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Comparison between nonperiodized resistance training and nonlinear periodization on muscular peak power in Brazilian soccer players

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ABSTRACT
Background: For decades the literature has been investigating the ideal dose-response regarding the frequency, intensity and volume of training that optimize the increase in muscle strength and power in athletes and non-athletes. **Objective:** Evaluate the effects of strength training from a nonlinear (NLP) and non-periodized (NP) model on muscular peak power in soccer players. **Methods:** Twelve male junior football players from a professional team in Cabo Frio (Brazil) were recruited and randomly divided into two groups (6 in each group). The groups were randomly divided into: G1 - (Body mass: 64.7 ± 6.5 kg; Height: 172.3 ± 5.8 cm; % fat: 5.1 ± 2.7; Age: 17.5 ± 1.0 years) performed RT with NLP model; G2 - (Body mass: 66.1 ± 4.7; Height: 177.1 ± 6.1 cm; % fat: 5.1 ± 1.2, age: 17.6 ± 0.5 years) performed RT with NP model. Both groups are subjected to 12 weeks of training. PNL strength training consisted of weight training sessions on alternate days, 3 times a week, the rest intervals were 120s among the exercises and included 10 exercises. NLP distribution was as follows: Day 1 (3x4-6 maximum repetitions [RM] with rest intervals of 120 sec between sets); Day 2 (3x8-10RM with 60-90 rest intervals between sets); and day 3 (3x12-15RM with rest intervals of 60 sec between sets). NP training performed the same duration, weekly frequency, exercises and number of sets (3 sets 8-10RM and 60-90 sec rest intervals). Before and after NP and NLP training, muscle peak, speed and agility were evaluated. **Results:** The ANOVA with mixed model showed no significant interaction between group and moment ($F(1,10) = 0.133$; $p=0.72$), and no significant main effect for group ($F(1,10) = 0.032$; $p=0.86$) in muscular peak power. There was a significant main effect for moment ($F(1,10) = 14.872$; $p=0.003$), where were showed that Post-training presented higher values of muscular peak power compared to Baseline ($p= 0.003$). **Conclusion:** It is concluded that both training organization models are effective and can be used to develop peak muscle power.
Keywords: Strength training; Weight training; Athletic performance; Sports performance.

BACKGROUND

For decades the literature has been investigating the ideal dose-response regarding the frequency, intensity and volume of training that optimize the increase in muscle strength and power in athletes and non-athletes(1-3). The use of strength training designed to increase underlying strength and power qualities in elite athletes is common, and there is sufficient evidence for strength training programs to continue to be an integral part of athletic preparation in team sports(4).

The most common of these plans is linear also termed classic or strength/power periodization (LP) and nonlinear periodization (NLP), and some research indicates greater strength gains with daily nonlinear periodization(5). Rhea et al. showed that NLP was more effective in eliciting strength gains compared to LP in subjects advanced in resistance training (RT)(6). However, the meta-analysis determined that there were no differences in the effectiveness of linear vs. undulating periodization on upper-body or lower-body strength, and the authors suggest that the short-term of studies and the previous training history of participants can were identified as potential confounding factors in the interpretation of findings(7).

To develop and to retain upper-body and lower-body strength and power in athletes are crucial components to excelling in all sports, and periodized training manner to retain power and develop strength in the upper and lower body should be prescribed (i.e., 3-6 sets of 4-10 repetitions of 70-88% 1RM)(8). Hartmann reportedly that advanced athletes during the in-season necessity in the habitual use of ≥80% 1 RM, and should perform power-based strength training twice per week for to improve to reach peak performance in vertical jump power(9).

However, Hoffman et al.(10) showed that NLP and LP demonstrated increased in height of vertical jump in American football athletes after 7 weeks of strength training, without difference between periodization models. Thereby, the results do not provide a clear indication as to the most effective training program for strength and power enhancements. Smith et al.(11) propose three models of strength training: model prioritized hypertrophy, model prioritized maximum strength, and model prioritized muscular power. No training model showed significant increases in maximum height countermovement vertical jump after ten weeks of training. Ten weeks of training is not enough time to promote improvements in speed, agility and power when there is already a previous adaptation by the athlete.

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Some questions remain inconclusive. First if 12-week strength training bring about improvements in muscular power. Second if is there a difference between NLP and a hypertrophy training model (nonperiodized) on muscular power. Thus, the objective this study was assess the effects of NLP and nonperiodized on muscular peak power, postulating that NLP will enhance muscular power in comparison to nonperiodized.

METHODS

Experimental Approach to the Problem

Twelve male junior football players from a professional team in Cabo Frio (Brazil) were recruited and randomly divided into two groups: Group 1 (G1; n=6 subjects) were underwent 12 weeks of the NLP and group 2 (G2; n=6) were underwent 12 weeks of hypertrophy-based RT (nonperiodized). Before and after the of strength training (NP and NLP), there was visits for determination of anthropometric characteristics and muscular peak power assessment. ANOVA with mixed models were used to estimate differences in muscular peak power with factor within-subjects for moments (Baseline and Post-training) and between-subjects for training groups (NLP and NP).

Subjects

Twelve male junior football players from a professional team in Cabo Frio (Brazil) were recruited and randomly divided into two groups (6 in each group). The Group 1 (G1) (body mass: 64.7±6.5 kg; height: 172.3±5.8 cm; fat percentage: 5.1±2,7; age: 17.5±1.0 years) were underwent 12 weeks of NLP and group 2 (G2) (body mass: 66.1±4,7; height: 177.1±6.1 cm; fat percentage: 5.1±1.2, age: 17.6±0.5 years) were underwent 12 weeks of hypertrophy-based RT (nonperiodized). It is important to note that there were no differences between the training groups in the pre-test ($p > 0.05$) for anthropometric measurements. Inclusion criteria were training experience being at least 4 years, without cardiovascular or osteoarticular diseases. Exclusion criteria included lesions, refusal to voluntarily take part in the study, health status precluding data collection, use of ergogenic and/or food supplements that could alter test results.

Each participant signed a written consent form, and for participant under the age of 18 years parental consent was obtained. The experiment was approved by the institutional ethics committee of the Castelo Branco University, according to the Norms of Conduct in Human Research (CNS resolution 466/2012).

Anthropometric measurements

Body weight with minimal clothing was measured to the nearest 0.1 kg on a lever-type balance (Filizola model 31, Filizola S.A., São Paulo, Brazil). The height were evaluated with a stadiometer (Sanny ES 2020, São Paulo, Brazil). The body density and body fat percentage were calculated according to the equation of Jackson and Pollock and Siri, respectively[12,13]. Skinfolds were measured with a using Lange's adipometer (Switzerland) of 1-mm precision. Were used the skinfold thickness of triceps, subscapular, mid-axillary, pectoral, abdominal, suprailliac and thigh. All reference points were in accordance with the recommendations of the International Society for the Advancement of Kinanthropometry[14].

Muscular peak power Assessment

Muscular peak power was assessed with a countermovement jump (CMJ). Each participant performed 3 tests in maximal CMJ performance with 1-minute recovery interval between each test. The height of subject was measured and recorded with the subject passing a chalk on the middle finger of the dominant hand. Standing, with the dominant shoulder at the side of the wall, the subject raises his hand as high as possible and makes the mark on the wall with the dirty finger of chalk. The height of the CMJ was recorded as the difference between the highest chalk mark and the maximum height reached in CMJ. Muscular peak power (MPP) was estimated using the equations developed by Sayers *et al.*[15]: MPP (W) = (60.7) + (jump height [cm]) + 45.3 x (body mass [kg]) - 2055. Muscular peak power in CMJ is strongly associated with weightlifting ability and can be a valuable tool for assessing weightlifting performance[16]. The CMJ procedures adopted were as follows:

1) Five minutes of aerobic exercise was performed on the cycloergometer, with an intensity of 60% of the estimated maximum heart rate, as a form of previous warm-up.

2) It was allowed the subjects to perform some repetitions as a procedure of prior familiarization with the CMJ.

3) The subjects were instructed to perform the CMJ as high as possible, with the maximum possible velocity and at the earliest stage of the transition from the eccentric to the concentric phase;

Training Protocol

NLP strength training consisted of weight training sessions performed on alternate days for 12 weeks, 3 times a week, and which included 10 exercises (hack squat, leg extension, leg curl, hip adduction, calf raise, lat pull down, bench press, shoulder press, abdominal crunch, back extension) performed on fitness equipment (Righetto, Brazil). The rest intervals were 120 s between exercises. The protocol training was weekly and the same order was used in subsequent weeks. Nonperiodized (NP) strength training was of the same duration, weekly frequency, exercises and number of sets as the NLP strength training. The rest intervals were 120 s between exercises. Exercise intensity was controlled by the OMNI-RES scale[17]. The details of the training protocols are shown in the table 1.

Table 1. Training protocols for the nonperiodized, and nonlinear periodization groups.

	Day 1	Day 2	Day 3
NLP	3x4-6RM (120”)	3x8-10RM (60-90”)	3x12-15RM (60”)
Nonperiodized	3x8-10RM (60-90”)	3x8-10RM (60-90”)	3x8-10RM (60-90”)

***Note:** RM= repetitions maximum;”=rest intervals between sets in seconds.

Experimental Procedures

On the first occasion, the subjects were invited and signed a written consent form, and were submitted to an anthropometric assessment. After the anthropometric assessment, twelve male junior football players from a professional team in Cabo Frio (Brazil) were randomly divided into two groups: Group 1 (G1; n=6 subjects) were underwent 12 weeks of the NLP and group 2 (G2; n=6) were underwent 12 weeks of hypertrophy-based RT (nonperiodized). Before and after the of strength training (NP and NLP), there was visits for determination of muscular peak power assessment. For muscular peak power assessment, each participant performed 3 tests in maximal CMJ performance with 1-minute recovery interval between each test. Before and after the12-week study, the players were subjected to the assessements conducted by the same qualified investigator. Subjects were also informed to maintain their regular food diet routine before performing the visits.

Statistical Analyses

Data normality for each anthropometric variable was assessed through Shapiro-Wilk test. ANOVA with mixed models were used to estimate differences in muscular peak power with factor within-subjects for moments (Baseline and Post-training) and between-subjects for training groups (NLP and NP). In case of significant F values, a post hoc test, with an adjustment by Bonferroni, was used for multi-comparison purposes. The level of significance was set at $p \leq 0.05$, and data were presented as mean ± SD. Statistics were performed using the Statistical Package for the Social Sciences 23.0 (SPSS).

Effect size analysis was conducted to report the magnitude of pre-post differences within each group for muscular peak power. Was used the equation proposed by Cohen[18]: mean differences of moments (post - pre) divided by root square of the sum of standards deviation and classification was in according with the proposed by Rosenthal[19]. Effect sizes were classified as trivial (*d* <0.19), small (*d* = 0.20-0.49), moderate (*d* = 0.50-0.79), large (*d* = 0.80-1.29) and very large (> 1.30).

RESULTS

In baseline, the data of muscular peak power demonstrated homogeneity and homoscedasticity (p>0.05). ANOVA with mixed model showed no significant interaction between Group and Moment ($F_{(1,10)} = 0.133$; p=0.72), and no significant main effect for Group ($F_{(1,10)} = 0.032$; p=0.86) in muscular peak power. There was a significant main effect for moment ($F_{(1,10)} = 14.872$; p=0.003). Post-hoc analysis showed that Post-training presented higher values of muscular peak power compared to Baseline (p= 0.003) (Figure 1).

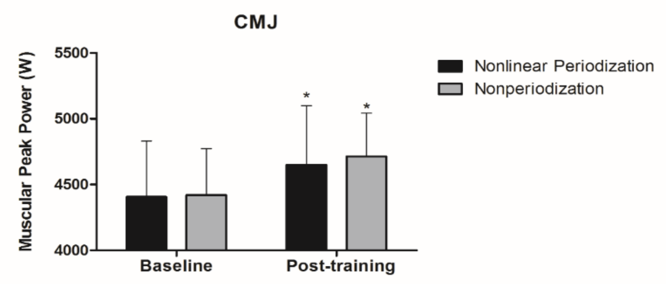

Figure 1. Chronic effects of nonperiodized and nonlinear periodization strength training on muscular peak power (MPP). *Post-training > Baseline (p=0.003).

Effect size analysis showed that NP induced large pre-post improvements in muscular peak power. In contrast, in the NLP there were moderate pre-post improvements in muscular peak power (Table 2).

Table 2. Baseline vs. Post-training for muscular peak power (MPP). Data are expressed as the mean±SD in watts.

	Nonlinear Periodization			Nonperiodization		
Outcome	Baseline	Post-training	ES	Baseline	Post-training	ES
MMP	4407.3±423.0	4650.7±449.2	0.55	4420.2±353.3	4714.5±328.5	0.86

DISCUSSION

The goal of this study was to assess the effects of NLP and NP strength training on muscular peak power. Our results suggest that NLP and NP strength training may be effective to improve muscular peak power.

In a previous recommendation, it was suggested that in order to improve muscular power, there is a need to include strength training aimed at muscular power twice a week. In addition, the training load should be above 80% of 1RM for significant gains in muscle power to occur[9]. Our results are contrary to these recommendations. Both forms of strength training (NLP and NP) were effective in improving muscle power. Nevertheless, NP strength training showed a greater effect size compared to NPL strength training (NP= 0.86 vs NLP= 0.55).

Another important point is the level of training of subjects. The previous training history of participants may have influenced the results of the study[7]. In our research the subjects were in the middle of the competition season, but we had as limitation of the study not to assess the level of strength training by the subjects. Perhaps this limitation may explain the possible result found. However, Hoffman et al[10]. used subjects experienced resistance trained and showed that NLP and LP demonstrated increased in height of vertical jump in American football athletes after 7 weeks of strength training, without difference between periodization models. However, both in linear and non-linear periodization, specific power exercises were used, which may justify the positive result on muscular power. In the LP subjects performed a 4-week power phase, and NLP would alternate from a power workout (3–5 RM in the power exercises and 1–2 RM in Olympic movement exercises, with a 3-minute rest between each set) to a hypertrophy workout (9–12 RM in the power exercises and 5–6 RM in the Olympic movement exercises, with a 1-minute rest between sets). Moreover, during the last 5 weeks of training, all subjects participated in a 3-d.wk^{-1} speed and agility training program[10]. The specificity of training may have influenced the improvement of muscle power, even in short-term training.

In our strength training proposal, no specific exercise of muscle power was used. We use basic character strength exercises and commonly used in gym settings. In addition, training time is relatively short (12 weeks) for improvements in muscle power. In athletes with previous adaptation, Smith et al.[11] suggest that ten weeks of training is not enough time to promote improvements in speed, agility and power. Even so, both forms of strength training were effective in increasing muscle power, without no difference between training (NLP vs NP).

A major limitation of our study was that we did not verify the strength training level of the subjects. The tests performed were extremely practical and applied, however, the use of more sophisticated tests becomes increasingly important in the field of strength and conditioning. Perhaps these factors were decisive for the results found. Another important point was not to have quantified the training of speed and agility. It may be that this type of training influenced our findings.

PRATICAL APPLICATIONS

This study suggests that strength training be beneficial to improve muscular peak power in short time (12 weeks). The fact that we do not use power-based strength training suggest the potential benefit of hypertrophy-based strength training and nonlinear periodization strength training. Although recommendations indicate the need for performed power-based strength training twice per week for to improve to reach muscular peak power in CMJ, it is always necessary for strength training to be accomplished, and this is very important for the knowledge of technicians and physical trainers.

Disclosure of interest

The authors declare that they have no competing interest.

Authors' contribution: Sandro Legey, Sílvio Roberto Barsanulfo and Sérgio Machado contributed equally in all phases of the project; Murilo Lamego; Braulio Pinheiro and Pedro Augusto Inacio participated in the collection and part of the writing of the final document; Alberto Sá Filho participated in multiple revisions and the writing of the final document.

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