Comparisons Between Low-Intensity Resistance Training With Blood Flow Restriction and High-Intensity Resistance Training on Quadriceps Muscle Mass and Strength in Elderly

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[1]*Laboratory of Neuromuscular Adaptations to Strength Training, School of Physical Education and Sport, University of São Paulo;* [2]*Laboratory of Exercise Physiology, School of Physical Education, State University of Campinas; and* [3]*Department of Physical Education, Center of Biological Sciences and Health, Federal University of São Carlos–UFSCar*

Abstract

Vechin, FC, Libardi, CA, Conceição, MS, Damas, FR, Lixandrão, ME, Berton, RPB, Tricoli, VAA, Roschel, HA, Cavaglieri, CR, Chacon-Mikahil, MPT, and Ugrinowitsch, C. Comparisons between low-intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly. *J Strength Cond Res* 29(4): 1071–1076, 2015—High-intensity resistance training (HRT) has been recommended to offset age-related loss in muscle strength and mass. However, part of the elderly population is often unable to exercise at high intensities. Alternatively, low-intensity resistance training with blood flow restriction (LRT-BFR) has emerged. The purpose of this study was to compare the effects of LRT-BFR and HRT on quadriceps muscle strength and mass in elderly. Twenty-three elderly individuals, 14 men and 9 women (age, 64.04 ± 3.81 years; weight, 72.55 ± 16.52 kg; height, 163 ± 11 cm), undertook 12 weeks of training. Subjects were ranked according to their pretraining quadriceps cross-sectional area (CSA) values and then randomly allocated into one of the following groups: (a) control group, (b) HRT: 4 × 10 repetitions, 70–80% one repetition maximum (1RM), and (c) LRT-BFR: 4 sets (1 × 30 and 3 × 15 repetitions), 20–30% 1RM. The occlusion pressure was set at 50% of maximum tibial arterial pressure and sustained during the whole training session. Leg press 1RM and quadriceps CSA were evaluated at before and after training. A mixed-model analysis was performed, and the significance level was set at $p \le 0.05$. Both training regimes were effective in increasing pre- to post-training leg press 1RM (HRT: ~54%, $p < 0.001$; LRT-BFR: ~17%, $p = 0.067$) and quadriceps CSA (HRT: 7.9%, $p < 0.001$; LRT-BFR: 6.6%, $p < 0.001$); however, HRT seems to induce greater strength gains. In summary, LRT-BFR constitutes an important surrogate approach to HRT as an effective training method to induce gains in muscle strength and mass in elderly.

Key Words quadriceps cross-sectional area, thigh blood pressure cuff, muscle hypertrophy, aging

Introduction

Aging is characterized by a number of structural and functional changes in the organism that lead to a progressive loss of muscle strength and mass (7–9,18). In this regard, physical exercise, namely, resistance training (RT), has been widely recommended to offset some of the age-related impairments in functionality and alterations in body composition (4,12,13,24).

Current recommendations advocate that RT should be performed at least twice a week with moderate-to-vigorous intensity to maintain or enhance muscle strength and mass (2,3). Despite the previously demonstrated effectiveness of high-intensity RT (HRT) (4,12,13,24,29), the heavy load implicated in this form of training may not be suitable to the entire elderly population, including the frail elderly, novice RT practitioners, and older individuals with joint and cardiorespiratory impairments (19,21,25).

An alternative approach to HRT is the combination of low-intensity RT (e.g., 20–30%, one repetition maximum [1RM]) with blood flow restriction (LRT-BFR). Low-intensity RT with blood flow restriction has been alleged to induce similar gains in muscle mass and strength, as

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compared with conventional HRT in different populations (e.g., athletes and health young adults) (1,14,17,27,28). The clinical application of this intervention constitutes an interesting approach to RT in elderly population, as older individuals are often unable to exercise at high intensities.

However, data regarding the effects of LRT-BFR in older individuals are still scarce (14,31). To the best of our knowledge, only 1 study has addressed the effects of this training method on lower limb muscle strength in older individuals (14). The authors reported similar gains in lower limb 1RM in a direct comparison between LRT-BFR and HRT. However, no study has provided a comparative assessment of the 2 methods in respect of its effects on muscle mass in elderly population. The sole study that has investigated the effects of LRT-BFR on muscle mass in older individuals (31) did not have an HRT group, warranting further investigations.

Thus, the aim of this study was to compare the effects of 12 weeks of either LRT-BFR or HRT on quadriceps muscle strength and mass in elderly individuals.

Methods

Experimental Approach to the Problem

We used a repeated measures design to assess the effectiveness of LRT-BFR in increasing the muscle strength and mass in older individuals. Subjects were ranked in quartiles according to their initial quadriceps cross-sectional area (CSA) and then randomly allocated into one of the following groups: control group (CG) ($n = 7$; age, 66.0 ± 5.0 years; weight, 69.3 ± 16.1 kg; height, 1.61 ± 0.1 m), HRT ($n = 8$; 62.0 ± 3.0 years; 68.7 ± 15.3 kg; 1.60 ± 0.1 m), and LRT-BFR ($n = 8$; 65.0 ± 2.0 years; 79.3 ± 17.9 kg; 1.70 ± 0.1 m). Two weeks before the commencement of the training program (PRE), quadriceps CSA (assessed by magnetic resonance imaging [MRI]) and muscle strength (assessed by the 1RM test) were evaluated. Importantly, the subjects performed 2 familiarization sessions to get acquainted with the leg press 1RM test procedures before testing. The 1RM test was performed 48 hours after the last familiarization session. Afterward, subjects underwent 12 weeks of training, 2 times per week. The CG maintained daily live activities. The leg press 1RM was reassessed at the sixth week to adjust the training loads. The quadriceps CSA and leg press 1RM were also assessed at the end of the intervention (post: 5 days after the completion of the last training session).

Subjects

Twenty-three healthy older individuals (14 men and 9 women; age range is 59 – 71 years old) volunteered to participate in this study. The inclusion criteria were not to have cardiac disease, arterial hypertension, diabetes mellitus, or any musculoskeletal conditions in the lower extremities that precluded the participation in the training protocols and tests proposed and not to have participated in a RT program for at least 6 months before the study. All of the participants provided their informed consent, and the experimental protocol was approved by the University's Ethics Committee. The study was conducted in conformity with the policy statement regarding the use of human subjects by the Declaration of Helsinki.

One Repetition Maximum Test

Leg press strength was assessed using the 1RM test on the leg press machine (45° leg press, G3-PL70; Matrix, São Paulo, Brazil) following the Brown and Weir (5) recommendations. Briefly, the protocol consisted of a 5-minute general warm-up on an ergometric bicycle at 60 rpm and 25 W. This was followed by a specific warm-up consisting of 1 set of 10 repetitions at 50% of the estimated 1RM, followed by 1 set of 3 repetitions at 70% of the estimated 1RM with 1-minute rest between sets. After a 3-minute rest period, the subjects had up to 5 attempts to achieve their 1RM. A 3-minute rest interval was respected between attempts, and the higher load achieved (fully eccentric-concentric movement with 90° range of motion) was considered as the 1RM.

Quadriceps Cross-Sectional Area

Quadriceps CSA was obtained through MRI (Signa LX 9.1; GE Healthcare, Milwaukee, WI, USA). Participants were positioned lying in a supine position with the knees extended and legs straight. An initial reference image was obtained to determine the perpendicular distance from the greater trochanter of the femur to the inferior border of the lateral epicondyle of the femur, which was defined as the segment length. Quadriceps CSA was measured at 50% of the segment length with 0.8-cm slices for 3 seconds. The pulse sequence was performed with a field of view between 400 and 420 mm, time of repetition of 350 milliseconds, eco time from 9 to 11 milliseconds, 2 signal acquisitions, and a matrix of reconstruction of 256 × 256 mm. The images were then transferred to a workstation (Advantage Workstation 4.3; GE Healthcare) to determine quadriceps CSA. The quadriceps muscle was identified and was delimitated through tracing in triplicates by a specialized researcher, and the mean values were used for further analysis. The coefficient of variation between measurements was 1.89%.

Determination of the Blood Flow Restriction Training Pressure

An 18-cm wide cuff was placed on the proximal portion of the thigh (inguinal fold region) and inflated until blood pulse absence was observed through auscultation with a vascular Doppler probe (DV-600; Marted, São Paulo, Brazil) placed over the tibial artery. The investigator released the pressure slowly until the first arterial pulse could be detected, which was considered the systolic pressure at the tibial artery. Cuff pressure was set at 50% of the maximum tibial arterial pressure throughout the experimental period. However, subjects repeated this procedure once a week to adjust the training pressure if needed. The average cuff pressure over the training period was of 71 ± 9 mm Hg. The cuff was maintained inflated throughout the entire training sessions.

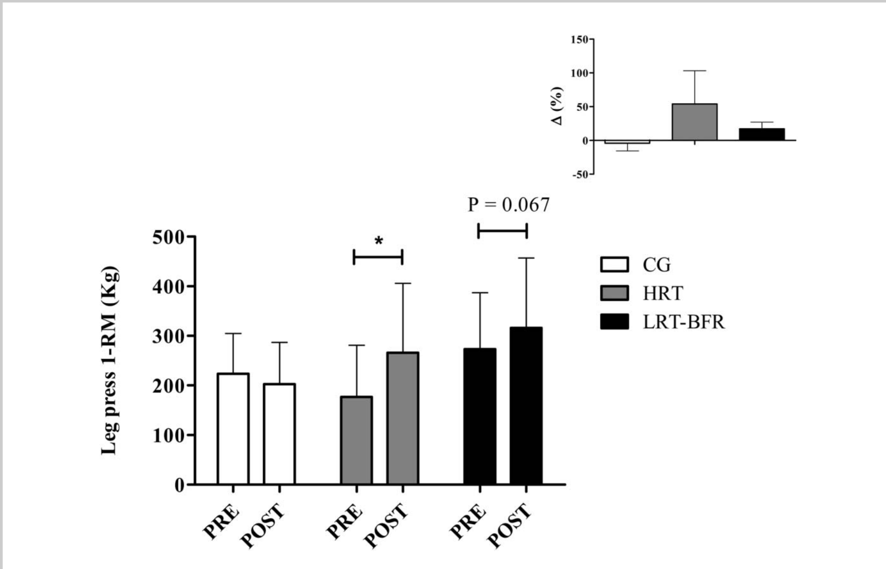

Figure 1. Pre- and post-training leg press 1RM values for the CG, HRT, and LRT-BFR. Inset: delta percentage (pre- to post-training) of each group. Data are presented as mean ± *SD*. *Significant within-group differences (pre- to post-training) ($p \leq 0.05$). RM = repetition maximum; CG = control group; HRT = high-intensity resistance training; LRT-BFR = low-intensity resistance training with blood flow restriction.

Training Protocol

The subjects performed the 45° leg press exercise (G3-PL70; Matrix), 2 days per week for 12 weeks. The HRT group performed 4 sets of 10 repetitions with a load corresponding to 70% 1RM in the first 6 weeks of training. Load was increased to 80% 1RM for the remaining weeks. The LRT-BFR group performed a total of 4 sets, 1 set of 30 repetitions and 3 sets of 15 repetitions, with a load corresponding to 20% 1RM in the first 6 weeks of training. Then, load was increased to 30% 1RM for the following weeks. A 1-minute rest period was granted between sets for both groups. Both training protocols were defined based on the fact that their effectiveness and safety have been individually tested elsewhere (12,14,29,31). The range of motion at the knee joint during the leg press exercise was of 90°. Subjects were asked to execute the concentric and the eccentric phases of the exercise in 2 seconds.

Statistical Analyses

Data normality and equality of variance were assessed through the Shapiro-Wilk's and Levene's tests, respectively. To test between-group values for quadriceps CSA and 1RM, a one-way analysis of variance was performed ($p > 0.05$). A mixed model was performed for each dependent variable, assuming group (CG, LRT-BFR, and HRT) and time (pre- and post-training) as fixed factors and subjects as a random factor. Whenever a significant F value was obtained, a Tukey's adjustment was performed for multiple comparison purposes. The significance level was set at $p \leq 0.05$. All of the statistical tests were performed using SAS version 9.3 for Windows (SAS Institute Inc., Cary, NC, USA). Although no between-group differences were found at baseline, a visual inspection detected somewhat discrepant leg press 1RM values between the experimental groups. Thus, a mixed model assuming groups as a fixed factor, subjects as a random factor, pretest

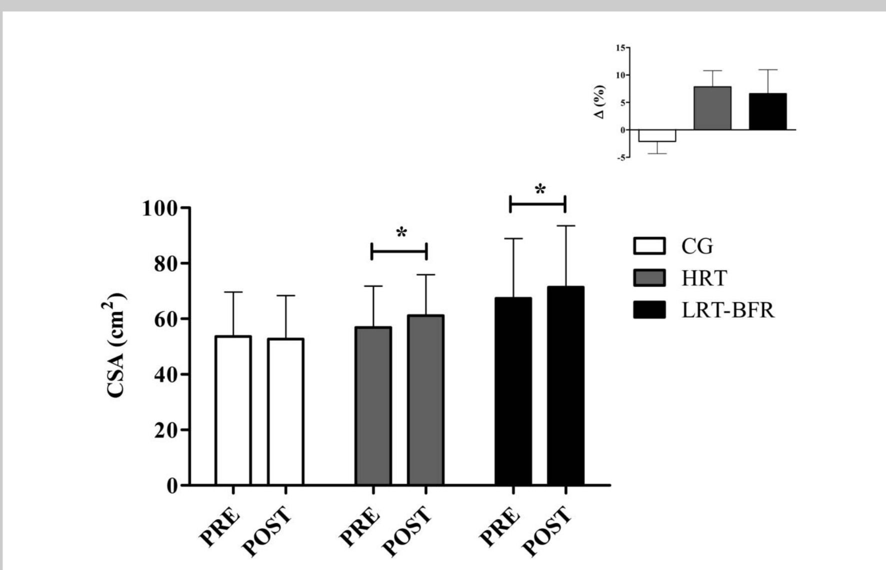

Figure 2. Pre- and post-training quadriceps CSA for the CG, HRT, and LRT-BFR. Inset: delta percentage (pre- to post-training) of each group. Data are presented as mean ± *SD*. *Significant within-group differences (pre- to post-training) ($p \leq 0.05$). CSA = cross-sectional area; CG = control group; HRT = high-intensity resistance training; LRT-BFR = low-intensity resistance training with blood flow restriction.

initial 1RM values as a covariate, and individuals' delta change (%) as dependent variable was used. This analysis was performed to adjust individual delta change values to the covariate (i.e., pretest values). Then, the estimated mean and *SD* delta changes (i.e., adjusted by the covariate) from each group were used to calculate effect sizes (ES) and not for hypothesis test purposes. Several authors have suggested the use of ES for within-group and between-group comparisons, as they do not give a dichotomic answer (i.e., significant or not significant) and are able to deal with highly variable data (23). Thus, ES confidence intervals (CIs) of the differences (ES_{CLdiff}) were calculated using a noncentral *t* distribution to perform within-group and between-group comparisons. Positive and negative CIs (i.e., did not cross zero 0) were considered as significant. Results are expressed as mean ± *SD*.

Results

The leg press 1RM values were significantly increased for the HRT group (pre: 177 ± 104 kg, post: 266 ± 140 kg; $p < 0.001$), and a trend toward significantly greater values ($p = 0.067$) was observed for the LRT-BFR group (pre: 273 ± 114 kg, post: 316 ± 141 kg) (Figure 1). The CG showed no differences in the leg press 1RM values from the pre- to post-training tests (224 ± 81 kg and 203 ± 84 kg, respectively; $p = 0.998$). ES_{CLdiff} analysis for the 1RM data showed an ES (ES: 1.50; 95% CI: 0.78–2.41) between HRT and CG. A smaller, although practically relevant ES (ES: 0.59; 95% CI: 0.03–1.22), was found between LRT-BFR and CG. An ES (ES: 0.92; 95% CI: 0.33–1.61) was found when comparing HRT and LRT-BFR.

Quadriceps CSA increased significantly over time both in the HRT (pre: 56.9 ± 14.9 cm^2, post: 61.1 ± 14.8 cm^2; $p < 0.001$) and LRT-BFR groups (pre: 67.4 ± 21.5 cm^2, post: 71.4 ± 22.1 cm^2; $p < 0.001$). No changes in quadriceps CSA were observed in the CG (pre: 53.6 ± 16 cm^2, post: 52.7 ± 15.7 cm^2; $p < 0.395$) (Figure 2).

Discussion

This was the first study to compare the effectiveness between LRT-BFR and HRT on gains in lower limb muscle function and mass in elderly. Our main findings were that LRT-BFR and HRT promoted increases in leg press 1RM, and both methods were similarly effective in inducing increase in quadriceps CSA in a cohort of older individuals. However, relevant differences in strength gains were observed between the 2 training groups (LRT-BFR: ~17%; HRT: ~54%) after the ES analysis.

Decreases in muscle function commonly observed with aging are greatly related to impairments in muscle strength (10,26). In this respect, strategies aiming to increase muscle strength and preserving functionality in elderly are of interest. High-intensity RT has been consistently shown to increase muscle strength in older individuals. For instance, Wallerstein et al. (29) demonstrated that 16 weeks of HRT induced significant improvements in lower limb maximum dynamic strength. Similarly, Lohne-Seiler et al. (20) reported significant gains in leg press 1RM after an 11-week HRT program. In this study, the HRT group presented significant improvements in leg press 1RM (~54%), whereas the LRT-BFR group had a tendency toward a significant increase ($p = 0.067$; ~17%). Although the findings of the HRT group are in line with the literature (8,12), one may speculate that the smaller increase observed in the LRT-BFR group may be somehow related to the lower occlusion pressure (~71 mm Hg; 50% of maximum tibial artery pressure) applied when compared with previous studies in the literature (14,31). Importantly, the dissonant occlusion pressures are mostly due to the differences in cuff width between studies. In this respect, we opted for a wider cuff (18 cm), as it has been previously demonstrated that the wider the cuff, the lower the pressure required to occlude circulation (e.g., an 18-cm wide cuff would require ~140 mm Hg to fully occlude blood flow, whereas a 4.5-cm cuff requires more than 360 mm Hg of pressure to induce full BFR) (6,30). However, despite the lack of within-group (LRT-BFR) significant differences in this study, our results are very similar to those of Karabulut et al. (14), who found increases of ~20% in leg press 1RM after a 6-week LRT-BFR using much higher occlusion pressures (~205 mm Hg) but using a narrower cuff (5 cm). In the Karabulut et al. (14) training schemes, they performed 3 sets (30 × 15 × 15) of 2 leg exercises (leg extension and leg press) with a load corresponding to 20% 1RM. Thus, they used a training volume (i.e., sets × repetitions) that was the double of the volume used in this study and achieved similar strength increments but with only 6 weeks of training. Furthermore, using a similar training protocol to Karabulut et al. (14), for 12 weeks, Yasuda et al. (31) reported increments of ~33% in leg press 1RM. These findings suggest that LRT-BFR may require a higher training volume to produce greater strength increments. Alternatively, the blunted response of LRT-BFR on strength when compared with HRT may be, at least partially, explained by the lesser neural adaptation observed after this training method. In fact, previous studies have demonstrated no changes in the activation level (as assessed by either surface electromyography or twitch interpolation) of upper limb muscles after LRT-BFR in healthy young subjects with low loads (20–30% 1RM) (16,22). Additional studies dedicated to investigate the effects of LRT-BFR on neuromuscular adaptations in the elderly population are necessary to further elucidate this issue.

Maintaining or enhancing skeletal muscle mass is imperative to preserve or rescue impaired functionality with aging (10,26). Regarding the HRT group, the findings presented here (i.e., 7.9% increase in CSA) are within the range reported in the literature. For instance, increases in quadriceps CSA ranging from 6.5 to 10% have been reported after a short-term HRT (24,29). Nevertheless, high loads, as those used in regular HRT, may not be suitable to a part of the elderly population (e.g., frail elderly, novice RT practitioners, or even older individuals with joint and/or cardiorespiratory impairments) (19,21,25). In this study, the alternative training method (i.e., LRT-BFR) was shown to be just as effective as regular HRT on improving quadriceps CSA (i.e., 6.6%). Accordingly, Yasuda et al. (31) demonstrated a similar increase (~8.0%) in muscle CSA; however, it is important to note that the subjects undertook double the exercise volume as compared with this study over the same time period (i.e., 12 weeks). Although these data are somewhat hard to reconcile, as total volume of exercise has been demonstrated to influence the hypertrophic response to RT (11,15), it may be suggested that training volume may not be as effective in producing muscle hypertrophy in BFR-RT protocols as when performing regular HRT. This suggestion should be addressed in future studies.

In summary, this was the first study to provide data on the direct comparison of LRT-BFR and HRT on a cohort of elderly population, supporting the use of a lower-intensity (and perhaps safer) RT strategy as a surrogate to a high-load RT program. We demonstrated that both training regimes were effective to increase quadriceps CSA and leg press 1RM; however, HRT seems to induce greater gains in strength.

Practical Applications

Increases in muscle strength and mass are of great importance to the maintenance and/or rescue of the independence in elderly. Physical exercising, namely HRT, has been widely recommended as an effective strategy to counteract the losses in functionality and lean mass related with aging. However, an important part of the elderly population present comorbidities that often preclude the usage of HRT; thus, alternative forms of exercising able to induce similar neuromuscular adaptations while preserving feasibility are in need. In this context, LRT (i.e., 20–30% 1RM) combined with partial BFR (50% of the maximum tibial arterial pressure) constitutes an effective alternative approach to HRT in inducing gains in muscle strength and mass in elderly individuals.

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