and muscles. In addition, Fatouros et al. (2005) reported that a decrease in body weight and/or fat mass may improve adiponectin. In a review, Boussadila et al. (2010) concluded that physical training improves fitness levels and affect body composition, which could increase adiponectin levels. In addition, our group has demonstrated that reduced endotoxin levels are also related to the improvement in insulin resistance (Lira, Carnevali, et al., 2012).

The weight and fat mass were reduced significantly and similar in all groups (baseline vs. post long-term training). In AT group the FFM decreased, whereas HOMA-IR, insulin, total cholesterol, and LDL-c concentration reduced in LP and DUP (baseline vs. post long-term training). It is proposed that the exercise including aerobic and strength training enhances the translocation of GLUT 4 to the muscle cell membrane, hence increasing the glucose uptake (Jessen & Goodyear, 2005). Nevertheless, Vaspelkissil (2006) found an increased expression of glucose transporter 4, IRS-1 associated PI-3 kinase, AKT activity, aPKC in the skeletal muscle of rats submitted to resistance training. It is worth mentioning that after long-term treatment HOMA-IR values in both, LP and DUP groups, reached normality values for adolescents (< 2) according to Schwimmer et al. (2003).

There was a significant improvement in inflammatory status since adiponectin, the anti-inflammatory adipokine, increased significantly after the long-term intervention and reduction of HOMA-IR—an index that presents association to inflammatory pathways. Our group (de Mello et al., 2011; Lira, Carnevali, et al., 2012; Lira, Rosa, et al., 2012) showed reduced inflammatory status after changing their lifestyle in the interdisciplinary program.

These results suggest that strength training plays a complementary role in the IR control, as previously demonstrated with DUP in a short-term intervention (Foschini et al., 2010), and consequently improves pro-inflammatory status by increasing adiponectin levels. In the present study both, LP and DUP, were more effective after long-term when compared to AT to reach normal IR values, when baseline vs. post-long-term training were compared. Therefore, we hypothesize that both, LP and DUP, trainings may stimulate the mechanisms involved in the role of adiponectin on homeostasis energy and inflammatory processes related to obesity. However, the reduced number of subjects, in parts, may be associated with the reduced
Table 3
Anthropometrics, biochemical and physiological variables of AT, LP and DUP groups at baseline, after short and long-term intervention.

<table>
<thead>
<tr>
<th>Predominant aerobic training (N = 20)</th>
<th>Linear periodization (N = 13)</th>
<th>Daily undulating periodization (N = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM (kg)</td>
<td>Basal Short-term Long-term</td>
<td>Basal Short-term Long-term</td>
</tr>
<tr>
<td>BM (wt/ht²)</td>
<td>99.7 ± 3.1 91.8 ± 2.7 # 90.6 ± 3</td>
<td>99.4 ± 3.8 90.6 ± 3.6 # 88.5 ± 3.2</td>
</tr>
<tr>
<td>% Fat</td>
<td>35.1 ± 0.9 32.4 ± 0.9* 31.8 ± 1.1</td>
<td>36.4 ± 1.6 33.1 ± 1.5* 32.2 ± 1.3</td>
</tr>
<tr>
<td>Fat mass (Kg)</td>
<td>40 ± 1.7 37.9 ± 1.7 35.6 ± 2.1</td>
<td>47.4 ± 2.2 40.7 ± 2.2* 37.4 ± 2.4</td>
</tr>
<tr>
<td>FFM (Kg)</td>
<td>59.8 ± 2.5 56.8 ± 2 58.1 ± 2.4</td>
<td>51.6 ± 1.8 53.2 ± 2 55.7 ± 2.3</td>
</tr>
<tr>
<td>Visceral fat (cm)</td>
<td>0.83 ± 0.1 0.78 ± 0.1 0.77 ± 0.1</td>
<td>0.75 ± 0.1 0.79 ± 0.1 0.79 ± 0.1</td>
</tr>
<tr>
<td>%FOX</td>
<td>46.8 ± 4.4 57.5 ± 2.8 57.6 ± 3.5</td>
<td>64.1 ± 3.5 55.8 ± 3.7 54.6 ± 4.6</td>
</tr>
<tr>
<td>%CHO</td>
<td>34.2 ± 4.9 25 ± 3.2 17.9 ± 3.6</td>
<td>16 ± 4.5† 26 ± 5.2 20 ± 4.7</td>
</tr>
<tr>
<td>% PRO</td>
<td>18 ± 1.2 20.1 ± 1.1 24.4 ± 1.3</td>
<td>19 ± 1.5 22 ± 1.4 23 ± 2.2</td>
</tr>
<tr>
<td>RMR (Kcal)</td>
<td>1870 ± 92.6 1765 ± 87.2 1489 ± 83.3</td>
<td>1877 ± 131.4 1608 ± 108.5 1651 ± 117.5</td>
</tr>
<tr>
<td>TG (mg/dL)</td>
<td>98.9 ± 10.7 77.9 ± 8 70.2 ± 8.4</td>
<td>81.9 ± 8.6 67.9 ± 5.3 77.1 ± 11</td>
</tr>
<tr>
<td>Total cholesterol (mg/dL)</td>
<td>162.5 ± 8.9 155.5 ± 6.2 159.9 ± 8.9</td>
<td>164.4 ± 8.5 148.3 ± 7.8</td>
</tr>
<tr>
<td>LDL-c (mg/dL)</td>
<td>93.3 ± 8 92.9 ± 5.4 95.4 ± 7.4</td>
<td>105.1 ± 7.3 90.8 ± 7.3</td>
</tr>
<tr>
<td>Adiponectin (μg/mL)</td>
<td>4.7 ± 0.84 6 ± 0.31 4.4 ± 0.45</td>
<td>10 ± 1.7† 12.1 ± 7.45 12.5 ± 10.35</td>
</tr>
</tbody>
</table>

Values were expressed by mean ± standard error; η². BM = body mass; BMI = body mass index; FFM = fat free mass; QR = respiratory quotient; FOX = fat oxidation; CHO = carbohydrate oxidation; PRO = protein oxidation; RMR = resting metabolic rate; TG = triglycerides (33–129 mg/dL); total cholesterol (<170 mg/dL); LDL = low density lipoprotein (<130 mg/dL); adiponectin = 5–30 μg/mL.

Ω Values adjusted by adiponectin basal values covariant (ANCOVA) p ≤ 0.05.

# Basal vs. short-term for the same group p ≤ 0.05 (ANOVA for repeated measures).
* Basal vs. long-term for the same group p ≤ 0.05 (ANOVA for repeated measures).
† Short-term vs. long-term for the same group p ≤ 0.05 (ANOVA for repeated measures).
a1 Basal AT group vs. basal LP group.
a2 Short-term AT group vs. short-term LP group.
a3 Long-term AT group vs. long-term LP group.
b1 Basal AT group vs. basal DUP group.
b2 Short-term AT group vs. short-term DUP group.
b3 Long-term AT group vs. long-term DUP group.
c1 Basal LP group vs. basal DUP group.
statistic power in the present study, and futures studies are needed for a better understanding of the mechanism involved.

In general, studies have shown that moderate aerobic training promotes an improvement in body composition and cardiovascular risk factors (Lambers, Van Laethem, Van Acker, & Calders, 2008; Sanches et al., 2014; Wilund, Feeney, Tomayko, Weiss, & Hagberg, 2009). In fact, in the present study, after long-term intervention, only AT group showed a reduction in TG (baseline vs. post long term training). However, total cholesterol and LDL-c decreased in LP and DUP, in agreement with previous studies (Elmahgoub et al., 2009). These results suggest more investigation in order to compare both models of training in other cardiovascular risk factors, considering obese adolescents. Recently, Lira, Rosa, et al. (2012) have reviewed the effects of intensity and type of exercise (aerobic and strength) on lipoprotein profiles. The authors highlighted the higher energy expenditure achieved by associating volume and intensity, which seems to promote prominent changes in lipoprotein.

Considering anthropometric variables on baseline vs. long-term training, LP and DUP protocols were also more efficient to improve the body composition by promoting maintenance of FFM in DUP and enhance in LP, while AT group showed a reduction in short-term. Interestingly, the inclusion of strength training with low load in AT group after short-term therapy promoted maintenance of lean mass, reinforcing the importance of RT.

Another important finding in the present investigation is the strong negative correlation between RMR and %PRO which suggests that RMR decreased in AT and DUP, probably due to a slowdown of metabolic rate and reduction of lean mass and metabolic rate (Lazzer et al., 2004). Other studies have shown that there were no differences between the aerobic and strength training and the intensity of exercise may have influence on the maintenance of the RMR, (Byrne & Wilmore, 2001; Lee, Sedlock, Flynn, & Kamimori, 2009) and on the type of the substrate recruited (Kang et al., 2009).

In the present study, although baseline data, apparently, seems to be different, there is no statistically significant difference, with the exception of the RMR variable. We cannot ignore the possibility that baseline data—the parameters of metabolic, in particular, may have been more influenced by the selection of the type of substrate recruited, as well as the inflammatory processes involved. The authors highlighted the higher energy expenditure achieved by associating volume and intensity, which seems to promote prominent changes in lipoprotein.

In conclusion, the results of the present study demonstrated that the three types of the training program improve the BM, BMI, and fat mass, highlighting the benefits of the interdisciplinary therapy. Both, LP and DUP, were more effective than AT to improve insulin sensitivity, metabolic and lipids profile, as well as the inflammatory state by increasing adiponectin levels, when compared baseline values with long-term training.

Thus, we can observe that exercise is an important method to support the treatment of obesity by improving metabolic parameters that are altered in this disease. However, more research is necessary to understand the mechanisms of weight loss process, especially if other different types of periodization are more efficient than those studied. As examples, we can suggest the aerobic periodization and how its results could be optimized, and also, compare these three presented types of physical training associated with interdisciplinary long-term therapy in obese on adipokines and key hormones in the control of energy balance.
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