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Low- and high-volume strength training induces similar neuromuscular improvements in muscle quality in elderly women

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ABSTRACT

The aim of this study was to compare the effects of low- and high-volume strength training on strength, muscle activation and muscle thickness (MT) of the lower- and upper-body, and on muscle quality (MQ) of the lower-body in older women. Twenty apparently healthy elderly women were randomly assigned into two groups: low-volume (LV, $n = 11$) and high-volume (HV, $n = 9$). The LV group performed one-set of each exercise, while the HV group performed three-sets of each exercise, twice weekly for 13 weeks. MQ was measured by echo intensity obtained by ultrasonography (MQ_{EI}), strength per unit of muscle mass (MQ_{ST}), and strength per unit of muscle mass adjusted with an allometric scale (MQ_{AS}). Following training, there was a significant increase ($p \leq 0.001$) in knee extension 1-RM ($31.8 \pm 20.5\%$ for LV and $38.3 \pm 7.3\%$ for HV) and in elbow flexion 1-RM ($25.1 \pm 9.5\%$ for LV and $26.6 \pm 8.9\%$ for HV) and in isometric maximal strength of the lower-body ($p \leq 0.05$) and upper-body ($p \leq 0.001$), with no difference between groups. The maximal electromyographic activation for both groups increased significantly ($p \leq 0.05$) in the vastus medialis and biceps brachii, with no difference between groups. All MT measurements of the lower- and upper-body increased similarly in both groups ($p \leq 0.001$). Similar improvements were also observed in MQ_{EI} ($p \leq 0.01$), MQ_{ST}, and MQ_{AS} ($p \leq 0.001$) for both groups. These results demonstrate that low- and high-volume strength training promote similar increases in neuromuscular adaptations of the lower- and upper-body, and in MQ of the lower-body in elderly women.

1. Introduction

The decline of lower- and upper-body isometric and dynamic muscle strength is a consequence of the aging process (Hakkinen et al., 1996; Klein et al., 2001). It is attributed to the loss of muscle mass that results from a decrease in the number of muscle fibers, atrophy of the remaining muscle fibers (sarcopenia) (Aagaard et al., 2010; Andersen, 2003), and reduction in the maximal voluntary activation of the agonist muscle (Jakobi and Rice, 2002). Additionally, the decline in the muscle quality (MQ) of the lower-body has been proposed as another consequence of the aging process (Arts et al., 2010; Lynch et al., 1999).

Originally, MQ was defined as strength per unit of muscle mass, also known as specific tension (MQ_{ST}) (Lynch et al., 1999; Tracy et al., 1999). Thus, MQ may be a superior indicator of muscle function in elderly people than strength alone (Dutta et al., 1997), because it provides an estimate of the contribution of muscle mass and neural factors to strength (Castro et al., 1995). Lynch et al. (1999), after analyzing data from 703 subjects of various ages, observed that the decline in leg MQ_{ST} was modest or nonexistent until the subjects were in their 50s. However, the authors noted an accelerated decline after the fifth decade for both men and women. Likewise, Ivey et al. (2000b) observed that leg MQ_{ST} was significantly less in elderly women than in young subjects. Recently, several authors have utilized another methodology to calculate MQ (Cadore et al., 2012), adjusting units of muscle mass by an allometric scale (MQ_{AS}, $F_m \propto m^{2/3}$), according to the proposal to adjust strength for body size (Jaric et al., 2002). Furthermore, other studies have reported the assessment of MQ without utilizing strength per unit of muscle mass, but have used echo intensity from images obtained via ultrasonography (MQ_{EI}). In one of these studies, Arts et al. (2010), after evaluating the rectus femoris MQ_{EI} of men and women, observed age-related decreases in MQ_{EI}. Similarly, Fukumoto et al. (2012) reported age-related decreases in rectus femoris MQ_{EI}, also indicating significant negative correlations between MQ_{EI} and knee extensor muscle strength and muscle thickness (MT) of the rectus femoris.

A well-designed strength training program is an efficient method for mitigating several impairments related to the aging process via increases in muscular strength, muscle mass, maximal voluntary activation and knee extensor MQ (Cadore et al., 2012; Ivey et al., 2000b; Tracy et al., 1999). Although the benefits of strength training for

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elderly people are well known, there is still some controversy, mainly regarding the ideal training volume (i.e., sets × reps × load) for optimizing neuromuscular gains (Hass et al., 2001; Marshall et al., 2011).

Several previous studies with young individuals have compared the effects of low- and high-volume strength training, indicating that high-volume training results in greater gains in strength, muscle activation and muscle mass than low-volume training (Hanssen et al., 2012; Kemmler et al., 2004). In contrast, other studies have not found any differences between low- and high-volume training gains (Bottaro et al., 2011; Cannon and Marino, 2010; Hass et al., 2000). Although there are many studies comparing the effects of low- and high-volume training, only a few studies have been performed with elderly subjects (Cannon and Marino, 2010; Galvão and Taaffe, 2005). Cannon and Marino (2010) observed that after 10 weeks, low-volume (one-set) and high-volume (three-sets) strength training induced similar increases in strength, muscle volume, agonist activation and MQ of knee extension in elderly women. Nevertheless, the authors did not evaluate the influence of strength training volume on upper-limb neuromuscular adaptations or MQ evaluated by MQ_{AS} and MQ_{EI}. Thus, the aim of our study was to compare the effects of low- and high-volume strength training on neuromuscular adaptations of the lower-and upper-body and on the MQ_{ST}, MQ_{AS} and MQ_{EI} of the lower-body in elderly women.

2. Methods

2.1. Subjects

Twenty healthy elderly women aged 60 to 74 years who had not participated in a resistance-training program for at least 3 months, volunteered for the study. Subjects were carefully informed of the purpose, procedures, benefits, risks and discomfort that might result from this study. Thereafter, subjects gave their written informed consent to participate. All procedures were approved by the Institutional Research Ethics Committee. Included in the study were all volunteers, nonsmokers, free of cardiovascular diseases, and metabolic and musculoskeletal limitations to physical exercise. Elderly women with conditions that could interfere with neuromuscular function and unable to perform some exercises of the training program were excluded from the study. Moreover, subjects were not currently taking antihypertensive, cardiovascular or metabolic medications.

2.2. Experimental design

The total duration of the present study was 13 weeks (i.e. 26 total training sessions). The subjects were tested on two separate occasions, before start of the study (week 0) and after 13 weeks of training, by the same investigators using identical procedures. During the period of this study the subjects were instructed to avoid changes in diet and their recreational physical activities (e.g. walking, jogging and biking) during the course of the study. These activities were similar between both groups.

2.3. Training program

Participants trained for 13 weeks, completing two sessions per week on nonconsecutive days (i.e. 26 total training sessions). They were randomly assigned to either a low-volume (LV; $n = 11$; 64.6 ± 3.1 years; 66.4 ± 5.1 kg; 162.9 ± 5.8 cm) or high-volume (HV; $n = 9$; 63.9 ± 2.3 years; 64.1 ± 7.2 kg; 163.2 ± 4.9 cm) group. Both groups trained according to similar procedures, differing only in the number of sets. The LV group performed one set per exercise, while the HV group performed three sets per exercise. In each workout, they performed the following exercises in the this order: bilateral knee extension, lat pull-down, bilateral leg press, elbow flexion, bilateral leg curl, bench press, triceps extension, hip abduction and adduction and abdominal crunch A minimum of 48 h rest was required between workouts. All training sessions were monitored and supervised by at least two trained investigators.

The training intensity was controlled using the number of repetition maximum (RM) as in previous studies (Cadore et al., 2012; Hanssen et al., 2012), thus the heaviest possible weight was used for the designated number of repetitions. During the first 6 weeks both groups trained with an intensity of 20 RM; during weeks 7–10, they trained at 12–15 RM; and during the final three weeks they trained at 10 RM. The training load used per exercise was increased from 2.5 to 5.0 kg for the next workout when subjects were able to perform more repetitions than prescribed. 2-min rest between sets was given for the HV group. All subjects were instructed to perform each repetition with a duration of 2 s concentrically and 2 s eccentrically. During all training program the HV group performed the workouts in a less amount of time than LV group (≃50–60 min for HV group and ≃20–25 min for LV group).

2.4. Maximal dynamic strength

Subjects performed one-repetition maximum (1-RM) tests of knee extension (bilateral) and preacher curl elbow flexion (unilateral) (World-Sculptor, Porto Alegre, Brazil). The same investigator, with identical subject/equipment positioning, conducted the pre- and post-tests. Before 1-RM tests, subjects were carefully familiarized with the testing procedures and performed 10 repetitions with a light resistance as warm-up. Thereafter, resistance was increased until they were unable to lift the additional weight through a full range of motion using proper technique. Muscle action velocity for each repetition (2 s concentric and 2 s eccentric) was controlled by an electronic metronome (Quartz, CA, USA). All 1-RM values were determined within 3–5 attempts, with 3-min rest between each attempt. At post-testing 1-RM was performed 3–5 days after the last training session. Test–retest reliability intraclass correlation coefficients (ICC) for knee extension and elbow flexion 1-RM were 0.96 and 0.90, respectively.

2.5. Lower- and upper-body isometric maximal strength

Bilateral maximal isometric strength of the lower- and upper-body was measured on a leg press machine and an elbow flexion preacher curl bench (World-Sculptor, Porto Alegre, Brazil), respectively, using a load cell (Primax, São Paulo, Brazil) connected to an analog to digital (A/D) converter (Miotol 400, Porto Alegre, Brazil). In the lower-body test, subjects were positioned on the leg press machine with hip, knee and ankle joints at 90°. Subjects were asked to exert maximal force against the leg press platform. The upper-body test was performed with subjects sitting on the machine with both armpits supported on the preacher bench with shoulder and elbow flexion at 60° (90° relative to the floor) and holding a bar with both hands supinated. The bar was attached to the load cell, which was fixed to the floor, and subjects were instructed to exert maximal force against the bar. In both tests, subjects performed three 5-second maximal isometric actions with 3-min rest between actions and 20 min rest between activities. Verbal encouragement was given during both tests. The force–time curve signal was obtained in real-time using Miograph software (Miotec-Equipamentos Biomédicos, Porto Alegre, Brazil) with an acquisition rate of 2000 Hz, recorded on a personal computer (Dell, São Paulo, Brazil) digitized and analyzed with SAD32 software (developed by the Engineering School of the local university, Porto Alegre, Brazil). The highest force value (Kg) of three attempts was utilized for subsequent statistical analyses. After training period, the maximal isometric strength of the lower- and upper-body tests was performed 5–7 days after the last training session.