Chronic Effect of Strength Training with Blood Flow Restriction on Muscular Strength among Women with Osteoporosis

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ABSTRACT

Silva J, Neto GR, Freitas E, Pereira Neto E, Batista G, Torres M, Sousa MS. Chronic Effect of Strength Training with Blood Flow Restriction on Muscular Strength among Women with Osteoporosis. JEPonline 2015;18(4):33-41. The aim of this study was to analyze the chronic effect of strength training (ST) combined with blood flow restriction (BFR) on maximal dynamic strength (MDS) in osteoporotic women. Fifteen elderly women with osteoporosis, aged 62.2 ± 4.53 yrs, took part in the study. They were proportionally randomized into three groups: (a) low-intensity strength training with BFR (LI+BFR); (b) high intensity exercise (HI); and (c) control (CON). Experimental groups performed knee extensions for 12 wks, 2 times wk⁻¹. The CON subjects maintained their normal daily activities. They did not perform any type of exercise during the study period. The one-repetition maximum (1-RM) test was performed to assess MDS pre-test and at 6th- and 12th-wks. Outcomes showed significant increases in the MDS when the pre-test and the 12th-wk values were compared for the HI and LI+BFR groups (P<0.001; P=0.004), respectively. The ES of LI+BFR was also effective in improving MDS levels. Therefore, this method of intervention might be an effective alternative for special groups, particularly osteoporotic women.

Keywords: Strength Training, Osteoporosis, Women, Kaatsu
INTRODUCTION

In Brazil, it is estimated that ~10 million people suffer from osteoporosis (9). According to the World Health Organization (22), this disease is the second-largest health care problem in the world followed by cardiovascular disorders. Osteoporosis is a metabolic bone disorder characterized by decreased bone mineral density (BMD) with deterioration of the bone microarchitecture. The disorder occurs most frequently after menopause (20). Combined with the decrease in muscle mass, BMD decreases the capacity to produce strength that leads to increased skeletal fragility and fractures due to falls (13). On the other hand, strength training (ST) is an excellent treatment to increase the size and strength of the muscles to help maintain and/or increase BMD in people with osteoporosis (2). As a result, there is anticipated reduction in the risk of falls along with an increase in functional capacity (8).

Thus, high-intensity ST improves the performance of daily activities among older adults and people with osteoporosis (21,28,26). The physiological mechanisms associated with high-intensity ST (≥ 70% of one-repetition maximum, 1-RM) and improvements in BMD are attributed to the stress imposed on the joints, the muscles, and the skeletal structures in which the muscles originate and insert (6). Yet, several studies show that low-intensity ST (20 to 50% of 1-RM) combined with blood flow restriction (BFR) produces similar strength and muscle mass gains without causing great stress to the joints resulting from high-intensity ST (1,11,16). This means the combination of ST with BFR may be a better alternative, especially at the beginning of the training sessions to increase muscle strength and muscle mass in older adults.

The low-intensity ST with BFR method is carried out with the use of an inflatable cuff to restrict blood flow to and from the muscles. The BFR results in significant intramuscular changes and neural activity (25,27) that is associated with a rapid recruitment of type II motor units (18). These are also changes observed in high-intensity ST that are important for developing strength, increasing muscle mass, and improving functional capacity.

While the benefits of performing ST with BFR among older adults without osteoporosis are already documented [e.g., increased muscle strength (10,30), improved bone markers (4,11,17), and improved hormonal response (7,23)], the purpose of this study was to analyze the chronic effect of strength training (ST) combined with BFR on maximal dynamic strength (MDS) in osteoporotic women.

METHODS

Subjects
Fifteen osteoporotic women agreed to participate as subjects in this study. They were proportionally randomized into three groups: (a) low-intensity ST group with blood flow restriction (LI+BFR); (b) high-intensity ST group (HI); and (c) control group (CON), which was not exposed to exercise (refer to Table 1 for subject characteristics). The sample size was calculated using G*Power 3.1® software (Ausseldorf, Bundesland, Germany). Based on a post-hoc analysis, an alpha level of P≤0.05, a correlation coefficient of 0.5, and an effect size of 0.80 were used for n = 15 subjects. We found that the sample size was sufficient to provide 80.9% statistical power. To calculate the sample size, the procedures suggested by Beck were adopted (3).
Table 1. Sample Characteristics.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control (n=5)</th>
<th>HI (n=5)</th>
<th>LI+BFR (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>62.20 ± 4.08</td>
<td>61.80 ± 6.01</td>
<td>62.60 ± 4.33</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>152.96 ± 6.59</td>
<td>150.56 ± 4.85</td>
<td>151.78 ± 5.99</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>58.52 ± 12</td>
<td>57.32 ± 8.56</td>
<td>63.98 ± 11.91</td>
</tr>
</tbody>
</table>

Note: Values are expressed as the means ± standard deviations; HI = high-intensity group; LI+BFR = low-intensity group combined with blood flow restriction.

Women with the following characteristics were included in the study: (a) chronological age greater than 50 yrs; (b) six months without performing lower-limb strengthening activities; and (c) previous diagnosis of osteoporosis with a T-score lower than -2.5 SD. After the study’s possible risks and benefits were explained, the subjects signed an informed consent form prepared in accordance with the Declaration of Helsinki. The study was approved by the Human Research Ethics Committee under protocol no. 100/13.

Instruments

**Determination of BFR**
The BFR procedure was performed by vascular Doppler (MedPej® DV-2001, Ribeirão Preto, State of São Paulo - SP, Brazil), in which the transducer was placed on the posterior tibial artery. A blood pressure cuff (18 cm in width and 80 cm in length) was secured to the thigh (inguinal fold) and inflated to the point that the auscultatory pulse of the tibial artery was interrupted (15). The tourniquet pressure used during the training protocol was set as 80% of the pressure required for complete BFR in the resting state (15). The cuff was deflated between the series. The mean pressure used throughout the exercise protocol was 104.20 ± 7.88 mm Hg.

**Maximum Strength Measure (1-RM)**
The MDS (1-RM) was determined following the recommendations of the American Society of Exercise Physiologists (5) and was performed using a leg extension machine (Body Fitness, Brazil) unilaterally (right lower limb). The sample subjects were instructed not to perform physical activities or strenuous efforts for at least 24 hrs prior to the tests. To warm up, a series of 5 to 10 repetitions of knee extensions were performed on the same machine on which the test was performed, with a load of 40% of the perceived 1-RM. After 1-min of rest, the subjects performed a second series of 3 to 5 repetitions with 60 to 80% of the perceived 1-RM load. Subsequently, the subjects tried to perform a maximum repetition. The load was measured regardless of the goal being achieved or not. The subjects had at most five attempts with 5-min intervals between them to allow for measurement of the 1-RM. In case the 1-RM could not be measured in these five attempts, this process was repeated after 72 hrs. No pause was allowed between the concentric and the eccentric phase of a repetition or between repetitions. The maximum strength was evaluated pre-test and at the 6th-wk and the 12th-wk.
**Procedures**

**ST Program**
The ST program lasted 12 wks. It was designed with two weekly sessions separated by a 48-hr interval (totaling 24 sessions). The exercise used was unilateral knee extension (right leg). The experimental groups performed a 3-min warm-up on a stationary bicycle. The HI group performed the exercise with four series until concentric failure with a load corresponding to 80% of 1-RM and a 2-min rest interval between series (mean of 8.0 ± 2.01 repetitions per series; Figure 1A). The LI+BFR group performed four series, until concentric failure, with a load corresponding to 30% of 1-RM, a 30-sec rest interval between series (mean of 7.0 ± 3.38 repetitions per series), and the BFR using an inflatable cuff (Figure 1B). The CON subjects maintained their normal daily activities without a commitment to any type of physical exercise or strenuous activity involving the lower limbs throughout the study’s intervention period and until the post-test was performed.

![Diagram of training sessions](image)

**Figure 1.** Description of training sessions (alternate days) of groups HI (A); LI + BFRS (B); RM = repetition maximum; HI = high-intensity group; LI+BFR = low-intensity group combined with blood flow restriction.

**Statistical Analyses**
The descriptive results are expressed as the means ± standard deviations. The effect size was used to determine the magnitude of changes between the assessed time-points (24), and the percentage variation (Δ%) was used to express possible differences in muscle strength between the first and the third evaluations (post-test). Analysis of variance of repeated measures [3 x 3; protocols (BRF vs. HI vs. CON) x time (pre-test vs. 6th-wk vs. 12th-wk)] followed by the Bonferroni’s post hoc test were used to evaluate the effects of exercise for all dependent variables. The significance level adopted was P≤0.05. No assumption of the use of the parametric statistics was violated. All analyses were
performed in the statistical software Statistical Package for the Social Sciences (SPSS) version 20.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

In the intergroup comparison of the MDS, significant differences were observed at the 6th-wk when evaluating LI+BFR vs. CON groups \((P=0.004)\) and at the 12th-wk when evaluating LI+BFR vs. CON and HI vs. CON groups \((P=0.004\) and \(P=0.017\), respectively) (Table 2). In the intragroup analysis, the HI group exhibited a significant difference when comparing pre- vs. 6th-wk, pre- vs. 12th-wk and 6th-wk vs. 12th-wk \((P<0.001, ES = 1.44, \Delta\% = 18.35; P<0.001, ES = 2.77, \Delta\% = 34.5; P=0.002, ES = 1.39, \Delta\% = 13.65\), respectively). For the LI+BFR group, there was a significant difference when comparing pre- vs. 6th-wk and pre- vs. 12th-wk \((P=0.006, ES = 5.71, \Delta\% = 0.30; P=0.004, ES = 0.63, \Delta\% = 10.59\). The CON group did not exhibit significant differences between the three assessed time-points \((P>0.05)\).

Table 2. Comparative Analysis of Maximum Dynamic Strength (1-RM) between the Study Groups.

<table>
<thead>
<tr>
<th>RM</th>
<th>Control</th>
<th>HI</th>
<th>LI+BFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-6th-WK</td>
<td>27.98 ± 3.74</td>
<td>27.78 ± 3.45</td>
<td>35.85 ± 6.72</td>
</tr>
<tr>
<td>12th-WK</td>
<td>27.94 ± 3.76</td>
<td>32.88 ± 3.21*</td>
<td>37.90 ± 5.71*</td>
</tr>
</tbody>
</table>

Note: *Significant differences between pre- and 6th-wk, pre- and 12th-wk and 6th-wk and 12th-wk \((P<0.05)\); HI = high-intensity group; LI+BFR = low-intensity group combined with blood flow restriction.

DISCUSSION

This study analyzed the chronic effect of ST combined with BFR on the MDS of women with osteoporosis. The data from this study show significant increases in MDS in the two assessment time-points after the intervention program started in both experimental groups, but with no significant differences between them. These results corroborate those obtained by Mosti et al. (19), who observed increased maximum strength levels after a high-intensity intervention period (85 to 90% of 1-RM) over 12 wks. The same authors also observed improved BMD levels. In the study by Mosti et al. (19), the exercises were performed 3 times·wk\(^{-1}\), while in the present study, the exercises were performed 2 times·wk\(^{-1}\) without BFR. In the present study, considering that significant increases in MDS were observed with and without BFR, we can infer that performing the exercises 2 times·wk\(^{-1}\) with and without BFR seems to be sufficient to observe increased MDS in the analyzed periods and in the studied population. Thus, ST with BFR may be an alternative for improving MDS levels provided that a high volume of exercise is performed (greater than or equal to 2 times·wk\(^{-1}\)).

The effects of exercise with BFR for increasing muscle strength (11,29) are well known. This improvement is justified by increased muscle hypertrophy and neuromuscular adaptations (29). Several studies have also observed increased muscle strength when using ST with BFR in older adults (10,12,30). However, to the best of our knowledge, the present study is the first to study the effects of ST with BFR in a population of subjects with osteoporosis.
Based on studies by Karabulut et al. (10) and Yasuda et al. (30), it seems that performing ST with BFR promotes increased muscle strength in older adults whether or not they have osteoporosis. When analyzing the studies by Karabulut et al. (10) and Yasuda et al. (30) and comparing them to the present study, one observes that even when exercises are performed unilaterally, strength gains may be similar to those obtained when exercises are performed bilaterally (i.e., ST with BFR can be performed both unilaterally and bilaterally to increase the strength of older adults). Thus, we speculate that there was an increase in muscle strength levels for the LI with BFR and HI groups and that a consequent increase in MDS would occur. This result would be a counterpoint for the assertion that high-intensity and high-impact ST would be the only effective way of increasing levels of strength, hypertrophy, and gain in the formation or maintenance of bone mass (21,26,28).

Several studies have observed positive effects of ST with BFR on bone markers (4,11,17). Although ST with BFR has shown positive effects for bone metabolism, and its contribution for the recovery of bone trauma has been reported (17), it is not yet clear how this training affects bone metabolism. In a study conducted with a population of elderly men (11) that used the knee extension exercise with BFR, positive responses were observed in osteoblast activity and muscle strength. Similarly, Kim et al. (14) reported positive increases in both bone turnover markers and muscle cross-sectional area in older adults who trained with and without BFR. However, subjects who performed high-intensity training exhibited the greatest gains and showed improved bone turnover, based on higher responses of the bone anabolic marker for that type of exercise. Similarly, Bemben et al. (4) observed that, after a session of ST with BFR, the analyses of bone markers of absorption and reabsorption indicated an increase in osteoblast activity and a decrease in osteoclast activity. Thus, ST with BFR seems to be effective for developing bone tissue because it indicates a positive response in bone rehabilitation (14). Based on the above and on the articles mentioned previously, it seems that similarly to high-intensity ST, ST with BFR can improve bone markers.

Thus, based on the abovementioned findings and the data from the present study, ST performed in combination with BFR is effective for increasing MDS in the elderly population with osteoporosis. Because improvements in bone markers were observed in other studies with the use of BFR, it is reasonable to expect that this method will be an alternative intervention in this population. However, further studies are needed to assess the efficacy of using ST with BFR in the BMD of elderly populations with osteoporosis. Therefore, we recommend that high- and low-intensity training with BFR be used to prevent and control osteoporosis.

**CONCLUSIONS**

Low-intensity ST combined with BFR seems to be effective for increasing MDS in elderly women with osteoporosis. Thus, this method seems to be an effective alternative for special population groups, especially in women with osteoporosis.

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