Linear and Daily Undulating Resistance Training Periodizations Have Differential Beneficial Effects in Young Sedentary Women

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Abstract

The aim of this randomized controlled study was to verify the impact of a 12-weeks muscular endurance (ME) training of high repetitions (i.e., 15–30) with 2 different periodization models on body composition, maximal strength, muscular endurance and cardiorespiratory fitness. Twenty eight sedentary women aged 20–35 years were randomly assigned to: control (CON) (n = 8), linear periodization (LP) (n = 10) and daily undulating periodization (DUP) (n = 10). LP and DUP models significantly improved body composition, maximal strength and ME. However, no significant changes were detected for cardiorespiratory fitness. LP showed a higher body fat loss (−12.73%) compared to DUP (−9.93%) (p = 0.049), and systematically higher effect sizes (ES) when compared with DUP for maximal strength and cardiorespiratory fitness parameters (e.g. ES = 0.53 for ventilatory threshold). In contrast, DUP exhibited a significantly (p = 0.002) greater ME gain (129.43%) compared to LP (70.72%) in bench press, and greater ES in all exercises. It may be suggested that LP performed with a high number of repetitions may be considered an appropriate periodization model for untrained young women that would likely lead to the improvement of body composition and maximum strength performance, whereas DUP is more effective for the development of ME.

Introduction

Currently, strong evidence has suggested the appropriateness of resistance training (RT) when looking for health benefits in adult sedentary people [8]. Moreover, the Position Stand of the American College of Sports Medicine (ACSM) has recommended periodized RT for healthy individuals with different training goals [1]. Interestingly, a recent study has suggested that women have a greater response to periodized RT when compared to men [10]. Consequently, periodized RT could be considered an effective and interesting method for the improvement of women’s health, functional capacity and therefore quality of life.

For young women, appearance-related issues are the most critical factors on the initial involvement in fitness club memberships [17]. This suggests that while the functional and physiological changes may be considered the more important health-related achievements of a RT program, sedentary women could be more worried about the effects of RT on body composition. Contrary to men, this change in body composition is often oriented to lowering body mass and fatness with no or little increments in muscle mass. In this regard, the changes in body composition could be linked to the employment of different weight loads. For example, lifting medium-to-high loads could be more associated to males’ training as indicated from muscle mass gains (i.e. hypertrophy) [1], whereas it may be suggested that training with light loads could be preferred by women as they are more interested in body fat loss. Consequently, effective and attractive RT programs are needed for women not previously experienced in RT because of potential differences in appearance-related motivations between genders [11]. This could impact adherence of women to RT.

The main forms of RT periodizations described in the literature are the linear (LP) and the undulating (UP) approaches, respectively [12,20]. Briefly, the LP increases intensity gradually while training volume is reduced as training progresses, whereas the UP is characterized by more frequent alterations in intensity and volume. Previ-
ous studies have shown significant and positive outcomes after both periodized forms of RT in women, with higher levels of maximum and submaximal strength, power, and muscular endurance [10, 12–15, 20]. Interestingly, the majority of these studies have reported an increase or maintenance of body mass despite a lowering in body fatness, with only one study [21] focused on muscular endurance (ME) reporting a leg circumference reduction but with no additional information on body composition. Therefore, more studies in sedentary women are needed with regard to the higher effectiveness of periodization model for body composition and strength performance changes after a RT intervention.

In general, it is expected that an effect of RT will result in muscular function whereas its impact on cardiorespiratory fitness is less pronounced. This aspect is of further interest for the consideration of RT as an effective and complete exercise mode for health and functional capacity. Previously, no studies have reported any change in cardiorespiratory variables after RT for sedentary women. Cesar et al. [4] found no change in maximum oxygen uptake (VO2max) nor ventilatory threshold (VT) after a 12-week training program that consisted of 3 sessions per week with 3 sets of 15 repetitions until failure in various exercises. From the results of this study [4], it may be suggested that the load employed could have favored more the muscular adaptations instead of the cardiorespiratory fitness. Considering that a higher volume (e.g., repetitions) and shorter rest interval (work to rest ratio) with lighter loads could have more influence on aerobic capacity with a less effect on hypertrophy [1], it may be speculated that a training regimen with such characteristics may be more appropriate when looking for specific changes in cardiorespiratory fitness but, to the best of our knowledge, this hypothesis has not been addressed.

Therefore, the current study was designed to test the hypothesis that a periodized training regimen with a high number of repetitions per set (e.g., 20–30) could favor an improvement of cardio-respiratory variables (i.e., VO2max and VT) with a concurrent weight loss and muscular strength gains in sedentary women. Additionally, we aimed to compare the effectiveness of both LP and UP of equated load for the achievement of these objectives.

Methods

Twenty eight young women volunteered for participation in this study. Subjects were chosen according to the following criteria: aged between 20–35 years, non-obese (body mass index ≤26 kg·m²), with no disease, no practice of regular training 6 months before the initiation of the study, and were not users of nutritional supplements. The participants were randomly distributed into 3 groups: linear periodization (LP, n = 10; 25.20 ± 4.35 years; 64.14 ± 9.79 kg; 28.53 ± 4.10% body fat), daily undulating periodization (DUP, n = 10; 27.40 ± 2.80 years; 61.72 ± 7.82 kg; 24.84 ± 3.28% body fat), and control group (CON, n = 8; 23.40 ± 1.29 years; 167 ± 0.06 cm; 61.60 ± 8.58 kg; 25.75 ± 2.66% body fat). Control group remained sedentary during the 12-week intervention. The 3 groups showed no significant differences for the pre-training characteristics (p ≤ 0.05). All participants were informed of all the risks before the investigation and signed an informed written consent. The present research was approved by the Research Ethics Committee of the Methodist University of Piracicaba (protocol n° 83/03). The procedures were in accordance with guidelines for experimentation with human participants. Additionally, the study meets the ethical standards of the International Journal of Sports Medicine [6].

After a 2-week familiarization period (4 sessions per week) in which a 15 repetitions maximum (15RM) test was assessed for every exercise, body composition was determined by skinfold thickness measurements taken with a Lange skinfold caliper. The equation of Jackson, Pollock & Ward [9] for women was used to estimate body fat percentage. In this equation, the sum of triceps, suprailiac, and thigh skinfolds is used. After the determination of body fat percentage, fat mass (kg) and fat-free mass (kg) were subsequently estimated.

One day after anthropometric evaluations, one-repetition maximal tests (1RM) were performed. All procedures for 1RM determination were conducted according to the descriptions of Brown & Weir [3]. The exercises chosen for 1RM tests were: barbell bench press, 45° leg press (Cybex International, Medway, MA), and standing arm curl. The pre-training 1RM tests were determined on 3 separate days with 2 days between them (ICC > 0.9) as previously described [18].

ME trials were performed 48 h after 1RM tests with the same exercises. All the procedures for ME determination followed the suggestions of Rhea et al. [21]. One and a half min after a specific warm-up performed with one set of 10 repetitions at 40% of 1RM, participants executed the highest number of repetitions as possible with 50% of 1RM until concentric failure. This procedure was repeated 2 more times, with 2 days between evaluation sessions (ICC > 0.9). The exercises selected for ME tests were the same as those selected for the strength assessment. The order of the exercises was randomized in each testing session. 48 h after strength assessments, all participants were submitted to an incremental running test in the laboratory on a motorized treadmill (Inbrasport, ATL, Brazil). The initial velocity was of 4 km·h⁻¹ during 3 min, with increments of 1 km·h⁻¹ every minute until 10 km·h⁻¹. After this, treadmill was inclined by 2.5% every minute until volitional exhaustion [4]. Oxygen consumption, carbon dioxide and pulmonary ventilation were measured every 20 s with a metabolic gas analyzer (VO2000, Aerospot Medical Graphics, USA). The highest oxygen consumption value reached during the test was considered the VO2max while the VT was determined by the ventilatory method [22]. Additional exhaustion criteria were: respiratory exchange ratio (RER) > 1.1 and maximum heart rate < 10 bpm of the age-predicted HMax. Heart rate (HR) was monitored with a 5-s interval during the test. The VT was identified by 2 experienced researchers following the criterion of an exponential increase in the expired ventilation (VE) curve with concomitant increase in carbon dioxide production. The selection of the periodization programs was based on the results of a previous investigation [17]. There were 2 session types for both programs (Table 1). The exercises order was always the same with 3 sets until failure were performed. 1–2 min rest was given between each set as proposed by Rhea et al. [21]. At the end of each training session, 3 sets of 20–30 repetitions of abdominal crunches were also performed. The average duration of each repetition was 3–4 s, taking into account the concentric and eccentric phases of the movement. In LP participants performed 3 sets of 30RM, in the second week 3 sets of 25RM, in the third week 3 sets of 20RM and in the fourth week 3 sets of 15RM. This pattern of volume and inten-
Table 1  Exercises sequence performed during 12 weeks of LP and DUP.

<table>
<thead>
<tr>
<th>Training A (sessions 1 and 3)</th>
<th>Training B (sessions 2 and 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) barbell bench press</td>
<td>1) 45° leg press</td>
</tr>
<tr>
<td>2) incline dumbbell press</td>
<td>2) leg extension</td>
</tr>
<tr>
<td>3) shoulder press</td>
<td>3) leg curl</td>
</tr>
<tr>
<td>4) lateral raise</td>
<td>4) glute kickbacks</td>
</tr>
<tr>
<td>5) standing arm curl</td>
<td>5) hip abduction and adduction</td>
</tr>
<tr>
<td>6) hammer dumbbell curl</td>
<td>6) seat calf raise</td>
</tr>
<tr>
<td>7) triceps extension</td>
<td>7) front lat pull-down</td>
</tr>
<tr>
<td>8) dumbbell elbow extension</td>
<td>8) seated row</td>
</tr>
</tbody>
</table>

4 weekly sessions, 2 days per week A training was performed (Monday and Thursday) and 2 days per week B training was performed (Tuesday and Friday).

Table 2  Muscular endurance training program for both groups (4 sessions per week).

*LP group (n = 10)

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 sets of 30RM</td>
<td>3 sets of 25RM</td>
<td>3 sets of 20RM</td>
<td>3 sets of 15RM</td>
</tr>
<tr>
<td>week 5</td>
<td>week 6</td>
<td>week 7</td>
<td>week 8</td>
</tr>
<tr>
<td>3 sets of 30RM</td>
<td>3 sets of 25RM</td>
<td>3 sets of 20RM</td>
<td>3 sets of 15RM</td>
</tr>
<tr>
<td>week 9</td>
<td>week 10</td>
<td>week 11</td>
<td>week 12</td>
</tr>
<tr>
<td>3 sets of 30RM</td>
<td>3 sets of 25RM</td>
<td>3 sets of 20RM</td>
<td>3 sets of 15RM</td>
</tr>
</tbody>
</table>

*DUP group (n = 10)

weeks 1-3-5-7-9-11 Day 1 and 2-3 sets of 30RM Day 3 and 4-3 sets of 25RM
weeks 2-4-6-8-10-12 Day 1 and 2-3 sets of 20RM Day 3 and 4-3 sets of 15RM

*sartiness was repeated 3 times in the 12 weeks of training. Different from the LP, in which the intensity and volume changed each week, in the DUP training program volume and intensity were modified in the same week. For the DUP in weeks 1, 3, 5, 7, 9 and 11, participants trained on days 1 and 2 with 3 sets of 30RM and on days 3 and 4 with 3 sets of 25RM. In weeks 2, 4, 6, 8, 10 and 12, participants trained on days 1 and 2 with 3 sets of 20RM and on days 3 and 4 with 3 sets of 15RM (Table 2). Volume and intensity were modified differently for each group (Table 2). However, mean volume (total repetitions performed) and intensity over the entire 12 weeks of training were equal for the LP and DUP groups. The difference between groups was the time and sequence in the training volume and intensity.

For both programs (Table 2), the intensity was increased weekly by ~5%. All sessions were individually supervised by one researcher. Training loads were monitored in each session according to the increase in muscle capacity of the participants. For both experimental groups, a recovery week occurred between the 5th and 6th week in which the subjects performed only 2 training sessions (Monday and Friday), with 2 sets of 15 repetitions not to failure at approximately 60% of 15RM.

All data are presented as mean ± standard deviation. The normality of the data was tested by using the Shapiro Wilk test. Variables were compared by intra- and intergroup analysis with ANOVA repeated measures and a Student’s t-test for independent samples. In all calculations the alpha level was set at p < 0.05. Reliability of the dependent variables was determined using an intraclass correlation coefficient (ICC), Cohen’s D was employed as a measure of effect size (ES). The software package used for all analyses was Statistica® 6.1 (Stat. Soft Inc., Tulsa, OK, USA).

Results

The changes in body composition are presented on Table 3. The LP and the DUP exhibited a significant decrease in body fat percentage and fat mass after the 12-week training program (p = 0.036). LP presented a higher body fat percentage loss (~12.73%) compared to DUP (~5.99%) (p = 0.049). There was a significant decrease in body fat percentage after the 12-week training program for both groups. LP presented a higher body fat percentage loss (~12.73%) compared to DUP (~5.99%) (p = 0.049).
significant increase in fat-free mass for both experimental groups (p≤0.001). The control group did not exhibit any change in body composition.

Both experimental groups exhibited a significant increase (p=0.001) in maximal strength in all the exercises evaluated (Table 3). Effect size analysis showed greater ES for LP in all exercises. As expected, the control group did not experience any change after the 12-week period.

Both experimental groups exhibited a significant increase in ME in all the selected exercises (p=0.001). There was a group time×interaction for bench press (p=0.030), showing that DUP had a significantly higher ME increase (129.43 %) compared to LP (70.72 %) (Table 3, p=0.002). All effect size results were large for DUP in the exercises analyzed (Table 3).

There were no statistically significant differences in VO2max and VT after the training programs (Table 3). However, there were small ES in VO2max for both experimental groups with a moderate ES for the LP group in VT.

Discussion

This is the first study to compare the effects of 2 different resistance training periodization models designed for ME in untrained women. The main findings of the present study were that both LP and DUP models induced significant changes in both body composition and strength performance, but not in cardiorespiratory variables. Although no statistically significant differences were observed between experimental groups for most of the evaluated parameters, LP showed systematically higher effect sizes when compared with DUP for all the recorded variables, except for muscular endurance. Additionally, the moderate effect size observed in cardiorespiratory variables in the LP but not in DUP suggest that LP may be considered an appropriate periodization model for untrained young women.

Regarding the changes in body composition, it is interesting to note that LP was more effective than DUP in reducing the percentage of body fat (12.73 vs. 9.93%; p=0.049). Previously, Rhea et al. [21] did not show any difference between periodization models in reducing leg circumference in a group of untrained men and women that performed a training program designed for muscular endurance. Kraemer et al. [13] reported no differences in body fat after various training regimes during a 6-month period in young untrained women. In contrast, Marx et al. [15] observed a significant reduction in body fat after 12 weeks of 2 resistance training programs (i.e., 8–12 repetitions to failure), but with the high-volume group (i.e., 4 days per week). Thus, while it seems that training volume is important for reducing body fatness, the current study provides evidence of the higher effectiveness of LP for this objective. Therefore, from a dose–response perspective, the findings of our study are interesting because a similar response to previous studies in this parameter was observed but with a more-ease-to-perform training that may favor a greater tolerance and adherence in untrained women.

Another relevant finding was the significant increment in fat free mass in both groups (4.64 and 3.45 % for LP and DUP, respectively). This finding is in agreement with previous studies exhibiting significant increments in lean body mass after different training programs but more based on power and hypertrophy. Furthermore, it should be noted that the fat free mass gains of the untrained women of the current study are of a similar magnitude [15] to those reported in previous studies with training programs specifically designed for hypertrophy, or even higher [13,14] when considering the same training period (i.e., 12 weeks). Therefore, although surprising, the training programs of this study resulted in important lean body mass gains in untrained women but with no differences observed between periodization models. To date, determining the best periodization model to increase fat-free mass is difficult. It seems that LP and DUP elicit superior results in this parameter compared with reverse linear periodization (RLP) [21]. Again, training loads of the current study were equated therefore the appropriateness of the comparison in the current study is justified.

With regard to maximal strength, both LP and DUP exhibited significant and important improvements in all the exercises evaluated with no significant differences between them. Interestingly, the greater ES were observed after LP (Table 3). Moreover, the magnitudes of the improvements in these parameters are greater to those reported previously in the study of Rhea et al. [21] with a program designed for local muscular endurance (i.e., 9.1 % in the LP group for leg press), but similar to those reported by Cesar et al. [4] (i.e., 40.5 % for leg press and 24.1 % for bench press) with another program oriented to ME (i.e., 3 ×15; 60 s of rest between sets). Although similar maximum strength gains may be expected after both LP and DUP, the ES analysis demonstrated a greater magnitude for the LP model with these training loads. Therefore, the expected higher improvement of DUP with more intense training programs [15,19] was not confirmed with the low intensity loads of the current study. Additionally, an association between training intensity and strength gains was expected [1].

It is difficult to compare our results with other studies, because there are several differences in load intensity, microcycles’ length, and volume and intensity equalization. It is important to point out that the initial strength gains (1–8 weeks) due to strength training are primarily neural adaptations, and after this period strength gains are also influenced by increases in muscle mass [14]. Rhea et al. [20] reported that the significantly greater increases in maximal strength with DUP compared to LP during the first 6 weeks of training indicate that DUP may induce quicker neural adaptations than LP, even with equated training load and less time exposure to the same load. However, it is important to note that Rhea and colleagues used heavy loads (4–8 RM).

ME also increased for LP and DUP. Surprisingly, DUP group expressed significant higher gains in bench press compared with LP. Although not significant, DUP group also exhibited superior ES in 45° leg press and arm curl ME. The results of our study highlight superior increments in ME for DUP program compared with LP in untrained women using low intensity and high number of repetitions. This is contrary to a previous report with muscular endurance programs in which no difference was observed between LP and DUP models, but with a reported higher improvement in a reverse linear periodization (RLP) [21]. Therefore, while the higher effectiveness of RLP could be due to the greater volume at the end of the program [21] as training volume is highly related to endurance muscular performance [16], the current study suggests a greater improvement in ME with the employment of DUP with a high number of repetitions per set in a group of untrained young women. Whereas this result may seem surprising, a possible explanation is that DUP exerts higher stress on the neuromuscular system, so that there could be greater adaptations, leading to an increase in ME [20].
Alternatively, it may be speculated that the greater training volume of the DUP in the last 2 weeks of training could favor a greater ME performance at the end of the training period, as previously proposed by Rhea et al. [21] with RLP. Further studies are warranted for the assessment of such results with other training loads and RLP in women.

It should be pointed out that, according to Rhea et al. [20, 21] and Prestes et al. [18, 19], the major methodological problem of the comparisons between periodizations is that in several studies intensity and volume were not equated. Another question raised in the present study is the use of 1-week microcycles for LP, as this comparison also needs elucidation since 4 week microcycles are commonly applied.

Contrary to our hypothesis, the experimental groups did not exhibit significant improvements in VO₂max nor in VT after the training period. Nevertheless, the ES analysis revealed greater gains in the LP model and more specifically in VT. This finding is interesting and suggests a greater impact of LP in cardiorespiratory fitness. Previously, some strength training studies investigated cardiorespiratory variables in trained [2, 7] and untrained [4] women with no changes observed in VO₂max [2, 4] anaerobic threshold [7] or VT [4]. This confirms the difficulty of strength training alone for inducing significant changes in cardiorespiratory fitness.

However, since strength training has been demonstrated to influence endurance performance via greater economy [7], a better functional capacity may be expected as previously reported in the study of Kraemer et al. [13] from the greater 2 mile-loaded run performance in all the training groups. Moreover, given that concurrent strength and endurance training are highly effective for such improvements [5], we may suggest that a brief aerobic warm-up plus the employed training programs could be sufficient to significantly improve the current results in the LP model.

Another import issue is the work to rest ratio, as the rest interval between sets and exercises is an important variable and may affect chronic adaptations. It may be speculated that shorter rest intervals could result in superior cardiovascular improvements [1].

It is worthy to mention that these results are dependent on the models of periodization, microcycles’ duration, population characteristics and training background, and volume and intensities selected. Additional research is needed to clearly show the superiority of different periodization models for several objectives, such as maximal strength, muscular endurance and power in this and other populations. The present study has some limitations that should be considered, such as the low number of participants and time of intervention. Additionally, metabolic and hormonal measures should also be included in future studies.

**Conclusion**

The main purpose of the present study was to verify the effect of 2 different RT periodization models on body composition, maximal strength, muscular endurance and cardiorespiratory fitness. In summary, the comparison of the effectiveness of both LP and DUP revealed the superiority of LP for body composition, maximum strength performance and cardiorespiratory fitness improvements, while the DUP was more effective for ME performance in a group of sedentary young women.

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**References**


