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Effects of non-linear periodisation training on the explosive force and plasma testosterone

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Summary

Study aim: To evaluate the effects of two strength training programmes on the explosive force of lower extremities and total testosterone levels in plasma of Brazilian football players.
Material and methods: A group of 24 male football players aged 16 – 19 years participated in a 12-week training: non-linear periodised (NLP) or non-periodised (NP), 12 subjects each. Before and after training period, all subjects performed countermovement vertical jump (CMJ), horizontal jump and Flegner's power test, and total testosterone concentrations were determined in plasma.
Results: Significant, training-induced changes in CMJ were found in both groups; by 7.4% ($p<0.05$) in the NLP group and by 8% ($p<0.001$) in NP group. Also in the long jump (SBJ) significant ($p<0.05$) changes were noted in both groups, by 0.9 and 4.4%, respectively. Serum testosterone concentrations significantly ($p<0.05 – 0.01$) increased post-training in both groups and the increase was significantly ($p<0.01$) greater in the NLP than in NP group.
Conclusion: A larger number of athletes in future studies, as well as other sport categories and levels and a longer training period would be advisable in order to strengthen the causal inferences between the variables studied.

Key words: Resistance training – Muscle strength – Testosterone

Introduction

Explosive force is an important measure of physical fitness of football players [9,15,16,31,33]. This applies particularly to lower extremities due to high acceleration requirements [3,17,42]. Strength training in Brazilian football players is thus important for perfecting motor skills [8] and preventing injuries [10,44].

Strength training is known to induce specific adaptive neuromuscular and hormonal responses [43]. The degree of neuromuscular adaptation was shown to be related to training volume, relative loads, type of exercise, and rest periods between contractions [18]. Previous studies demonstrated positive correlations of plasma total testosterone levels with sprint and explosive power performances [2] which was attributed to its anabolic properties [34] bringing about gains in muscle mass, muscle strength and aerobic endurance [40]. Heavy resistance exercise is known to produce an acute increase of total testosterone in serum and to be a stimulus for muscle fibre hypertrophy [26].

Explosive force can be developed through sport-specific resistance exercises or by other activities such as weight training [35,42]. Adjusting the stimuli by varying loads and numbers of series and repetitions may produce increased physical strength. Such planned alteration of programme variables is called periodisation, which may be linear or non-linear [3,4,12].

Linear periodised strength training increases gradually in intensity with a slight alteration to each microcycle every 2 to 4 weeks [3,21]. This periodisation model was developed to reach peak strength within a specific time frame specific for given sport. In team sports like football, no priority is given to a specific time of year. This is because the number of points accumulated over the season is the decisive factor, requiring athletes to maintain optimal strength throughout the competition period [13].

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On the other hand, training stimuli vary in the non-linear periodisation mode but not in a specific manner. The variations in volume and intensity occur in microcycles, not in different mesocycles [3]. This periodisation training model may improve maximal strength and motor adaptation compared to non-periodised programmes [21,32], suggesting its high efficiency especially in high-demanding sports [13,30,36].

The aim of this study was to evaluate the effects of two resistance training programmes – one non-linear and the other non-periodised, on the explosive force of lower extremities and on total testosterone levels in plasma of Brazilian football players.

Material and Methods

Subjects: A group of 24 male junior football players from a professional team in Cabo Frio, Brazil, aged 16 – 19 years, volunteered to participate in the study. They attended all training sessions, their training experience being at least 4 years. All of them were examined medically and found fully qualified. 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. All subjects and their parents submitted written consents to participate in the study which was approved by the local Committee of Ethics in accordance with the Helsinki Declaration. The subjects were randomly assigned into two groups, 12 subjects each: non-linear periodised (NLP) and non-periodised (NP).

Methodology: Before and after the12-week study, the players were subjected to the following examinations conducted by the same qualified investigator: anthropometric measurements, blood sampling and explosive force tests.

The following data were recorded: body height (cm) using a stadiometer (Sanny ES 2020, Brazil), body mass (kg) using medical scales (Filizola PL 180, Brazil), body mass index (BMI), skinfold thickness (triceps, subscapular, mid-axillary, pectoral, abdominal, suprailliac and thigh) using Lange's adipometer (Switzerland) of 1-mm precision. Skinfold measurements served to evaluate fat percentage [20]. All reference points were in accordance with the recommendations of the International Society for the Advancement of Kinanthropometry [28].

Blood (10 ml) was withdrawn in the morning, in the preprandial state, from the antecubital vein into serum tubes (Venosafe, Terumo, Belgium) by a qualified technician. Whole blood was centrifuged at 3500 rpm (Megafuge 1.0R, Heraeus, Germany) for 10 min and stored at -20°C until assayed. Serum total testosterone concentrations were determined using ELISA assay kits (Diagnostic Biochem, Canada Inc.).

Explosive force was assessed using three tests, separated by at least 5-min intermissions, in the following order:

Standing broad jump (SBJ): The subject is positioned with his feet parallel to the starting point and at the command "go", jumps forward, with a simultaneous thrust of the legs and free arm movement in order to reach the furthest point possible on the Starret ABS (Brazil) tape measure. The best result of three attempts, separated by 30-s rest periods, was recorded [29].

Countermovement jump (CMJ): The subject starts in standing position, alongside the vertical graduated surface, one arm raised over the head, and makes a mark with fingers at the highest point possible. Then the subject jumps as high as possible, with free arm movement permitted. The results (in cm) are expressed as the difference between the jump mark and the reach-up mark. Three attempts were made spaced by 30-s rest periods, the best result being recorded [22].

Flegner's power test – maximal power in 10 consecutive jumps (FPT): The player performs 10 consecutive jumps as fast and far as possible, feet kept parallel and without stepping forward upon landing. The start was not prompted by command to avoid including reaction time (latency); thus, foot movement was the signal to start the chronometer (Oregon SL210, Brazil). Jump distance was measured from the starting line to the last point of foot-floor contact [29]. Total distance and total time were used to calculate Absolute Anaerobic Power Unit (AAPU).

Strength training programme: Non-linear periodised (NLP) strength training consisted of weight training sessions performed on alternate days for 12 weeks, 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 in three sets on fitness equipment (Righetto, Brazil). Subjects executed 4 – 6 repetitions-maximum (RM) at the first weekly session, 8 – 10 RM at the second and 12 – 15 at the third. The same order was used in subsequent weeks. The rest intervals between exercise sets amounted to 120, 60 – 90 and 60 s, respectively, and 120 s between exercises. Non-periodised (NP) strength (weight) training was of the same duration, weekly frequency, exercises and number of sets as the previous training. Repetitions maximum amounted to 8 – 10, and rest intervals to 120 s between exercises and 60 – 90 s between sets for all training sessions. Total training volume and number of sets multiplied by the number of repetitions was at the end of each week in both models alike. Exercise intensity was controlled by the OMNI-RES scale [39].

Data analysis: The Shapiro-Wilk's and Levene's tests were applied to assess the distributions of data. Repeated measures ANOVA was used to assess the within- and between-group differences, followed by Tukey's *post hoc* test, the level of $p \leq 0.05$ being considered significant; SPSS 14.0 software was used in data analysis.

Results

The recorded data are presented in Tables 1 and 2. The training induced significant changes in the CMJ in both groups; by 7.4% ($p<0.05$) in the NLP group and by 8% ($p<0.001$) in NP group. Also in the long jump (SBJ) significant ($p<0.05$) changes were noted in both groups, by 0.9 and 4.4%, respectively. Serum testosterone concentrations significantly ($p<0.05 - 0.01$) increased post-training in both groups and the increase was significantly ($p<0.01$) greater in the NLP than in NP group.

Table 1. Mean values (±SD) of somatic variables of young male football players subjected to 12-week non-linear periodised training (NLP) or non-periodised training (NP)

Group Variable	NLP (n = 12)	NP (n = 12)
Age (years)	17.5 ± 1.1	17.7 ± 0.5
Body mass (kg)	64.7 ± 6.6	66.1 ± 4.8
Body height (cm)	172.3 ± 5.9	177.1 ± 6.1
BMI	21.8 ± 1.5	21.1 ± 1.1
Fat (%)	5.2 ± 2.8	5.1 ± 1.3

Table 2. Mean values (±SD) of explosive force variables and serum testosterone concentrations in young male football players subjected to 12-week non-linear periodised training (NLP) or non-periodised training (NP)

Group	NLP (n = 12)		NP (n = 12)	
Variable	Pre	Post/Pre ratio (%)	Pre	Post/Pre ratio (%)
CMJ (cm)	58.2 ± 3.4	7.4 ± 9.3*	57.3 ± 2.6	8.0 ± 4.7***
SBJ (cm)	231.3 ± 13.5	0.9 ± 1.1*	236.2 ± 21.2	4.4 ± 5.4* º
FPT (kg.m/s)	216.6 ± 30.4	2.0 ± 5.8	228.5 ± 26.5	3.3 ± 8.1
Testosterone (ng/dl)	4.3 ± 1.5	91.4 ± 23.0***	3.9 ± 1.1	50.4 ± 25.3*** º

Legend: CMJ – Counter-movement jump; SBJ – Standing broad jump; FPT – Flegner's power test; Significantly different from the respective 'Pre' value: * $p<0.05$; *** $p<0.001$; º Significantly ($p<0.05$) different from the respective value in NLP group

Discussion

Rhea *et al.* [36] studied young subjects aged 19 – 23 years engaged in recreational weight training. A significant gain in maximal strength was recorded during leg press exercises when non-linear periodised single-set (26%) and multiple-set (56%) programmes were applied for 12 weeks. They found that multiple-set, non-linear periodisation weight training elicited greater gains than the non-periodised single-set model (30%). These results differ from those obtained in this study, although intervention time and the non-linear periodised multiple-set programme were similar. This may have been due to the initial training level of recreational weight lifters being lower than that of our football players who showed greater adaptive potential [11].

In another study [38] involving 60 collegial level weight lifters (30 men and 30 women, mean age 21 years), the same authors found significant increases in maximal strength of lower extremities determined by the 1 RM test in leg extension, in the non-linear periodised (by 9.8%) and linear periodised (by 9.1%) groups, as well as a non-significant increase in the reverse linear periodisation (RLP) programme (by 5.6%). In another study [37] on 20 male collegiate-level weight lifters aged 21.6 ± 2.3 years, undergoing 3 weekly training sessions for 12 weeks, significant ($p<0.05$) increases were recorded in leg press and bench press exercises in the two training groups (NLP and LP). Mean strength gain in LP was 14.4% and 25.6% for the bench press and leg press, respectively, compared to 28.8% and 55.8% in the NLP group. The NLP group achieved greater strength gains during the training period ($p<0.05$), compared to the LP group. Training programmes, duration and number of weekly sessions were similar to those used in this study, but with different results. While these investigations used only strength exercises, subjects in the present study underwent a complete training regime involving all the important physical qualities required of football players. They were also influenced by the sport itself during the competitive period. Thus, concurrent training may inhibit the development of explosive force compared to the strength training alone [1].

In a study on 30 college tennis players, Kraemer *et al.* [23] applied a 9-month NLP and NP strength training with 3 weekly sessions and found greater increases in mean CMJ results in the NLP than in NP groups (50 and 37%, respectively). These findings differ from those presented here despite similarities in strength training models, weekly frequency and explosive force tests, probably because of differences in study duration, training procedures and participation in sport events. Since the subjects of this study had previous experience in strength training and in applied tests, it could be inferred that the training loads were insufficient to produce significant muscle fibre hypertrophy and neural adaptations [27]. Another reason could be the use of mechanical equipment instead of free weights, as the latter training more closely resembles specific sport movements. Thus, non-specific training may have affected the results [35]. Inasmuch the increases in strength and muscle associated with strength training may be partly influenced by increased testosterone secretion or by increased number of testosterone receptors in muscle cells [5,6,41], the reports on resting testosterone levels remain controversial [26].

In this study, plasma testosterone levels increased significantly in both groups (NLP and NP), significantly higher values being noted in NLP than NP group. These findings corroborate the abovementioned study of Kraemer *et al.* [23] on 30 college tennis players subjected to NLP and NP strength training lasting 4 months; the increase in plasma testosterone was more pronounced following NLP training compared to NP (18.2% vs. 11.1%). Such increases were attributed to a stimulating effect of lactate and catecholamines during resistance exercises [7,14].

Izquierdo *et al.* [19] observed that free testosterone levels rose by 5.6% in 11 untrained men aged 46 ± 2 years submitted to NLP strength training for 16 weeks. Despite the differences in age and fitness, the reported effects of NLP strength training were consistent with those of the present study. Kraemer *et al.* [24] reported significant increases in free serum testosterone levels in men engaged in recreational activities (29.8 ± 5.3 years) who underwent non-linear periodised strength training for 10 weeks. Their results agree with those of this study, in which the same methodology was used. This suggests that the type of training used in the present investigation may generate positive responses for this hormone in individuals differing in physical fitness. It ought to be emphasised that all those studies compared one specific routine against another and the number of different periodised and non-periodised routines, based on a variety of exercise variables, that could be implemented is virtually unlimited.

Summing up, significant training-induced increases in serum testosterone were found in both groups but were more emphasised following the NLP than NP programmes. This suggests that the NLP-related load of the neuromuscular system was higher than in case of NP due to varying training intensities. This may optimise muscle fibre hypertrophy and strength development since increased hormone concentrations create a favourable anabolic environment [41]. Those suggestions, however, are inconsistent with the effects observed in this study; namely, significant changes in the explosive force were noted in both groups, the improvement being significantly higher in the NP than in NLP groups. Larger number of athletes in future studies, as well as other sport categories and levels and longer training periods would thus be advisable in order to strengthen the causal inferences between the variables studied.

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