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Research article

Early Adaptations to Six Weeks of Non-Periodized and Periodized Strength Training Regimens in Recreational Males

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Abstract
This study compared quadriceps muscle cross-sectional area (CSA) and maximum strength (1RM) after three different short-term strength training (ST) regimens (i.e. non-periodized [NP], traditional-periodization [TP], and undulating-periodization [UP]) matched for volume load in previously untrained individuals. Thirty-one recreationally active males were randomly divided into four groups: NP: n = 9; TP: n = 9; UP: n = 8 and control group (C): n = 5. Experimental groups underwent a 6-week program consisting of two training sessions per week. Muscle strength was assessed at baseline and after the training period. Dominant leg quadriceps CSA was obtained through magnetic resonance imaging (MRI) at baseline and 48h after the last training session. Results: The 1RM increased from pre to post only in the NP and UP groups (NP = 17.0 %, p = 0.002; UP = 12.9 %, p = 0.03), respectively. There were no significant differences in 1RM for LP and C groups after 6 weeks (TP = 7.7 %, p = 0.58, C = 1.2 %, p = 1.00). The CSA increased from pre to post in all of the experimental groups (NP = 5.1 %, p = 0.0001; TP = 4.6 %, p = 0.001; UP = 5.2 %, p = 0.0001), with no changes observed in the C group (p = 0.93). Conclusion: Our results suggest that different ST periodization regimens over a short-term (i.e. 6 weeks), volume load equated conditions seem to induce similar hypertrophic responses regardless of the loading scheme employed. In addition, for those recreational males who need to develop muscle strength in the short-term, the training regimen should be designed properly.

Key words: Periodization, exercise prescription, training load, muscle hypertrophy.

Introduction

Strength training (ST) has been extensively used by athletes and strength and conditioning coaches as an effective tool to improve both strength and muscle mass (Kraemer et al., 2003; Tricoli et al., 2005). Despite the above, researchers have continuously attempted to optimize training stimuli in order to maximize strength and hypertrophy gains.

Periodized training, as opposed to constant-load training regimens (i.e. non-periodized training [NP]), has been advocated as a more efficient method to induce neuromuscular adaptations in response to ST (Ratamess et al., 2009). The current literature describes two main ST periodization models: i) the classic or traditional periodization (TP), in which the training load progresses from high-volume low-intensity to low-volume high-intensity loads over time; and ii) the undulating periodization (UP), which alternates between high-volume low-intensity training sessions and low-volume high-intensity sessions within a training week (Monteiro et al., 2009; Ratamess et al., 2009).

Currently, a significant body of literature supports the concept that periodized ST programs are more effective in inducing strength gains when compared with NP ones (Fleck, 1999; Ratamess et al., 2009; Stone et al., 2000; Willoughby, 1993). Conversely, the conclusions regarding the effectiveness of periodized ST programs on muscle mass gains are still equivocal (Baker et al., 1994; Kraemer et al., 2004; Kok et al., 2009). Despite the fact that previous studies have demonstrated greater changes in fat-free mass (FFM) (Kraemer et al., 2003; Prestes et al., 2009), and muscle thickness (Simao et al., 2012) following periodized ST regimens, no study has compared the efficacy of periodized (either TP or UP) *versus* NP regimens in muscle mass accretion. Although aforementioned studies provide suggestive evidence of positive changes in muscle mass, none of them have directly assessed muscle cross-sectional area (CSA), thus hampering further conclusions.

In addition, as changes in muscle CSA can be detected after just 3-wk of ST (Seynnes et al., 2007), identifying which training regimen induces greater increments in CSA in a short-term scenario can be advantageous for those sports where ST has to be performed within short-phase as well for strength and conditioning practitioners.

Therefore, the purpose of this study was to compare maximum strength and muscle CSA (using a gold standard method) improvements after short-term NP, TP, and UP training regimens matched for volume load in recreationally male active individuals. We hypothesized that volume-matched ST programs will produced similar maximum strength and muscle CSA improvements.

Methods

Experimental design
In order to evaluate the effects of distinct ST periodization regimens on muscle strength and quadriceps CSA, we designed three different ST programs matched

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Table 1. Participant's demographics. Data are means (± SD).

Variable	C (n = 5)	NP (n = 9)	TP (n = 9)	UP (n = 8)
Age (y)	25.4 (3.5)	25.0 (7.7)	26.2 (7.3)	23.8 (4.3)
Height (cm)	1.74 (.06)	1.73 (.06)	1.73 (.05)	1.77 (.05)
Body mass (kg)	77.7 (12.1)	81.4 (12.3)	75.9 (9.7)	74.7 (10.1)
1RM (kg)	120.8 (18.0)	140.7 (23.9)	141.1 (19.5)	149.5 (34.6)
CSA (mm^2)	8983.3 (832.3)	8801.0 (832.3)	8689.4 (770.8)	8616.8 (1495.0)

C=control group, NP= non-periodized, TP= traditional-periodized, UP= undulating-periodized, CSA= cross-sectional area, 1RM= maximum dynamic strength test.

for volume load: a NP, a TP, and an UP training program. This study defined volume load as sets x repetitions x mass lifted (kg); therefore, any differences in the training-induced adaptations (i.e. muscle strength or muscle CSA) would be attributable to the periodization model and not to differences in training volume load.

We chose to investigate physically active instead of strength-trained individuals as this study aimed to identify the training regimen with the most potential to induce skeletal muscle hypertrophy on a short-term basis.

Muscle strength and quadriceps CSA [evaluated by magnetic resonance imaging (MRI)] were assessed at baseline and after six weeks of training. The current study adds to the existing literature by comparing the effects of two periodized ST models with a NP training regimen using a gold-standard measurement of ST-induced muscle hypertrophy.

Participants

Thirty-seven recreationally active male physical education students engaged in sports such as soccer, volleyball, and basketball, but not undergoing regular strength training for at least six months prior to the experimental period, volunteered for this study. Initially, participants were classified into quartiles according to their quadriceps cross-sectional area (e.g. CSA, mm^2). Then, participants from each quartile were randomly assigned to the experimental groups (Table 1). After the initiation of the experimental protocol, six participants withdrew due to personal reasons. These withdrawals, and the smaller sample sizes used post-stratification may restrict statistical power in this study. Participants were free from health problems and/or neuromuscular disorders that could affect their ability to complete the training protocols. In addition, they were oriented to maintain their normal diet and refrain from taking nutritional supplements and performing endurance exercises during the experimental period. On average, participants completed 98% of the training sessions. The study was approved by the local Institution's Ethics Committee. All of the subjects were informed of the inherent risks and benefits prior to signing an informed consent form.

Muscle cross-sectional area (CSA)

Dominant leg quadriceps CSA was obtained through MRI (Signa LX 9.1, GE Healthcare, Milwaukee, WI, USA). The dominant leg was determined by asking the participants the preferred leg used to kick a soccer ball. Participants laid on the device in a supine position with the knees extended. Velcro stripes were used to restrain leg movements during image acquisition. An initial image was captured to determine the perpendicular distance from the greater trochanter to the inferior border of the lateral epicondyle of the femur, which was defined as the thigh length. Quadriceps cross-sectional image was acquired at 50% of the segment length in 0.8 cm slices for three seconds. The pulse sequence was performed with a view field between 400 and 420 mm, time repetition of 350 milliseconds, eco time from 9 to 11 milliseconds, two signal acquisitions, and matrix of reconstruction of 256 x 256. The images were transferred to a workstation (Advantage Workstation 4.3, GE Healthcare, Milwaukee, WI, USA) for quadriceps CSA determination. In short, the segment slice was divided into the following components: skeletal muscle, subcutaneous fat tissue, bone, and residual tissue. Finally, quadriceps muscle CSA was assessed by computerized planimetry by a blinded researcher (Figure 1). The coefficient variation (CV) for the quadriceps CSA assessments was 2.1%.

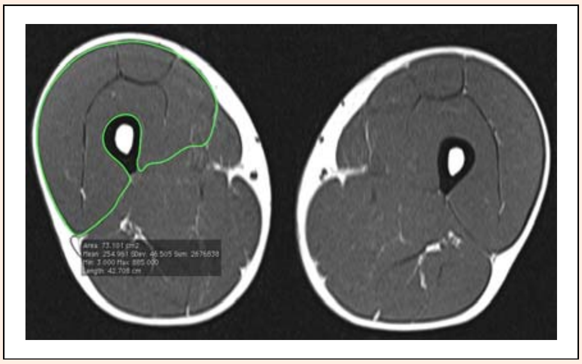

Figure 1. Overview of the traced dominant leg quadriceps CSA.

Familiarization

All of the participants completed three familiarization sessions interspersed by a minimum of 72 hours prior to the commencement of the study. During the familiarization sessions, participants performed a general warm-up consisting of five minutes of running at 9 $km \cdot h^{-1}$ on a treadmill (Movement Technology®, Brudden, Sao Paulo, Brazil) followed by three minutes of whole body light stretching exercises. After warming-up, the participants were familiarized with the squat exercise 1RM testing protocol. The individuals were considered acquainted to the 1RM test, when the coefficient of variation between familiarization sessions two and three was <5%. Body position and foot placement were determined with measuring tapes fixed on the bar and on the ground, respectively. In addition, a wooden seat with adjustable heights was placed behind the subject in order to keep the bar displacement and knee flexion angle (~90°) constant on each squat repetition. Participants' positioning were recorded during the familiarization sessions and reproduced throughout the study.

Maximum dynamic strength test (1RM)

After the familiarization procedures (72 hours after the last familiarization session), lower-limb 1RM was assessed using the squat exercise on a conventional Smith machine (Portico®, São Paulo, Brazil). Testing protocol followed previous suggestions (Brown and Weir, 2001). In brief, participants ran for five minutes at 9 $km \cdot h^{-1}$ on a treadmill (Movement Technology®, Brudden, São Paulo, Brazil) followed by lower-limb light stretching exercises and two warm-up sets of squat exercise. During the first set, participants performed eight repetitions with 50% of the estimated 1RM. In the second set, they performed three repetitions with 70% of the estimated 1RM, with 3-minute rest intervals between them. After the second warm-up set, participants rested for 3 minutes. Then, each participant had up to five attempts to achieve the 1RM load (i.e. the maximum weight that could be lifted once with the proper technique), with a 3-minute interval between trials. Each lift was deemed successful as described by the International Powerlifting Federation rules (Gilbert and Lees, 2005). Strong verbal encouragement was given throughout the test. The coefficient variation (CV) between maximum strength assessments was of 2.8%.

Training programs

The participants underwent a 6-week (two training sessions per week) hypertrophy-oriented lower-limb strength training regimen. The target strength training intensity was 6-12 maximal repetitions (RM) for the two exercises performed (i.e. squat and knee extensions, Table 2). The squat exercise was performed on a conventional Smith machine (Portico®, São Paulo, Brazil) and the knee extension exercise was performed on a pin-loaded weight machine (Portico®, São Paulo, Brazil). A 2-min rest interval was allowed between sets while 3 minutes were respected between exercises. All of the exercises were performed with constant speed, 2-sec eccentric and 2-sec concentric muscle actions, and a 90º range of motion at the knee joint.

The periodization programs adopted for each of the three experimental groups are presented in Table 2. Importantly, the volume load [sets x repetitions x mass lifted (kg)] was equated across all of the experimental groups. No significant between-group differences were observed in volume load per training session: NP: 4237.2 ± 536.4 kg; TP: 4171.1 ± 571.5 kg; UP: 4741.7 ± 918.3 kg (F = 1.55; p = 0.24), or total volume load: NP: 51,513.9 ± 6,251.3 kg; TP: 48,872.5 ± 7,329.3 kg; UP: 56,900.7 ± 11,019.7 kg (F = 1.98; p = 0.17).

Statistical analysis

After normality (*i.e.* Shapiro Wilk) and variance assurance (*i.e.* Levene), a mixed model was performed for each dependent variable, assuming group (NP, TP, UP, and C) and time (pre and post) as fixed factors, and participants as a random factor (SAS 9.2, SAS Institute Inc., Cary, NC, USA). Whenever a significant F-value was obtained, a post-hoc test with a Tukey's adjustment was performed for multiple comparison purposes (Ugrinowitsch et al., 2004). Finally, within-group effect sizes (ES) (pre- to post- changes) were calculated using Cohen's d (Cohen, 1988). The significance level was previously set at $p < 0.05$. Results are expressed as mean ± standard deviation (SD).

Results

Maximum dynamic strength (1RM)

No significant between-group differences in the maximum dynamic strength were detected at baseline. The 1RM squat increased significantly in the NP and UP groups from the pre to post assessments: NP: 17.0 ± 8.75%, ES: 1.00, p = 0.002; UP: 12.9 ± 9.9%, ES: 0.51, p = 0.03. There were no pre- to post-test significant differences in 1RM for the C and TP groups: C: 1.2 ± 6.1%, ES: 0.23, p=1.0; TP: 7.7 ± 11.0%, ES: 0.60, p=0.58 (Figure 2A).

Quadriceps muscle cross-sectional area (CSA)

No significant between-group differences in the muscle CSA were detected at baseline. The quadriceps CSA in the dominant leg increased significantly in all of the experimental groups from pre- to post-assessments: NP: 5.1 ± 2.1%, ES: 0.45, p = 0.0001; TP: 4.6 ± 3.2%, ES: 0.51, p = 0.001; UP: 5.2 ± 2.7%, ES: 0.30, p = 0.0001. No significant differences were observed in the pre- to post-test CSA for the C group (1.2 ± 4.0%, ES: 0.12, p = 0.93) (Figure 2B).

Discussion

The current study investigated the effects of different short-term ST periodization regimens (i.e. TP, LP, and UP) on muscle CSA and maximum strength improvements. We hypothesized that volume-matched ST programs would produce similar muscle CSA and

Table 2. Non-periodized and periodized ST programs throughout 6 weeks.

Groups		Weeks 1-4 Monday	Weeks 1-4 Thursday	Weeks 5-6 Monday	Weeks 5-6 Thursday
NP	Squat	3x8	3x8	3x8	3x8
	Knee extensor	2x8	2x8	2x8	2x8
TP	Squat	3x12	2x12	4x8	4x8
	Knee extensor	2x12	2x12	2x8	2x8
UP	Squat	2x12	3x8	3x10	4x6
	Knee extensor	3x12	3x8	2x10	2x6

NP= non-periodized, TP= traditional-periodized , UP= undulating-periodized

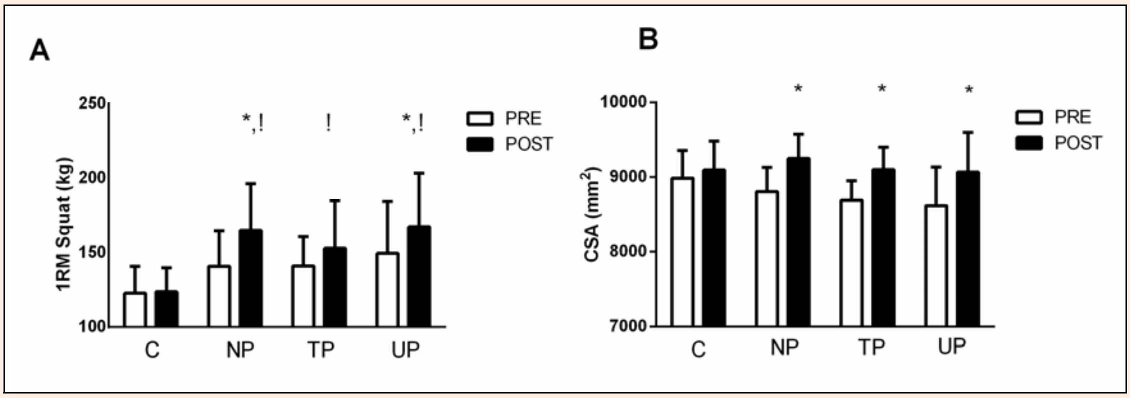

Figure 2. Pre- and post-test maximum dynamic strength and quadriceps muscle CSA (mean ± SD) for the control (C), non-periodized (NP), traditional-periodized (TP) and undulating-periodized (UP) groups. * indicates $p < 0.05$ for within-group comparisons. !indicates $p < 0.05$ when compared with the C group.

maximum strength increases. We partially confirmed our proposed hypothesis as after 6 weeks of ST in recreationally active males, only the NP and UP groups significantly increased muscle strength (17.0% and 12.9%, respectively). In addition, as hypothesized, the dominant leg quadriceps CSA increased similarly in all of the experimental groups from pre- to post-training assessments (i.e. ranging from 4.6% to 5.2%), with no differences between groups.

Currently, no consensus exists regarding which periodization training regimen is more effective in producing gains in muscle strength and hypertrophy (Apel et al., 2011; Buford et al., 2007; Kok et al., 2009; Rhea et al., 2002). However, it is well established that some type of periodization should be adopted in order to maximize ST-induced muscle adaptations (Stone et al., 2000). Although our data demonstrated that the NP and UP training regimens were effective in increasing 1RM after only 6 weeks of training, the TP group showed no significant strength gains after the training period in physically active males. The latter is not in accordance with previous studies that have demonstrated greater strength gains after TP and UP when compared with NP regimens (Monteiro et al., 2009; Stone et al., 2000). For instance, Stone et al. (2000) have demonstrated that after 12 weeks of ST, the TP training regimen increased 1RM squat to a greater extent than NP (e.g. 14.9% and 9.9%, respectively). It is noteworthy that these two studies evaluated subjects with either previous experience in ST or with 1RM to body weight ratio ≥ 1.3 in the squat exercise, which may have influenced the results, especially when compared with other data regarding non strength-trained individuals, as those reported herein.

Importantly, in our study, despite the fact that the training groups were matched for volume load, the TP group performed about half of their training at a lower intensity (i.e.12RM) than the UP and NP groups, which trained at greater intensities (i.e. around 8RM on the average) for the majority of the intervention. This was necessary as a TP regimen presumes increases in training intensity throughout the training period. In this regard, our findings are in agreement with those of Campos et al. (2002). These authors demonstrated that heavy-load (i.e. 3-5RM) training improved 1RM squat largely than moderate- or light-load training (i.e. 9-11 RM, and 20-28RM, respectively) in volume load equated conditions. Collectively, these data support the idea of a "repetition maximum continuum", in which the training adaptations in maximum strength are thought to be specific to the number of repetitions allowed by the resistance (Anderson and Kearney, 1982; Campos et al., 2002; Fleck and Kraemer, 1988; Mitchell et al., 2012 Anderson and Kearney, 1982). Second, the proper ST design should consider the training background of participants, mostly when the purpose of the training regimens is to develop muscle strength.

However, it is important to note that in spite of the non-significant differences in the TP group 1RM, we found a greater ES when compared to the UP group (e.g. 0.60 vs. 0.51). Furthermore, a 7.7% increase in maximum strength after six weeks of ST may still be beneficial to strength and conditioning practitioners and athletes who need to improve muscle strength in short-term periods.

Regarding the muscle hypertrophy data, the current study was the first to use a gold-standard method to compare the effects of periodized (i.e. TP and UP) ST regimens with a NP one. Our findings demonstrated that regardless of the loading scheme employed, muscle CSA significantly increased in a comparable fashion across all of the experimental groups. It is possible that when volume load is equated between groups (i.e. sets x repetitions x mass lifted), a threshold range for muscle hypertrophy - that is not dependent on variations in the training load - may exist. For instance, Burd et al. (2010) have demonstrated that low-load high volume resistance exercise was equally effective in inducing acute muscle anabolism than high-load low volume resistance exercise. Accordingly, Kumar et al. (2009) demonstrated a plateau in acute myofibrillar protein synthesis when resistance exercise was performed within a range varying from 60 to 90% of 1RM. Our contention is further supported by long-term studies that have analyzed muscle thickness (Simao et al., 2012) and fiber CSA (Campos et al., 2002) after a wide range of exercise intensities. For instance, Simão et al. (2012) found that a wide range of RM (i.e. from 3 to 15RM) resulted in similar gains in muscle thickness after 12 weeks of either TP or UP training. In addition, Campos et al. (2002) found no between-group significant differences in fiber CSA increases after 8 weeks of training at either 3-5 or 9-11RM.

Conclusion

Our results suggest that different ST periodization regimens over a short period of time (i.e. 6 weeks) can distinctly affect the gains in maximum strength. On the other hand, volume load equated conditions seem to induce similar hypertrophic responses regardless of the loading scheme employed. In addition, the proper distribution of the training loads is a recurrent issue in ST. Despite the previous suggestions that a periodized ST may be more effective in inducing strength gains than NP training, the periodization model should be carefully chosen when considering a short-term training period. The load progression inferred in a TP model implies that low loads should constitute the first few microcycles of the training program. Therefore, as demonstrated in the present study, the magnitude of the strength gains may be lower when using a TP rather than an UP or even a NP training model in a short-term scenario.

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Key points

- Muscle hypertrophy occurs within six weeks in recreationally active men regardless the ST training regimen employed.
- When the total volume is similar, training at greater intensities will demonstrate superior gains in the 1RM performance.
- Some caution should be exercised when interpreting our findings since long-term periodized regimens could produce different training-induced responses.

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