Time Course of Resistance Training–Induced Muscle Hypertrophy in the Elderly

Manoel E. Lixandrão,[1,2] Felipe Damas,[2] Mara P.T. Chacon-Mikahil,[1] Claudia R. Cavaglieri,[1] Carlos Ugrinowitsch,[2] Martim Bottaro,[3] Felipe C. Vechin,[2] Miguel S. Conceição,[1] Ricardo Berton,[1] and Cleiton A. Libardi[1,2,4]

[1]*Faculty of Physical Education, University of Campinas, Campinas, Sao Paulo, Brazil;* [2]*School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil;* [3]*College of Physical Education, University of Brasilia, Brasilia, Brazil; and* [4]*Department of Physical Education, Center of Biological and Health Sciences, Federal University of Sao Carlos, Sao Carlos, Sao Paulo, Brazil*

Abstract

Lixandrão, ME, Damas, F, Chacon-Mikahil, MPT, Cavaglieri, CR, Ugrinowitsch, C, Bottaro, M, Vechin, FC, Conceição, MS, Berton, R, and Libardi, CA. Time course of resistance training–induced muscle hypertrophy in the elderly. *J Strength Cond Res* 30(1): 159–163, 2016—Extended periods of resistance training (RT) induce muscle hypertrophy. Nevertheless, to date, no study has investigated the time window necessary to observe significant changes in muscle cross-sectional area (CSA) in older adults. Therefore, this study investigated the time course of muscle hypertrophy after 10 weeks (20 sessions) of RT in the elderly. Fourteen healthy older subjects were randomly allocated in either the RT (*n*: 6) or control group (*n*: 8). The RT was composed of 4 sets × 10 repetitions (70–80% 1 repetition maximum [1RM]) in a leg press machine. The time course of vastus lateralis muscle hypertrophy (CSA) was assessed on a weekly basis by mode-B ultrasonography. Leg press muscle strength was assessed by dynamic 1RM test. Our results demonstrated that the RT group increased leg press 1RM by 42% ($p \le 0.05$) after 10 weeks of training. Significant increases in vastus lateralis muscle CSA were observed only after 18 sessions of training (9 weeks; $p \le 0.05$; 7.1%). In conclusion, our training protocol promoted muscle mass accrual in older subjects, and this was only observable after 18 sessions of RT (9 weeks).

Key Words ultrasonography, cross-sectional area, vastus lateralis muscle

Introduction

Acute resistance training (RT) stimulus associated with adequate provision of amino acids leads to periods of positive net protein balance (15), that is, greater muscle protein synthesis than breakdown (13,16). Chronically, periods of positive net protein balance promote muscle mass accrual, which is assessed by increases in muscle cross-sectional area (CSA) (9,25).

Several studies have shown muscle mass accrual after chronic periods of RT (11,14,23,24), although there are limited data regarding the time window necessary to detect significant muscle hypertrophy (6,19). For instance, a time-course study from DeFreitas et al. (6) observed thigh muscle CSA augments (i.e., ~7%) after only 3–4 weeks (9–12 sessions) of RT in young subjects. Similar increases in quadriceps muscle CSA (i.e., ~6%) were observed in young subjects after only 3 weeks (~9 session) of flywheel-based RT (19). However, it is important to highlight that the time course of muscle hypertrophy has only been analyzed in young individuals. Thus, it is difficult to generalize these results to different populations such as the elderly.

Previous data have demonstrated an RT anabolic resistance in older individuals (10). Specifically, older individuals presented lower muscle protein synthesis response compared with younger ones, after a relative load-matched RT session (10). As increases in muscle protein synthesis are crucial to muscle hypertrophy, this results suggests that older subjects may present impairments or delays in muscle hypertrophic response to RT. Understanding the time course of muscle hypertrophy in the elderly is necessary, because muscle mass is an important component of the muscle force production capacity, which is critical for independency and healthy maintenance of this population (7).

To the best of our knowledge, no study has investigated the time course of muscle hypertrophy in older individuals. Therefore, the aim of this study was to investigate the time course of the vastus lateralis muscle CSA hypertrophic response during 10 weeks of RT in the elderly.

Address correspondence to Dr. Cleiton A. Libardi, c.libardi@ufscar.br.

30(1)/159–163

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Methods

Experimental Approach to the Problem

We used an RT protocol to investigate the time course of muscle hypertrophy in the elderly (Figure 1). At baseline (Pre), the vastus lateralis muscle CSA was assessed by mode-B ultrasound/ultrasonography (US) and magnetic resonance imaging (MRI). Afterward, the participants engaged in 2 familiarization sessions to get acquainted with the leg press exercise and testing procedures. Seventy-two hours after the last familiarization session, maximum dynamic muscle strength (1 repetition maximum [1RM]) test was assessed in the 45° leg press exercise. Thereafter, subjects in the RT group engaged in an RT protocol for 10 weeks with 2 sessions per week (Monday and Thursday, total of 20 training sessions). The vastus lateralis muscle CSA was assessed every 2 RT sessions using the US, every Monday before training session (this procedure is described thoroughly in the methods session–US acquisition). In the fifth week of training, 1RM was reassessed to progress RT workload. After 10 weeks of training (Post), the vastus lateralis muscle CSA (US and MRI to RT, and only MRI to control group [CG]) and 1RM were reassessed. The CG was instructed to not engage in regular physical activity or any training program throughout the experimental period. The CG performed only the Pre and Post testing procedures (MRI and 1RM).

Subjects

Fourteen subjects (8 men and 6 women) participated in this study. They were randomly allocated in one of the 2 groups: RT (n: 6 [4 men and 2 women]; age: 60.3 ± 2.7 years; height: 163.3 ± 9.0 cm; body weight: 68.5 ± 14.3 kg) or CG (n: 8 [4 men and 4 women]; age: 65.7 ± 4.6 years; height: 161.1 ± 10.1 cm; body weight: 69.2 ± 16.1 kg). The subjects were not considered physically active (i.e., not engaged in any systematized resistance or aerobic training for at least 6 months before the study). To be included in this study, all subjects performed an exercise electrocardiogram supervised by a medical doctor. The exclusion criteria were (a) present cardiovascular diseases; (b) diabetes; (c) arterial hypertension; (d) musculoskeletal disorders; (e) hormone therapy replacement; and (f) use of any medication or supplement that could potentially affect the training-induced adaptations. All subjects were informed about the purpose and risks of this study and signed an informed consent document. The study was approved by the research ethics committee of the local university.

Maximum Dynamic Muscle Strength Test

Maximum dynamic muscle strength was assessed by 1RM test in the 45° leg press exercise (G3-PL70; Matrix, São Paulo, Brazil) following the American Society of Exercise Physiologists recommendations (4). Initially, subjects performed a 5-minute warm-up in a stationary bicycle. Thereafter, a specific warm-up was performed in the leg press. The specific warm-up consisted of 1 set × 8 repetitions at 50% 1RM followed by 1 set × 3 repetitions at 70% 1RM, with 1 minute of rest between sets. Three minutes after the warm-up, subjects performed the first 1RM attempt. Subjects had up to 5 attempts to achieve the 1RM load. The rest interval between 1RM attempts was set of 3 minutes. Subjects were verbally encouraged by the researchers during the 1RM attempts.

Vastus Lateralis Muscle Cross-Sectional Area

The MRI and US images were acquired in the right thigh while subjects were positioned in a supine position, with the knees extended and the legs straight, by an experienced researcher. Subjects laid down for 20 minutes to allow fluid shift before the assessments (2). The legs were restrained with Velcro straps to avoid hip internal or external rotation and allow the subjects relax the leg muscles both during the assessments. First, the vastus lateralis muscle CSA was obtained through MRI (Signa LX9.1; GE Healthcare, Milwaukee, WI, USA). In short, 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 thigh length. Vastus lateralis muscle CSA was acquired at 50% of the thigh length in 0.8-cm slices for 3 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, 2 signal acquisitions, and matrix of reconstruction of 256 × 256 (this procedure has been reported elsewhere (11)).

For the US images' acquisition, an experienced researcher identified the location of the lateral epicondyle of the femur. Then, 1 edge of a paquimeter was placed on the lateral epicondyle of the femur while the other edge was moved up to the point corresponding to 50% of the distance between the greater trochanter and the lateral epicondyle of the femur, which was the same distance used in the MRI assessment. This point was marked with semipermanent ink and was used as a reference. Finally,

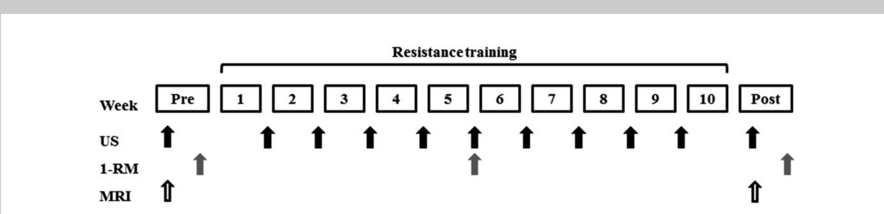

Figure 1. Experimental approach to the problem. 1RM = 1 repetition maximum dynamic muscle strength test; MRI = magnetic resonance imaging; US = mode-B ultrasonography.

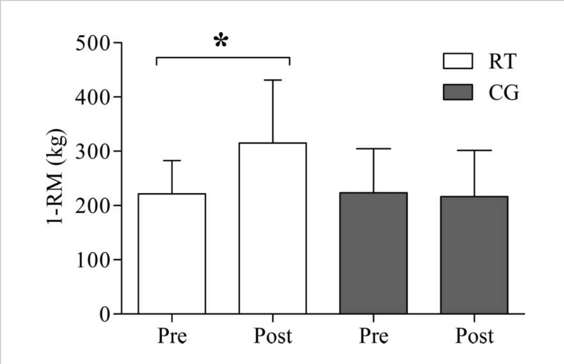

Figure 2. Maximum dynamic muscle strength test (1RM) before (Pre) and after (Post) the experimental protocols. *Significantly different from pretest to posttest ($p \leq 0.05$). CG = control group; RT = resistance training group.

the skin was transversally marked every 2 cm from the reference point toward the medial and lateral aspects of the thigh to orient US probe displacement. A B-mode US using a 7.5-MHz linear-array probe (Philips, VMI, industry and commerce Ltda, Lagoa Santa, Brazil) was aligned with the transversal ink markers in the skin. Sequential US images were acquired aligning the superior edge of the probe with each mark in the skin following a middle-to-lateral direction. To avoid deforming the tissue with the pressure applied on the US probe, a generous amount of conductive gel was used. After data collection, the images of the vastus lateralis muscle were reconstructed following the procedure described by Lixandrao et al. (12). To investigate the time course of muscle hypertrophic response, the vastus lateralis CSA was assessed on a weekly basis (i.e., after 2 RT sessions) by the US technique. To reduce residual effects of the last RT session, such as edema-induced muscle swelling, the US measurements were performed 96 hours after Thursday training sessions (i.e., on Monday before training session). To reproduce the same exact location for the weekly US measurements, we used the lateral epicondyle of the femur as reference because this can be easily identified.

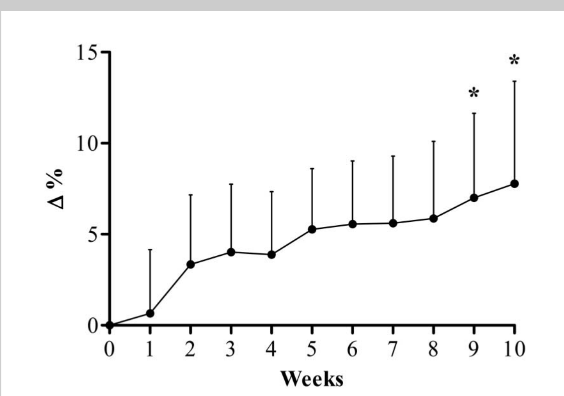

Figure 3. Time course of vastus lateralis muscle cross-sectional area after the resistance training. δ = (Post × 100)/(Pre − 100). *Significantly different from the moment before ($p \leq 0.05$).

Resistance Training

Initially, the subjects warmed up in a stationary bicycle for 5 minutes. Afterward, subjects performed 4 sets × 10 repetitions with a 1-minute rest interval between sets in a 45° leg press machine (G3-PL70; Matrix). In the first 5 weeks of training, the exercise intensity was set at 70% 1RM, based on the pretest values; for the last 5 weeks, exercise intensity was increased to 80% of the retested 1RM (assessed at the middle of the RT period). The range of motion at the knee joint during the leg press was set to ~90°. Subjects were asked to perform the concentric and the eccentric phases of the exercise in 2 seconds.

Statistical Analyses

An unpaired T-test analysis was performed to test for differences between groups at baseline. The analysis for 1RM and MRI (Pre vs. Post) was performed by a mixed model for repeated measures (random factor: subjects; fixed factors: group [CG and RT groups] and time [Pre and Post]) with Tukey's post hoc test. The vastus lateralis muscle CSA comparison between the MRI and US assessments was performed using a mixed model (random factor: subjects; fixed factors: group [MRI and US methods] and time [Pre and Post]) with Tukey's post hoc test. The US vastus lateralis muscle CSA (time-course) was analyzed with Friedman's nonparametric test for repeated measurements followed by Dunn's post hoc test only for the RT group. The reproducibility of the measurement is presented as the typical error (TE): *SD* of difference between measurements of day 1 and $\frac{2}{\sqrt{2}}$. The minimal difference (MD) as proposed by Weir (22) was calculated as following: $MD = TE \times \sqrt{2} \times 1.96$. The significance level adopted was $p \leq 0.05$.

Results

There was no difference in 1RM and MRI vastus lateralis CSA at baseline between groups ($p > 0.05$).

The 1RM showed significant increases after training period only for the RT group (42%, Pre: 163 ± 49 vs. Post: 258 ± 120; $p \leq 0.05$; Figure 2). The MRI vastus lateralis CSA significantly increased only for the RT group (8.4%, Pre: 18.5 ± 4.1 vs. Post: 20.0 ± 4.3; $p \leq 0.05$). There were no differences in the vastus lateralis muscle CSA, as assessed by the MRI and US techniques at the pretest (i.e., MRI CSA vs. US CSA) and the posttest (i.e., MRI CSA vs. US CSA) for the RT group ($p > 0.05$).

The vastus lateralis CSA measured by US (time-course) demonstrated significant increases in muscle size after the ninth (18 RT sessions) and tenth (20 RT sessions) weeks of training (7.1%, Pre: 18.5 ± 3.9 vs. Ninth week: 19.8 ± 4.1; $p \leq 0.05$; and 7.8%, Pre: 18.5 ± 3.9 vs. 10th week: 19.95 ± 4.0; $p \leq 0.05$; Figure 3). The TE of measurement for vastus lateralis CSA assessment using the US was 0.41 cm^2 (2.3%). The MD for the vastus lateralis muscle CSA was of 1.14 cm^2 (6.2%).

Discussion

This study aimed to investigate the time course of the vastus lateralis muscle CSA hypertrophy induced by RT in the elderly. Our main results are that older subjects present significant muscle hypertrophy in the vastus lateralis muscle CSA after 18 sessions of RT (9 weeks).

The increases in muscle strength (42%) and vastus lateralis CSA (~7–8% measured by MRI and US) highlights the efficacy of our exercise protocol in promoting neuromuscular adaptations in older subjects (>60 years). Previous studies reported increases in muscle strength and CSA after 6–16 weeks of RT in older subjects (>60 years; ~30–55% and ~6–8%, respectively), and the magnitude of our results seems to be in consonance with these findings (8,18,20,21). In this study, the time course of muscle hypertrophy was assessed by the US image reconstruction technique. The concurrent validity of the imaging reconstruction technique has been described elsewhere (17). Additionally, our group has confirmed the low TE of the CSA assessment by the US imaging reconstruction technique even when using a larger and more heterogeneous sample (12). It is important to state that we had technical issues with the US image acquisition during the CG assessment. Thus, we used the MRI muscle CSA assessment (Pre and Post) to determine the variance of the data for the CG. The vastus lateralis CSA results from the MRI demonstrated that CG did not present significant changes in muscle size after the intervention period. Regarding the training group, both methods MRI and US showed similar increases in vastus lateralis CSA (Pre vs. Post comparison). Collectively, these results emphasize the validity of the US imaging reconstruction technique, used herein, to quantify RT-related adaptations. Furthermore, to highlight our muscle hypertrophic response measured by US, we used the MD proposed by Weir (22). In short, this procedure uses the reliability of measurement (i.e., TE) and estimates the MD necessary to consider that vastus lateralis hypertrophy in fact occurred; this procedure has been previously used in training studies (1). According to our reliability results (TE: 0.41 cm^2; coefficient of variation: 2.2%), the increases in vastus lateralis CSA should be greater than 1.14 cm^2 (6.2%) to be considered as training-induced hypertrophy. As the increases in vastus lateralis CSA were approximately 1.5% greater than the MD (7.7–6.2%: 1.5%), it can be stated that the training protocol used herein indeed produced muscle hypertrophy.

Muscle hypertrophic response to RT protocols has been extensively studied (11,14,23,24). However, to the best of our knowledge, only 2 studies investigated the time course of muscle hypertrophy (6,19), both in young subjects. Seynnes et al. (19) demonstrated significant increases in quadriceps muscle CSA after 9–10 sessions of RT, that is, between the third and fourth weeks of training in young subjects. However, hypertrophy assessments were 10 days apart. Thus, earlier increases in muscle CSA could have been detected with a shorter time window between measurements. Additionally, the training protocol consisted of 4 sets × 7 repetitions in a flywheel leg-extension machine. This training method has been considered as a strong stimulus for muscle hypertrophy, because it requires high torques to break the rotation of the inertial mass, which can explain the earlier muscle hypertrophy response to RT. The study from DeFreitas et al. (6) measured the thigh muscle CSA after every 3 RT sessions. The results showed significant increases in thigh muscle CSA after 9–12 RT sessions (consisted of 3 sets to failure in the leg press and leg extension), that is, between the third and fourth weeks of training in young subjects.

As aging seems to hamper the anabolic response to RT (3,5), it is important to understand the effect of RT protocols to counteract the anabolic resistance phenomenon in older subjects. Our results showed that the elderly present significant increases in the vastus lateralis muscle CSA after 18 RT sessions (9 weeks); an apparently greater time period than previously reported for young individuals (9–12 RT sessions; 3–4 weeks) (6,19). Interestingly, these results seem to be in consonance with Kumar et al. (10), whereas elderly subjects presented lower myofibrillar muscle protein synthesis after an acute RT session as compared with younger subjects. Although above mentioned information might suggest a delayed hypertrophic response to RT in older subjects, other variables may have affected the precision when comparing our findings with previous ones in young subjects. For instance, RT exercise intensity, mode, volume, frequency, and training status may have influenced the reported training-related adaptations (Phillips, 2000 #46). Thus, as only older individuals were assessed in this study, it is difficult to ascertain if there are any differences in the time-course adaptations after RT between young and older individuals. Future studies should compare the time course of muscle hypertrophic response between ages after similar RT regimes.

It is important to highlight that this is the first study to investigate the time course of muscle hypertrophy in older subjects. In summary, 10 weeks of 1 exercise (leg press) RT were effective to significantly augment muscle strength and muscle mass in the elderly. However, our results demonstrated that the elderly present significant increases in muscle hypertrophy only after 18 sessions of RT (9 weeks) when only 1 RT exercise is performed; these results might suggest a hampered anabolic response to each RT session in the elderly.

Practical Applications

The aging process seems to reduce the anabolic response to each RT session. Nevertheless, the elderly are still capable to respond to resistance exercise, demonstrating significantly hypertrophy after a training period. However, it might be that older subjects present impairment in muscle adaptation compared with younger ones, as demonstrated by the possible later hypertrophic response of the elderly. Thus, practitioners and coaches seeking to improve muscle size in older subjects may need to extend the training period to promote significant increases in muscle size, or modulate other training variables, such as load, volume, frequency, to induce (possibly) more quickly increases in muscle mass.

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