ORIGINAL ARTICLE

Combining practical blood flow restriction with elastic band resistance training neither affects strength nor muscle thickness in young males

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ABSTRACT

The purpose of this study was to determine the effect of eight weeks of elastic band resistance training (EBRT) program associated with practical blood flow restriction (BFR) on muscle strength and hypertrophy. Fourteen physically active male participated in an eight-week upper limbs EBRT program, with one limb under BFR and the other with free blood flow (EBRT+BFR). Bilateral and unilateral elbow flexion exercises were performed three times a week, with three sets of 15 repetitions in each upper limb. Blood flow restriction was produced by an extensive band, implementing the pressure stipulated at 25% of the resting upper arm circumference. Significant main effect for time was found in elbow flexors muscle thickness measured with ultrasound to both training conditions, but no significant interactions in the time x group were identified. Relative strength gains measure with a dynamometer were -0.5 ± 10.2 % and 0.5 ± 12.1 % in the arms trained with EBRT and EBRT+BFR, respectively. The relative gains in elbow flexor muscle thickness were 1.8 ± 6.2 % with EBRT training and 5.5 ± 6.7 % in EBRT+BFR (both $p > .05$). In conclusion, applying BFR to an EBRT was not superior at increasing upper limb muscular strength or hypertrophy in young adults compared to EBRT alone.
Keywords: Sport medicine, Muscle hypertrophy, Isometric strength, Strength training, Military personnel.

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INTRODUCTION

Resistance training with blood flow restriction (BFR) is a safe and effective method to promote strength gains and muscle hypertrophy (Patterson et al., 2019). This method uses an inflated cuff at the proximal end of the limbs during the exercise; restricting arterial blood inflow to the limb increases metabolic stress and stimulates muscle hypertrophy mechanisms (Loenneke et al., 2012).

Traditionally, to obtain good gains in strength and hypertrophy, training with a minimum resistance of 65% of the maximum dynamic strength (1 maximum repetition - 1RM) and six to 12 repetitions for each muscle group is recommended (Schoenfeld et al., 2016). However, for populations unable to mobilize high overload, low-intensity resistance training programs, ranging from 10 to 50% of 1RM (Takarada et al., 2000b; Lopes et al., 2019), combined with BRF, have been proven to be a strategy quite adequate. This population includes individuals who practice neuromuscular training with straps or elastic bands.

The Brazilian Army recommends elastic band resistance training (EBRT) as an alternative to maintain the physiological effects of military physical training on the neuromuscular system, mainly when the military cannot perform regular training or attend a gym (Brazil, 2020). Regarding the effects on strength, Lopes et al. (2019) indicated, in their systematic review with meta-analysis, that EBRT is a strategy that produces results similar to those generated by conventional gym equipment.

However, the effects on muscle mass gains have yet to be studied, and the available results come from studies with older people. Colado and Triplett (2008) demonstrated that hypertrophy in older women who trained with elastic bands was lower than in those who performed conventional resistance training.

Studies that investigated the effects of the application of BFR to low-intensity elastic bands resistance training observed that this procedure was capable of causing increases in muscle thickness similar to those caused by EBRT with moderate to high intensities in older women submitted to eight weeks of EBRT of upper limbs (Thiebaud et al. al., 2013). Similar findings were reported by Yasuda et al. (2015) in older men, who demonstrated significantly higher gains in the cross-sectional area of elbow extensors and flexors after 12 weeks of elastic bands resistance training combined with BFR than among older people who only performed EBRT.

According to Yasuda et al. (2014), applying BRF favours muscle activation. Their findings indicated a progressive increase in biceps and triceps muscle activation, monitored by electromyography, during elastic bands resistance training combined with BFR but not in the control condition, which performed the same exercises with free blood flow.

As muscle activation is a key factor for hypertrophy, the application of BFR to EBRT sessions could be significant adjuvant for strength and muscle mass gain in individuals who train with elastic bands. Furthermore, given the limited scientific evidence on the effects of EBRT on hypertrophy, especially in young adults, the proposed study aims to monitor the strength and hypertrophy gains resulting from an EBRT program combined with blood flow restriction in healthy young people.

This knowledge can contribute to a better understanding of the physiological adaptations inherent to physical training, aiming at prescribing a safe and more efficient method.

MATERIALS AND METHODS

Sample

Fourteen physically active male soldiers undergoing academic training at the School of Physical Education of the Army participated in the study. All of them were healthy and presented their latest results of routine medical examinations. The participants' mean (SD) age, stature, and body mass were 27.5 ± 2.8 years, 179.0 ± 7.1 cm, and 78.5 ± 6.9 kg, respectively. The exclusion criteria were possible recent upper limb injury, participation in regular resistance training programs for upper limbs in the last three months, and the use of ergogenic aids of any kind.

A minimum sample size of 12 participants would be stipulated to detect an effect size (ES) of 0.35. This value was obtained from a study from our laboratory examining the chronic effects of BFR on upper body strength gains. According to Beck (2013), for power analysis, the type of analysis was set to repeated measures ANOVA with within-between interaction, the required power was set to 0.80, alpha was set to .05, and the correlation between repeated measures was set to r = 0.5 (G∗Power software, v.3.1.9.2).

All participants received a detailed verbal explanation of the study procedures and risks involved in the experimental procedures, and they signed a written informed consent form before participating in the study. The Army Physical Training Center Ethical Review Board approved the study under protocol #5.441.190.

Measures and procedures

Study design

The participants underwent eight weeks of EBRT in the upper limbs in free blood flow and BFR conditions. The BFR condition was applied in one of the arms, randomly distributed between the dominant and non-dominant limbs. Before and after the training period, measures of muscle strength, muscle thickness, arm circumference, and skinfolds of the upper limbs were taken. The first training session occurred five days after the initial tests, and the last one was held 72 hours before the last evaluation. During the study, all participants were constantly instructed not to perform any upper limb exercise not foreseen in conventional military physical training nor to adhere to any diet different from the usual one.

Practical blood flow restriction

Blood flow restriction was produced by an extensive band measuring 60 cm x 4 cm, implementing the pressure stipulated at 25% of the resting upper arm circumference.

Wilson et al. (2013) indicated that a rating of seven subjective perceived exertion (RPE on a 0-10 scale) corresponds to a moderate intensity of restriction that would be sufficient to generate appropriate metabolic responses to exercise. According to Aniceto et al. (2021), this RPE is achieved by performing a BFR of 25% of the upper limb circumference. For example, an individual with an arm circumference of 30 cm should receive a band tied to the extension 7.5 cm smaller than his arm circumference; that is, the researcher should tighten the band until the marking corresponds to 22.5 cm.

Training description

The volunteers were presented to the EBRT and BFR procedures through a familiarization session before the training period. On this occasion, they were asked to perform the movement with the band without tightening, tied to the upper limb, and without pressure. Then, they did the exercises with the elastic band, implementing the pressure stipulated at 25%.

Bilateral and unilateral elbow flexion exercises were performed three times a week, with three sets of 15 repetitions in each upper limb and 1-minute rest between sets. This protocol followed the Brazilian Army's Neuromuscular Training with Rubber Bands Instruction Booklet.

Purple elastic bands (Elastos Ind/Com Fisioterapia e Esportes, RJ, Brazil), equivalent to 4.8-9.1 kgf (according to data provided by the manufacturer), were used for the bilateral elbow flexion exercise. Black elastics, equivalent to 4.1-7.5 kgf were used for unilateral elbow flexion training. In the last three weeks of the protocol, a green elastic band (equivalent to 2.1-3.9 kgf) was added to both exercises.

The bilateral elbow flexion exercise was performed with the subjects standing up, with their feet parallel, knees slightly flexed, and hands in supination, holding the handles of the elastic band, which was attached to the volunteer's feet (Figure 1).

The individuals remained seated for the unilateral elbow flexion movement, with the elastic band under the foot ipsilateral to the upper limb that would perform the exercise. The subject held the elastic band with the hand in supination while the triceps region of the arm rested on the distal medial part of the thigh during the movement (Figure 1).

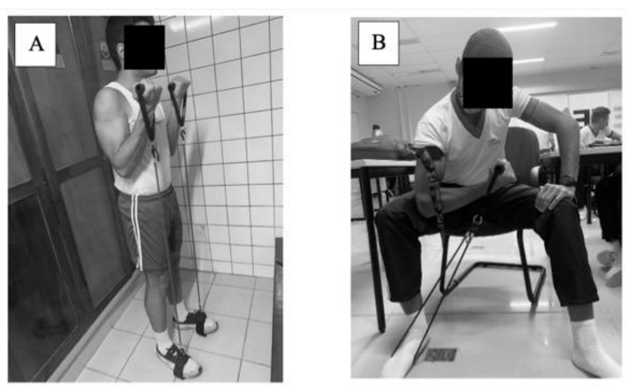


Figure 1. Example of the bilateral (A) and unilateral (B) elbow flexion exercises.

Muscle thickness and anthropometric measurements

Body mass, stature, muscle thicknesses, arm circumference and biceps skinfolds were measured by an experienced anthropometrist. Reproducibility of these measures was previously investigated in our laboratory (10 subjects, 2 measurements). Test-retest reliability yielded intraclass correlation coefficients of 0.96 for flexors muscle thickness, 0.99 for arm circumference, and 0.94 for biceps skinfolds, with a coefficient of variation of 0.7%, 0.5% and 3.2%, respectively.

Each individual was positioned in dorsal decubitus with arms extended along the body. Subsequently, the anatomical point on the upper part of the edge of the acromion, aligned with the lateral edge point located on the most proximal and lateral edge of the head of the radial bone, was marked. Afterward, the equidistant point between the two points was marked. The biceps point used to obtain the ultrasound measurement is located in the anterior portion of the biceps, at the height corresponding to the mid-acromial-radiale.

The images were obtained by an experienced evaluator using ultrasound equipment (GE Logiq, GE Healthcare, USA) with a 40 mm linear transducer, frequency of 10 MHz, and 6 cm of image depth. The transducer was moved over the skin with a conductive gel at the bicipital point.

The muscle thickness of collected images was analysed using public domain software ImageJ (National Institutes of Health, USA) to quantify measurements. Figure 2 illustrates an example of an image obtained by ultrasound.

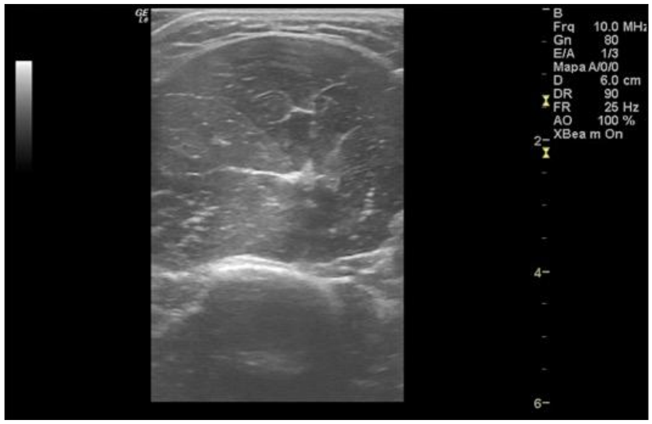


Figure 2. Typical ultrasound image of elbow flexor muscles at the biceps point.

Muscle strength measurement
The maximum unilateral isometric strength of the elbow flexor muscles was assessed using an adapted back dynamometer (Figure 3) (Smedley T.K.K. 5002, Takei Physical Fitness Test Type-3, Japan), which consists of a tensile strain gauge with a maximum capacity of 300 kgf.

The tests were applied at a 90º angle of elbow flexion. To start the procedure, the participants remained standing, with feet parallel to the dynamometer platform, knees slightly flexed, and hands in supination. The dynamometer was attached to a steel chain with a handle, which the subject used to perform elbow flexion. The maximum force used for analysis was the highest value presented after three attempts of 5 s, interspersed by 30 s. Participants received verbal stimuli during the tests to perform as hard as possible (Figure 3).

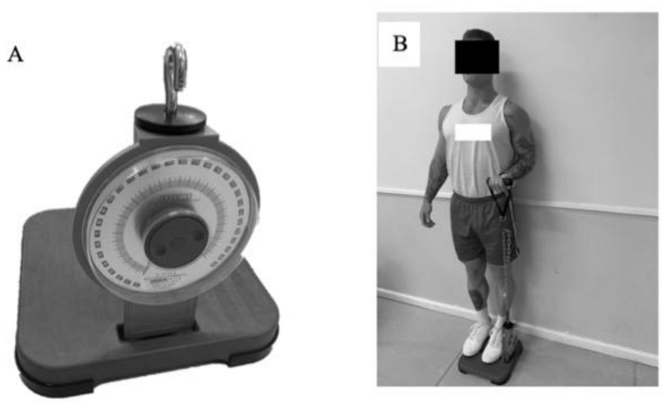


Figure 3. Illustration of the dynamometer (A) and the position used for elbow flexor muscle testing (B).

Statistical analysis
Two-way ANOVA with repeated measures in the second factor (time) was used to determine the effect of the independent variables, i.e., between-subjects factors (training with free blood flow or blood flow restriction)

and within-subjects factor of time on the dependent variables of muscle thickness and maximal isometric strength for the elbow flexors. All statistical analyses were performed using commercially available software (IBM SPSS Statistics for MacBook, Version 20.0; IBM Corp. Released 2011, Armonk, NY: IBM Corp.). All statistical analyses were tested at 95% probability.

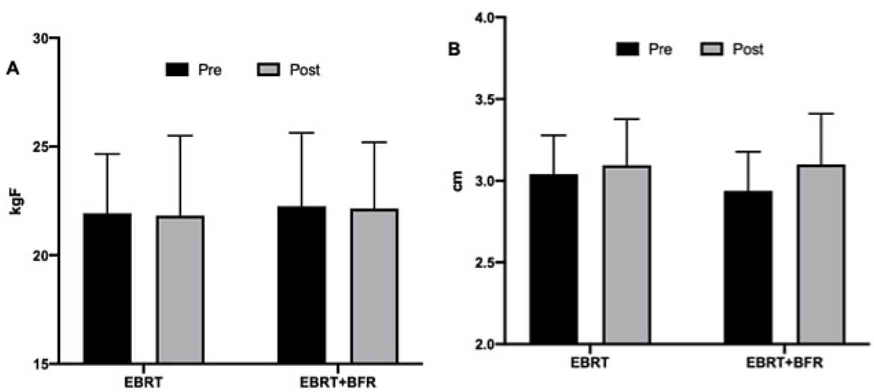
RESULTS

None of the volunteers reported adverse reactions during or after the exercise protocols. The mean upper arm circumference of participants receiving BFR treatment was 32,7 ± 1.8 cm, and the tightness produced by the extensible band during BFR exercise was 24,5 ± 1.3 cm, equivalent to 25% BFR.

Table 1. Changes in anthropometric measures in response to an elastic band resistance training (EBRT) and an elastic band resistance training combined to blood flow restriction (EBRT+BFR).

	EBRT		EBRT+BFR	
	Mean (SD)	Change (%)	Mean (SD)	Change (%)
Arm circumference (cm)				
Pre	32.5 (1.9)	0.1 (0.9)	32.5 (1.8)	0.1 (0.6)
Post	32.6 (2.3)		32.6 (2.0)	
Biceps skinfold (mm)				
Pre	3.2 (1.1)	-22.2 (20.4)	3.1 (1.1)	-20.2 (20.6)
Post	2.5 (1.2)		2.5 (1.1)	

Note. Significant main effect for time in both variable (p < .05).



Note. Significant main effect for time in muscle thickness (p < .05).

Figure 4. Changes in maximum unilateral isometric (A) and muscle thickness (B) of the elbow flexors in response to an elastic band resistance training (EBRT) and an elastic band resistance training combined to blood flow restriction (EBRT+BFR).

As shown in Table 1, both exercise modalities significantly increased subjects' arm circumference and significantly similarly decreased their biceps skinfold (time mean effect). However, no difference was detected between groups.

Figure 4 illustrates a significant main effect for time in muscle thickness variables to both training conditions. No significant interactions in the time x group were identified, indicating that EBRT was as efficient as EBRT+BFR in eliciting muscle mass gains in upper limbs. However, no significant differences were identified in isometric strength in response to the training period.

Relative strength gains were -0.5 ± 10.2 % and 0.5 ± 12.1 % in the arms trained with EBRT and EBRT+BFR, respectively (p = .824). While the relative gains in elbow flexors muscle thickness were 1.8 ± 6.2 % with EBRT training and 5.5 ± 6.7 % in EBRT+BFR (p = .063).

DISCUSSION AND CONCLUSIONS

The primary purpose of this study was to monitor gains in strength and hypertrophy resulting from an elastic band resistance training (EBRT) program combined with or without blood flow restriction (BFR). The significant findings were that changes in strength and muscle mass following EBRT performed on the elbow flexors during eight weeks were similar to the obtained by EBRT combined with BFR.

In the same direction, literature about the effects of practical BFR method, i.e., using rubber tubes or elastic wraps to reduce blood perfusion, has suggested that this procedure is as effective as conventional resistance training in promoting strength gains (Luebbers et al., 2014; Yamanaka et al., 2012).

It is important to note that the individuals did not significantly increase their elbow flexion strength with the training proposed here. Previous studies on the topic are scarce, and those available were conducted with older people. In the study by Thiebaud et al. (2013), for example, older women showed significant strength gains in both the EBRT group and the EBRT+BFR group after eight weeks of training. Yasuda et al. (2015) subjected older people of both sexes to elbow extension and flexion exercises using EBRT combined with or without BFR. They only observed significant gains in strength at the end of 12 weeks in the group that combined EBRT+BFR.

When gathering the available evidence on the isolated effects of EBRT on strength gains, unlike what was observed in the present study, the literature indicates that EBRT can provide strength gains in young, healthy men (Lopes et al., 2019). The failure of our protocol to result in significant gains in strength may have resulted from insufficient resistance of the elastic bands to cause adequate muscle activation. Muscle activation is a variable identified as essential for equalizing strength gains between exercises performed with elastic bands or conventional machines (Aboodarda et al., 2016).

Although we chose the elastic bands according to the volunteers' perception of effort and increased the resistance in the final third of the study, the resistance was still below what was necessary to trigger relevant adaptations in strength. While traditional resistance training must recruit all or almost all motor units since the beginning of the exercise (Kukulka & Clamann, 1981), the BFR possibly recruits a smaller number of motor units since most studies determine the number of repetitions, avoiding muscle failure. Then, the adopted protocols in these studies may have a different impact on the recruitment of motor units. (Yasuda et al. al., 2014).

On the other hand, muscle thickness did increase in both arms, suggesting that adding BFR to the elastic band training was ineffective at amplifying the hypertrophic effects of EBRT. The two previous studies that investigated the effects of EBRT combined with BFR were conducted with older people and found different results from ours. Thiebaud et al. (2013) pointed out that EBRT and EBRT+BFR could increase upper limb muscle thickness after eight weeks. Yasuda et al. (2015) demonstrated that significant gains in the cross-sectional area of elbow flexor and extensor muscles occurred only after EBRT combined with BFR. EBRT alone did not cause significant changes after 12 weeks.

The exact mechanism responsible for the hypertrophy process in BFR training is unknown, but several possibilities exist to explain the mechanisms. When BFR is associated with low-intensity training, there is an increase in the stimulus to muscle hypoxia, and, therefore, fundamental metabolic stress is produced to induce the mechanisms that would explain morphological adaptation. We can mention the release of anabolic hormones (Reeves et al., 2006; Takarada et al., 2000a), the reduction in the availability of myostatin (Laurentino et al., 2012), and cell swelling (Loenneke et al., 2012).

In the present study, the lack of additive hypertrophic effect of BFR on EBRT may be due to some reasons, including the applied BFR pressure. We used an adjustment based on the volunteers' arm circumference (Aniceto et al., 2021). However, this pressure was insufficient to determine the blockage of venous return, producing a reduced response in the metabolic stress expected to optimize muscular adaptations. Furthermore, the length of the training program (8 weeks in duration encompassing 15-20 workouts per subject) likely needed to be longer for differences to emerge in the training protocols if a difference exists. It is noteworthy that the relative gains in elbow flexors muscle thickness were 1.8 ± 6.2% with EBRT training and 5.5 ± 6.7 % in EBRT+BFR (p = .063), indicating a tendency for more pronounced effects in the EBRT+BFR group over eight weeks. Thus, future studies employing a more extended training duration could increase the ability to detect significant changes in some variables.

Some methodological limitations apply to the current study. First, there may be better ways of assessing muscle strength than maximum strength testing on isometric equipment. Isokinetic dynamometry, considered the gold standard in assessing muscular strength and is more reliable and valid than other methods (Farrell and Richards, 1986), is suggested. There may also have been significant individual differences in the relative exercise intensity. One difficulty in using EBRT is determining the exact exercise intensity offered by the elastic bands between individuals.

Another aspect to be considered may be the cross-transfer effect. Resistance exercises performed unilaterally, where each limb works independently can indeed exhibit what is known as the cross-transfer effect. This phenomenon suggests that this effect occurs due to neural adaptations and possibly hormonal responses that benefit both limbs despite training only one. It underscores the interconnectedness and shared neural pathways between the limbs during resistance training (Wong et al., 2024).

In conclusion, this study demonstrated that using BFR in conjunction with an EBRT was not superior at increasing upper limb muscular strength or hypertrophy in young adults compared to EBRT alone.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Data collection and analysis were performed by André Soares, Rafael Siqueira and Claudia Meirelles. Statistical analysis was performed by Ramon Franco and Claudia Meirelles. The first draft of the manuscript was written by Claudia Mello Meirelles and Paulo Gomes and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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