Comparison of Linear and Reverse Linear Periodization Effects on Maximal Strength and Body Composition

Jonato Prestes,[1] Cristiane De Lima,[2] Anelena B. Frollini,[2] Felipe F. Donatto,[2] and Marcelo Conte[3]

[1]*Physiological Sciences Department, Exercise Physiology Laboratory, Federal University of São Carlos, São Paulo, Brazil;* [2]*Health Sciences Department, Physical Education Post-Graduation Program, Methodist University of Piracicaba, Piracicaba, São Paulo, Brazil; and* [3]*Superior School of Physical Education, Jundiaí, São Paulo, Brazil*

Abstract

Prestes, J, De Lima, C, Frollini, AB, Donatto, FF, and Conte, M. Comparison of linear and reverse linear periodization effects on maximal strength and body composition. *J Strength Cond Res* 23(1): 266–274, 2009—There are few studies that have compared different periodization methods for strength and hypertrophy. The aim of this study was to verify the effect of a 12-week strength training program with different periodization models on body composition and strength levels in women ranging from 20 to 35 years of age. Participants had a minimum of 6 months of experience in strength training, and they were divided into two groups: linear periodization (LP, $n = 10$) and reverse linear periodization (RLP, $n = 10$). Intensity was increased weekly; LP began with 12–14 maximal repetitions (RM), reaching loads of 4–6RM, and RLP began with 6–4RM and finished with 12–14RM. In all exercises, three sets were accomplished; number of repetitions and rest between sets and exercises were in accordance with weekly prescribed intensity. Training was performed 3 days per week. The evaluations were baseline evaluation (A1), after 4 weeks of training (A2), after 8 weeks (A3), after 12 weeks (A4), and after 1 week of detraining (A5). Fat mass and fat-free mass, maximum strength (bench press, lat pull-down, arm curl, and leg extension) were evaluated. There was an increase in fat-free mass and a decrease in fat mass in A4 compared with A1 only for the LP group. Both the LP and RLP groups presented significant gains in maximum strength levels in all exercises analyzed. However, for LP, the increases were greater when compared with RLP. In practical terms, LP is more effective for strength and hypertrophy as compared with RLP, and 1 week may be an adequate period for application of detraining without causing decreases in the performance of the parameters analyzed.

Key Words periodization, strength training, strength

Introduction

The scientific literature has highlighted the benefits of strength training with the objective of increasing health, physical fitness, and life span (2,4,11). Among the benefits are increases in strength, power, muscular endurance, and fat-free mass. These improvements in physical fitness can be achieved through variations in prescription patterns, such as weekly frequency, number of series, exercises and repetitions, rest between series and exercises, movement velocity, and joint angle.

In this sense, the importance of prescribing exercise systematically and individually has grown, considering all the variables inherent to this process. The aim of periodization includes maximizing the overload principle and allowing a better relation between stress/recovery (26). Strength training periodization is a relevant tool in designing an exercise program for regular strength training practitioners.

Among the periodization models, there is the classical linear periodization (LP), which divides a strength training program into different periods or cycles: macrocycles (9–12 months), mesocycles (3–4 months), and microcycles (1–4 weeks), gradually increasing the training intensity while decreasing the training volume within and between cycles (26). Reverse linear periodization (RLP) follows the modification in intensity and volume, however, in a reverse order as compared with LP, increasing volume and reducing intensity (27). Another model also used is daily undulating periodization (DUP), which consists of increasing and decreasing intensity and volume, with the alterations occurring within the same week; that is, the variation of training components is more frequent and lasts for shorter periods (9).

Address correspondence to Jonato Prestes, jonatop@gmail.com.

23(1)/266–274

Journal of Strength and Conditioning Research

In a comparison between periodized and nonperiodized programs, superiority of periodized training for increasing muscle strength was shown when compared with nonperiodized training (20). Indeed, studies that compared LP with nonperiodized models have shown LP to be more efficient in producing positive alterations in body composition and maximal strength (7,19).

Only one study, conducted by Rhea et al. (27), has compared the efficiency of LP, DUP, and RLP periodizations with the objective of increasing local muscular endurance in young strength trained men and women. The intensity used by the authors was 15–25 maximal repetitions (RM); the results showed that RLP was more efficient for increasing local muscular endurance in comparison with LP and DUP. However, it raises a question: what would be the result if RLP and LP were compared when using higher intensities, between 4 and 14RM?

Because no studies comparing RLP and LP performed with the aim of increasing strength and hypertrophy have been found, the objective of the present research was to compare the efficiency of LP and RLP in training directed towards increasing muscle mass in previously trained women.

Methods

Experimental Approach to the Problem

The main objective of the present study was to compare the efficiency of LP and RLP in improving maximal strength levels and body composition, using loads between 4 and 14RM. Another aim was to verify the effects of 1 week of detraining, in the absence of any exercise, on maximal strength and body composition. In this research, the volume and intensity of both periodizations were equated as recommended by Rhea et al. (26,27), allowing a better comparison among LP and RLP models. To date, this is the first research that has compared LP and RLP applying loads of 4–14RM and that has additionally analyzed alterations in strength and body composition after 1 week of detraining in these periodization models.

Subjects

Twenty women were recruited and randomly divided into two groups (10 women in each group). The participants were selected in accordance with the following criteria: age between 20 and 35 years old; a minimum 6 months of previous experience with strength training before the beginning of the study; and not being users of any type of ergogenic supplements. According to the American College of Sports Medicine (2), the individuals were considered "trained." The other subject characteristics are presented in Table 1. It is worth pointing out that the groups were homogeneous, so no statistically significant differences were found between them in the variables analyzed before the strength training intervention (Table 1). All participants trained at least three times per week, with three sets of 10RM in the 6 months before the beginning of the study intervention. The following evaluations were conducted: before the beginning of the exercise program (A1), at the 4th week after the beginning of the strength training (A2), at the 8th week (A3), at the 12th week (A4), and at 1 week of detraining (A5). Each participant was informed of all the risks before the investigation and signed an informed consent document, which was approved by the Escola Superior de Educação Física research ethics committee for human use (protocol no. 012/06). The procedures were in accordance with guidelines for the use of human subjects set forth by the American College of Sports Medicine.

Table 1. Baseline subject characteristics.

Variables	LP	RLP
Age (y)	27.6 ± 1.15	26.2 ± 0.92
Height (m)	1.62 ± 0.01	1.62 ± 0.02
Body mass (kg)	56.83 ± 1.57	55.78 ± 1.85
Body mass index	21.69 ± 0.53	21.29 ± 0.54
Training experience (y)	1.4 ± 0.68	1.6 ± 0.45

LP = linear periodization; RLP = reverse linear periodization.

The LP column shows data from the first baseline evaluation for the LP group ($n = 10$); the RLP column shows data from the first baseline evaluation for the RLP group ($n = 10$). The values were expressed by mean ± standard error of the mean ($p \leq 0.05$).

Body Composition

Body composition was assessed using skinfold thickness measurements taken with a Lange skinfold caliper. The equation of Jackson et al. (17) for women (18–55 years old) was used to estimate body fat percentage. In this equation, the sum of triceps, suprailiac, and thigh skinfolds is used. After this procedure, fat mass (kg) and fat-free mass (kg) were estimated.

Strength Assessments

On the day after the anthropometric evaluations, maximal strength tests were performed using 1RM. In the week before the initial evaluations, the participants were instructed to avoid training. During the 12 weeks of training, the tests were performed in the recovery weeks (70% of 1RM). To obtain reliable baseline strength values, the pretraining 1RM trials were performed on three separate days, with several days between them. A high interclass correlation was found between the second and the third 1RM trials ($R = 0.98$). The greatest 1RM determined from the last two trials was used for the baseline measurement. After 10 minutes of light treadmill running, the individuals executed a specific warm-up of eight repetitions with 50% of estimated 1RM (according to the previous loads used by the participants in their training routine), followed by three repetitions with 70% of estimated

1RM. The subsequent trials were performed for one repetition with progressively heavier weight until the 1RM was determined within three attempts, using 3- to 5-minute rest periods between trials (23). The range of motion and movement standardization of the exercises was conducted according to the descriptions of Brown and Weir (5). The exercises chosen for the analyses of maximal strength evolution were bench press, lat pull-down, arm curl, and leg extension.

Local Muscular Endurance Assessments

The local muscular endurance test was conducted 48 hours after maximal strength tests. The test was accomplished by execution of repetitions to exhaustion. After a short period of light aerobic warm-up, participants performed as many repetitions as possible without stopping or pausing between repetitions with a fixed cadence. The resistance comprised 50% of the individual's body mass (27). The exercises selected for the application of this test were the arm curl and leg extension. As in the 1RM test, to ensure the reliability of the baseline measure, this procedure was repeated on a separate day, and the highest number of repetitions was recorded, with high interclass correlation for both trials ($R = 0.99$).

Strength Training

The strength training applied in this study presented the characteristics of LP or RLP. In LP, training intensity is increased each microcycle (1–4 weeks), and the volume is decreased. The number of repetitions was decreased (maintaining the minimal quantity of repetitions established for the weekly prescribed intensity) by reason of the increased intensity. The strength training periodizations are shown in Figures 1 and 2. The intensity was increased every week in LP and reduced every week in RLP (Figure 1). The periodizations applied were based on previous studies published in the literature (4,19,26). The training loads were adjusted in each training session and evaluated as the participants' strength increased; that is, the training was conducted with maximal repetitions (Figure 2).

The exercising sequence is presented in Figure 2, and training was conducted in three workouts per week. The program was divided into training A and B, so that on Monday and Friday, training A was performed, and, on Wednesday, training B was performed. In the next week, training A was performed on Wednesday, and training B was performed on Monday and Friday. The consecutive weeks followed this same order for the training sessions. For all listed exercises, three series until voluntary concentric failure were performed, and the number of repetitions and rest intervals between series and exercises was followed according to the weekly intensity prescribed, as shown in Figure 1. The average duration for the training sessions was 50 minutes, and, for the repetitions, it was 3–4 seconds, taking into account the concentric and eccentric phases of the movement. All sessions were individually supervised by a strength and conditioning specialist.

The strength training was performed for 12 weeks (Figure 1). The load increase occurred for three consecutive weeks. At the 4th, 8th, and 12th weeks the load was decreased to 12RM, and the participants reduced their training frequency from three to only two weekly sessions (Figure 1). These weeks were planned to provide an optimal recovery of the participants. Another important variable considered was that for both training groups, the intensity and the volume were

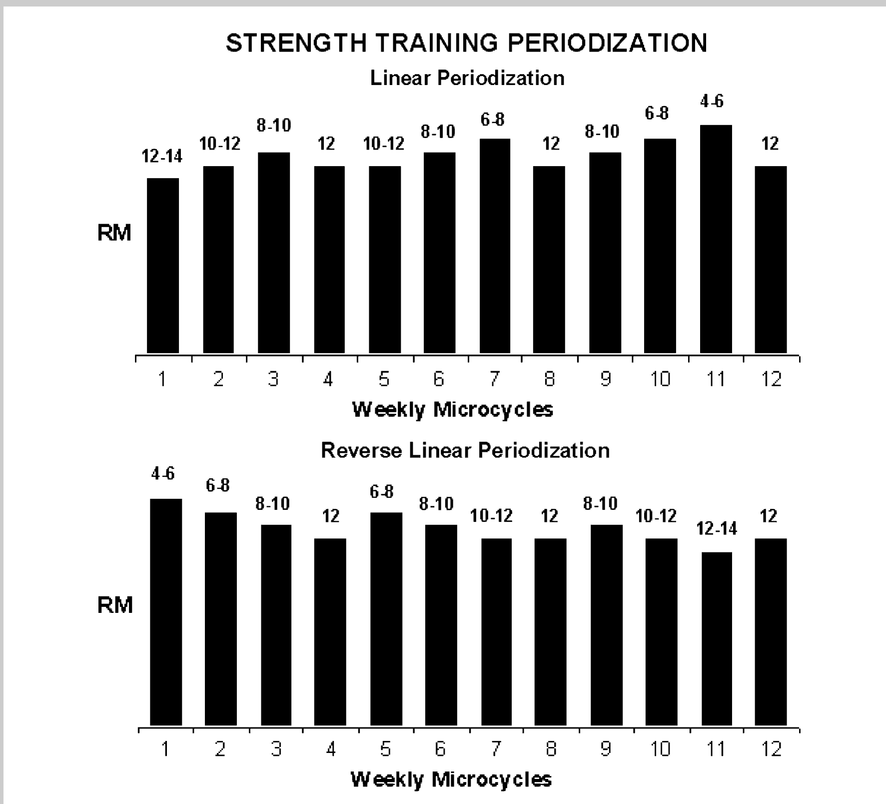

Figure 1. Load distributions represented by maximal repetitions (RM) in each weekly microcycle of linear and reverse linear periodization strength trainings.

STRENGTH TRAINING PROGRAM

Performed exercises	
Training A	Training B
1. Bench press	1. Back squat
2. Inclined chest fly	2. Leg extension
3. Dumbbell shoulder press	3. Leg curl
4. Lateral raise	4. Glute kickbacks
5. Standing arm curl	5. Hip abduction
6. Biceps preacher curl	6. Hip adduction
7. Triceps extension	7. Standing calf raise
8. Close-grip bench press	8. Lat pull-down
	9. Seated row

Series X Repetitions	Rest interval
3 X 12 - 14 repetitions	45s
3 X 10 - 12 repetitions	1min
3 X 8 - 10 repetitions	1min and 20s
3 X 6 - 8 repetitions	1min and 40s
3 X 4 - 6 repetitions	2min

Figure 2. Exercises divided into A and B training, number of series, repetitions, and rest intervals performed for each microcycle training in linear and reverse linear periodizations.

equated, as recommended by Rhea et al. (26,27). All sessions were individually supervised by experienced strength and conditioning specialists who directly monitored training sessions.

Complementary Aerobic Training

In the 12 weeks of training, two weekly 30-minute aerobic sessions were conducted. These sessions consisted of treadmill running at a speed adjusted according to the target heart rate achieved (THR) of 60%, determined by the equation proposed by Karvonen et al. (18): THR = % (HRmax − HRrest) + HRrest, where % = selected work percentage, HRmax = maximal heart hate, and HRrest = resting heart hate. Heart rate was monitored in all training sessions by a heart rate monitor. The estimated HRmax was calculated from the Tanaka et al. (29) equation: HRmax = 208 − (0.7 × age), specific for healthy adults. It has been previously shown that a complementary aerobic training performed two times per week does not exert negative influence on the muscle strength variables (19,31). Additionally, the participants were instructed to maintain their normal food intake during the research.

Statistical Analyses

All data are presented as mean ± *SEM*. The statistical analysis was initially done by the Shapiro-Wilk normality test and by the homoscedasticity test (Bartlett criterion). All variables presented normal distribution and homoscedasticity, so the repeated-measures analysis of variance (ANOVA) (two groups at five time points) was used, and when the difference presented was significant, the Tukey post hoc test for multiple comparisons was applied. To determine that there were no differences between the two groups for the variables analyzed, before the training began, Student's *t*-test was used. In all calculations, a critical level of $p \leq 0.05$ was fixed. Test-retest reliability for maximal strength was determined using an intraclass correlation coefficient (ICC) (10). The software package used was Statistica 6.1.

Results

Body Composition

A significant decrease in fat mass (17.76%, $p = 0.04$) was observed in the evaluation after 12 weeks for LP (A4L) in comparison with the baseline evaluation of LP (A1L). However, in the other evaluations for LP and RLP, no statistically significant differences were observed in fat mass (Table 2).

Table 2. Anthropometric variables during 12 weeks of strength training.

AV	Groups	A1	A2	A3	A4	A5
FM	LP	13.46 ± 0.62	11.91 ± 0.90	11.83 ± 1.01	11.07 ± 0.93*	11.13 ± 0.95
	RLP	14.39 ± 1.03	13.80 ± 0.97	13.32 ± 0.96	12.79 ± 0.93	12.34 ± 0.65
FFM	LP	43.37 ± 1.03	46.03 ± 0.85†	45.68 ± 0.75†	46.44 ± 0.95*†	46.72 ± 0.96*†
	RLP	41.39 ± 1.33	41.93 ± 1.30	42.34 ± 1.24	42.92 ± 1.23	42.68 ± 1.12
BF%	LP	23.05 ± 0.80	20.58 ± 1.15	20.38 ± 1.25	19.23 ± 1.25*	19.09 ± 1.23*
	RLP	25.06 ± 1.61	24.02 ± 1.59	23.25 ± 1.56	22.31 ± 1.38	22.76 ± 1.47

AV = anthropometric variables; FM = fat mass (kg); FFM = fat-free mass (kg); BF% = body fat percentage (%); LP = linear periodization ($n = 10$); RLP = reverse linear periodization ($n = 10$). A1 = baseline evaluation; A2 = evaluation after 4 weeks of training; A3 = evaluation after 8 weeks of training; A4 = evaluation after 12 weeks of training; A5 = evaluation after 1 week of detraining. *Significant statistical difference in relation to A1; †significant statistical difference between the periodizations in the same week of evaluation. The values were expressed by mean ± standard error of the mean ($p \leq 0.05$).

There was an increase in fat-free mass of 6.62% ($p = 0.04$) and 7.18% ($p = 0.02$) for LP in A4L and after 1 week of detraining (A5L), respectively, in relation to A1L (Table 2). On the other hand, no significant alterations were found in fat-free mass for the RLP group during the study (Table 2). Finally, fat-free mass was significantly increased in all evaluations for the LP group (evaluation after 4 weeks of training: A2L→8.91%, $p = 0.01$; evaluation after 8 weeks of training: A3L→7.32%, $p = 0.03$; A4L→7.58%, $p = 0.03$; A5L→8.65%, $p = 0.01$) in comparison with RLP group.

There was a significant decrease of 16.58% in body fat percentage ($p = 0.01$) for the LP group in A4L and a decrease of 17.19% ($p = 0.01$) in A5L compared with baseline (Table 2). In contrast, for the RLP group, no statistically significant differences were observed in body fat percentage between the evaluations or in comparison with LP (Table 2).

Maximal Strength

Bench Press. The LP group presented significant increases in bench press maximal strength of 10.66% ($p = 0.04$) in A3L, 14.57% ($p = 0.01$) in A4L, and 17.38% ($p = 0.01$) in A5L in comparison with A1L (Figure 3A). Furthermore, in the LP group, increases of 10.68% ($p = 0.02$) in A4L and 13.62% ($p = 0.01$) in A5L were found in comparison with A2L for the bench press (Figure 3A). For the RLP group, significant increases in bench press maximal strength were observed in A4LR (16.15%, $p = 0.04$) and A5LR (16.59%, $p = 0.04$) in comparison with A1LR. No statistically significant

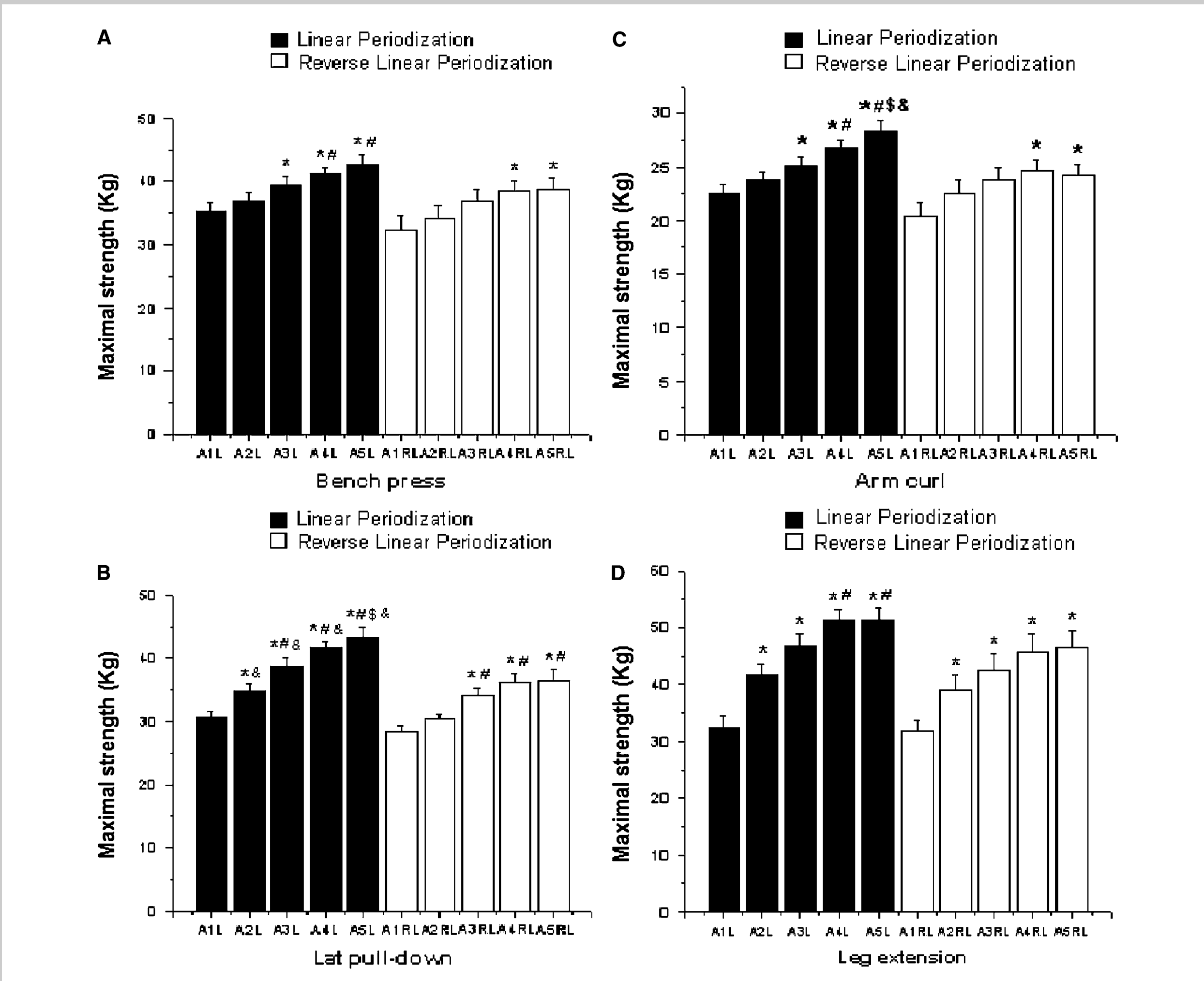

Figure 3. Maximal strength levels for bench press, lat pull-down, arm curl, and leg extension exercises. Black squares refer to the linear periodization group ($n = 10$), and white squares refer to the reverse linear periodization group ($n = 10$). A1 = baseline evaluation; A2 = evaluation after 4 weeks of training; A3 = evaluation after 8 weeks of training; A4 = evaluation after 12 weeks of training; A5 = evaluation after 1 week of detraining. * Statistically significant difference in comparison with A1; # statistically significant difference in comparison with A2; $ statistically significant difference in comparison with A3; & statistically significant difference between the periodizations in the same week of evaluation. The values are expressed as mean ± *SEM* ($p \leq 0.05$).

differences were found between the LP and RLP groups in the bench press (Figure 3A).

Lat Pull-Down

The LP group presented a significant increase in all evaluations during the training period (A2L, A3L, A4L) and in A5L in comparison with the baseline evaluation. This increase was 12.07% ($p = 0.01$) in A2L, 21.14% ($p = 0.01$) in A3L, 26.45% ($p = 0.01$) in A4L, and 29.5% ($p = 0.01$) in A5L (Figure 3B). The LP group also showed increases of 10.31% ($p = 0.03$) in A3L, 16.35% ($p = 0.01$) in A4L, and 19.82% ($p = 0.01$) in A5L in comparison with A2L (Figure 3B). Moreover, in A5L there was a significant increase in lat pull-down strength of 10.6% ($p = 0.03$) in comparison with A3L (Figure 3B).

For the RLP group there were increases in lat pull-down strength in A3LR (16.96%, $p = 0.01$), A4LR (21.55%, $p = 0.01$), and A5LR (21.98%, $p = 0.01$) when compared with A1LR (Figure 3B). Furthermore, for lat pull-down, the RLP group presented an increase of 11.12% ($p = 0.01$) in A3LR, 16.03% ($p = 0.01$) in A4LR, and 16.49% ($p = 0.01$) in A5LR in comparison with A2LR (Figure 3B).

In the comparison between the periodizations, LP was superior to RLP in lat pull-down strength, so significant increases were observed in all evaluations performed during the training and after 1 week of detraining in LP in comparison with the same evaluations in RLP. The increases were 12.65% ($p = 0.01$) in A2, 11.86% ($p = 0.01$) in A3, 13% ($p = 0.01$) in A4, and 16.13% ($p = 0.01$) in A5 (Figure 3B).

Arm Curl

For the LP group, there was a significant increase of 9.96% ($p = 0.04$) in arm curl strength in A3L, 15.67% ($p = 0.01$) in A4L, and 20.42% ($p = 0.01$) in A5L when compared with A1L (Figure 3C). The LP group also presented significant increases of 11.19% ($p = 0.01$) in A4L and 16.20% ($p = 0.01$) in A5L in comparison with A2L (Figure 3C). An increase of 11.62% ($p = 0.01$) in A5L was observed when compared with A3L. For the RLP group, arm curl strength showed increases of 17.07% ($p = 0.01$) in A4LR and 15.7% ($p = 0.03$) in A5LR when compared with A1LR. No statistically significant differences were found between the other evaluation periods for the RLP group in the arm curl (Figure 3C). When the periodizations were compared, the LP group showed an increase in arm curl strength of 14.79% ($p = 0.01$) in A5L in comparison with the RLP group in the same evaluation period (Figure 3C).

Leg Extension

There was a significant increase in leg extension maximal strength in all evaluations (A2, A3, A4, and A5) for both periodizations (LP and RLP) in comparison with A1. The evaluations A2L, A3L, A4L, A5L, A2LR, A3LR, A4LR, and A5LR showed increases of 22.30% ($p = 0.01$), 30.62% ($p = 0.01$), 36.84% ($p = 0.01$), 36.84% ($p = 0.01$), 18.46% ($p = 0.04$), 25.35% ($p = 0.01$), 30.26% ($p = 0.01$), and 31.76% ($p = 0.01$), respectively (Figure 3D). However, for the LP group, increases of 18.71% ($p = 0.01$) in A4L and 18.71% ($p = 0.01$) in A5L were observed in comparison with A2L in the leg extension (Figure 3D).

Local Muscular Endurance

No statistically significant differences were observed in local muscular endurance for arm curl and leg extension in the evaluations performed during the study (A1, A2, A3, A4, A5) for both groups (LP and RLP) (Table 3).

Intraclass Correlation Coefficient

According to the Fleiss (10) classification, maximal strength in bench press, leg extension, and arm curl presented moderate to good reliability for the LP and RLP groups. On the other hand, maximal strength in lat pull-down presented poor reliability for the LP and RLP groups (Table 4).

Discussion

The aim of the present study was to compare maximal strength gains and alterations in body composition after two different periodizations with loads between 4 and 14RM in trained women. The volume and intensity of LP and RLP were equal and lasted a period of 12 weeks, plus a detraining week. The results show that both LP and RLP induce increases in maximal strength for the upper and lower body. However, LP produced a higher percent increase in strength,

Table 3. Local muscular endurance (LME) during the study.

LME	Groups	A1	A2	A3	A4	A5
Arm curl	LP	18.4 ± 1.73	18.5 ± 1.79	21.2 ± 2.35	19.2 ± 1.54	19.5 ± 1.51
	RLP	21.3 ± 2.26	17.7 ± 1.56	20.5 ± 1.55	20.8 ± 1.48	20.2 ± 1.73
Leg extension	LP	16.5 ± 1.24	16.1 ± 1.26	17.2 ± 1.44	15.8 ± 1.28	16.2 ± 1.11
	RLP	17.4 ± 1.03	16.5 ± 1.43	18.9 ± 1.87	18.8 ± 1.73	19.5 ± 2.71

LP = linear periodization ($n = 10$); RLP = reverse linear periodization ($n = 10$). A1 = baseline evaluation; A2 = evaluation after 4 weeks of training; A3 = evaluation after 8 weeks of training; A4 = evaluation after 12 weeks of training; A5 = evaluation after 1 week of detraining. The values were expressed by mean ± standard error of the mean ($p \leq 0.05$).

Table 4. Test-retest reliability intraclass correlation coefficient (ICC) for maximal strength.

Maximal strength	ICC		Fleiss (10) reliability classification
Groups	LP	RLP	For both groups
Bench press	0.80	0.75	Moderate to good
Lat pull-down	0.20	0.31	Poor
Leg extension	0.70	0.70	Moderate to good
Arm curl	0.60	0.70	Moderate to good

LP = linear periodization ($n = 10$); RLP = reverse linear periodization ($n = 10$).

for the upper and lower body, in comparison with RLP. Therefore, although the participants of the present study had a minimum of 6 months of experience in strength training, on the basis of these results, the modifications of training loads with the periodizations applied constituted a new stimulus for them.

A variety of studies have shown the benefits of strength training programs in improving strength (21,24,28). Indeed, other authors have conducted studies with LP models (7,19,22), and the results have emphasized that LP was efficient in inducing positive alterations in body composition and maximal strength. Similarly, the present study results show that the group submitted to LP increased fat-free mass in all evaluations and decreased body fat percentage after 12 weeks of training, and that these values remained decreased after 1 week of detraining in comparison with baseline measurements. These alterations were not detected for the RLP group.

The strength gains during the first weeks of training are more dependent on neural adaptations (1–8 weeks); therefore, after this period, more significant alterations may occur in muscle mass and fat mass, assuming that these modifications can be detected earlier, but to a lesser extent (8). This is in agreement with the present study, because more pronounced alterations with regard to body composition occurred after 12 weeks of training. Similarly, other studies found increases in fat-free mass, showing an average increase of 2–4% with strength training and similar periods of analysis to those of the present study (6,19).

Hunter et al. (16) found that after 25 weeks of periodized strength training with variable intensities (50 to 65 to 80% of 1RM in the same week) and 3 days of weekly frequency, there were significant decreases in body fat (kg) and body fat percentage (%) in elderly men and women. Corroborating, Prestes et al. (25) verified that linear strength training periodization associated with aerobic training for 16 weeks promoted reductions in body fat percentage and in abdominal and waist circumference. In contrast, Kraemer et al. (19) did not observe decreases in fat body after 6 months of periodized strength training in young detrained women.

The purpose of the present research in choosing LP was based on several studies that have used this model (3,4,19,26,27), and also because of the great application in practice. On the other hand, only one study by Rhea et al. (27) was found that had directly compared the effects of LP with those of RLP. However, the goal of the loads used by the authors was to increase local muscular endurance. Therefore, to date, this is the first study to compare LP and RLP using higher loads, between 4 and 14RM.

The results of the present study show a significant gain in maximal strength levels for all tested exercises (bench press, lat pull-down, arm curl, and leg extension), with more pronounced increases in LP. In accordance with the present study, several studies have reported gains in maximal strength levels after LP with the objective of muscle hypertrophy (3,15,19).

Among the mechanisms involved in strength increases are motor unit firing rate and increased neural drive, decrease in antagonist muscle coactivation and addition of new myonuclei by activation of satellite cells and myofibers (muscle hypertrophy), and others (1,8,14).

During the initial 4 weeks of training in the present study, there was an increase in maximal strength in lat pull-down and leg extension and after 8 weeks in bench press and arm curl for the LP group, without significant modifications occurring in body composition (which were observed only after 12 weeks of training), emphasizing that the initial adaptations for strength increase were the results of neural factors, predominantly. Interestingly, another important finding was that although RLP began with higher training loads in comparison with LP, manifestations of strength gain were delayed in this group, and no body composition alterations were detected for RLP.

In local muscular endurance, no significant statistical alterations were observed for LP and RLP in arm curl and leg extension. In contrast to the present study, Rhea et al. (27) have proposed a comparison between LP, RLP, and DUP with 15 weeks of training, involving three series varying from 15, 20, and 25RM, organized according to each periodization model. The authors conclude that the gradual increase in volume and decrease in intensity (by RLP) was more effective for increasing local muscular endurance.

However, the present study shows that RLP is not the most effective periodization model for strength gains. Indeed, LP was a more effective method for increasing strength when compared with RLP. Therefore, the higher loads used in this study were possibly not a specific stimulus to increasing local muscular endurance.

Nevertheless, the present study found that LP had more significant results in the variables analyzed (maximal strength and body composition) in comparison with RLP, and these alterations were directly related to intensity applied (4–14RM). In this study, a missing comparison was a DUP group, as Rhea et al. (26,27) have shown superior results in maximal strength for DUP compared with either LP or RLP.

Interestingly, after 1 week of detraining, in which no exercise was performed, there was no decrease in maximal strength and no negative alterations in body composition. In fact, for muscle strength, a percent increase was found during this week; however, there were no statistically significant differences in these values in comparison with the evaluation made after 12 weeks. Other studies have shown that after 8–12 weeks of detraining, muscle strength can decrease significantly, with values between 12 and 68% (13,30).

Gibala et al. (12) found that after 10 days of reduced training, positive effects on strength were observed in trained individuals. In this sense, there are several questions raised by the professionals involved in strength training and conditioning. If an individual stops training, how long does it take for strength to decrease significantly? For how long can a regularly trained individual stop training without decreasing performance and fat-free mass and increasing fat mass? The answers to these questions are complex and depend on a series of factors, such as individual physical fitness, type of strength training, and nutritional and genetic factors.

Yet, at least in a population with similar characteristics to those of the individuals in the present study, a detraining week seems to be efficient for maintaining muscle strength and body composition, after a 12-week period of strength training in LP and RLP models.

Practical Applications

Linear periodization strength training with 4–14RM for 12 weeks can induce positive effects on body composition by increasing fat-free mass and decreasing body fat, which was not observed for RLP. However, LP and RLP can induce significant gains in maximal strength for the upper and lower body. On the other hand, as regards local muscular endurance, both in LP and RLP at intensities between 4 and 14RM, no increase was observed. From this aspect, it is clear that the increases in strength manifestations depend on training specificity.

Another important finding of the present research was that after 1 week of detraining, no negative effects were observed in upper- and lower-body strength and body composition. These results have direct implications in strength training and conditioning practice, considering that, for young, trained women, 1 week may be an adequate period for application of detraining without causing a decrease in the performance of the parameters analyzed.

With regard to the model of periodization applied, LP presented more positive effects on body composition and maximal strength in comparison with RLP, when intensity was between 4 and 14RM. There is a possibility for LP to be more effective as it allows for more quality training with the lead up to heavier weights at the end. Other comparisons with DUP, LP, and RLP using different intensities and populations are required.

References

1. Adams, GR. Exercise effects on muscle insulin signaling and action invited review: autocrine/paracrine IGF-I and skeletal muscle adaptation. *J Appl Physiol* 93: 1159–1167, 2002.
2. American College of Sports Medicine. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 34: 364–380, 2002.
3. Baker, D, Wilson, G, and Carlyon, R. Periodization: the effect on strength of manipulating volume and intensity. *J Strength Cond Res* 8: 235–242, 1994.
4. Brown, LE. Nonlinear versus linear periodization models. *Strength Cond J* 23(1): 42–44, 2001.
5. Brown, LE and Weir, JP. Procedures recommendation I: accurate assessment of muscular strength and power. *J Exerc Physiol* 4: 1–21, 2001.
6. Chilibeck, PD, Calder, AW, Sale, DG, and Webber, CE. Twenty weeks of weight training increases lean tissue mass but not bone mineral mass or density in healthy, active young women. *Can J Physiol Pharmacol* 74: 1180–1185, 1996.
7. Chilibeck, PD, Calder, AW, Sale, DG, and Webber, CE. A comparison of strength and muscle mass increases during resistance training in young women. *Eur J Appl Physiol* 77: 170–175, 1998.
8. Deschenes, MR and Kraemer, WJ. Performance and physiologic adaptations to resistance training. *Am J Phys Med Rehabil* 81: S3-S16, 2002.
9. Fleck, SJ. Periodized strength training: a critical review. *J Strength Cond Res* 13: 82–89, 1999.
10. Fleiss, JL. *The Design of Clinical Experiments.* New York: John Wiley & Sons, 1986.
11. Fry, AC. The role of resistance exercise intensity on muscle fibre adaptations. *Sports Med* 34: 663–679, 2004.
12. Gibala, MJ, MacDougall, JD, and Sale, DG. The effects of tapering on strength performance in trained athletes. *Int J Sports Med* 15: 492–497, 1994.
13. Graves, JE, Pollock, ML, Leggett, SH, Braith, RW, Carpenter, DM, and Bishop, LE. Effects of reduced training frequency on muscular strength. *Int J Sports Med* 9: 316–319, 1988.
14. Häkkinen, K, Alen, M, Kallinen, M, Newton, RU, and Kraemer, WJ. Neuromuscular adaptation during prolonged strength training, detraining and re-strength-training in middle-aged and elderly people. *Eur J Appl Physiol* 83: 51–62, 2000.
15. Herrick, AB, and Stone, WJ. The effects of periodization versus progressive resistance exercise on upper and lower body strength in women. *J Strength Cond Res* 10: 72–76, 1996.
16. Hunter, GR, Wetzstein, CJ, McLafferty, JR, Zuckerman, PA, Landers, KA, and Bamman, MM. High-resistance versus variable-resistance training in older adults. *Med Sci Sports Exerc* 33: 1759–1764, 2001.
17. Jackson, AS, Pollock, ML, and Ward, A. Generalized equations for predicting body density of women. *Med Sci Sports Exerc* 12: 175–182, 1980.
18. Karvonen, M, Kentala, K, and Musta, O. The effects of training heart rate: a longitudinal study. *Ann Med Exptl Biol Fenn* 35: 307–315, 1957.
19. Kraemer, WJ, Nindl, BC, Ratamess, NA, Gotshalk, LA, Volek, JS, Fleck, SJ, Newton, RU, and Häkkinen, K. Changes in muscle hypertrophy in women with periodized resistance training. *Med Sci Sports Exerc* 36: 697–708, 2004.
20. Kraemer, WJ, Ratamess, N, Fry, AC, Triplett-McBride, T, Koziris, LP, Bauer, JA, Lynch, JM, and Fleck, SJ. Influence of resistance training volume and periodization on physiological and performance adaptations in collegiate women tennis players. *Am J Sports Med* 28: 626–633, 2000.

21. Kraemer, WJ, Volek, JS, Clark, KL, Gordon, SE, Incledon, T, Puhl, SM, Triplett-McBride, NT, McBride, JM, Putukian, M, and Sebastianelli, WJ. Physiological adaptations to a weight-loss dietary regimen and exercise programs in women. *J Appl Physiol* 83: 270–279, 1997.

22. Marx, JO, Ratamess, NA, Nindl, BC, Gotshalk, LA, Volek, JS, Dohi, K, Bush, JA, Gomez, AL, Mazzetti, SA, Fleck, SJ, Häkkinen, K, Newton, RU, and Kraemer, WJ. Low-volume circuit versus high-volume periodized resistance training in women. *Med Sci Sports Exerc* 33: 635–643, 2001.

23. Matuszak, ME, Fry, AC, Weiss, LW, Ireland, TR, and McKnight, MM. Effect of rest interval length on repeated 1 repetition maximum back squats. *J Strength Cond Res* 17: 634–637, 2003.

24. Nindl, BC, Harman, EA, Marx, JO, Gotshalk, LA, Frykman, PN, Lammi, E, Palmer, C, and Kraemer, WJ. Regional body composition changes in women after 6 months of periodized physical training. *J Appl Physiol* 88:2251–2259, 2000.

25. Prestes, J, Frollini, AB, Borin, JP, Moura, NA, Júnior, NN, and Perez, SEA. Efeitos de um treinamento de 16 semanas sobre a composição corporal de homens e mulheres. *Rev Bras Ativ Fis Saúde* 11: 19–28, 2006.

26. Rhea, MR, Ball, SB, Phillips, WT, and Burkett, LN. A comparison of linear and daily undulating periodization with equated volume and intensity for strength. *J Strength Cond Res* 16: 250–255, 2002.

27. Rhea, MR, Phillips, WT, Burkett, LN, Stone, WJ, Ball, SB, Alvar, BA, and Thomas, AB. A comparison of linear and daily undulating periodized programs with equated volume and intensity for local muscular endurance. *J Strength Cond Res* 17: 82–87, 2003.

28. Ross, R, Janssen, I, Dawson, J, Kungl, AM, Kuk, JJ, Wong, SL, Nguyen-Duy, TB, Lee, S, Kilpatrick, K, and Hudson, R. Exercise-induced reduction in obesity and insulin resistance in women: a randomized controlled trial. *Obes Res* 12: 789–798, 2004.

29. Tanaka, H, Monahan, KD, and Seals, DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol* 1: 153–156, 2001.

30. Thorstensson, A. Observation on strength training and detraining. *Acta Physiol Scand* 100: 491–493, 1977.

31. Volpe, SL, Walberg-Rankin, J, Rodman, KW, and Sebolt, DR. The effect of endurance running on training adaptations in women participating in a weight lifting program. *J Strength Cond Res* 7: 101–107, 1993.