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STRENGTH GAINS AFTER TEN-WEEKS OF DAILY NON-LINEAR PERIODIZATION BETWEEN CONCURRENT VERSUS RESISTANCE TRAINING

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Abstract

Objective: To investigate the effects of 10-weeks of concurrent training versus resistance training on strength gains for lower-body muscles.

Methods: Thirty physically active women were divided into two groups: resistance training (RT; 72.55 ± 12.58 kg, 153 ± 0.05 cm) and concurrent training (CT; 62.79 ± 8.14 kg; 153 ± 0.06 cm). One repetition maximum (RM) loads for each subject was estimated for leg press 45° (LP45), leg curl (LC) and leg extension (LE) resistance exercises. The training program underwent 20 training sessions (10 weeks) with the frequency of two sessions a week. For the RT group the daily non-linear periodization was adopted over the 10 weeks following this model: Zone A (70-85% of 1RM), Zone B (85% of 1RM) and Zone C (60-70% of 1RM). In the CT group was adopted the same RT program and also 20-minute of aerobic exercise.

Results: Maximum strength (1RM) of the lower-body muscles showed significant increase in RT (P = 0.001) and CT (P = 0.001) groups for the LP45 exercise; and LE (RT: P = 0.002; CT: P = 0.003), respectively, between the pre and post-test measures. Considering the differences between experimental protocols, higher strength gains were found for LP45 (P = 0.001) and LE (P = 0.002) exercises for RT compared to CT protocol. No significant differences were noted for LC exercise between protocols considering also the results intra-group (P = 0.098).

Conclusion: Therefore, if the goal of exercise program is to achieve greater strength gains, the RT should be performed isolated than combined with aerobic exercise in the same training session.

Key words: *aerobic exercise; endurance; concurrent training; muscle strength*

Introduction

Several studies have shown that concurrent resistance and aerobic exercises with high-intensity loads may compromise the magnitude of strength and power development [1-4]. The major consideration about the performance of concurrent exercise in the same training session is that endurance exercise may affect the neuromuscular system's ability to generate maximal force [5].

However, previous studies reported no interference in strength development adopting concurrent resistance and aerobic training over a short term [6-8]. Studies investigating the interaction of these two diverse types of training provide strong evidence that concurrent training does not impair endurance development as measured by maximal aerobic power [1,4,9]. It is also believed that for optimal strength and endurance enhancement, special attention should be paid to the order and duration of the training sessions [4]. Recently, concurrent training, relative to resistance training alone, has been shown to result in enhancement in strength [3], hypertrophy [10], and power [9].

Several explanations have been suggested to explain the interference induced by concurrent training on neuromuscular and physiological adaptations. One of the more popular theories is the chronic interference hypothesis, which postulates that the addition of endurance training results in overreaching [10] and overtraining and stimulates competing adaptations over a long-term training program[11]. Overreaching is currently thought to be responsible for the concurrent adaptations due to the high-volume, high-intensity, or high-frequency training bouts [9], particularly when bouts of exercise result in large amounts of skeletal muscle damage.

However, recently findings reported that an acute concurrent resistance and endurance training promoted greater molecular anabolic response than resistance training alone [12]. These acute findings were subsequently also investigated with a global muscle responses to a similar training program [10]. It was found that the concurrent training produced greater increase in muscle size, compared with resistance training isolated [10].

Therefore, the manipulation of resistance training methodological variables (i.e., number of exercises per session, repetitions per set, or sets per exercise) is another issue that has received considerable research attention. Nevertheless, most studies seem to support the contention that the adaptation to typical resistance training is different when combined with endurance training. In addition, the training volume and frequency may also influence the amount of incompatibility observed. Thus, the purpose of this study was to investigate the chronic effects of 10-weeks of daily non-linear periodization during concurrent versus resistance training sessions on strength gains for lower-body muscles with recreationally trained women.

Methods

Participants

The study started with 30 recreationally trained women between 35 and 55 years who were divided into two groups: resistance training (RT; 72.55 ± 12.58 kg, 153 ± 0.05 cm) and concurrent training (CT; 62.79 ± 8.14 kg; 163 ± 0.06 cm), both groups with 15 subjects. All visits took place at the same time on each day. All participants had previous RT experience (mean 3.5 ± 1.2 years), averaging four 60-minute sessions per week using 1- to 2-minute rest intervals between sets and exercises. The current study was approved by the Institutional Human Experimental Committee at the Federal University of Amazonas(CAE 0045.0.115.000-09). Written informed consent was obtained from all participants prior to participation, in accordance with the Declaration of Helsinki. Prior to participation in the study, all participants completed a Physical Activity Readiness Questionnaire. Participants with any functional limitation or medical condition that could influence their ability to perform the testing or experimental protocols were excluded from the current study. Eight women completed the study in each group due to the exclusion criteria. The participants were instructed to do not perform any type of exercise 48h before the test or training sessions.

Strength tests

One repetition maximum (RM) loads for each subject was estimated from the equation 1RM = load lifted/[1.0278 - (0.0278 x maximum repetitions)] for leg press 45° (LP45), leg curl (LC) and leg extension (LE) resistance exercises [13]. The first 2 testing sessions focused on measures of strength and anthropometry. At each of these sessions, training loads were assessed using a 10RM test for LP45, LC and LE exercises on machines (Life Fitness, IL, USA). If the participant did not attain 10 repetitions in the first attempt, the weight was adjusted by 4 to 10 kg, and a minimum of 5 minutes of rest was given before the next attempt [14]. Only three trials were allowed per testing session and 10 minutes of rest was adopted between exercises. The test and retest were conducted with a minimum interval of 48 hours. LP45, LC and LE exercises were alternated during test and retest. The following strategies were adopted to reduce the margin of errors in the data collection procedures [15]: (a) Standardized instructions were given before the tests such that the person being tested would be aware of the entire routine involved in the data collection; (b) the individual being tested was instructed on the proper technique of the exercise execution; (c) all subjects were given standardized verbal encouragement throughout the tests; and (d) all tests were conducted at the same time of the day for every session.

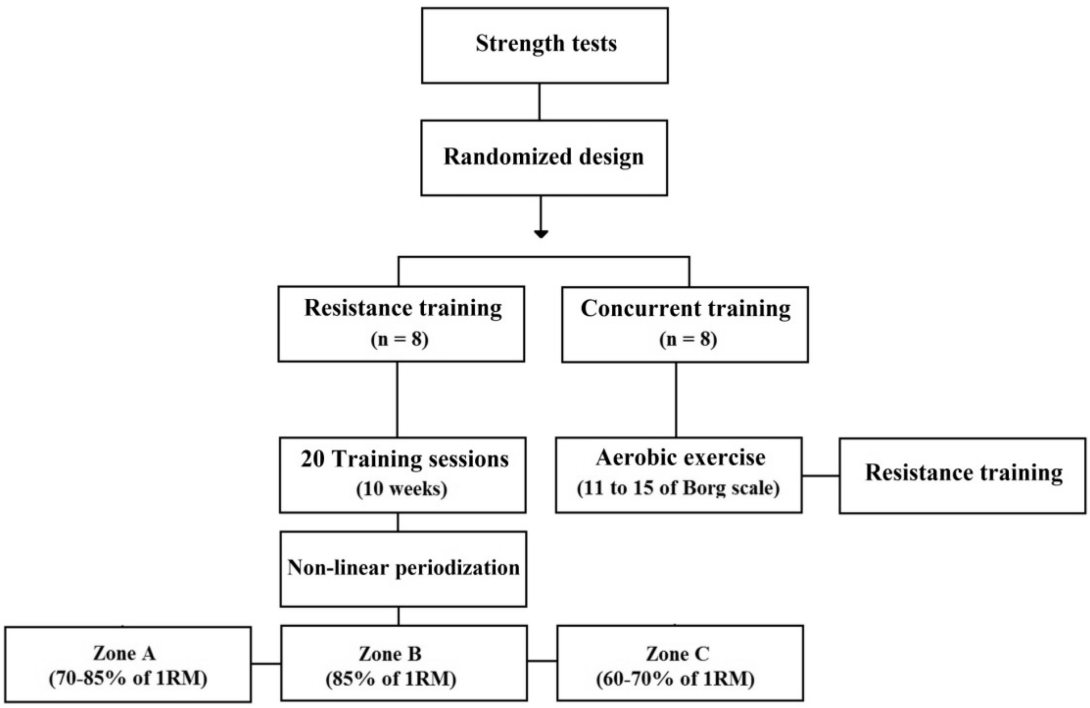

Fig. 1. *Study design*

Exercise Program

In the second week, the experimental groups (RT and CT) were separated following a randomized cross-over design (Fig. 1).The training program underwent 20 training sessions (10 weeks), with the frequency of two sessions a week, adopting at least 48 hours of interval between sessions. The strength tests were applied in the first week before the training sessions and at the end of 10^{th} week. Additionally, the strength gains were evaluated through the loads obtained in the 10RM test.

All resistance training sessions started with a general warm-up (ending with four repetitions in the LP45 with 70% 1RM performed with maximal intended concentric velocity). For the RT group the daily non-linear periodization was adopted over the 10 weeks following this model: Zone A (70-85% of 1RM), Zone B (> 85% of 1RM) and Zone C (60-70% of 1RM) and that sequence was followed until the last training session. The exercise program was composed by: LP45, LC, LE, bench-press, lat pull down, biceps curl, triceps curl and abdominal crunch. Two-minute of rest intervals was applied between sets and exercises for the three training zones. In the CT group was adopted the same RT program and also 20-minute of aerobic exercise was performed at the intensity corresponding to values between 11 and 15 (light – hard) (on 6 to 20 scale) on the scale of perceived exertion [16] before the resistance exercise program. The participants were instructed to performer three sets repetition to failure for all exercises for both groups during the resistance training sessions. The participants had previous experience with Borg scale.

Statistical analysis

The10RM test–retest reliability was calculated through the intraclass correlation coefficient (ICC = $(MS_b - MS_w)/[MS_b + (k-1)MS_w)]$), where MS_b = mean-square between, MS_w = means-square within, and k = average group size. The normality and homoscedasticity of the data was analyzed via the Shapiro-Wilk test and Bartlett test of Sphericity ($P = 0.167$); subsequently, all variables presented normal distribution and homoscedasticity. One-way repeated-measures analysis of variance (ANOVA) was used to determine whether there were significant main effects or interactions for type of training (RT and CT). Post-hoc tests with the Tukey correction were employed when necessary. The level of statistical significance was set at 0.05 for all tests. In order to determine the magnitude of the effect, the effect of size was used [17]. The statistical analysis was performed with SPSS version 17.0 (Chicago, IL, USA).

Results

The ICCs showed higher reliability (between 0.82 and 0.98) for 10RM test with the resistance exercises adopted in the current study. The strength gains for lower limb exercise via 10RM test showed significant increase in RT ($P = 0.001$) and CT ($P = 0.001$) groups for the LP45 exercise; and LE (RT: $P = 0.002$; CT: $P = 0.003$), respectively, between the pre and posttest measures (Table 1). This was not true for LC exercise (RT: $P = 0.446$; CT: $P = 0.428$). Considering the differences between experimental protocols, higher strength gains were found for LP45 ($P = 0.001$) and LE ($P = 0.002$) exercises for RT compared to CT protocol. No significant differences were noted for LC exercise between protocols ($P = 0.098$).

Large effect size were noted for LP45 and LE in pre and post measures for RT group, on the other hand, the LC showed a moderate effect size. In the CT group, the effect size was moderate for LP45 and small for LE and LC resistance exercises.

Discussion

The key findings of the current study was higher strength gains found in the RT group for LP45 and LE exercises when compared to CT group with recreationally trained women. The exercises LP45 and LE showed significant improvements in the loads obtained in 10RM test for both protocols, but when comparing the post-test (inter-group) measures, the RT group showed significantly greater improvements than CT. However, the LC exercise showed no significant changes when comparing pre and post-test in intra-groups and inter-groups comparisons after 10-weeks of training. These findings are in agreement with previous studies which suggested that isolated RT is more efficient for strength gains than CT [3,7,9,18].

Table 1.*The values of 1RM test and effect size (ES) for leg press 45 (LP45),leg extension (LE) and leg curl (LC) in groups concurrent training (CT) and resistance training (RT). *Values expressed as mean (standard deviation)*

	Resistance Training			Concurrent Training		
	Pre (kg)	Post (kg)	Effect Size	Pre (kg)	Post (kg)	Effect Size
LP45	131(10.96)	172.5(11.33) *#	3.77 (Large)	123.2(14.74)	139.46 (25.55)*	1.14 (Moderate)
LE	26.7(3.97)	33.7(5.17)*#	1.76 (Large)	23.7(5.67)	27.07(6.34)*	0.59 (Small)
LC	17.5(2.88)	20(1.80)	0.86 (Moderate)	14(3.16)	16(2.33)	0.63 (Small)

* Significant difference for intra-group with the pre-test; # Significant difference inter-group for the post test.

Levin et al. [19] also noted that after 6 weeks of intervention on trained cyclers the 1RM loads increased 25% for squat exercise in the group that performed isolated RT and 6.6% for CT. These findings suggested that higher strength gains were found when isolated RT was performed. Physiological hypotheses confirm the deleterious effect of aerobic exercise on strength performance. The aerobic exercise activate AMPK stimulation which in turn phosphorylates TSC2 [12]. TSC2 when activated exerts breaking effect on mTOR, and mTOR activation also triggers a cascade of signals to promote adaptations associated with resistance exercise [5]. The inhibitory effect on this flag, collaterally exercised by the activation of AMPK, may possibly cause injury on the final results expected by the stimulus strength [20,21].

Significant increases on 10RM loads were found for LP45 and LE after 20 training sessions for RT and CT groups. Similar results were noted by Chtara et al. [22], who observed that after 24 training sessions for lower limb, the loads obtained in 1RM test increased significantly ($P < 0.01$) for all experimental groups: resistance (+17.0%), resistance followed for aerobic exercise (+12.2%), aerobic exercise followed by resistance exercise (+10.6%), aerobic group (+6.2%), and the control group (+5.6%).

Residual fatigue from a previous endurance session may cause a reduction in the quality of subsequent strength performance by compromising the ability of the neuromuscular system to rapidly develop force [3] and/or reducing the absolute volume of strength training that could be performed in such a condition [23]. The hypothesis based on acute effect, pointing towards the importance of the ordering which activities are performed.

This fact seems to illustrate a limitation of the current study. Davitt et al. [24] investigated the effect of the exercise order in a group of women, and observed no difference between groups for any of the physiological markers of performance, including measures of force, regardless of whether the participants had started with aerobic or resistance exercise. This result suggests the fragility of a paradigm that defending in favor of the implementation of the first stimulus, either aerobic or resistance exercise, according to the priority of training, leavings in doubts the credibility assigned to the acute hypothesis against the damaging effects of concurrent training as hypothesized being arising from a possible fatigue caused by residual first activity.

No differences were found in 10RM loads of LC exercise inter and intra-group after the 20 training sessions. These results may be associated to the exercise order adopted for lower-body exercises in the current study, considering that the hamstring muscles has important role during LP45. This condition induced a higher level of muscle fatigue which may compromise the strength performance of hamstring during LC exercise due to the previous evidences which indicated that exercise order play an important role in a acute and chronic strength gains [25,26]. It has been suggested that the main effect (i.e., neural, hypertrophic, metabolic, and hormonal responses) and subsequent adaptations to resistance training partially depend on the total number of repetitions performed by an individual [7].

In the current study was adopted a daily non-linear periodization for RT program with three training zones: A (70-85% of 1RM), B (85% of 1RM) and C (60-70% of 1RM) with light to moderate loads. This model of periodization is frequently associated to higher strength gains due to a better recovery and muscle adaptation because of the variations on training stimulus [27,28]. In this sense, moderate increases in training volume have been shown to lead to further improvement in strength [29]. However, it appears that once a given a higher volume is reached, an additional increase in training volume does not develop more gains and can even lead to reduced performance in experience resistance-trained subjects [11].

On the other hand, the daily non-linear periodization of RTmay not prevent the negative effect of aerobic exercise on strength gains. However, Chtara et al. [22] divided the training session between muscular endurance and power. The groups in these studies showed low strength gain. In the current study, there was a variation in the intensity (70-85 % 1RM), (> 85% 1RM) and C (60-70% 1RM) between the characteristics of hypertrophy and maximal strength, which may be responsible for the increasing in muscle strength, especially in group RT.

Previous studies have also shown that short-term high-intensity concurrent resistance and endurance training may compromise the magnitude of strength and power development [1,3,30]. Therefore, it appears that the manipulation of training volume and/or intensity is critical to avoid potential interferences in concurrent training [8,23,31], especially when high-intensity RT is performed concurrently with regular endurance training with well-trained athletes [11].

It is important to highlight that the current study has limitations such as the prescription of the endurance training which may compromise the control of training intensity. However, the current study did not measure the activation of cell signaling, such a theory rightly supports the findings reported here. Additionally, some important variables such as $\dot{V}O_2max$ and muscle thickness were not measure to analyze possible morphological and physiological responses.

Conclusion

In conclusion, the isolated RT was more efficient to promote larger strength gains than CT for lower-body resistance exercises (LP45 and LE). It also appears that exercise order had an important influence in the results of the current study, since the LC exercise performed after theLP45 showed no significant improvements. Therefore, if the goal of exercise program is to achieve greater strength gains, the RT should be performed isolated than combined with previous aerobic exercise with low to moderate intensity.

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Declaration of interest

The authors do not have any conflict of interest.

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