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Nonlinear Periodization Maximizes Strength Gains in Split Resistance Training Routines

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AU1 Gizele A. Monteiro,[1] Ivan da Cruz Piçarro,[1] and Carlos Ugrinowitsch[4]

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Abstract

Monteiro, AG, Aoki, MS, Evangelista, AL, Alveno, DA, Monteiro, GA, Piçarro, IDC, and Ugrinowitsch, C. Nonlinear periodization maximizes strength gains in split resistance training routines. *J Strength Cond Res* 23(4): 000–000, 2009—The purpose of our study was to compare strength gains after 12 weeks of nonperiodized (NP), linear periodized (LP), and nonlinear periodized (NLP) resistance training models using split training routines. Twenty-seven strength-trained men were recruited and randomly assigned to one of 3 balanced groups: NP, LP, and NLP. Strength gains in the leg press and in the bench press exercises were assessed. There were no differences between the training groups in the exercise pre-tests ($p > 0.05$) (i.e., bench press and leg press). The NLP group was the only group to significantly increase maximum strength in the bench press throughout the 12-week training period. In this group, upper-body strength increased significantly from pre-training to 4 weeks ($p < 0.0001$), from 4 to 8 weeks ($p = 0.004$), and from 8 weeks to the post-training ($p < 0.02$). The NLP group also exhibited an increase in leg press 1 repetition maximum at each time point (pre-training to 4 weeks, 4–8 week, and 8 weeks to post-training, $p < 0.0001$). The LP group demonstrated strength increases only after the eight training week ($p = 0.02$). There were no further strength increases from the 8-week to the post-training test. The NP group showed no strength increments after the 12-week training period. No differences were observed in the anthropometric profiles among the training models. In summary, our data suggest that NLP was more effective in increasing both upper- and lower-body strength for trained subjects using split routines. AU3

Key Words leg press, bench press, resistance exercise

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Introduction

Resistance training has been used extensively to increase fitness and sport performance. It has been demonstrated to augment maximum strength, power, jumping ability, tennis service velocity, and running economy (2,5,12,14,17).

The optimization of physiological strain is of paramount importance if strength gains are to be maximized throughout the training period. A periodic alteration in training load (i.e., periodized training) has been reported as an effective way to optimize physiological strain and thereby produce greater increments in muscle strength than a constant load training paradigm (i.e., nonperiodized [NP] training) (5,10). Nonetheless, similar performance improvements have also been reported when comparing short-term periodized and NP resistance training regimens (1).

In addition to the equivocal results regarding the effectiveness of periodized and NP training models, there is also considerable debate with respect to the most appropriate periodization model. The extant literature describes 2 periodization models: a linear model in which training loads progress from high volume and low intensity, to low volume and high intensity, over the course of several weeks (1); and a nonlinear model in which high-volume and low-intensity sessions are alternated with low-volume and high-intensity sessions within a training week. Rhea et al. (9) reported greater strength-endurance improvements after a reverse LP than with NLP. Nevertheless, Rhea et al. (8) also reported greater maximum strength improvement after a nonlinear training program compared with a linear one. To further complicate the issue, Buford et al. (1) reported no differences between linear periodization (LP) and nonlinear periodization (NLP) models. Thus, there appears to be a lack of agreement on the most appropriate periodization model to improve muscle strength. However, coaches and trainers tend to use NLP models because they may avoid accommodation to the training load and optimize the physiological strain.

In addition, the American College of Sports Medicine (ACSM) recommends split routines (6) to maximize strength gains among intermediate-advanced resistance-trained individuals and athletes. With split routine training paradigm, individuals train different body parts on each training session within a week to allow proper muscle recovery and to maximize training loads (e.g., lower body on Monday and Wednesday; upper body on Tuesday and Thursday). The ACSM expands this recommendation suggesting that split training routines should also require the periodization of the training load (6).

However, to the best of our knowledge, there is no scientific evidence to recommend a specific training load regimen (i.e., NP, LP, or NLP) when using split training routines. Based on ACSM guidelines and a recent meta-analysis (10), we hypothesized that periodized training models (i.e., linear and nonlinear) will produce greater strength improvements than the NP training regimen. Furthermore, we hypothesized that the NLP will produce greater strength improvements than the LP based upon coaches and trainers experience. Therefore, the aim of this study was to compare strength improvements after 3 months of split routines following an NP, an LP, or an NLP training load regimen.

Methods

Experimental Approach to the Problem

The purpose of our study was to determine the most appropriate loading regimen–NP, LP, and NLP–when using split training routines. Training volume was equated between groups and divided into 3 mesocycles (3 months). Each mesocycle consisted of 3 loading microcycles and 1 recovery microcycle. Assessments included anthropometric profiles and strength gains in the leg press and in the bench press exercises.

Subjects

Twenty-seven healthy males were recruited from college weight training classes. All individuals trained at least 4 days a week in the past 2 years and performed bench presses and squats in their regular training routines. Nutritional supplementation was disallowed for a period beginning 1 month before the onset of the training intervention and for the duration of the study. Subjects were distributed in a balanced and randomized fashion into the NP (26.6 ± 2.2 years, 177.1 ± 2.0 cm, and 81.6 ±3.9 kg), the LP (27.6 ± 2.7 years, 177.4 ± 3.18 cm, and 81.1 ± 2.8 kg), and the NLP (28.1 ± 2.9 years, 180.3 ± 4.8 cm, and 82.2 ± 7.9 kg) groups. Subjects were informed of the experimental risks and signed an informed consent form before the investigation. The investigation was approved by an institutional review board for use of human subjects.

Testing Proceedings

Subjects were tested pre-training, 4 weeks, 8 weeks, and post-training (12 weeks) on the 1 repetition maximum (1RM) test
AU4 for bench press and leg press. The bench press test was performed in a standard free-weight bench press station (Cybex), and the leg press was performed in a 45° leg press (Cybex). For 1RM testing, all subjects were required to warm up and perform light stretching before performing approximately 10RM with a light resistance for each exercise. They then performed between 4RM and 6RM to complete the warm-up process. After a 3-minute rest, subjects had up to 5 trials to achieve the 1RM load (e.g., maximum weight that could be lifted once with proper technique), with a 3-minute interval between trials. The same researcher conducted all 1RM tests. Pre- and post-training anthropometric measures of weight, lean mass, fat mass, and % fat mass were taken. Height was measured to nearest to 0.1 cm using a height rod AU5
(Sanny, Brazil). Body weight with minimal clothing was AU6
measured to the nearest 0.1 kg on a lever-type balance (Filizola, Brazil) in a fasted state after emptying the bladder. Skinfold thickness measurements were taken at biceps, AU7
triceps, subscapular, and suprailiac sites with skinfold calipers (Lange; Beta Technology Inc.). Skinfolds were incorporated into the age- and sex-matched equations (3) to derive body density. Body fat percentage was calculated using standard AU8
procedures, from which the LBM was derived.

Training Protocol

Table 1 describes the training program for all experimental T1
groups. Training volume was equalized to avoid any overload effect between groups. Training period was divided into 3 mesocycles with 4 microcycles each. This structure allowed us to increase the training load in the first 3 weeks of the mesocycles (i.e., loading microcycles) and to reduce it in the last week of each mesocycle (i.e., recovery microcycle).

Training sessions in the 3 loading microcycles were divided into sessions A and B. The A session was composed of the following exercises: bench press, inclined bench press, declined bench press, lateral rises, military press, triceps pull-down, and barbell French press. The B session was composed of the following exercises: leg press, hamstring curl, squat, row, lat pull-down, chin up in the Gravitron, biceps curl, and preacher curl. On the recovery microcycles, subjects performed a single exercise for all body parts every other day (bench press, military press, triceps pull-down, leg press, lat pull-down, and biceps curl).

Statistical Analyses

Data normality was assessed through Shapiro-Wilk test, and standard visual inspection and all variables presented normal distribution. A mixed model having group (NP, LP, and NLP) and time (pre and post) as fixed factors and subjects as a random factor was used for each anthropometric variable. In addition, mixed models were used to estimate differences in strength gains between training groups for both the leg press and the bench press (15). However, the time factor had 4 levels (pre-training, 4 weeks, 8 weeks, and post-training). In case of significant F values, a post hoc test, with an adjustment by Tukey, was used for multi-comparison purposes. Significance was set at $p \leq 0.05$, and data were presented as mean ± SD.

Results

It is important to note that there were no differences between the training groups in the pre-test ($p > 0.05$) for both

TABLE 1. Training protocols for the nonperiodized, linear periodization, and nonlinear periodization groups.*

	Monday Session A	Tuesday Session B	Wednesday	Thursday Session A	Friday Session B
Nonperiodized					
Microcycle 1	3 × 8–10RM		Off	3 × 8–10RM	
Microcycle 2	3 × 8–10RM		Off	3 × 8–10RM	
Microcycle 3	3 × 8–10RM		Off	3 × 8–10RM	
Microcycle 4	3 × 8–10RM	Off	3 × 8–10RM	Off	3 × 8–10RM
Linear periodization					
Mesocycle 1	3 × 12–15RM		Off	3 × 12–15RM	
Mesocycle 2	3 × 8–10RM		Off	3 × 8–10RM	
Mesocycle 3	3 × 4–5RM		Off	3 × 4–5RM	
Microcycle 4	3 × 12–8–4RM	Off	3 × 12–8–4RM	Off	3 × 12–8–4RM
Nonlinear periodization					
Microcycle 1	3 × 12–15RM		Off	3 × 8–10RM	
Microcycle 2	4 × 4–5RM		Off	3 × 12–15RM	
Microcycle 3	3 × 8–10RM		Off	4 × 4–5RM	
Microcycle 4	3 × 12–8–4RM	Off	3 × 12–8–4RM	Off	3 × 12–8–4RM

*1RM = 1 repetition maximum.

exercises (i.e., bench press and leg press). This suggests that training status was equivalent across groups before the onset of the experimental training protocol (Figures 1 and 2).

Only the NLP group increased maximum strength in the bench press after the 12-week training period. Upper-body strength increased significantly from pre-training to 4 weeks ($p < 0.0001$), from 4 to 8 weeks ($p = 0.004$), and from 8 weeks to post-training ($p < 0.02$) (Figure 1).

The between-group comparison indicated a trend toward greater maximum bench press values for the NLP group at week 4, compared with NP and LP groups ($p = 0.09$ and $p = 0.08$, respectively). On the other hand, NLP group presented greater bench press 1RM than the NP and LP groups at 8 weeks and at post-training ($p < 0.006$). There were no differences between the LP and the NP at any time point (Figure 1).

The NLP group increased leg press 1RM at each time point (pre-training to 4 weeks, 4–8 weeks, and 8 weeks to post-training, $p < 0.0001$). The LP group presented strength increments only after the eighth training week ($p = 0.02$), but there were no further strength increases from the 8-week to

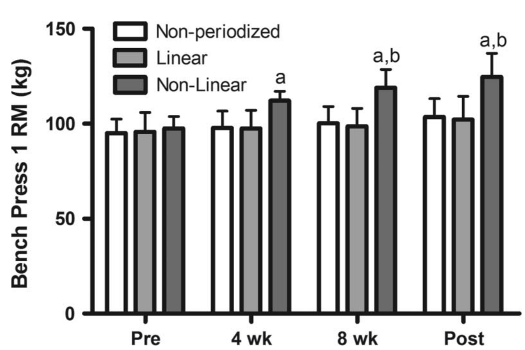

Figure 1. Bench press 1RM values (kg) for the nonperiodized, the linear periodization, and the nonlinear periodization groups at pre-training, 4-week, 8-week, and post-training (12 weeks) tests (mean and *SD*). a–Bench press value greater than at the previous time point ($p < 0.02$). b–Nonlinear bench press value greater than linear and nonperiodized groups at the same time point ($p < 0.001$).

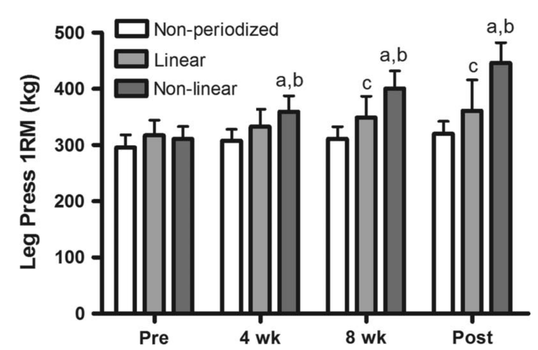

Figure 2. Leg press 1RM values (kg) for the nonperiodized, the linear periodization, the nonlinear periodization groups at pre-training, 4-week, 8-week, and post-training (12 weeks) tests (mean and *SD*). a–Leg press value greater than at the previous time point ($p < 0.0001$). b–Nonlinear leg press value greater than linear and nonperiodized groups at the same time point ($p < 0.046$). c–Leg press value greater than pre-test value ($p < 0.02$).

the post-training test. The NP group showed no strength increment after the 12-week training period (Figure 2).

The comparison of leg press strength between groups, at each time point (4 weeks, 8 weeks, and post-training), revealed that the NLP group had greater strength ($p < 0.046$) than the other 2 groups. In addition, there was no difference between LP and NP groups at 4-week, 8-week, and post-training tests ($p > 0.24$) (Figure 2).

F3 Figure 3 displays subjects' leg press and bench press strength at the 4 testing instants for the NLP, LP, and NP groups. The NLP presented greater strength increase than the other groups looking at individual data.

No difference was observed for anthropometric parameters among all groups pre-training (Table 2). In addition, no change was also detected over time (pre- vs. post-training). T2

Discussion

The purpose of this study was to compare strength improvements after a training period using split routines following NP, LP, and NLP models. Our main findings were that the NLP model was more effective in increasing maximum strength than both the LP and NP models. Furthermore, the LP model did not outperform the NP model, as we hypothesized.

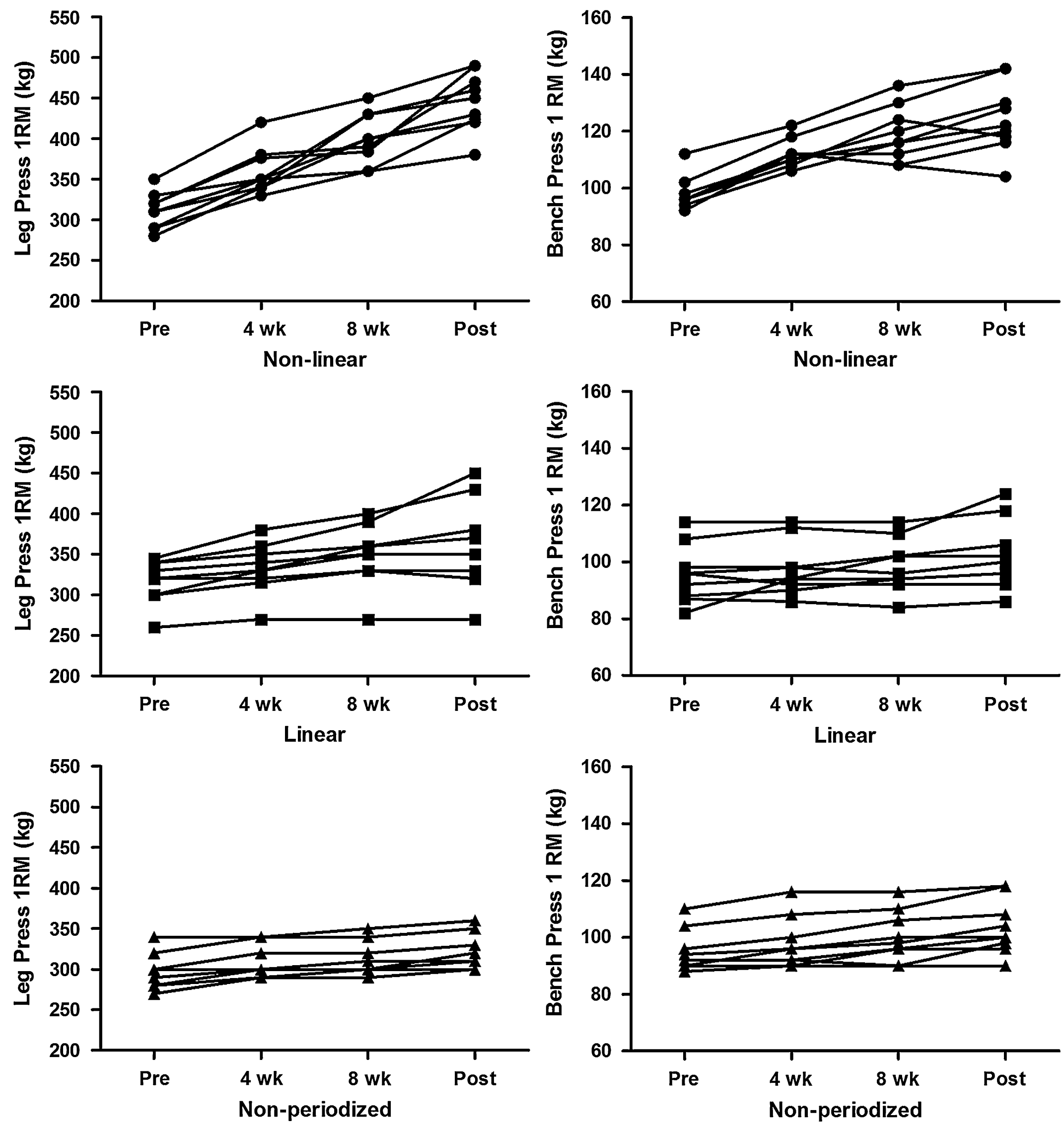

Figure 3. Individual response of the nonlinear, linear, and nonperiodized groups at pre-training, 4 weeks, 8 weeks, and post-training for both leg press and bench press exercises.

Table 2. Anthropometric profile of the nonperiodized, linear periodization, and nonlinear periodization training groups, pre- and post-training.*†

	Pre-training	Post-training
Nonperiodized		
Body weight (kg)	81.6 ± 3.9	81.9 ± 4.3
% Body fat	15.2 ± 2.3	18.5 ± 3.0
Lean mass (kg)	68.9 ± 4.4	66.8 ± 3.9
Fat mass (kg)	12.7 ± 1.9	15.1 ± 2.6
Linear periodization		
Body weight (kg)	81.1 ± 2.8	81.1 ± 3.3
% Body fat	13.9 ± 1.8	12.9 ± 1.3
Lean mass (kg)	69.5 ± 2.4	70.3 ± 2.8
Fat mass (kg)	11.6 ± 1.6	10.8 ± 1.3
Nonlinear periodization		
Body weight (kg)	82.2 ± 7.9	81.8 ± 7.2
% Body fat	14.3 ± 2.1	13.3 ± 2.2
Lean mass (kg)	70.3 ± 5.3	70.5 ± 5.4
Fat mass (kg)	11.8 ± 3.0	11.4 ± 2.8

*1RM = 1 repetition maximum.
†Data are presented as mean ± *SD*.

The NLP produced strength gain (i.e., pre- to post-training) effect sizes of 4.6 and 2.9 for the leg press and bench press, respectively. On the other hand, the LP and NP groups had effects sizes of 1.1 for the leg press (both groups) and of 0.6 and 1.0 for the bench press, respectively. The difference in strength gains between groups was very large, indicating a greater efficiency of the NLP model in producing training adaptations. Our findings are in accordance with the existing literature, which suggests that the NLP model is more effective in increasing strength. For instance, Rhea et al. (8) reported strength gains for the LP of 14.4 and 25.7% and for the daily NLP of 28.8 and 55.8%, for bench press and leg press, respectively. A few authors (11,13) have described that training load variability is critical to enhance adaptations. When the load is kept constant, the body becomes desensitized, thereby decreasing the magnitude of the training adaptations (8). Based on this assumption, it would seem logical to assume that as variability is added to training stimuli, greater adaptations should occur. In this way, it might be expected that the LP model would enhance strength more than the NP model. However, there was no difference between the LP and NP models for both exercises at the post-training test. On the other hand, the NLP group increased strength more than the NP group. Thus, we partially support our first hypothesis that periodized training would outperform NP training regimens. Our data further suggest that a higher of variability is required for trained individuals because the strength increments were more pronounced in the NLP group than in the LP group, supporting our second hypothesis. Thus, our findings add evidence toward a higher efficiency of NLP models, even when using split training routines.

Another interesting comparison is the magnitude of strength gains produced by NLP models using whole body routines and split routines. Our NLP training protocol increased bench press and leg press strength by 28 and 43%, respectively. Buford et al. (1) reported smaller increments for the bench press (17.5%) but higher values for the leg press (79%) using whole body routines. However, these authors used untrained subjects, whereas we used trained individuals. In fact, the training status seems to be important because Rhea et al. (8) reported similar strength gains (28.8 and 55.8% for the bench press and for the leg press, respectively) in individuals with at least 2 years of resistance training experience and whole body training routines. Although there is variability in the strength gains, it appears that split training routines were not more effective than whole body training routines used by others (1,8), irrespectively of the training status. Strength coaches and athletes believe that split routines allow individuals to train at a maximal effort level for a given intensity, producing higher muscle strain on a specific session. These routines would facilitate recovery due to the alternation in the muscle group trained. This does not appear to be the case because AU9 the studies that used whole body exercises (1,8) achieved similar strength increments than the present study, using trained subjects. Additional evidence is needed to support that statement.

Strength coaches also recognize the importance of recovery microcycles at the end of each mesocycle to accelerate the recovery process and as a result increase training adaptations. As mentioned before, our strength gains were similar to that reported by Rhea et al. (8), even though they did not use recovery microcycles throughout the 12-week training period. Thus, the effectiveness of recovery microcycles should also be investigated because long training periods (i.e., greater than 12 weeks) may lead to training load accumulation when using both whole body and split training regimens.

The lack of change in the anthropometric profiles suggests that neural factors may have been more important to the observed increases in strength than morphological adaptations, specifically for the NLP group. Even though Moritani and DeVries (7) described that neural adaptations would occur during the first weeks of training, it has been suggested that strength increments due to neural adaptations should also occur in highly trained athletes (4). Once more, training load variability may influence these adaptations because of motor unit recruitment. Low-repetition high load sets (i.e., 5RM) recruit most of the motor neuron pool on each repetition, whereas high-repetition medium load sets (i.e., 12–15RM) do not recruit all the available motor units on each repetition due to the size principle. However, West- AU10 gaard and De Luca (16) suggested in a fatiguing contraction, fast - low resistance to fatigue motor units rotate to maintain force production. It seems reasonable to suggest that the typical training loads described above may recruit all available motor units through distinct patterns. The periodical change in the motor unit recruitment pattern imposed by the NLP group may have induced greater neural adaptations and thus strength increments.

As a conclusion, NLP should be used with split training routines to increase both upper- and lower-body strength for advanced trained subjects.

Practical Applications

Intermediate-advanced resistance-trained individuals and athletes usually use split routines in their training programs. Thus far, there was no recommendation on the most appropriate periodization model when using these routines. Our data clearly demonstrated that NLP is more effective than the LP and NP models to increase strength combined with split training routines. Thus, individuals seeking for fitness improvement should use NLP when using split routines.

Coaches and trainers should be aware that split routines tend to decrease the specificity of the strength exercises due to the isolation of specific muscle groups, which may reduce the degree of transference of the strength gains to sport skills. On the other hand, split routines could be well combined with technical and tactical drills to decrease the stress imposed to a specific joint. For instance, it may be prejudicial to the knee joint of an athlete to perform heavy leg strength training previously to a session that requires a high number of vertical jumps (e.g., volleyball spiking drills and basketball rebounding drills).

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