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Research in Sports Medicine
An International Journal

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/gspm20

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RESEARCH IN SPORTS MEDICINE
https://doi.org/10.1080/15438627.2020.1853546

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Is stronger better? Influence of a strength phase followed by a hypertrophy phase on muscular adaptations in resistance-trained men

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ABSTRACT

Although used by resistance-trained individuals, it is unknown if increasing muscle strength prior to hypertrophy training leads to greater muscle growth and strength gains. We investigated muscle thickness and maximum strength in 26 resistance-trained men who were randomly assigned to either: STHT, consisted in a 3-week strength-oriented training period (4x1-3 repetition maximum [RM]) prior to a 5-week hypertrophy-oriented period (4x8-12RM), or HT, which comprised an 8-week hypertrophy-oriented training period. *Vastus lateralis* muscle thickness, and back squat and leg-press 1-RM were assessed at pre, third week, and after 8 weeks of training. When pre-to-post changes are compared, STHT induced greater muscle growth ($p = 0.049$; 95%CI = 0.15–3.2%; $d = 0.81$) and strength gains in the back squat ($p = 0.015$; 95%CI = 1.5–13%; $d = 1.05$) and leg-press 45° ($p = 0.044$; 95%CI = 0.16–9.9%; $d = 0.79$) compared to HT. Our results support the use of a period to increase muscle strength prior to an HT to increase muscle thickness and maximum strength in resistance-trained men.

ARTICLE HISTORY
Received 17 June 2020
Accepted 6 October 2020

KEYWORDS
Muscle hypertrophy; maximal strength; volume load; resistance training

Introduction

Recent findings indicate that hypertrophy-oriented training with a wide range of loads performed to failure elicits similar muscle growth (Counts et al., 2016; Fink, Kikuchi, & Nakazato, 2018; Fink, Kikuchi, Yoshida, 2016; Jenkins et al., 2016; Lasevicius et al., 2019; Morton et al., 2016; Schoenfeld et al., 2015). However, when volume load (sets x reps x weight) is equalized, protocols with higher loads may induce greater muscle growth and strength gains than those with lower loads (Holm et al., 2008). For instance, Campos et al. (2002) compared the effects of three resistance training protocols with similar volume loads (i.e., 4 × 3–5 repetition maximum [RM] vs. 3 x 9–11RM vs. 2 x 20–28RM) on muscle fibre hypertrophy and strength. After 8 weeks of training, a hypertrophic effect was observed only for the protocols with higher loads (i.e., 4 x 3–5RM and 3 x 9–11RM), whereas no significant muscle growth was observed in the low load regimen (i.e., 2 x 20–28RM). Concerning maximum strength, while all groups increased 1-RM, the heavier

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protocols induced a greater 1-RM improvement. Additionally, Lasevicius et al. (2018) observed that when low- (i.e., 20% of 1-RM) and high-load (i.e., 80% of 1-RM) resistance training are matched for volume load, high-load was superior for inducing muscle growth and strength compared to low-load.

It has been suggested that several factors can stimulate muscle growth and that mechanical tension plays an important role in mediating hypertrophy adaptations (Rindom et al., 2019; Tidball, 2005; Zanchi & Lancha, 2008). The mechanical stress on each muscle fibre exerts regulatory actions on mechanisms involved in adaptations to resistance training and plays some role as a key driving factor to enhance muscle growth (Tidball, 2005). Then, one should consider increasing maximal strength prior to a hypertrophy-oriented resistance training period, especially in resistance-trained men who have a smaller window for adaptation (Ahtiainen et al., 2003). It is conceivable that the use of a strength-oriented training, which may be characterized by near maximal loads (e.g., >90% of 1-RM) and few repetitions (e.g., 1–4 repetitions) (Dankel et al., 2017; Schoenfeld et al., 2016), increases maximal strength and allows practitioners to use heavier absolute loads during the later hypertrophy-oriented training, augmenting mechanical stress in each active muscle fibre (Rindom et al., 2019).

The use of strength-oriented training period prior to a hypertrophy-oriented training period is commonly used by resistance-trained men; however, to the best of authors' knowledge, no study investigated the effects of increasing muscle strength prior to hypertrophy training on muscle growth and strength gains. Therefore, the aim of this study is to investigate changes in muscle thickness and maximum strength of a strength-oriented training period prior to a hypertrophy-oriented training period compared with hypertrophy-oriented training period in resistance-trained men. We hypothesized that the increasing muscle strength prior to hypertrophy training may allow practitioners to use heavier absolute loads during the later hypertrophy-oriented training, induced greater muscle growth and strength gains.

Materials and methods

Participants

Thirty-eight resistance-trained men volunteered for this study, but due to personal reasons unrelated to the study, 12 did not complete all the procedures and data for the remaining 26 are presented. Participants were matched in pairs according to baseline *vastus lateralis* muscle thickness, and then randomly assigned to one of the two experimental groups: hypertrophy-oriented training period (HT) (n = 11; 23 ± 3 years, 76 ± 7 kg, 178 ± 7 cm, 4 ± 3 years of experience) and strength-oriented training period and hypertrophy-oriented training period (STHT) (n = 15; 23 ± 4 years, 76 ± 8 kg, 176 ± 5 cm, 5 ± 3 years of experience). All of them were free from cardiovascular and muscular disorders and they should had relative strength in the back squat (1-RM/body mass) >1.5 kg/kg of body mass. All participants were instructed to avoid the consumption of alcohol and tobacco prior to the tests, and not to perform strenuous exercise 72-h prior to the tests. During the study, participants were strictly instructed to maintain their normal dietary habits. All participants were informed about the procedures, benefits, discomforts and possible risks of the study and signed a free and informed consent before participation. The University's Research Ethics Committee approved the experimental protocol.

Study design

This was a balanced (using *vastus lateralis* muscle thickness) and randomized, parallel-group repeated-measures design, which investigated the effects of increasing muscle strength before a hypertrophy-oriented programme on muscle thickness and maximum strength in resistance-trained males. Before the beginning of the experimental period, all the participants were asked to perform the same lower limb training routine for 3 weeks. Thereafter, participants performed two familiarization sessions with the 1-RM test interspersed by at least 72 h. *Vastus lateralis* muscle thickness, back squat and leg-press 45° 1-RM were assessed at least 72 h after the familiarization sessions. If the difference between the loads lifted in the familiarization sessions and in the testing session was greater than 5%, a second testing session was performed. After muscle thickness assessment, participants were matched in pairs and assigned to one of the two groups: one of them consisted of a 3-week strength-oriented training period prior to a 5-week hypertrophy-oriented period, while the other group comprised 8-week hypertrophy-oriented training period Training sessions were performed twice a week for 8-weeks. Additionally, muscle thickness and 1-RM were assessed after the third week and at the end of the study. A 72-h interval after the last training session was adopted to measure muscle thickness and 1-RM. Volume load (i.e., sets x repetitions x load) was monitored but not balanced between groups.

Muscle thickness

Ultrasonography (Nanomaxx, Sonosite®, Bothell, USA) was used to determine the thickness of the *vastus lateralis* using a linear array probe with a frequency of 5–10 MHz. Muscle thickness was assessed at 60% of the distance between the greater trochanter of the femur and lateral epicondyle of the knee. Before the commencement of the experimental protocol, these specific sites were marked with a semi-permanent marker and participants were instructed to keep their mark throughout the duration of the study to maintain consistency of measurement site. To obtain the images, subjects laid supine with their legs fully extended and their muscles relaxed for a period of 10 min. A water-soluble gel was applied to the transducer to aid acoustic coupling and remove the need to contact the skin; eliminating deformation of the tissues underneath the probe. Scans were performed on the dominant leg with the transducer parallel-oriented to the skin. The same blinded investigator performed all of the ultrasound assessments. The image was saved for later analysis of muscle thickness by measuring the distance between the muscle–fat and muscle–aponeurosis interface using ImageJ© software (ImageJ v. 1.43, National Institute of Health, Bethesda, USA). Three images were taken and measured three times each. The average was retained for latter analysis. Muscle thickness was assessed at least 72 h after the familiarization sessions, after the 6th session (i.e., 3 weeks) and after the 16th session (i.e., 8 weeks). Before the beginning of the experimental period, muscle thickness was assessed in two days for measures of reproducibility and the typical error and the coefficient of variation (CV) in our study were 0.01 cm and 0.7%, respectively.

Maximal dynamic strength (1-RM)

Maximal dynamic strength for back squat and leg press 45° exercises was obtained following the procedures recommended by American Society of Exercise Physiologists (Brown & Weir, 2001). Participants performed a 5-min general warm-up of cycling in a cycle ergometer with a low-load, followed by 3 minutes of light stretching of the lower limbs. After that, they performed a specific warm-up consisting of one set of eight repetitions at approximately 50% of 1-RM with 1-min rest and one set of three repetitions at approximately 70% of 1-RM. Both loads were estimated based on the familiarization sessions. Three minutes after the specific warm-up, participants had up to five attempts to achieve their 1-RM (i.e. maximum load that could be lifted once in a complete cycle of the exercise). A complete cycle was deemed successful if the participant flexed their knees (110º) starting from 0° (full extension) and returned to the starting position in a controlled manner in both exercises. There was a 5-min interval between exercises. The 1-RM was assessed before, after 3-weeks and at the end of the study (8-weeks). A 72-h rest minimal interval after the training session was adopted to perform the 1-RM test. Participants were considered acquainted to 1-RM testing procedures if the difference between the familiarization and testing sessions was lower than 5%.

Training protocols

Before the beginning of the experimental period, all the participants were asked to perform the same lower limb (i.e., back squat and leg press 45°) training routine (i.e., 4 × 8–12 RM) twice a week for 3 weeks. This training period was not supervised and aimed at standardizing training volume. Thereafter, training protocols (HT and STHT) were performed twice a week for 8 weeks. Both groups performed the back squat and the leg press 45°, in that order, with 5 min rest interval between exercises. Before training sessions, participants warmed-up with one set of eight repetitions at 50% of 1-RM and one set of three repetitions at 70% of 1-RM in back squat, with 1-min rest. HT performed four sets of 8–12RM, with 1-min rest interval between sets throughout the training period. Training load was adjusted if participant performed more than 12 repetitions or less than 8 repetitions. STHT was divided into two phases, the first phase (weeks 1–3) was maximal strength-oriented with four sets of 1–3RM and 3-min rest interval between sets; in the second phase (weeks 4–8) participants performed the same training protocol as HT. Concentric failure was established as inability to complete two repetitions in a full range of motion (i.e., flex their knee [110º] starting from full extension [0º] and return to the starting position). Both load and number of repetitions for each set were recorded for calculation of volume load.

Statistical analysis

Data were visually inspected for the existence of outliers (box-plots) and tested for normality (Shapiro-Wilk), and are presented as mean, standard deviation (SD), 95% confidence intervals of the difference (95%CI) and pre-to-post changes (Δ%). For measures of reproducibility, test-retest for muscle thickness employed the typical error and CV. Normality was verified with Shapiro-Wilk test. Two-way repeated measure ANOVA was used to analyse muscle thickness, 1-RM and mean of absolute load of all sets in each exercise in the periods of 1–3 weeks and 4–8 weeks. When a significant F value was found, Bonferroni's multiple comparisons test was used for multiple comparisons purpose. Independent t-test was used to compare pre-to-post percentage changes in muscle thickness, 1-RM and total volume load. Significance level was set at $p \leq 0.05$. Also, eta-squared ($\eta 2$) was calculated according to Cohen (1973) for calculating an effect size for multiple comparison and Cohen's d was calculated for difference between two means (Cohen, 2013). The qualitative descriptors for the eta-squared with ratios of 0.02, 0.13 and 0.26 indicating small, moderate and large changes, respectively (Cohen, 1988) and for the Cohen's d was classified according to Rhea (2004) for trained individuals: trivial (<0.25), small (0.25 to 0.50), moderate (>0.50 to 1.0) and large effects (>1.0).

Results

There was a difference in total volume load between groups in the back squat (HT = 46,809 ± 9,695 Kg; STHT = 36,589 ± 10,844 Kg; p = 0.004; 95% CI = 4,700–21,710 kg; d = 1.0) and leg press 45° (HT = 146,659 ± 31,534 Kg; STHT = 109,330 ± 25,601 Kg; p = 0.001; 95% CI = 17,885–64,133 kg; d = 1.3).

When comparing the mean absolute load between groups in the same period, the absolute load was higher in STHT protocol in the 1–3 weeks in the back squat (95% CI = 21–58 kg; d = 2.2) and leg press 45° (95% CI = 50 − 152 kg; d = 2.0) compared to HT protocol, but there was no difference between groups in 4–8 weeks in the back squat (95% CI = −5.3–32 kg; d = 0.8) and leg press 45° (95% CI = −8.3–93 kg; d = 0.9). Mean data are presented in Table 1. Muscle thickness and 1-RM were not different between protocols at baseline. For the differences between pre-to-post percentage changes between groups, the STHT protocol induced higher muscle growth than the HT protocol (p = 0.049; 95% CI = 0.15–3.2%; d = 0.81). When analysing percentage differences between pre- to post-test values in 1-RM test, strength gains in the back squat (p = 0.015; 95% CI = 1.5–13%; d = 1.05) and leg press 45° (p = 0.044; 95% CI = 0.16–9.9%; d = 0.79) were larger in STHT compared with HT protocol. Mean data are presented in Table 2 and individual pre-to-post percentage changes are presented in Figure 1.

Table 1. Mean and SD of absolute load of all sets in each exercise in the periods of 1–3 weeks and 4–8 weeks.

	Back Squat (kg)		Leg Press 45° (kg)	
	HT	STHT	HT	STHT
1–3 Week	76 ± 13	116 ± 23*	249 ± 36	351 ± 70*
	Post-Hoc; p < 0.001		*Post-Hoc*; p < 0.001	
4–8 Week	81 ± 14#	95 ± 22 #	258 ± 43 #	301 ± 54#
	Post-Hoc; p = 0.212		*Post-Hoc*; p = 0.120	
ES	η2 = 0.041		η2 = 0.035	
Group effect	p = 0.003		p = 0.003	
Time effect	p < 0.001		p < 0.001	
Interaction	p < 0.001		p < 0.001	

*p ≤ 0.05 compared to HT. #p ≤ 0.05 compared to 1–3 week period. HT = hypertrophy-oriented training protocol; STHT = strength-oriented training and hypertrophy-oriented training protocol; ES = effect size.

Table 2. *Vastus lateralis* muscle thickness (mm, Mean ± SD) and 1-RM values (kg, Mean ± SD) values at pre, 3 weeks and post 8 weeks of training in each protocol.

	Muscle Thickness (mm)		Back Squat (kg)		Leg Press 45° (kg)	
	HT	STHT	HT	STHT	HT	STHT
Pre	22.8 ± 2.0	22.6 ± 2.8	117 ± 15	116 ± 25	357 ± 58	357 ± 71
3-Weeks	23.4 ± 2.2*	22.8 ± 2.9*	121 ± 16*	132 ± 28*	367 ± 62*	386 ± 68*
Post	23.8 ± 2.0*	24.0 ± 2.9*	133 ± 14*	140 ± 29*	391 ± 66*	408 ± 76*
ES	$\eta 2 = 0.061$		$\eta 2 = 0.18$		$\eta 2 = 0.09$	
Group effect	$p = 0.870$		$p = 0.529$		$p = 0.649$	
Time effect	$p < 0.001$		$p < 0.001$		$p < 0.001$	
Interaction	$p = 0.003$		$p = 0.001$		$p = 0.011$	

*$p < 0.05$ compared to pre-test value. HT = hypertrophy-oriented training protocol; STHT = strength-oriented training and hypertrophy-oriented training protocol; ES = effect size.

Discussion

The aim of this study was to investigate changes in muscle thickness and strength of a strength-oriented training period prior to a hypertrophy-oriented training period compared with only hypertrophy-oriented training period in resistance-trained men. *Vastus lateralis* muscle thickness and maximum strength increased in both groups. However, when we analysed the pre- to post-delta changes, STHT induced greater muscle growth and strength gains than HT. It is noteworthy to mention that STHT group trained with a significant lower volume load than HT group.

STHT increased muscle strength in back squat and leg press 45° to a greater extent than HT. Our findings are in line with those of Mangine et al. (2015), who observed greater strength gains after a strength-oriented training protocol compared to a hypertrophy-oriented training in resistance-trained men. However, it contradicts those of Mattocks et al. (2017), who reported similar strength gains after strength-oriented (i.e., 5 sets of 1-RM) and hypertrophy-oriented training protocols (i.e., 4 sets of 8–12RM) in untrained participants. We believe equivocal results are a consequence of participant's training status, as naïve individuals respond similarly (e.g., increase in muscle mass and strength) to different stimuli (Mitchell et al., 2012; Ogasawara et al., 2013). As training progresses, the window of adaptation diminishes, and training loads should be higher to increase muscle strength (American College of Sports, M, 2009; Toigo & Boutellier, 2006). In addition, it should be considered that high-load training with loads close to the test can favour specific adaptations (e.g., neural adaptations) to increase performance. Therefore, according to the principle of specificity, it resembles the test's demands to a larger extent (Aagaard et al., 1996; Cronin et al., 2001) and induces larger increases in maximal strength. However, it is worth mentioning that the strength-oriented training was used five weeks before the final 1-RM testing and our findings cannot be explained by the principle of specificity. The initial strength-oriented period possibly increased participants' ability to activate exercising muscle (Fisher et al., 2017; Jenkins et al., 2016), which may have been carried throughout the next five-week period leading to greater strength gains.

Muscle thickness increased more in STHT than in HT protocol. The increase in muscle thickness observed in the HT group corroborates with the study of Zaroni et al. (2018), which found a ~ 5% increase in *vastus lateralis* muscle thickness in resistance-trained men after 8 weeks of hypertrophy-oriented training. Even though differences between protocols on absolute loads during the 4-8-week period were non-significant, effect size

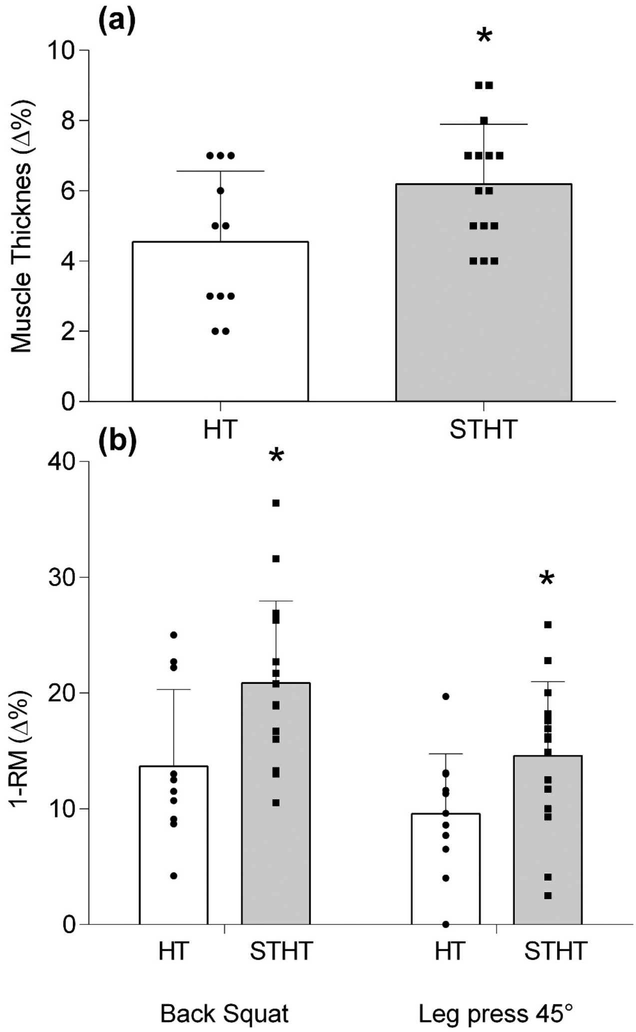

Figure 1. Individual (circles and squares) and mean (± SD) of pre to post delta changes (Δ%) in muscle thickness (Figure 1(a)) and 1-RM (Figure 1(b)) in the back squat and leg press 45° for HT and STHT. *p ≤ 0.05 compared to HT. HT = hypertrophy-oriented training protocol; STHT = strength-oriented training and hypertrophy-oriented training protocol.

between weights lifted by both groups was moderate in the back squat (d = 0.8) and in the leg-press 45° (d = 0.9) favouring STHT. It is has been reported that mechanical load-induced signals are one of the most widely recognized regulators on mechanisms involved in enhanced muscle growth during resistance training (Jorgenson et al., 2020). Possibly heavier loads augment mechanical stress and muscle activation (Gonzalez et al., 2017; Rindom et al., 2019), mainly of type II fibres, which have greater growth capacity (Van Wessel et al., 2010). Thus, our data suggest that strength-oriented training phase allowed participants to lift heavier loads during the hypertrophy-oriented training period increasing mechanical tension that ultimately led to a greater hypertrophic adaptation.

Interestingly, despite the greater muscle growth observed in the STHT group, volume load was lower in STHT in both exercises compared to the HT. These results are contrary to those of Schoenfeld et al. (2017) and Radaelli et al. (2015), where a dose-response relationship between weekly training sets and muscle growth was observed. Higher training volume load may increase both the magnitude and duration of protein synthesis (Burd et al., 2010). However, our results are in agreement with Aube et al. (2020) who compared different weekly training sets (i.e., 12, 18 and 24 sets) in resistance-trained men and did not report any relationship between weekly training sets and muscle growth. Also, Ostrowski et al. (1997) did not observe any difference between different weekly training sets (i.e., 3, 6 and 12 sets) in resistance-trained men. Although these studies analysed weekly sets, only Aube et al. (2020) reported the volume load, they demonstrated that a 194,000 kg difference in volume load between 24 and 12 sets groups did not produce any differences in hypertrophic adaptations. Nevertheless, in the current study the sets for both groups were equivalent, and the disparity was due to the repetitions and load. It is our understanding that it is not well established whether muscle hypertrophy is volume load-dependent in resistance-trained individuals when the load varies over a training period.

This study is not without limitations. The protocols were performed only in lower limbs, which may limit extrapolation to other muscle groups such as upper limbs and trunk. These results were observed in resistance-trained men, and generalization to other populations, such as adolescents, women and elderly, should be made with caution. It is suggested that participants' diet may contribute to changes in muscle size (Sahni et al., 2015). In the present study, we did not control individuals' diets. However, controlling dietary intake seems to have little influence on muscle hypertrophy in healthy individuals, as a recent review indicated that self-reported dietary habits did not differ between low- and high-responders to muscle hypertrophy (Roberts et al., 2018). Moreover, we did not investigate molecular responses to the different training regimens and future research is required to assess the effects of modifying training stimulus on the proteins associated with anabolic signalling pathway in resistance-trained individuals.

In summary, personal trainers, strength and conditioning coaches and practitioners should consider including a short period of low-volume high-load strength-oriented training prior to a hypertrophy-oriented training period to enhance muscle growth and strength gains in trained individuals.

Acknowledgments

The authors would like to thank the participants in this investigation for their time, effort, and support. The authors are grateful to Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP (2014/20369-1) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES (2018/23-p4748).

Disclosure statement

The authors reported no potential conflict of interest.

Funding

This work was supported by the Fundação de Amparo à Pesquisa do Estado de São Paulo-FAPESP under Grant 2014/20369-1; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES under Grant 2018/23-p4748.

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