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Randomised Study

Effects of different strength training volumes and subsequent detraining on strength performance in aging adults

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ABSTRACT

The purpose of the present study was to investigate the volume-dependence of upper-body strength performance improvement and the retention effects after detraining in aging adults. Eighteen healthy, untrained, middle-aged volunteers were randomized into two groups: low volume (LV), mean = 494 kg. and high volume (HV), mean = 686 kg. load. Participants were tested and retested before a 12-week (2 times/week) period of RT for baseline values (pre-); after 6 weeks (middle) and 12 weeks of training (post-), and 12 weeks after interruption (detraining – no systematic exercise). On each test day, a five-repetition maximum (5-RM) for the seated row; handgrip strength test (HGS); and local muscular endurance for elbow flexors (LME) were carried out. Participants performed seated row training 2 times per week with a rest interval of at least 48 h between sessions. After 24 sessions of RT (resistance training), LME significantly increased in both groups ($p < 0.05$), without differences between groups (14 vs. 18%, for LV and HV, respectively). In addition, 5-RM increased in both the LV (22%) and HV (20%) groups. There were no significant increases in HGS in either group (LV 3% and HV 6%). After detraining, both groups lost up to 15% of LME and 5-RM. In untrained, middle-aged adults, there is an increase in maximal dynamic strength and local muscular endurance, independent of volume chosen. Furthermore, after 12 weeks detraining, the loss does not decrease to baseline values.

1. Introduction

Strength losses during the aging process induce a reduction in the capacity to perform daily living activities involving higher demands (i.e., walking, sitting, and climbing stairs), mainly when the lower limbs are the focus (Clark and Manini, 2010). However, reduction in strength of the upper limbs can also be observed, which could cause deficits in daily activities such as transporting and displacing loads, support when standing up from a chair, and personal hygiene. According to recent meta-analyses (Arnold and Bautmans, 2014), resistance training (RT) seems to be an effective intervention to counteract the effects of strength loss. Among the variables involved in an RT program, stimulus to increase strength seems to be intrinsically linked to volume-intensity ratio (volume load).

Recent literature reviews have observed marked effects of the relationship between volume and intensity on strength gains of different populations (Fisher et al., 2013; Fisher et al., 2016; Schoenfeld, 2013), nonetheless, few studies have investigated the effects on upper limbs in aging populations, as the majority of studies have focused their investigation on the effects on lower limbs (Reid et al., 2014; Walker et al., 2015). Regarding upper limbs, it seems only Radaelli et al. (2013a,b) investigated the effects of different training volumes (1-set vs. 3-sets), and both groups demonstrated similar elbow flexor muscle thickness gains after 13 weeks of training (11.2 ± 6% for 1-set and 12.5 ± 5.6% for 3-sets). In

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addition, in studies assessing young people, no difference was observed when comparing different volumes (1-set vs. 3-sets) on maximal strength, lean free mass, and cross sectional area of different muscles (i.e., trapezius and biceps brachii muscles) (Bottaro et al., 2011; Hanssen et al., 2013; Rønnestad et al., 2007).

Besides neuromuscular improvements during the training period, it is also interesting to have information on the retention of training effects after detraining. Fatouros et al. (2005) investigated the effects of exercise intensity (low intensity: 3 × 16 x 50–55% of one-repetition maximum (1-RM) and high intensity: 3 × 8 x 80–85% 1-RM) on upper limb maximum strength, and observed an increase after training (low intensity: 66% and high intensity: 91%, $p < 0.05$). During detraining, upper limb strength returned to baseline values within 8 months of detraining in the low intensity group, but remained increased in the high intensity group throughout detraining. Similarly, Harris et al. (2007) assessed the effects of three different RT volumes (2 × 15 repetitions maximum (RM), 3 × 9-RM, or 4 x 6-RM) on upper limb strength, as well as training retention, and the results showed significant increases in maximal strength with training (44–51%; $p < 0.05$), without differences between groups. In addition, significant strength decreases induced by detraining occurred in all training groups after 6 and 20 weeks of detraining, independent of prior training volume (4.5% at 6 weeks and 13.5% at 20 weeks; $p < 0.04$). Although different numbers of sets (i.e., 1 vs. 3 sets) (Radaelli et al., 2013a,b), and different intensities (i.e., 60 vs. 90% of 1-RM) (Fatouros et al., 2005; Harris et al., 2007) have been investigated, to the best of the authors' knowledge, comparisons between different volumes and total work equated by different intensities (i.e., 3 sets of 5-RM vs. 1 set of 15-RM) are poorly investigated in aging people, especially in the upper limbs.

Although some previous studies have demonstrated positive effects of strength training on muscle strength, it is unclear whether the retention of these effects may be associated with prior training volume in middle-aged adults. To the best of the authors' knowledge, no study has investigated the effects of different strength training volumes on upper limb function after resistance training and detraining of the same period. Therefore, the first aim of the present study was to investigate the strength adaptations induced by different RT volumes in upper body limbs in middle-aged adults. The second purpose of this study was to verify retention of strength gains after 12 weeks of detraining. We hypothesized that different volume load would provide a different magnitude of maximal strength and local muscular endurance gains. In addition, we hypothesized that retention of the upper body maximal strength and local muscular endurance would be different between groups due to the different adaptations mentioned in the first hypothesis.

2. Methods

2.1. Participants

Participant recruitment was carried out through local announcements in the neighborhoods around the local University. All participants completed a specific health history and physical activity questionnaire and met the following inclusion criteria: 55 years old or more, physically independent, controlled hypertension (<140/90 mmHg), free from orthopedic dysfunction, and not performing any regular physical exercise during the 6 months preceding the beginning of the study. Participants presented a medical certificate from a cardiologist with no restrictions for participation in this study. Thirty men and women were eligible; however, after individual interviews, 10 were dismissed as they did not meet the inclusion criteria. The remaining 20 participants (12 women and 8 men) were randomly stratified into two experimental groups based on 5-RM: a group that performed RT in the high volume load ($n = 10$) or a group that performed RT in the lower volume load ($n = 10$). A total of 18 participants (63 ± 6 years; 77.1 ± 14.7 kg; 1.66 ± 0.01 m; and 27.74 ± 3.04 kg m^2) completed all stages of the experiment and were included in the analyses (see Fig. 1a). Two participants withdrew claiming muscular discomfort during the RT regime. Adherence to the program was satisfactory, with all subjects participating in >95% of the total sessions (missed no more than 1 session). Written informed consent was obtained from all participants after provision of a detailed description of study procedures. All procedures performed in this study were approved by a local Institutional Ethics Committee (n. 1.657.414) and followed the ethical guidelines of the Declaration of Helsinki.

2.2. Study design

The study was carried out over a period of 33 weeks divided into 3 periods as follows; in the first, a 4 week control period was applied after the test and retest; in the second, participants were tested again and randomly separated into two groups to perform 12 weeks (2 times/week) of RT according to the respective volume load (HV and LV); and after the end of the RT program, participants were given a 12-week period of detraining (third period), during which all participants were asked to maintain their daily activities, but not to engage in any kind of physical exercise regimen. At the baseline, middle of training, post-training, and post detraining periods, one week was used for physical assessment consisting of a five-repetition maximum strength test (5-RM), hand grip strength test (HGS), and local muscular endurance for elbow flexors (LME). The experimental design is displayed in Fig. 1b.

2.3. Procedures

2.3.1. Muscular strength

Dynamic strength (5-RM) for the seated row (SR) was performed using the same equipment (Riguetto®, São Paulo, SP, Brazil) used during training. The 5-RM test was used to determine strength increases as the subjects had no weight training experience (Radaelli et al., 2015). According to these authors, two factors support this choice: (a) when subjects do not train using overloads close to 1-RM; (b) subjects are untrained. These factors could affect exercise technique when using very heavy resistances, which would affect the accuracy of 1-RM testing; thus, 5-RM testing was chosen to determine strength. Before the pre-training 5-RM tests, all subjects performed familiarization during 6 sessions of 3 sets (1st set: 15 repetitions (reps); 2nd: 10 reps, and 3rd: 5 reps) without concentric failure. To minimize the error during the 5-RM tests, the following strategies were adopted (Simão et al., 2012): (a) standardized instructions concerning the testing procedures and exercise technique were given to participants; (b) the subject's exercise technique was monitored and corrected as needed, during all testing sessions; and (c) verbal encouragement was provided during the testing procedure. The 5-RM test was determined in fewer than 5 attempts with a rest interval of 5 min between attempts. No pause was allowed between the eccentric and concentric phases of a repetition or between repetitions. For a repetition to be considered successful, it was necessary to complete the range of motion (elbow flexion until 90°). The heaviest 5-RM resistance achieved in the different stages of evaluation was used in the statistical analysis. The 5-RM test-retest was conducted with a 48 h rest interval between tests. The intraclass correlation coefficient (ICC) between the 2 days of testing in the SR exercise was 0.92.

Upper limb local muscular endurance was measured by the 30-s arm curl test (Rikli and Jones, 2013). Participants were seated with

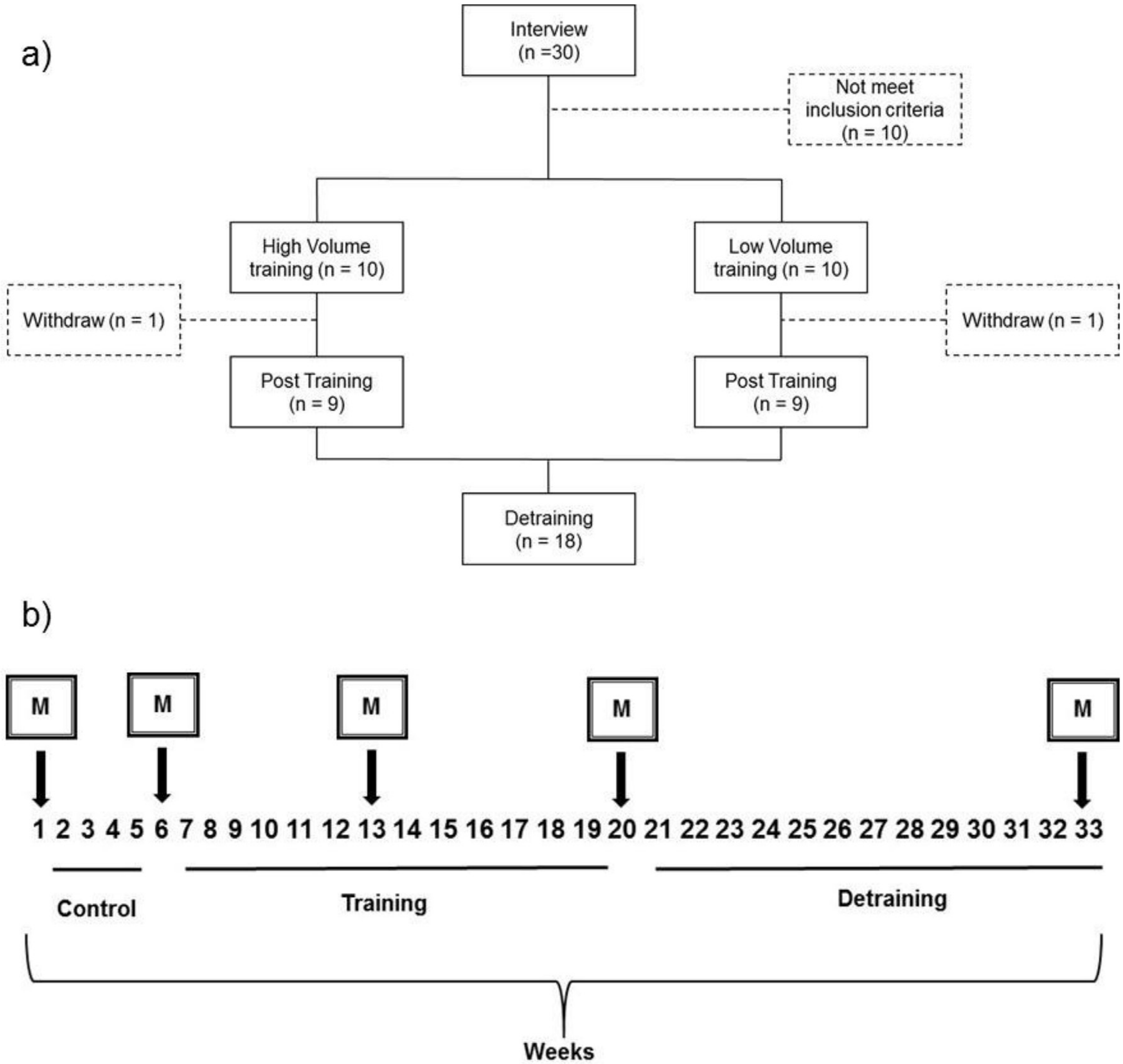

Fig. 1. Flow chart of participants (a); Experimental protocol (b). M = measurement.

the elbow extended (180° = full extension) holding a hand weight (men: 3.5 kg; women: 2.5 kg), feet flat on the floor, with the contralateral hand on the thigh of the same side. The participant was required to perform the maximum number of correct repetitions within their own range of motion (determined pre-test with visual inspection) in the given time. Repetitions performed with the elbow away from the body were not counted, and the participant was always guided to maintain the elbow fixed. Attempts were performed on both sides and the score attained used for analysis. Intraclass correlation coefficients (ICC) between the 2 days of testing were 0.92 and 0.82 for the right and left upper limbs, respectively.

The handgrip strength test (HGS) was carried out using an analogue hand dynamometer (Saehan Corporation, 973, Yangdeok-Dong, Masan 630–728, Korea). During the test, the participant was seated with the elbow flexed (90°) and wrist in a neutral position; the dynamometer handle in position II; and provision of support under the dynamometer. Both sides were measured, followed by calculation of the mean of two trials of grip strength for each hand (Massy-Westropp et al., 2011). Intraclass correlation coefficients (ICC) between the 2 days of testing were 0.89 and 0.96 for right and left upper limbs, respectively. The same appraiser applied all assessments, always in the same period of the day, and he was blind to the treatment allocation.

2.3.2. *Resistance training program*

Participants trained for 12 weeks, 2 times per week (Mondays and Wednesdays, or Wednesdays and Fridays), in the evening (totaling 24 training sessions). Subjects were randomly assigned to one of the two training groups: high volume load, performing 3 sets of 5-RM with a 2 min rest interval between sets; and, low volume load, performing 1 set of 15-RM. The experimental protocol was applied only in the seated row and the participants performed the exercise until momentary concentric muscular failure. Participants were instructed to exhale during the eccentric phase and inhale during the concentric phase while maintaining a constant cadence of movement of approximately 2:2 (ascendant and descendent phases, respectively). When subjects were able to perform more repetitions than predicted in each group protocol, the resistance training was increased by 2.5–5.0 kg in the following session. Immediately after completing each set in the seated row exercise, the Omni Scale was applied to assess rating of perceived exertion (RPE) with emphasis on local fatigue (Lins-Filho et al., 2012). A warm up was performed with 2 sets of traditional prone plank and supine bridge exercises (15 s isometric contraction per set) and one set with 50% of workout load for seated row.

Together with the seated row exercise, other muscle groups were exercised with subjects performing 2 sets of 10 repetitions without momentary concentric muscular failure in the following exercises: horizontal leg press, knee extension, seated leg curl, and chest press using elastic tubes. A 2 min rest interval was allowed between sets and exercises. Supervised RT was performed in the fitness room at the University. During all sessions participants were personally supervised by physical education professionals to help ensure consistent and safe performance.

Estimated 1-RM was calculated according to Brzycki (1993) and the following training variables calculated (Scott et al., 2016): Absolute volume load = sets X repetitions X weight lifted (kg); Volume load relative to specific repetition maximum = sets X repetitions X % repetition maximum for RR, where RR = repetition range.

2.4. Statistics

All values are reported as mean ± SD. Normality of distribution and homoscedasticity for outcome measures were tested using the Shapiro-Wilk test and Mauchly's criterion, respectively. Main training effects within and between groups were assessed by ANOVA repeated measure analysis (time [pre training vs. middle training vs. post training vs. detraining] X 2 group [low volume vs. high volume]). When a significant F level was identified, a Bonferroni post hoc test was performed to locate pairwise mean differences. Test-retest reliability was determined by calculating ICCs with a 2-tailed *t*-test used to determine whether a significant difference existed between the 2 tests for a variable at pre testing. An independent and dependent student t-test was applied to analyze the differences within and between groups after the control period, respectively. For RPE the effects during the weeks in both groups were analyzed by the Friedman test. Sample size was calculated using GPOWER software (version 3.0.1) with a target effect size = 0.9, αlpha = 0.05, power = 0.8, resulting in an estimated sample of 10 subjects per group. An alpha level of $p \leq 0.05$ was used to determine statistical significance. All statistical procedures were performed using SPSS 21 for windows (Statistical Package for the Social Science, IBM, Chicago, Ill, USA). Effect sizes (ES) were calculated and determined according to Rhea (2004).

3. Results

3.1. Control period

Control period values were similar between and within groups ($p > 0.05$). Results of local muscular endurance and the handgrip strength test ($p > 0.05$) were expressed using the average of the sides during the experimental protocol. Age and weight did not present differences between groups, ($p > 0.05$), (see Table 1).

3.2. Muscular strength

Dynamic strength in the seated row exercise (5-RM) did not present group × time interaction ($F_{(1,87)} = 0.16$, $p = 0.93$, $\eta^2_p = 0.01$) or group effect ($F_{(1,0)} = 0.34$, $p = 0.56$, $\eta^2_p = 0.02$). However, there was a time effect ($F_{(1,87)} = 73.51$, $p < 0.001$, $\eta^2_p = 0.82$) for both groups [low volume (LV) and high volume (HV)] presenting increases between pre *vs* middle training (LV: 22 ± 14%, ES = 0.74, and HV: 20 ± 16%, ES = 0.98, $p < 0.001$); pre *vs* post training (LV: 52 ± 27%, ES = 1.78 and HV: 46 ± 24%, ES = 2.3, $p < 0.001$); and, post training *vs* detraining (LV: −15 ± 7%, ES = −0.66 and HV: −14 ± 9%, ES = −0.47, $p < 0.001$), (see Fig. 2a).

Local muscular endurance (arm curl/30 s) did not present a group × time interaction ($F_{(1,51)} = 0.94$, $p = 0.44$, $\eta^2_p = 0.05$). However, a group effect was observed ($F_{(1,0)} = 6.35$, $p = 0.02$, $\eta^2_p = 0.28$), whereby the LV group was higher than the HV group, and a time effect ($F_{(1,51)} = 11.37$, $p < 0.001$, $\eta^2_p = 0.41$), with both groups ncreasing local muscular endurance from pre- to post-training (LV: 14 ± 19%, ES = 1.28, and HV: 18 ± 19%, ES = 0.98, $p = 0.016$); and both groups presenting a significant reduction comparing post-training *vs* detraining (LV: −13 ± 11%, ES = -1.03, and HV: −9±20%, ES = -0.77, $p = 0.026$). No changes were observed comparing pre- *vs* middle training (LV: 3 ± 14%, ES = 0.19, and HV: 6 ± 14%, ES = 0.28, $p > 0.05$), (see Fig. 2b).

For handgrip strength, there was no group × time interaction ($F_{(2,3)} = 0.73$, $p = 0.57$, $\eta^2_p = 0.04$); or group ($F_{(1,0)} = 0.01$, $p = 0.91$, $\eta^2_p = 0.00$); or time effects ($F_{(2.3)} = 3.21$, $p = 0.051$, $\eta^2_p = 0.16$). Handgrip strength values (kgf) were: pre-training (LV: 32 ± 9, and HV: 33 ± 8); middle training (LV: 33 ± 9, and HV: 34 ± 10); post-training (LV: 34 ± 11, and HV: 34 ± 9); and detraining (LV: 32 ± 9 and HV: 30 ± 9).

3.3. Training variables

There was no group × time interaction ($F_{(2,4)} = 1.25$, $p = 0.25$, $\eta^2_p = 0.07$) in the estimated % of 1-RM used by the groups during 12 weeks of training. However, there were time ($F_{(2,4)} = 9.8$, $p < 0.001$, $\eta^2_p = 0.38$) and group effects ($F_{(1,0)} = 32.7$, $p < 0.001$, $\eta^2_p = 0.67$) whereby the HV group (83%) presented greater values than the LV group (66%), as well as presenting increasing values throughout the training period (see Fig. 3a).

Volume load relative to specific repetition maximum (VLR) and absolute volume load (AVL) did not present similar results in group × time interaction ($F_{(2.4)} = 1.28$, $p = 0.23$, $\eta^2_p = 0.07$ and $F_{(1,98)} = 0.98$, $p = 0.38$, $\eta^2_p = 0.05$, respectively). However, there were time (VLR, $F_{(2,4)} = 10.09$, $p < 0.001$, $\eta^2_p = 0.38$ and AVL, $F_{(1,98)} = 35.51$, $p < 0.001$, $\eta^2_p = 0.68$) and group effects (VLR, $F_{(1,0)} = 32.72$, $p < 0.001$, $\eta^2_p = 0.67$ and AVL, $F_{(1,0)} = 8.36$, $p < 0.01$, $\eta^2_p = 0.34$) for volume load relative to specific repetition maximum

Table 1
Mean and standard deviation during control measurements for low (LV) and high (HV) volume groups.

	Low volume		High volume	
	pre control	pre training	pre control	pre training
Age (years)	65.8 ± 6.3	–	61 ± 5.8	–
5-RM (kg)	40.22 ± 11.2	40.78 ± 11	44.11 ± 8.2	43.55 ± 8.55
Weight (kg)	76.98 ± 17.89	77.5 ± 16.8	77.17 ± 12.02	76,3 ± 11
Arm curl-R (rep/30 s)	19.11 ± 1.9	18.89 ± 1.82	16.55 ± 2.35	16.55 ± 2.5
Arm curl-L (rep/30 s)	19.89 ± 2.52	19.56 ± 2.65	16.44 ± 2.92	16.55 ± 3.24
Handgrip-R (kg)	32.89 ± 8.84	32.44 ± 8.93	34.44 ± 9.88	33.33 ± 9.48
Handgrip-L (kg)	33.56 ± 10.28	32 ± 10.25	34.44 ± 9.38	33.55 ± 8.47

5-RM = five-repetition maximum (dynamic strength); L = left: R = right; rep/30-s- number of elbow flexion repetitions in 30 s.

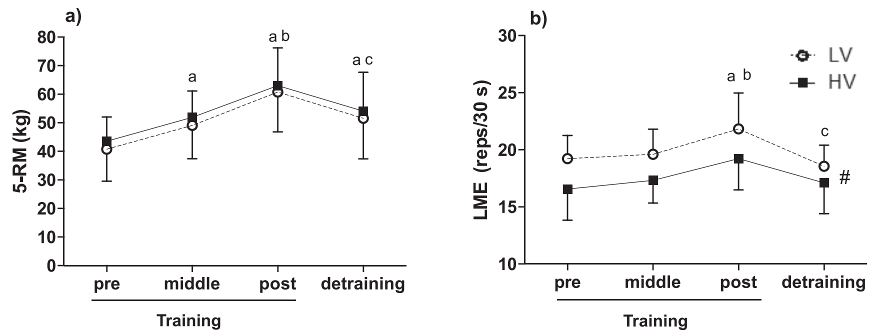

Fig. 2. Absolute values of maximal dynamic strength (a) and local muscular endurance (b) at pre-, middle, post-training, and detraining for low volume (LV) and high volume (HV) groups. Statistical difference for: [a]pre-training; [b]middle training; [c]post-training; # difference between LV and HV groups, ($p < 0.05$).

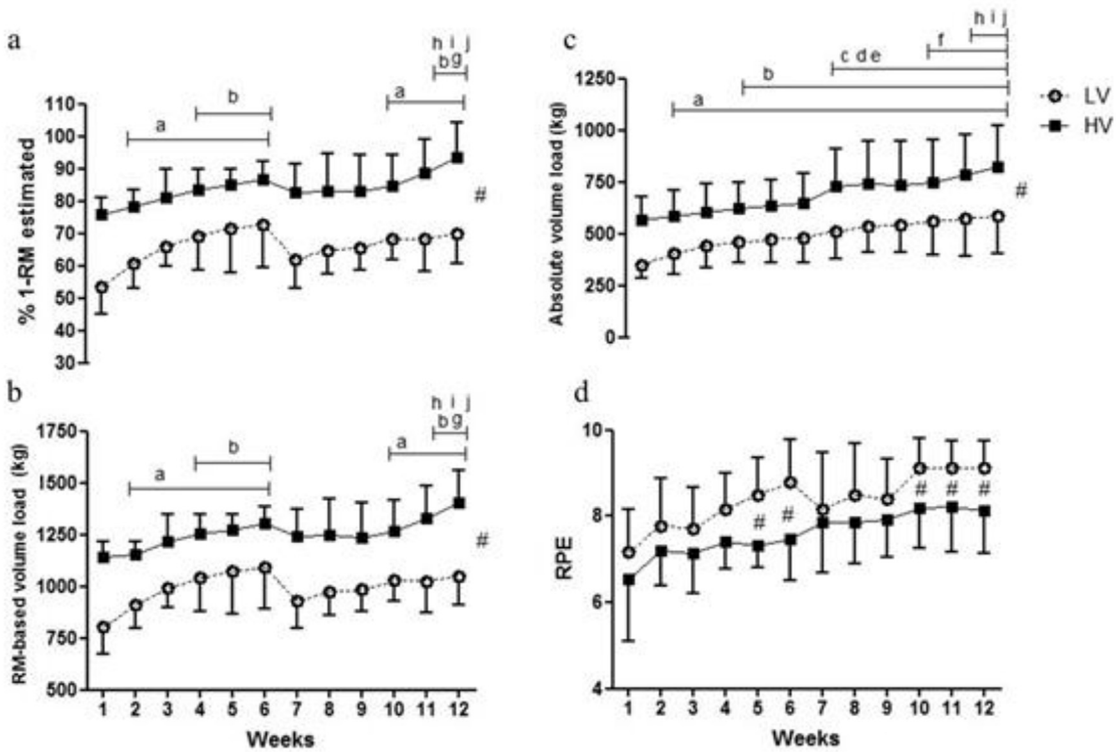

Fig. 3. Time-course of control training variables during the 12 training weeks: a) perceptual of estimated 1-RM; b) RM-based volume load (RMVL); c) Absolute volume load (AVL) and d) rating of perceived exertion (RPE) for low volume (LV) and high volume (HV) groups. Statistical difference ($p < 0.05$): a-1st week; b-2nd week; c-3rd week; d-4th week; e-5th week; f-6th week; g-7th week; h-8th week; i-9th week; j-10th week. # difference between LV and HV groups.

and absolute volume load, respectively. For all these variables, the HV group presented higher values than the LV group (see Fig. 3b and c). Conversely, the RPE was greater in the LV than HV with statistical difference in the 5th ($p = 0.005$), 6th ($p = 0.014$), 10th ($p = 0.026$), 11th ($p = 0.040$), and 12th ($p = 0.025$) weeks of training, (see Fig. 3d).

4. Discussion

The main findings of this study were that the LV and HV groups exhibited similar magnitude and time course of muscle strength (5-RM) and local muscle endurance (LME) gains, whereas there was no change in the handgrip strength after either RT regime. In addition, after 12 weeks of detraining, the 5-RM and LME values did not decrease to the pre-training level, which means retention of training gains was not dependent on RT volume load performed. We hypothesized that different volume loads of resistance training would provide a different magnitude of 5-RM, local muscular endurance, and handgrip strength. In addition, we also hypothesized that retention of the upper-body maximal strength, local muscular endurance, and handgrip strength would be different between groups due to the hypothetically different adaptations, so our hypotheses were refuted.

To our knowledge, no previous study has observed the effects of different training volumes of resistance training and the same time of detraining on upper limb maximal strength, local muscular endurance, and handgrip strength of middle-aged individuals. In the present study, we investigated the volume load effects in one exercise (i.e., seated row) involving back muscles (latissimus dorsi, trapezius and deltoid, spinal extensor muscle) (Wattanaprakornkul et al., 2011), which are important to control the hyperkyphosis process during aging (Katzman et al., 2010).

Our results showed that both resistance training protocols induced similar strength gains despite the different intensities [(HV group - 83% of estimated 1-RM and LV group, 66% of estimated 1-RM, $p < 0.001$), see Fig. 3a] and volumes used. These results are in agreement with previous studies (Fatouros et al., 2005; Galvão and Taaffe, 2005; Radaelli et al., 2013a,b), which showed an increase in the force produced independent of the training volume during the early phases of training (12–20 training weeks). In addition, elderly individuals may achieve similar strength adaptations when performing greater intensities (i.e., load correspondent to 5-RM) compared with lower intensities (i.e., 15-RM). Physiologically, the mechanisms to explain such force increases are supraspinal adaptations (Falvo et al., 2010); increases in maximal capacity of motor unit recruitment and excitability (Kamen, 2005); and increases in the muscle cross-sectional area (Frontera et al., 2003).

Some previous studies have compared the effects of different training volumes in elderly individuals. Galvão and Taaffe (2005) observed significant increases after intervention and between groups [1-set group (7.7%) and 3-set group (19.1%)] in the seated row 1-RM after 20 training weeks (2 sessions per week). In another study conducted by Radaelli et al. (2013a,b), a similar increase in maximal strength performance was observed in the elbow flexors 1-RM in 1-set (25.1%) and 3-set groups (26.6%) after 13 training weeks (2 per week). In addition, when investigating different intensities and volumes per set, Fatouros et al. (2005) found greater strength gains for the LV group (3×8 x 80–85% 1-RM) compared to the HV group (3×16 x 50–55% 1-RM) for chest press 1-RM, after 24 training weeks (3 sessions per week). Although we observed similar results, there are some differences between the studies mentioned above and the current study that should be taken into consideration. Firstly, in the present study only one exercise was applied under the experimental condition (seated row), while the other studies applied four exercises for the upper limbs, which increases the total volume load. Secondly, the other studies represented volume load by sets X repetitions or sets X repetitions X % 1-RM, while in the present study the volume load is represented relative to a specific range of maximal repetitions. In view of this, the RMVL was different between groups (i.e., 1255 kg for the HV group, and 991 kg for the LV group, respectively). However, although there were no differences between groups in maximal strength (see Fig. 2a), effect size was higher in the HV (2.3; large) compared to the LV (1.78; moderate), which may suggest some advantages of HV in the present study.

Along with improvement in maximal strength, local muscle endurance also improved for both groups, with moderate effect size for the LV (1.28) and small for the HV (0.98). Although LME is an important neuromuscular parameter, few studies have investigated the effects of training volume on this variable. Vincent et al. (2002) observed increases in both the low intensity group (i.e., $1 \times 13 \times 50\%$ 1-RM) and high intensity group (i.e., $1 \times 8 \times 80\%$ 1-RM), with no differences between groups, which might be explained by the fact that both groups used similar total training volume (i.e., low intensity: 650 kg and high intensity: 640 kg). Opposing results were found by Galvão and Taaffe (2005), since they demonstrated that the high volume group improved significantly more than the low volume group (44% vs. 10%) after 20 training weeks. Our results disagree with those of both studies, as similar gains were observed in both groups (HV and LV) after the intervention period (12 weeks). These discrepancies could be explained by different methods used to assess the LME, since we applied the 30-s arm curl test suggested by Rikli and Jones (2013), which is more specific for elderly people, and more commonly practiced from a clinical point of view; whereas the studies mentioned above assessed this variable using the maximal number of repetitions performed in the bench press. Although no differences were observed, the greater effect size observed in the LME of the LV compared to the HV may suggest an advantage to this RT regime, which is possibly explained by the specificity (i.e., greater number of repetitions).

Another excellent clinical parameter for upper limbs is handgrip strength, as it can be applied to different age groups (Massy-Westropp et al., 2011), and performance in this test is strongly and inversely related with mortality (Snih et al., 2002). Our results showed no significant increases or differences between groups. One factor which may explain the absence of gains after intervention is that the subjects of the present study did not present severe functional decline at baseline, and the baseline HGS shown by our subjects in both groups were the expected values for this age range [(men-LV = 38 kgf and HV = 35 kgf; women-LV = 29 kgf and HV = 30 kgf) according to Massy-Westropp et al. (2011).

Our second objective was to verify the training retention after 12 weeks of detraining in the different RT groups, and our hypothesis was refuted, since we believed the groups would present different magnitudes of losses after the detraining period. Both groups presented similar responses in muscle strength (5-RM) and LME retention, demonstrating similar declines in these values in comparison with post training values. However, even with these losses, muscle strength values were elevated when compared to pre training levels, remaining at the level of middle training.

Previously, two studies have raised two hypotheses to explain greater retention of maximal strength. Fatouros et al. (2005) showed higher intensity training could be more beneficial than low intensity training for maximal strength retention and Harris et al. (2007) suggested that total volume of training is more important than intensity. Our findings did not corroborate those found by Fatouros et al. (2005) and Harris et al. (2007), suggesting that retention of muscle strength is more related to magnitude of gains after the training, independent of the RT regime.

The present study has some limitations. First, the sample size is small and care is required in the extrapolation of our results. In addition, our results were observed in healthy aging individuals and should not be generalized to other elderly populations, such as the frail elderly. Participant allocation was based only on the 5-RM test, and it is possible a group allocation involving all tested variables would be more appropriate in future studies. On the other hand, among the strengths of our study, it should be pointed out that this is the first study to compare the effects of different volume loads on the upper-limb strength performance of middle-aged adults.

In summary, different volumes and absolute loads of resistance training induced similar improvements in upper body maximal strength (5-RM) and local muscular endurance in untrained aging individuals. From a practical standpoint, coaches and health professionals involved with resistance training for aging individuals can start the resistance training program with any volume of training (high or low), since both maximize upper-limb strength and LME gains. Moreover, independent of training volume, training retention is demonstrated, since the post detraining values remained above the pre-training levels.

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References

Arnold, P., Bautmans, I., 2014. The influence of strength training on muscle activation in elderly persons: a systematic review and meta-analysis. Exp. Gerontol. 58, 58–68.

Bottaro, M., Veloso, J., Wagner, D., Gentil, P., 2011. Resistance training for strength and muscle thickness: effect of number of sets and muscle group trained. Sci. Sports 26, 259–264.

Brzycki, M., 1993. Strength testing - predicting a one-rep max from reps-to-fatigue. J. Phys. Educ. Recreat. Dance 64, 88–90.

Clark, B.C., Manini, T.M., 2010. Functional consequences of sarcopenia and dynapenia in the elderly. Curr. Opin. Clin. Nutr. Metab. Care 13, 271–276.

Falvo, M.J., Sirevaag, E.J., Rohrbaugh, J.W., Earhart, G., 2010. Resistance training induces supraspinal adaptations: evidence from movement-related cortical potentials. Eur. J. Appl. Physiol. 109, 923–933.

Fatouros, I.G., Kambas, a, Katrabasas, I., Nikolaidis, K., Chatzinikolaou, A., Leontsini, D., Taxildaris, K., 2005. Strength training and detraining effects on muscular strength, anaerobic power, and mobility of inactive older men are intensity dependent. Br. J. Sports Med. 39, 776–780.

Fisher, J., Steele, J., Bruce-Low, S., Smith, D., 2013. Evidence-based resistance training recommendations for muscular hypertrophy. Med. Sport. 15, 147–162.

Fisher, J., Steele, J., Smith, D., 2016. High- and low-load resistance training: interpretation and practical application of current research findings. Sports Med. 1–8.

Frontera, W.R., Hughes, V.A., Krivickas, L.S., Kim, S.-K., Foldvari, M., Roubenoff, R., 2003. Strength training in older women: early and late changes in whole muscle and single cells. Muscle Nerve 28, 601–608.

Galvão, D.A., Taaffe, D.R., 2005. Resistance exercise dosage in older adults: single- versus multiset effects on physical performance and body composition. J. Am. Geriatr. Soc. 53, 2090–2097.

Hanssen, K.E., Kvamme, N.H., Nilsen, T.S., Rønnestad, B., Ambjørnsen, I.K., Norheim, F., Kadi, F., Hallèn, J., Drevon, C.A., Raastad, T., 2013. The effect of strength training volume on satellite cells, myogenic regulatory factors, and growth factors. Scand. J. Med. Sci. Sports 23, 728–739.

Harris, C., DeBeliso, M., Adams, K.J., Irmischer, B.S., T.A.S.G., 2007. Detraining in the older adult: effects of prior training intensity on strength retention. J. Strength Condit Res. 21, 813–818.

Kamen, G., 2005. Aging, resistance training, and motor unit discharge behavior. Can. J. Appl. Physiol. 30, 341–351.

Katzman, W.B., Wanek, L., Shepherd, J.A., Sellmeyer, D.E., 2010. Age-related hyperkyphosis: its causes, consequences, and management. J. Orthop. Sports Phys. Ther. 40, 352–360.

Lins-Filho, O.L., Robertson, R.J., Farah, B.Q., Rodrigues, S.L.C., Cyrino, E.S., Ritti-Dias, R.M., 2012. Effects of exercise intensity on rating of perceived exertion during a multiple-set resistance exercise session. J. Strength Condit Res. 26, 466–472.

Massy-Westropp, N.M., Gill, T.K., Taylor, A.W., Bohannon, R.W., Hill, C.L., 2011. Hand Grip Strength: age and gender stratified normative data in a population-based study. BMC Res. Notes 4, 127.

Radaelli, R., Botton, C.E., Wilhelm, E.N., Bottaro, M., Lacerda, F., Gaya, A., Moraes, K., Peruzzolo, A., Brown, L.E., Pinto, R.S., 2013a. Low- and high-volume strength training induces similar neuromuscular improvements in muscle quality in elderly women. Exp. Gerontol. 48, 710–716.

Radaelli, R., Fleck, S.J., Leite, T., Leite, R.D., Pinto, R.S., Fernandes, L., Simão, R., 2015. Dose-response of 1, 3, and 5 sets of resistance exercise on strength, local muscular endurance, and hypertrophy. J. Strength Condit Res. 29, 1349–1358.

Radaelli, R., Wilhelm, E., Botton, C., Bottaro, M., Cadore, E., Brown, L., Pinto, R., 2013b. Effect of two different strength training volumes on muscle hypertrophy and quality in elderly women. J. Sports Med. Phys. Fit. 53, 1–6.

Reid, K.F., Martin, K.I., Doros, G., Clark, D.J., Hau, C., Patten, C., Phillips, E.M., Frontera, W.R., Fielding, R. a., 2014. Comparative effects of light or heavy resistance power training for improving lower extremity power and physical performance in mobility-limited older adults. J Gerontol A Biol Sci Med Sci 70, 374–380.

Rhea, M.R., 2004. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J. Strength Condit Res. 18, 918–920.

Rikli, R.E., Jones, C.J., 2013. Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. Gerontol 53, 255–267.

Rønnestad, B.R., Egeland, W., Kvamme, N.H., Refsnes, P.E., Kadi, F., Raastad, T., 2007. Dissimilar effects of one- and three-set strength training on strength and muscle mass gains in upper and lower body in untrained subjects. J. Strength Condit Res. 21, 157–163.

Schoenfeld, B.J., 2013. Is there a minimum intensity threshold for resistance training-induced hypertrophic adaptations? Sports Med. 43, 1279–1288.

Scott, B.R., Duthie, G.M., Thornton, H.R., Dascombe, B.J., 2016. Training monitoring for resistance exercise: theory and applications. Sports Med. 46 (5), 687–689.

Simão, R., Spineti, J., de Salles, B.F., Matta, T., Fernandes, L., Fleck, S.J., Rhea, M.R., Strom-Olsen, H.E., 2012. Comparison between nonlinear and linear periodized resistance training. J. Strength Condit Res. 26, 1389–1395.

Snih, S. Al, Markides, K.S., Ray, L., Ostir, G.V., Goodwin, J.S., 2002. Handgrip strength and mortality in older Mexican Americans. J. Am. Geriatr. Soc. 50, 1250–1256.

Vincent, K.R., Braith, R.W., Feldman, R.A., Magyari, P.M., Cutler, R.B., Persin, S.A., Lennon, S.L., Gabr, A.H., Lowenthal, D.T., 2002. Resistance exercise and physical performance in adults aged 60 to 83. J J Am Geriatr Soc 50, 1100–1107.

Walker, S., Peltonen, H., Häkkinen, K., 2015. Medium-intensity, High-Volume "Hypertrophic" Resistance Training Did Not Induce Improvements in Rapid Force Production in Healthy Older Men. Age 37.

Wattanaprakornkul, D., Halaki, M., Cathers, I., Ginn, K.A., 2011. Direction-specific recruitment of rotator cuff muscles during bench press and row. J. Electromyogr. Kinesiol. 21, 1041–1049.