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Effects of Daily and Flexible Non-Linear Periodization on Maximal and Submaximal Strength, Vertical Jump and Speed Performance of Brazilian Army Skydivers

Fabien Pereira da Silva[1,2], José Vilaça-Alves[2,3], Leonardo Lopes de Souza[1,2], Juliano Spineti dos Santos[1,2,4], Tiago Figueiredo[1,2,5], Gabriel Andrade Paz[1,6*], Jeffrey M Willardson[7] and Humberto Miranda[1]

[1]*School of Physical Education and Sports, Rio de Janeiro Federal University, Brazil*

[2]*Sport Sciences Department, University of Trás-os-Montes e Alto Douro, Portugal*

[3]*Research Center in Sport Sciences, Health and Human Development (CIDESD), Portugal*

[4]*Department of Exercise Physiology, Fluminense Football Club, Brazil*

[5]*Physical Education Graduation Program, Estácio de Sá University, Brazil*

[6]*Biodynamic laboratory of Exercise, Health, and Performance, Castelo Branco University, Brazil*

[7]*Health and Human Performance Department, Rocky Mountain College, Billings, Montana, USA*

***Corresponding author:** *Gabriel Andrade Paz, School of Physical Education and Sports, Rio de Janeiro Federal University, Avenida Pau Brasil, 540-Ilha do Fundão-Cep: 21941-590 Rio de janeiro-RJ-Brazil, Tel: 55-21-25626808, Fax: 55-21-25626808, E-mail: gabriel.andrade.paz@gmail.com*

Abstract

Background: The purpose of this study was to analyze the effects of daily non-linear periodization (DNLP) and flexible (FNLP) models on maximal and submaximal strength, vertical jump and speed performance gains after 12 weeks of Brazilian army skydivers.

Methods: Twenty-one recreationally trained men were randomly divided into three groups: DNLP (n = 7; age 32.71 ± 8.53; height: 1.74 ± 0; weight: 81.57 ± 11.97), FNLP (n = 6; age 26.50 ± 7.18; height: 1.71 ± 0.05 and weight: 75.50 ± 12.73) and a control (CG. N = 8; age = 18.87 ± 0.59; height = 1.73 ± 0.046; weight = 71.67 ± 5.34). Before and after the 12 week of training each participant was evaluated for maximal (1-RM) and submaximal strength (8-RM) of bench press (BP) and leg press (LP) exercises, squat jump (SJ) and countermovement jump (CMJ) performance and speed test over 5 m, 60 m and 100 m.

Results: The DNLP and FNLP groups showed similar increases for 1-RM and 8-RM loads in BP and LP exercises, respectively ($p \leq 0.05$). Similar SJ and CMJ performance noted in posttest between FNLP and DNLP groups ($p \leq 0.05$). Both CG and FNLP groups showed an augmentation in time-performance of 60 m and 100 m speed test, respectively ($p \leq 0.05$). However, for 5 m speed test, similar decreasing in time-performance during posttest was noted under DNLP ($p = 0.001$) and FNLP ($p = 0.002$) groups.

Conclusion: The DNLP and FNLP models were equally effective in improving 5 m speed performance, maximal and submaximal strength after 12 weeks training period with recreationally trained Brazilian army skydivers.

Keywords

Resistance training, Power output, Muscle performance, Conditioning, Exercise

Introduction

Strength training is an important component of well-rounded exercise program and contributes to physical capacity and sports performance [1]. From the 1950´s onward, coaches increased the use of periodization in sports training, on the other hand, only after the 1960´s, first studies about periodization and training effectiveness was published [2]. In this way, researchers started to compare periodized versus the non-periodized strength training programs [3-5], and observed that subjects who performed periodized programs obtained greater strength gains when compared to subjects who performed the same exercise sequence adopting non-periodized exercise programs [2,6-8].

The periodization models was implemented with the goal to improve the maximum and submaximum strength and motor performance [5], and can be adapted to the athlete sport calendar to achieve specific program objectives [2]. The overall periodized plan is typically divided into seasonal phases or training cycles with two different formats, known as the linear periodization model and non-linear periodization [9,10]. The linear model initially involves performing strength training with high volume and low intensity, and then a progressive inversion of volume and intensity throughout the training program [8]. Conversely, non-linear periodization model involves daily and/or weekly changes in volume and intensity of training [9,11]. A few studies in the scientific literature indicated that the non-linear model seems to afford better results in strength gains than linear models [12,13]; however, other studies showed that there were no differences between these two periodization models [4,14].

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Regardless these controversial results, the non-linear models categorized as daily non-linear periodization (DNLP), weekly non-linear periodization (WNLP), and flexible non-linear periodization (FNLP) [4]. Programming for FNLP may vary daily or weekly, depending on the physical and psychological state of the individual [15]. The FNLP program has been associated to a potential to provide significant restorative properties, enhancing an athlete's physiological and psychological recovery processes [4,15].

Harries, et al. [4], in a recent systematic review and meta-analysis including 17 studies, reported that there was no significant differences between linear and non-linear periodization models on strength, and power gains novice and recreationally subjects. Thus, only one study investigated the effect of FNLP and DNLP. McNamara & Stearne [15] compared the effects of a FNLP versus a NLP model on strength and power gains in untrained men over 12 weeks, performing exercises for the trunk, lower, and upper body muscles. Both groups (FNLP and NLP) were given similar total training intensity and volume. The only difference between groups was that in FNLP group, the subjects were able to choose between training zones before starting the workout session. The authors found that using FNLP, the subjects achieved a significant improvement in strength for leg press exercise when compared to NLP model; however, no difference was noted for bench press and countermovement jump. The authors also mentioned that this gain might be associated to the fact that individuals could have gotten a better performance due to psychological factors, and the FNLP approach provides a better-individualized approach in matching the recovery capacity of the individual from session to session. However, there is still a lack of evidences about the chronic effects of different non-linear periodization models on physical performance parameters.

To the authors' knowledge, no previous study has compared the effects of two models of non-linear periodization models with trained men on measures of maximal and submaximal strength, and motor skill attributes. These data may help Coaches and strength training professionals during the exercise prescription in order to optimize the training outcomes. Therefore, the purpose of this study was to analyze the effects of DNLP and FNLP models on maximal and submaximal strength, vertical jump, and speed performance of Brazilian army skydivers. Our hypothesis was that FNLP model will be more effective to develop muscle strength and physical performance parameters attributed to a better training load adjustment before each strength training session.

Material and Methods

Subjects

Twenty-one men without strength training experience from 18 to 50 years volunteered to participate and signed a consent form. The participants included in this research did not consume dietary supplements in the form of carbohydrates, proteins or amino acids, nor were any of them taking anabolic steroids either before or while participating in this research. All the participants were active in approximately 2-4 hours of army activities or sports training 1–5times per week. All subjects answered the Physical Activity Readiness Questionnaire (PAR-Q) and signed an informed consent form before participation in the study according to the Declaration of Helsinki. The study procedures were approved through the Ethics Committee of the Rio de Janeiro State University. Subjects that had any potential functional limitation or medical condition that could be aggravated by the tests were excluded (Table 1).

All test participants were given informed on how to remain properly hydrated to avoid the influence of dehydration on strength performance. Body mass, height, and age are reported in table 2. The anthropometric data included body mass (Techline BAL-150 digital scale) and height (stadiometer Seca 208 Bodymeter).

Strength testing

Prior to pre-testing, subjects were submitted to a 2-week familiarization period in which they performed the same exercises as used in the training program, with the aim of standardizing the technique of each exercise. The sessions were performed according to

Table 1: Training program cycle*.

Exercises							
Muscle Resistance		**Hypertrophy**		**Maximum Strength**		**Power**	
A	B	A	B	A	B	A	B
Bench press straight	Pulled closed	Bench press straight	Pulled closed	Bench press straight	Pulled closed	Push press	Alternative jump
Incline bench press	Graviton	Incline bench press	Graviton	Incline bench press	Graviton	Dead Lift High Pull	Squat jump loaded
Decline bench press	Pulled	Decline bench press	Pulled	Decline bench press	Pulled	Hang high pull	Drop jump (Box ~50 cm)
Fly	Open rowing machine	Triceps forehead	Barbell arm	Hip adduction machine	Squats on the smith	Jerk	Deph jump (Box ~50 cm)
Shoulder adduction workout	Barbell arm	Barbell triceps French press	Barbell altering arm	Hip abduction machine	Deadlifts		
Shoulder adduction	Barbell altering arm	Hip adduction machine	Deadlifts	Plantar flexion machine	Leg press 45º		
Triceps forehead	Squats on the smith	Hip abduction machine	Leg press 45º				
Barbell triceps French press	Deadlifts	Plantar flexion machine	Stiff				
Hip adduction machine	Leg press 45º						
Hip abduction machine	Stiff						
Plantar flexion machine	Leg curl machine						
Plantar flexion standing	Leg extension machine						

*Classification of exercises per training session and valence strength. A = muscle group A (chest, shoulder, triceps, adductor and abductor leg muscles, and calf muscles); B = muscle group B (back, biceps, and leg muscles).

Table 2: Baseline anthropometric characteristics (means ± SD)*.

Groups	Age (y)	Height (m)	Weight (Kg)
CG (n = 8)	18.87 ± 0.59 (18-20)	1.73 ± 0.046 (1.67-1.82)	71.67 ± 5.34 (64.60-80.30)
DNLP (n = 7)	32.71 ± 8.53* (23-46)	1.74 ± 0.067 (1.63-1.84)	81.57 ± 11.97 (65.58-102.00)
FNLP (n = 6)	26.50 ± 7.18 (20-41)	1.71 ± 0.053 (1.66-1.80)	75.50 ± 12.73 (61.60-100.00)

CG: Control Group, DNLP: Daily Non-Linear Periodization Group, FNLP: Flexible Non-Linear Group.

*p = 0.03 between CG and DNLP.

Table 3: Periodization mode description.

Groups	Training duration	Stage	Dynamic load (RM)		Rest interval (min)
DNLP	1 to 12 weeks	1º TS	Endurance	2 × 12 - 15 (60% 1RM)	1
		2º TS	Hypertrophy	3 × 8 - 10 (80% 1RM)	2
		3º TS	Maximal strength	4 × 3 - 5 (90% 1RM)	3
		4º TS	Muscle power	6 × 5 (40% 1RM)	3
FNLP	1 to 12 weeks**		Endurance	2 × 12 - 15 (60% 1RM)	1
			Hypertrophy	3 × 8 - 10 (80% 1RM)	2
			Maximal strength	4 × 3 - 5 (90% 1RM)	3
			Muscle power	6 × 5 (40% 1RM)	3

*DNLP: Daily Non-Linear Periodization, FNLP: Flexible Non-Linear Periodization, TS: Training Session, RM: Repetition Maximum.

**The selection of the subject of training.

the training program, using a lightweight [16]. The 1-RM and 8-RM tests were performed on two nonconsecutive days for BP and LP. The two test sessions were separated by a 72 hours. The heaviest load achieved on the test days was considered the RM resistance of a given exercise [16]. Moreover, no other exercise was allowed in the period between the 1-RM and 8-RM test sessions.

To minimize error during the 1-RM and 8-RM tests, the following strategies were adopted [12]: (a) standardized instructions concerning the testing procedure were given to the subjects before the test; (b) subjects received standardized instructions on specific exercise technique; (c) verbal encouragement was provided during the testing procedure; (d) the mass of all weights and bars used was determined using a precision scale. If a 1-RM and 8-RM loads was not accomplished on the first attempt, the weight was adjusted by 4-10 kg and a minimum 5-minute rest was given before the next attempt. Ten-minute recovery period was adopted before the beginning of the next exercise test. Two days after the end of the training period, 1-RM and 8-RM tests were performed similarly to the pre-training tests to determine the strength data [11,16].

Countermovement jump and squat jump testing

A CMJ and SJ were tested on two separate days after 72 hours of rest. This testing protocol was used to determine jumping ability. All measurements were conducted according to standardized protocols [17]. The jump tests were performed in the same order: first, a CMJ followed by a SJ. Before the test, subjects performed a warm-up with dynamic stretching exercises (e.g., hip flexion, plantar flexion, knee flexion, shoulder flexion and extension) for about five minutes (e.g., one set of 30 second for each limb). Thereafter, subjects performed three attempts of each jump type. Three minutes of rest between each attempt were allowed for the same test, and 10 minutes between CMJ and SJ tests.

During the CMJ, subjects began in an erect standing position, moved into a half-squat position and then immediately jumped to allow the use of a stretch shortening cycle during the jump. The arms remained fixed during the jump. In the SJ, subjects performed a maximal vertical jump with hands on the waist, starting from an angle of 90º at the knee. In the CMJ, the subjects performed a maximal vertical jump starting from a standing position, with fixed arms. All jumps were performed on the Optojump (Optojump, Microgate,Italia) that recorded the flight time of all jumps [18]. The flight time was used to calculate the change in the height of the body's center of gravity [19]. Subjects performed three trials in each protocol, with additional trials being performed when a jump height exceeded 5% of the previous jump height. Three minutes of rest were provided between each attempt, and the highest result of each was used in the data analysis.

Speed tests

Sprint evaluation was performed through a speed test that was carried out in a straight line of 100 m. Times were measured using a two pairs of photocells system (Race Time 2, Microgate, Bolzano, Italy) positioned into two points: at the starting position and at the end of each distance. The distances used in this study were of 5 m, 60 m and 100 m. The shortest time achieved from the three attempts was used in the data analysis. All measurements were performed according to standard protocols [17].

Sprint tests were performed in the following order: 5 m, 60 m and 100 m, consecutively. Prior to the test, warm up exercises were carried out with joint exercises and light jogging for about 5 minutes. Afterwards, subjects performed three attempts for each distance tested; a "standing start" technique was adopted and each subject positioned their support foot. With the trunk slightly flexed, the time began after the subject pass through the optical beam positioned one meter in height and at a distance of 30 cm from the output starting position, and the subject who decided when begin the sprint. Five minutes of rest was allowed between each trial, and 10 minutes between each tested distance [20].

Training procedures

Subjects were randomly assigned to DNLP, FNLP, and CG groups after pre-training data was collected. A total of 48 training sessions was performed, divided into six training cycles of eight sessions each, performed four times per week, from Mondays to Fridays, with different load intensities (Table 1 and Table 3) [21]. Mono and multi-joint exercises were performed in the training program (Physical Optimus, Brazil). The exercises loads were increased in 10% every four weeks or when a subject was able to perform more than the prescribed number of repetitions for all sets of a given exercise. The duration of training sessions was 45 to 90 minutes. A 3-minute rest interval was instituted between each set and 5 minutes between exercises [1]. The control group did not take part in the strength training program and continued with their normal activities of Brazilian Army, consisted and long running and callisthenic exercises (pull ups on the bar, push ups, sit ups, squats and lunges exercises), in approximately 1-hour per day, and five days per week during the training period. The DNLP and FNLP only performed the strength training program during the research procedures. All training programs were supervised by a certified fitness professional, which monitored the training and recorded all data, including the length of each training session, the loads for each exercise, the rest intervals and the number of sets and repetitions of each subject throughout the study.

Statistical analyses

An exploratory analysis of all data was performed to characterize the values of the different variables in terms of central tendency and dispersion, and to detect possible outliers. In order to perform the inferential statistical analysis, it was necessary to evaluate the normal distribution of the collected data. Thus, an analysis of the type of distribution was performed using the Shapiro-Wilk test; homogeneity was verified through Levene test; and to verify sphericity, Mauchly test was performed. Significant differences between groups in the pre-training were verified by using a factorial ANOVA test. A baseline covariate was used when needed to generate a homogeneous baseline (BP and LP 1RM and 8RM tests and V5 m test) or to adjust age differences between groups in all variables analyzed. After setting these parameters and checking the assumptions using parametric tests, an ANOVA was used with repeated measures with the model (2 times X 3 groups) for all variables, with Bonferroni post-hocs. The effect size was also computed following for recreationally trained individuals in strength training (Trivial: < 0.35; Small: 0.35 – 0.80; Moderate: 0.80 – 1.50; Large: > 1.5) proposed by Rhea [22]. The significance level was

Table 4: One repetition maximum loads of Bench Press (BP) and Leg Press (LP) between groups.

	BP		Effect size	LP		Effect size
	Pre	Post		Pre	Post	
CG	78.5 ± 13.21	77.5 ± 15.15Ŧ	- 0.07 (Trivial)	183.75 ± 9.16	189.5 ± 26.44Ŧ	0.63 (Trivial)
DNLP	95.14 ± 21.48	122.86 ± 19.59*Ŧ	1.29 (Moderate)	244.0 ± 62.92*	318.57 ± 45.25*Ŧ	1.18 (Moderate)
FNLP	113.33 ± 16.03*	129.0 ± 8.17*Ŧ	0.98 (Moderate)	256.67 ± 32.99*	318.33 ± 43.09*Ŧ	1.88 (Large)

*Significant difference to Control Group (p ≤ 0.05); Ŧ Significant difference to pre and post (p ≤ 0.05); CG: Control Group, DNLP: Daily Non Linear Periodization Group, FNLP: Flexible Non-Linear Group.

Table 5: Eight repetition maximum loads of Bench Press (BP) and Leg Press (LP) between groups.

	BP		Effect size	LP		Effect size
	Pre	Post		Pre	Post	
CG	64.75 ± 10.69	69.25 ± 13.60Ŧ	0.42 (Small)	132.50 ± 11.65	151.50 ± 14.21Ŧ	1.37 (Moderate)
DNLP	82.86 ± 28.49*	106.00 ± 24.06*Ŧ	0.82 (Moderate)	203.57 ± 47.67	268.57 ± 46.43*Ŧ	1.64 (Large)
FNLP	95.67 ± 10.07*	116.67 ± 5.16*Ŧ	2.08 (Large)	211.66 ± 14.72*	265.00 ± 12.65*Ŧ	3.63 (Large)

*Significant difference to Control Group (p ≤ 0.05); Ŧ Significant difference to pre and post (p ≤ 0.05); CG: Control Group, DNLP: Daily Non Linear Periodization Group, FNLP: Flexible Non-Linear Group.

Table 6: Vertical squat and countermovement jump tests.

	CMJ (cm) SJ (cm)					
	Pre	Post	Effect size	Pre	Post	Effect size
CG	32.16 ± 5.09	23.81 ± 5.79 Ŧ	1.64 (Large)	31.15 ± 4.99	24.2 ± 5.42Ŧ	1.45 (Large)
DNLP	31.47 ± 4.68	31.19 ± 3.30*	0.05 (Trivial)	29.11 ± 4.21	29.15 ± 5.15*	0.01 (Trivial)
FNLP	36.57 ± 6.25	35.22 ± 5.71*	0.21 (Trivial)	36.06 ± 8.63	35.18 ± 6.87*	0.10 (Trivial)

*Significant difference to Control Group (p ≤ 0.05); Ŧ Significant difference to pre and post (p ≤ 0.05); CG: Control Group, DNLP: Daily Non-Linear Periodization Group, FNLP: Flexible Non-Linear Group, CMJ: Countermovement Jump, SJ: Squat Jump.

Table 7: Times at 100 meters speed test.

		Pre	Post	Effect size
5 m (s)	CG	0.99 ± 0.03	1.09 ± 0.04 Ŧ	3.3 (Large)
	DNLP	1.10 ± 0.05*	1.04 ± 0.89 Ŧ	1.2 (Large)
	FNLP	1.15 ± 0.13*	1.04 ± 0.11 Ŧ	0.9 (Moderate)
60 m (s)	CG	7.69 ± 0.09	8.04 ± 0.12 Ŧ	3.9 (Large)
	DNLP	8.15 ± 0.89	8.42 ± 0.91	0.3 (Tribial)
	FNLP	7.56 ± 0.35	8.08 ± 0.49 Ŧ	1.5 (Large)
100 m (s)	CG	12.68 ± 0.31	13.13 ± 0.19 Ŧ	1.5 (Large)
	DNLP	13.25 ± 1.29	13.91 ± 1.92	0.5 (Small)
	FNLP	12.21 ± 0.48	12.94 ± 0.85*Ŧ	1.5 (Large)

*Significant difference to Control Group (p ≤ 0.05); Ŧ Significant difference to pre and post (p ≤ 0.05); CG: Control Group, DNLP: Daily Non Linear Periodization Group, FNLP: Flexible Non-Linear Group.

maintained at $p < 0.05$. Statistical analyses of all data were performed using the SPSS statistical processing and analysis software (Statistical Package for Social Sciences, SPSS Science, Chicago, USA), version 21.

Results

According to table 2, a significant difference was observed in subjects' age, and a covariate was used to determine significance of comparisons. For the 1-RM tests, a significant time effect was observed for the BP ($F_{(1,16)} = 6.90$; $p = 0.018$) and LP ($F_{(1,16)} = 6.62$; $p = 0.020$). The DNLP and FNLP groups demonstrated significant increases between the pre and post-tests. Furthermore, a significant group effect was observed for the BP ($F_{(2,16)} = 11.858$; $p = 0.001$) and LP ($F_{(2,16)} = 7,66$, $p = 0.005$) exercises. The DNLP and FNLP groups demonstrated significantly greater gains versus the CG for BP and LP exercises, respectively.

Conversely, the CG demonstrated a significant decrease in 1-RM BP and a significant increase in 1-RM LP from the pre- to the post-test (Table 4). However, in FNLP group, large effect size was noted for the gains of 8-RM loads in LP exercise between the pre and posttest when compared to DNLP group (i.e., moderate). For the 8-RM loads, the DNLP ($p = 0.0001$) and FNLP ($p = 0.001$) groups demonstrated significant increases from the pre- to posttest compared to the CG for BP and LP exercises, respectively (Table 5). However, no difference was noted between DNLP and FNLP groups for BP and LP exercises ($p \leq 0.05$). Despite the lack of statistical difference, large effect size was noted for BP exercise under FNLP compared to DNLP group (i.e., moderated).

For the jump tests, a significant group effect was observed in flight time for the CMJ ($F_{(2,16)} = 4.899$, $p = 0.021$). The height of CMJ in posttest assessment was significantly greater in the DNLP and FNLP groups than the CG, respectively ($p \leq 0.05$). Additionally, for the CG, a significant decrease was observed in height of CMJ between the pre and posttest ($p \leq 0.001$; Table 6). Similar results were noted for SJ test in posttest measures ($p \leq 0.05$).

For the 5 meter sprint, a significant time-effect ($F_{(1,16)} = 18.086$; $p = 0.001$) and group effect ($F_{(2,16)} = 41.827$; $p < 0.0001$;) was observed ($p \leq 0.05$). The DNLP and FNLP groups showed higher values ($p < 0.05$) at the pre-test in relation to the CG (Table 7). However, significant decreasing in time-performance was noted under DNLP ($p = 0.001$) and FNLP ($p = 0.002$) groups between pre and posttest ($p \leq 0.05$), whereas the CG showed an augmentation in time-performance ($p = 0.001$). Therefore, the initial values of these variables across the three groups was used as a covariate in the inferential analysis to ensure comparison from the same baseline.

For the 60 meter sprint, neither time nor interactive effects were observed between groups. However, both the CG ($p = 0.002$) and FNLP ($p = 0.001$) groups showed a significant increasing in time-performance between the pre- and posttests. Thus, no difference was noted between pre and posttest under DNLP group ($p \leq 0.05$). For the 100 meter sprint, a significant time effect ($F_{(1,16)} = 7.118$; $p = 0.016$) and group effect ($F_{(2,16)} = 3.931$, $p = 0.040$) was observed. The CG ($p = 0.001$) and FNLP ($p = 0.001$) groups showed a significant increasing in time-performance between the pre and posttests, and there was also a significant difference ($p \leq 0.05$) between the FNLP and CG groups at the post-test. However, no difference was noted between pre and posttest under DNLP group ($p \leq 0.05$).

Discussion

The purpose of this study was to investigate the effects of DNLP and FNLP on maximal (e.g., 1-RM) and submaximal strength (8-RM) of BP and LP exercises, vertical jump, and speed performance. The main findings of the current study were that the novice subjects who underwent DNLP and FNLP training programs showed similar improvements in maximal and submaximal strength. These data were similar to those noted in previous studies reported in the scientific literature [3,4,7,10,11,15]. Contrasting our hypothesis, both non-linear periodization (e.g., DNLP and FNLP) programs were equally effective to increasing the strength gains in 1-RM and 8-RM testing.

Despite the similar strength gains noted in the current study, McNamara & Stearne [15] compared the effect of DNLP and FNLP for maximal strength and power gains of BP, LP exercises, and standing long jump with novice subjects over 12 consecutive weeks. The increasing in 1-RM load was significantly higher under FNLP group (+62 kg) when compared to DNLP group (+16 kg) for LP exercise. However, for the BP loads there was no difference between periodization models. This lack of significant differences between periodization models for BP exercises was associated to higher overall volume implemented for upper body muscles when compared to the lower body, which may compromised the work-to-rest ratio.

Regardless the variance analysis, in the current study, the effect size was classified as large for 1-RM loads improvements under FNLP group compared to DNLP group (e.g., moderate) in LP exercise. This large effect size was also noted for submaximal load gains (e.g., 8-RM) in BP exercise under FNLPD versus DNLP (e.g., moderate) group, respectively. These results indicated that the time-course of strength gains week per week may be affect by the load manipulation (i.e., periodization models) and muscle groups trained. In accordance with a meta-analysis conducted by Harries, et al. [4], a 12 weeks period is characterized as a short-term intervention, and this condition may not reflect the long-term effectiveness of different periodization models. Additionally, longer-term interventions are crucial in order to assess the related-advantage of greater recovery associated to FNLP model, considering that this model is often adopted with the goal to breaking strength plateaus than DNLP or other non-linear periodization schemes.

One of the benefits reported by McNamara & Stearne [23] is that under FNLP model, the subject is able to provide significant restorative properties, enhancing an athlete's physiological and psychological recovery processes. However, the neural adaptation process should be considered in this context. Prestes, et al. [10] compared maximal strength outcomes and body positioning between linear and reverse linear periodization. During the initial 4 weeks of training, they noted an increase in maximal strength in lat pull-down and leg extension and after 8 weeks in BP and arm curl for the linear model group. However, as reverse linear periodization group began with higher training loads in comparison with the linear group; the manifestations of strength gain were delayed in this group. However, there was still a lack of evidence about the time-course outcomes induced by different non-linear periodization models after 4, 8, and 12 weeks with novice subjects [24].

Considering the vertical jump performance (e.g., CMJ and SJ), both training groups (e.g., FNLP and DLNP) showed similar performance between pre and posttest. On the other hand, significant reduction was noted for both CMJ and SJ between pre and posttest measures under CG. However, previous studies showed significant increase in dynamic strength without additional improvements in vertical jump performance [25]. These evidences indicated that improvements in jumping ability might be independent of improvements in maximum dynamic strength. The jumping ability are often associated to the capacity to generate maximum power with efficient stretch shorten cycle technique [25,26]. In the current study, one of the factors that may be responsible for the maintenance of jumping performance under FNLP and DNLP groups were the plyometric exercises implemented during the power phase of the periodization model.

Significant reduction in time-performance during 5 m speed test was observed between pre to posttest measures under DNLP and FNLP groups. However, the CG showed significant increases in time-performance between pre and posttest. Besides these results, significant increasing in time-performance was noted during 60 m and 100 m speed test during between pre and posttest under CG and FNLP groups. Thus, no difference was noted between pre and posttest under DNLP group, considering 60 m and 100 m time-performance, respectively. The improvement in 5 m speed performance noted in the current study under DNLP and FNLP groups may be related to the structure of the strength training program, which involved plyometric and weightlifting based movements during the power cycle period. This type of training probably induced an increasing in the ability of the neuromuscular system to generate power via the application of force at higher rates. This capability would be evident over very short distances, such as 5 m. However, over longer distances, such as 60 m to 100 m, the maintenance of maximal velocity might be crucial to sprint performance than the initial acceleration component.

Therefore, one limitation in the current study is the short period monitored (e.g., 12 weeks) during the periodization programs implemented for novice subjects. Twelve weeks is a relative short period to draw conclusions between periodization models performed by novice subjects due to the neural adaptations induced over the initial weeks of strength training. The second limitation is that only two different non-linear periodization models were compared over 12 weeks. However, the periodization programs adopted in the current study are in consistence with previous studies and the characteristics of subject´s training level assessed [3,14,15,23]. Additionally, the current study provide practical evidences in respect to the implementation of both DNLP and FNLP periodization model considering maximal, submaximal, jumping, and speed parameters.

Conclusions

Based on the presented results, both DNLP and FNLP were effective in increasing maximum and submaximum strength of upper (e.g., bench press) and lower body exercises (e.g., leg press), vertical jump abilities, and also improving 5 meter sprint speed for novice subjects. However, DNLP and FNLP models were not effective in improving speed performance to 60 and up to 100 meters. Therefore, both DNLP and FNLP can be implemented with the goal to develop strength and physical performance attributes in novice subjects, which may help coaches and strength and conditioning professionals during the strength training prescription.

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Conflict of Interest

The authors have no perceived conflicts of interest to declare.

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