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Changes in Exercises Are More Effective Than in Loading Schemes to Improve Muscle Strength

Rodrigo M. Fonseca,[1] Hamilton Roschel,[1] Valmor Tricoli,[1] Eduardo O. de Souza,[1] Jacob M. Wilson,[2] Gilberto C. Laurentino,[1] André Y. Aihara,[3] Alberto R. de Souza Leão,[3] and Carlos Ugrinowitsch[1]

[1]*Department of Sport, Laboratory of Neuromuscular Adaptations to Strength Training, School of Physical Education and Sport, University of São Paulo, São Paulo, Brazil;* [2]*Department of Health Science and Human Performance, University of Tampa, Tampa, Florida; and* [3]*Department of Sport, Delboni Auriemo Diagnostic Imaging Sector: A Division of DASA, São Paulo, Brazil*

Abstract

Fonseca, RM, Roschel, H, Tricoli, V, de Souza, EO, Wilson, JM, Laurentino, GC, Aihara, AY, de Souza Leão, AR, and Ugrinowitsch, C. Changes in exercises are more effective than in loading schemes to improve muscle strength. *J Strength Cond Res* 28(11): 3085–3092, 2014—This study investigated the effects of varying strength exercises and loading scheme on muscle cross-sectional area (CSA) and maximum strength after 4 strength training loading schemes: constant intensity and constant exercise (CICE), constant intensity and varied exercise (CIVE), varied intensity and constant exercise (VICE), varied intensity and varied exercise (VIVE). Forty-nine individuals were allocated into 5 groups: CICE, CIVE, VICE, VIVE, and control group (C). Experimental groups underwent twice a week training for 12 weeks. Squat 1 repetition maximum was assessed at baseline and after the training period. Whole quadriceps muscle and its heads CSA were also obtained pretraining and posttraining. The whole quadriceps CSA increased significantly ($p \leq 0.05$) in all of the experimental groups from pretest to posttest in both the right and left legs: CICE: 11.6 and 12.0%; CIVE: 11.6 and 12.2%; VICE: 9.5 e 9.3%; and VIVE: 9.9 and 11.6%, respectively. The CIVE and VIVE groups presented hypertrophy in all of the quadriceps muscle heads ($p \leq 0.05$), whereas the CICE and VICE groups did not present hypertrophy in the vastus medialis and rectus femoris (RF), and in the RF muscles, respectively ($p > 0.05$). The CIVE group had greater strength increments than the other training groups (effect size confidence limit of the difference [ES_{CLdiff}] CICE: 1.41−1.56; VICE: 2.13–2.28; VIVE: 0.59–0.75). Our findings suggest: (a) CIVE is more efficient to produce strength gains for physically active individuals; (b) as long as the training intensity reaches an alleged threshold, muscle hypertrophy is similar regardless of the training intensity and exercise variation.

Key Words muscle hypertrophy, volume, intensity

Address correspondence to Carlos Ugrinowitsch, ugrinowi@usp.br.

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Introduction

Strength training (ST) has been widely recommended as an effective method to increase muscle strength and mass (12). Regarding the structure of an ST program, a positive relationship between training volume and gains in muscle strength and hypertrophy has been suggested (13,19,23), supporting the concept that training volume should be increased throughout an ST program to maximize its functional and phenotypical adaptations.

Although the relevance of volume increments to maximize ST adaptations is well established, the importance of the loading scheme (i.e., the combination of exercise intensity and volume within a training program) in optimizing the adaptations is still equivocal. Periodized loading schemes are claimed to produce superior gains in strength when compared with nonperiodized (NP) ones (13,15,18,27). However, results are far from uniform. For instance, previous studies demonstrated similar effects between NP, linear periodized, and nonlinear/undulating periodized loading schemes, with no significant differences between groups (2,6).

In addition to the effects on strength gains, skeletal muscle hypertrophy responses to different loading schemes are also controversial. Indeed, previous studies have demonstrated greater increases in fat-free mass and muscle thickness after periodized when compared with NP loading schemes (8,17,21). Although these changes are suggestive of positive alterations in muscle mass, very few studies have directly assessed muscle cross-sectional area (CSA) using a gold-standard method (i.e., magnetic resonance imaging [MRI]), after different ST loading schemes (7,9).

Another important issue is that the American College of Sports Medicine (12) and the National Strength and

Conditioning Association have advocated that changing/including exercises between microcycles can also enhance strength gains. This recommendation is based on cross-sectional surface electromyography and functional MRI data indicating that different exercises aiming to activate the same muscle group (e.g., squat and leg press exercises) may promote distinct motor unit recruitment (5,20,25). Consequently, one may speculate that changing/including exercises for the same muscle group within a training routine would optimize motor unit activation of the target muscle group, thus, maximizing gains in skeletal muscle strength and CSA over a given training period. However, to the best of our knowledge, no study has addressed the effects of exercise variation throughout a training period on skeletal muscle strength and CSA.

Finally, there is paucity of data regarding the chronic effects of combining different loading schemes and exercise variation in the initial phase of ST programs. Addressing this issue is critical to the strength and conditioning professionals, as this is the current training paradigm followed by many of them.

Therefore, the purpose of this study was to investigate the effects of different combinations of training intensities and exercises selection, as well as the combination of both, on muscle strength and CSA. Based on previous findings (10,11,26), we hypothesized that muscle hypertrophy would not be affected by the different loading schemes and exercise variation; however, the differences in motor unit recruitment provided by the exercise variation would produce superior gains in muscle strength. A secondary purpose of this study was to identify if the loading scheme and exercises variation would produce differences in the hypertrophy response of the quadriceps muscle heads.

Methods

Experimental Approach to the Problem

To evaluate the effects of different ST loading schemes, exercises selection and the combination of both on strength and the quadriceps femoris CSA, 4 different ST programs matched for training volume (i.e., sets × repetitions) were designed as follows: constant intensity and constant exercise (CICE), constant intensity and varied exercise (CIVE), varied intensity and constant exercise (VICE), and varied intensity and varied exercise (VIVE). The volume load throughout the 12-week period was progressively increased to simulate the initial phase of the ST periodization in all of the training groups, while maintaining the volume equated between groups.

Maximum dynamic strength test (1 repetition maximum [1RM]), left and right quadriceps femoris CSA, and right vastus lateralis (VL), vastus medialis (VM), vastus intermedius (VI), and rectus femoris (RF) muscles CSA (evaluated by MRI) were assessed at baseline and after 12 weeks of training.

Subjects

Seventy physically active males volunteered for this study. Participants were free from health problems and/or neuromuscular disorders that could affect their ability to complete the training programs. They were not engaged in any form of regular ST for at least 6 months before the study and were asked to refrain from any additional physical training during the experimental period. Initially, participants were classified into quartiles according to their quadriceps muscle CSA (CSA, in square millimeter). Then, participants from each quartile were randomly assigned to one of the 5 groups (the 4 ST groups and the control group). Twenty-one subjects withdrew from the study because of personal reasons (i.e., time-commitment related issues); hence, data from 49 individuals are presented. Descriptive data from the 4 training groups (i.e., CICE, CIVE, VICE, and VIVE) and the control group (C) are presented in Table 1. This study was approved by the Institution's Ethics Committee, and all of the participants were informed of the inherent risks and benefits before signing an informed consent form.

Familiarization

Before the commencement of the study, all of the participants completed 3 familiarization sessions interspersed by at least 72 hours. During the familiarization sessions, participants performed a general warm-up consisting of 5 minutes of running at 9 $km \cdot h^{-1}$ on a treadmill (Movement Technology, Brudden, São Paulo, Brazil) followed by 3 minutes of whole body light stretching exercises. After warming-up, the subjects were familiarized with the squat 1RM testing protocol in a regular Smith Machine (Cybex, Medway, MA, USA). The within-subject variance of the 1RM values was <5% between familiarization sessions 2 and 3. Each participant had his body position and foot placement in the squat exercise 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 participant to keep the bar displacement and knee angle (~90°) constant on each squat repetition. Participants' positioning were recorded during the familiarization sessions and reproduced throughout the testing and training sessions.

Muscle Cross-Sectional Area

Quadriceps CSA was obtained through MRI (Signa LX 9.1; GE Healthcare, Milwaukee, WI, USA). Participants laid down for 20 minutes before the MRI assessment. Then, they were positioned in a supine position with their knees fully extended in the device's bed. A Velcro strap was used to restrain leg movements and allow complete muscle relaxation during image acquisition (Velcro, Manchester, NJ, USA). All of the images were captured from both legs. 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. Cross-sectional area image was acquired at 50% of the segment length in 0.8-cm slices for 3 seconds. The

TABLE 1. Descriptive variables of the groups (mean ± *SD*).*

Variable	C (*n* = 10)	CICE (*n* = 10)	CIVE (*n* = 8)	VICE (*n* = 9)	VIVE (*n* = 12)
Age (y)	26.1 ± 4.3	24.2 ± 4.1	27.1 ± 4.1	22.5 ± 3.8	25.4 ± 3.3
Height (cm)	174 ± 4.6	177 ± 5.9	175 ± 2.2	178 ± 4.3	176 ± 4.2
Body mass (kg)	75.0 ± 4.8	76.0 ± 8.9	76.0 ± 4.7	75.0 ± 7.3	78 ± 7.1
1RM (kg)	111.0 ± 30.4	142.8 ± 24.6	120.0 ± 41.3	136.4 ± 24.4	113.3 ± 32.8
CSA (mm^2)	7,709.3 ± 1,376.8	8,463.9 ± 1,162.3	7,643.5 ± 1,556.3	8,145.5 ± 880.2	8,329.9 ± 1,435.8

*CSA = whole quadriceps cross-sectional area; 1RM = 1 repetition maximum test; CICE = constant intensity and constant exercise; CIVE = constant intensity and varying exercise; VICE = varying intensity and constant exercise; VIVE = varying intensity and varying exercise; C = control groups.

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, 2 signal acquisitions, and reconstruction matrix of 256 × 256. The images were transferred to a workstation (Advantage Workstation 4.3; GE Healthcare) for quadriceps CSA determination. In short, the segment slice was divided into the following components: skeletal muscle, subcutaneous fat tissue, bone, and residual tissue. Then, the CSA of the quadriceps muscle was assessed by computerized planimetry by a blinded researcher (Figure 1). The CSA of the right thigh VL, VM, VI, and RF muscles was also assessed after the same procedures.

Maximum Dynamic Strength Test (1 Repetition Maximum)

At least 72 hours after the last familiarization session, the squat exercise 1RM load was assessed on a conventional Smith machine (Cybex). Testing protocol followed the suggestions proposed by Brown and Weir (1). In brief, subjects ran for 5 minutes at 9 $km \cdot h^{-1}$ on a treadmill (Movement Technology) followed by 5 minutes of whole body light stretching exercises and 2 squat warm-up sets. During the first set, subjects performed 8 repetitions with 50% of the estimated 1RM. In the second set, they performed 3 repetitions with 70% of the estimated 1RM, with a 3-minute interval between them. After the second warm-up set, subjects rested for 3 minutes. Then, they had up to 5 attempts to achieve the 1RM load (i.e., maximum weight that could be lifted once with the proper technique), with a 3-minute interval between attempts. Strong verbal encouragement was given throughout the test.

Strength Training Programs

The subjects performed a 12-week, twice a week, hypertrophy-oriented lower-limb ST program. The loading schemes adopted for each of the 4 training groups are presented in Table 2.

Briefly, the targeted ST intensity was 6–10 maximal repetitions (RM) for all of the exercises performed, and a 2-minute rest was allowed between sets, whereas 3 minutes were respected between exercises. Experimental groups differed regarding the loading scheme and exercise employed. The CICE group performed only the squat exercise with a constant intensity (8RM) throughout the training period, whereas the CIVE group (constant intensity-varied exercise) performed not only the squat, but also the leg press, deadlift, and lunge exercises with 8RM. The VICE group performed only the squat exercise but at an intensity varying between 6 and 10RM throughout the training period. Finally, the VIVE group performed the 4 lower-limb exercises (i.e., squat, leg press, deadlift, and lunge) at intensities ranging from 6 to

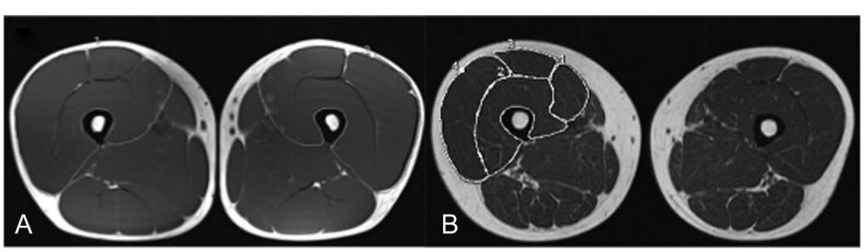

Figure 1. Right and left quadriceps femoris cross-sectional area (A), and vastus lateralis, vastus medialis, vastus intermedius e rectus femoris cross-sectiona area (B).

TABLE 2. Training protocols.*

	CICE	CIVE	VICE	VIVE
Weeks 1–4				
Exercise/volume/intensity	Squat: 4 × 8RM	Squat: 2 × 8RM Leg press: 2 × 8RM	Squat: 2 × 6RM Squat: 2 × 10RM	Squat: 1 × 6RM Squat: 1 × 10RM Squat: 1 × 6RM Leg press: 1 × 10RM
Weeks 5–8				
Exercise/volume/intensity	Squat: 6 × 8RM	Squat: 3 × 8RM Deadlift: 3 × 8RM	Squat: 2 × 6RM Squat: 2 × 8RM Squat: 2 × 10RM	Squat: 1 × 6RM Squat: 1 × 8RM Squat: 1 × 10RM Deadlift: 1 × 6RM Deadlift: 1 × 8RM Deadlift: 1 × 10RM
Weeks 9–12				
Exercise/volume/intensity	Squat: 9 × 8RM	Squat: 3 × 8RM Deadlift: 3 × 8RM Lunge: 3 × 8RM	Squat: 3 × 6RM Squat: 3 × 8RM Squat: 3 × 10RM	Squat: 1 × 6RM Squat: 1 × 8RM Squat: 1 × 10RM Deadlift: 1 × 6RM Deadlift: 1 × 8RM Deadlift: 1 × 10RM Lunge: 1 × 6RM Lunge: 1 × 8RM Lunge: 1 × 10RM

*CICE = constant intensity and constant exercise; CIVE = constant intensity and varying exercise; VICE = varying intensity and constant exercise; VIVE = varying intensity and varying exercise; C = control groups.

10RM. Notably, the training volume was equated across all of the experimental groups (repetitions × sets). The control group (C) did not perform any training during the experimental period.

Statistical Analyses

After normality (i.e., Shapiro-Wilk) and variance assurance (i.e., Levene), a mixed model was performed for the whole quadriceps muscle and each of its heads (i.e., VL, VM, VI, and RF) CSA, assuming group (CICE, CIVE, VICE, VIVE, 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 Tukey's adjustment was performed for multiple comparison purposes (24). The significance level was set at $p \leq 0.05$. A high variability in the between-groups pretest maximum dynamic strength values was identified because of the high number of dropouts. These dropouts unbalanced the initial equalization of maximum strength values, producing significant differences in the squat 1RM values between groups (i.e., 1-way analysis of variance; $p \leq 0.05$). Thus, a mixed model assuming groups as a fixed factor, subjects as a random factor, pretest initial 1RM values as a covariate, and individuals' delta change (%) as dependent

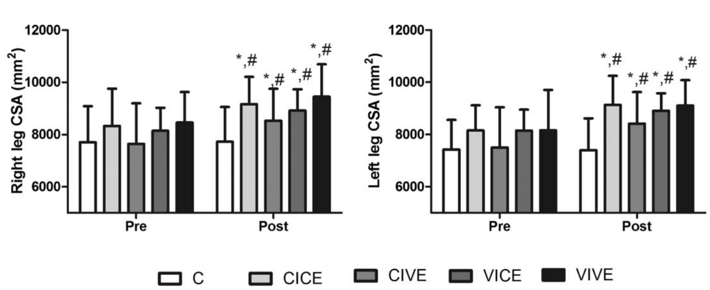

Figure 2. Left and right quadriceps femoris cross-sectional area, pretrianing and posttraining. CICE = constant intensity and constant exercise; CIVE = constant intensity and varied exercise; VICE = varied intensity and constant exercise; VIVE = varied intensity and varied exercise; and C = control groups. *Posttraining CSA values greater than pretraining values ($p \leq 0.05$); #Training groups CSA values greater than the control group at the posttraining assessment ($p \leq 0.05$).

TABLE 3. Vastus lateralis, VM, VI, and RF cross-sectional area (in square millimeter) for the C, CICE, CIVE, VICE, and VIVE groups, pretraining and posttraining.*

		VL	VM	VI	RF
C	Pre	2,855 ± 474	1,070 ± 159	2,988 ± 501	886 ± 268
	Post	2,857 ± 465	1,064 ± 200	3,016 ± 456	855 ± 222
CICE	Pre	3,212 ± 648	1,221 ± 201	3,472 ± 413	1,020 ± 174
	Post	3,514 ± 636†	1,318 ± 154	37,738 ± 468†	1,090 ± 180
CIVE	Pre	2,964 ± 452	1,090 ± 198	3,059 ± 588	1,012 ± 249
	Post	3,312 ± 473†	1,269 ± 282†	3,353 ± 456†	1,096 ± 263†
VICE	Pre	3,040 ± 393	1,217 ± 299	3,358 ± 612	959 ± 120
	Post	3,245 ± 405†	1,371 ± 278†	3,632 ± 534†	1,026 ± 112
VIVE	Pre	3,156 ± 536	1,166 ± 162	3,410 ± 486	1,018 ± 288
	Post	3,428 ± 517†	1,345 ± 206†	3,639 ± 504†	1,085 ± 318†

*VL = vastus lateralis; VM = vastus medialis; VI = vastus intermedius; and RF = rectus femoris; C = control; CICE = constant exercise-constant intensity; CIVE = constant intensity-varied exercise; VICE = varied intensity-constant exercise; VIVE = varied intensity-varied exercise.

†Posttraining values greater than pretraining values ($p \leq 0.05$).

variable was used. This analysis was performed to adjust individual delta change values to the covariate (i.e., pretest values). Then, the estimated mean and *SD* delta changes (i.e., adjusted by the covariate) from each group were used to calculate effect sizes and not for hypothesis test purposes. Several authors have suggested the use of effect sizes for within- and between-groups comparisons, as they do not give a dichotomic answer (i.e., significant or not significant) and are able to deal with highly variable data (16). Thus, effect size confidence intervals of the differences (ES_{CLdiff}) were calculated using a noncentral t distribution to perform within- and between-groups comparisons. Positive and negative confidence intervals (i.e., did not cross zero) were considered as significant. Results are expressed as mean ± *SD*.

RESULTS

Whole Quadriceps Muscle Cross-Sectional Area

The quadriceps muscle CSA increased significantly in all of the experimental groups from pretest to posttest in both the right and left legs: CICE: 11.6 and 12.0% ($p < 0.0001$); CIVE: 11.6 and 12.2% ($p < 0.0001$); VICE: 9.5 e 9.3% ($p < 0.0001$), and VIVE: 9.9 and 11.6% ($p < 0.0001$), respectively. Between-group comparisons revealed that all of the experimental groups increased quadriceps CSA when compared with the C group ($p \leq 0.02$), but they were not different from each other at the posttest ($p > 0.05$). There were no differences in muscle CSA for the C group after training ($p > 0.05$) (Figure 2).

Quadriceps Muscle Heads Cross-Sectional Area

The groups that varied exercises (i.e., CIVE and VIVE) in the training program presented hypertrophy in all of the quadriceps muscle heads ($p \leq 0.05$). The CICE group did not presented hypertrophy in the VM muscle ($p = 0.29$) and in the RF muscle ($p = 0.058$), and the VICE showed no hypertrophy in the RF muscle ($p = 0.12$) (Table 3).

Maximum Dynamic Strength (1 Repetition Maximum)

All of the experimental groups had significant increases in squat exercise 1RM when compared with the C group (ES_{CLdiff} CICE: 3.46–3.53; CIVE: 3.49–3.63; VICE: 2.16–2.23; and VIVE: 3.00–3.11). The CICE group had greater increments in maximum strength than the VICE group (ES_{CLdiff} 1.17–1.26). The training protocol with the highest variability (VIVE group) was more efficient in increasing maximum strength than the training protocol with the lowest variability (CICE group) (ES_{CLdiff} 0.73–0.84) and the one that only varied the intensity (VICE) (ES_{CLdiff} 1.55–1.61).

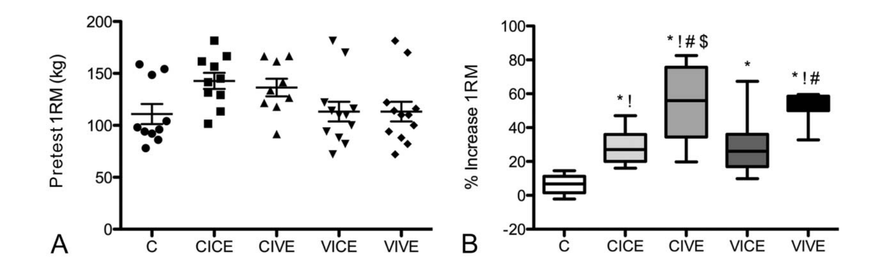

Figure 3. Individual squat exercise 1RM values at the pretraining assessment (A) and boxplot of the percentage change in squat exercise 1RM values from the pretraining to the posttraining assessment (B). CICE = constant intensity and constant exercise; CIVE = constant intensity and varying exercise; VICE = varying intensity and constant exercise; VIVE = varying intensity and varying exercise; and C = control groups. *Significant effect size of the difference in the squat exercise 1RM values when compared with the control group ($p \leq 0.05$). !Significantly greater effect size of the difference when compared with the VICE group ($p \leq 0.05$). #Significantly greater effect size of the difference when compared with the CICE group ($p \leq 0.05$). $Significantly greater effect size of the difference when compared with the VIVE group ($p \leq 0.05$).

The training protocol that varied the exercises but not the intensity (CIVE) was the most efficient in increasing maximum strength among all of the training groups (ES_{CLdiff} CICE: 1.41–1.56; VICE: 2.13–2.28; VIVE: 0.59–0.75). Figure 3 displays pretest squat 1RM values (Panel A) and the delta change (%) 1RM values from pretraining to posttraining (Panel B).

Discussion

The purpose of this study was to investigate the effects of different combinations of training intensities and exercises selection, as well as the combination of both, on muscle strength and CSA, while matching groups for training volume, on muscle hypertrophy and strength. The novel finding of this study is that varying exercises along the experimental period produces greater strength gains than variations in training intensity. Furthermore, it seems that varying training intensity and exercises, simultaneously, cannot be an appropriate strategy to increase maximum strength for physically active individuals. Finally, groups that varied exercises in the training program presented a more homogeneous hypertrophy among the quadriceps muscles (i.e., VL, VM, VI, and RF).

Our study demonstrated that regardless of the variation in intensity and exercise selection, the quadriceps CSA increased significantly and similarly in all of the experimental groups from pretest to posttest (increments ranged from 9.3 to 12.2%). In this regard, it seems that when training volume is equated between groups (i.e., sets × repetitions), and the intensity varies between 6 and 10RM, similar CSA gains are achieved regardless of the exercise variations. With respect to the ST intensity, recent findings have suggested that intensity variation might not be critical to induce muscle hypertrophy (7,14). For instance, Mitchell et al. (14) demonstrated that ST regimens in which participants had their legs assigned to either a 30 or an 80% 1RM exercise until failure produced similar CSA gains (e.g., 6.8 and 7.2%, respectively), after 10 weeks of training. In addition, other studies have demonstrated that varying the intensity between 3 and 15RM over 12 weeks of ST produced similar protein accretion between groups (21). Accordingly, training loads between 3 and 11RM over 8 weeks of training also resulted in similar muscle fiber CSA increments (3). Collectively, these findings suggest that variations in the training intensity do not seem to be critical to magnify muscle hypertrophic responses. Our data also do not support the hypothesis that exercise variations are determinant to muscle mass accretion, as the groups that varied exercises had similar gains in muscle CSA than the ones that just used a single exercise (i.e., squat). Thus, the findings of this study indicate that as long as the training load is sufficient to activate the protein synthesis machinery, muscle hypertrophy should occur independently of the changes in exercise throughout the training period.

Interestingly, the groups that varied exercises throughout the training program had hypertrophy among all of the quadriceps muscle heads. However, the group that varied neither the intensity nor the exercises (i.e., CICE) had no significant hypertrophy in the VM and RF muscles. The group that varied only the intensity (i.e., VICE) did not present hypertrophy in the RF muscle. Thus, it seems that different exercises are able to selectively activate the heads of a muscle group, such as the quadriceps femoris. Importantly, the differences between groups in the hypertrophy of the quadriceps muscle heads did not seem to affect the whole muscle hypertrophy, as the groups' responses were very alike.

Despite the significant increases in squat 1RM in all of the experimental groups (increments ranging from 23.1 to 53%), our findings do not completely support the hypothesis that variations in training intensity and exercises are more efficient to increase muscle strength. The training regimen in which the intensity was constant and the exercises were varied (i.e., CIVE) demonstrated greater strength gains when compared with those groups that did not vary the exercise selection (i.e., VICE and CICE), and the one that varied both exercises and training intensities (i.e., VIVE), over the 12-week training period. However, the group that varied both the training intensity and exercise selection (i.e., VIVE) demonstrated greater gains than the group that only varied exercise intensity (i.e., VICE) and the 1 with neither intensity nor exercise variation (i.e., CICE), emphasizing the importance of exercise variation in producing strength gains. Furthermore, variations in training intensity do not seem to be very effective in increasing strength as the CICE had greater increments in this variable than the VICE.

These findings may be due to the fact that both the criterion strength exercise and the exercises that were varied throughout the 12-week training period were all multijoint exercises (e.g., squat, leg press, deadlift, and lunge). It has been proposed that multijoint exercises require more complex neural responses than single-joint ones (4). Thus, the use of multijoint exercises might be an important component to optimize the neural drive to the active muscles maximizing strength gains. In addition, our data suggest that combining intensity and exercise variations in the same training program does not increase the efficacy of the ST in maximizing strength gains (i.e., VIVE) in physically active individuals. It may be speculated that the ability of previously untrained individuals to control several degrees of freedom in motor unit recruitment during the VIVE condition did not allow optimizing the neural drive and, thus, muscle force production capacity. It has been previously suggested that different intensities require the activation of distinct pools of motor units (20). However, fixing the exercise intensity reduces the degree of freedom in motor unit activation allowing individuals to optimize the movement pattern of the exercises performed and, therefore, the muscle force production capacity (22).

In summary, our data suggest that constant intensity training with varied exercises (CIVE) is more efficient to produce strength gains for physically active individuals. Furthermore, as long as the training intensity reaches an alleged threshold, whole muscle hypertrophy is similar regardless of the loading scheme and exercise variation. However, if a more homogeneous muscle hypertrophy response is required among the heads of multipennate muscles, varying exercises within the training routine seems to be more efficient than using just 1 exercise. Finally, it has to be tested if highly trained individuals would be able to handle a high degree of training variations (i.e., intensity and exercises) and achieve greater strength gains when compared with a program that only varies the exercises.

Practical Applications

Strength coaches usually vary the training intensity and exercises in an ST program. Our findings suggest that variations in training intensity are not critical to produce strength and muscle hypertrophy gains in the initial phase of an ST program. Varying exercises during this phase seem to be more important to maximize the neural drive and, therefore, the functional adaptations. In addition, exercise variation seems to produce a more complete muscle activation hypertrophying all of the heads of multipennate muscles.

Acknowledgments

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