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Investigating Strength Effects at the Shoulder Using Blood Flow Restriction

Green LL[1]*, Cupp JL[2], Cole E[3], Craig D[3], Crawford K[3], Hogan S[3], Holsted J[3], Lovell H[3] and Sarna M[3]

[1]Department of Physical Therapy, Arkansas State University, USA

[2]Department of Nutritional Science, Arkansas State University, P. O. Box 910 State University, USA

[3]Student Physical Therapist, Department of Physical Therapy, Arkansas State University, P. O. Box 910, State University, USA

Research Article

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***Corresponding author:** LaToya L Green, PT, DPT, Ed.D., Cert DN, Department of Physical Therapy, P. O. Box 910 State University, AR 72467, USA, Tel: (870)972-3610; Fax: (870)972-3652; Email: lgreen@astate.edu

Abstract

Introduction: The purpose of this study was to assess the effects of blood flow restriction (BFR) on proximal musculature of the upper extremity. This randomized control trial study design used manual muscle testing and one repetition maximum (1RM) as the main outcome measures to test the strength of the pectoralis major, lower trapezius, rhomboid, serratus anterior, and external rotator muscles.

Methods: Eleven males completed the following exercises two days per week for four weeks at the student recreation center: bench press plus, scapular retraction, shoulder external rotation (ER), and bent over rows. Six subjects received BFR to their dominant arm and performed four exercises at 20% of their 1RM. Five control (CON) subjects followed the American College of Sports Medicine (ACSM) strength and hypertrophy protocol at 70% of their 1RM.

Results: A significant difference was noted in both pectoralis major and lower trapezius strength ($p < 0.05$) and in 1RM for prone rows for the BFR group. A significant difference was noted in pectoralis major, lower trapezius, and external rotator strength and in 1RM for scapula retraction for the CON group. A significant difference was noted between groups for pre-training for the pectoralis major.

Conclusions: Completing BFR at 20% of 1RM produces the same post-training strength gains in the serratus anterior, external rotator, rhomboids, lower trapezius, middle trapezius, and pectoralis major muscles as the implementation of high resistance exercise. Based on the results of this study, lighter weights using a BFR protocol is as effective in gaining strength as using high resistance exercise.

Keywords: Resistance Training; Hypertrophy; Strength Gains; Upper Extremity

Introduction

Strengthening of the proximal shoulder stabilizers is important for any population. There is an association between increasing age and a decrease in muscle cross sectional area [1]. When compared to adults with intact rotator cuff muscles, adults with tears in the rotator cuff were more likely to have a decrease in muscle cross sectional area as well as an increase in fatty deposits in the muscle [1]. Fehringer, et al. [2] also examined the relationship between age and rotator cuff pathology. In an examination of 200 adults age 65 and older, 22% were found to have to have full thickness tears in the rotator cuff [2]. These tears were also correlated with a decrease in shoulder function [2]. Even after rotator cuff repair, it is common for muscle atrophy and fatty deposits to occur and decrease the overall muscle function [3]. In the athletic population, rotator cuff injuries can be common among overhead throwing athletes, specifically baseball pitchers. In a study by Tyler, et al. [4] on high school baseball pitchers, preseason supraspinatus weakness correlated with an increase in shoulders injuries. In addition, there has also been an association between external rotator weakness, supraspinatus weakness, and shoulder injuries in professional baseball pitchers [5]. It has been suggested that improving weaknesses in the supraspinatus and external rotators could decrease the likelihood of encountering a shoulder injury [4,5].

Training with loads greater than 70% of one repetition maximum (1RM) can be utilized to improve muscle strength and hypertrophy [6]. Traditionally, strength training of the proximal upper extremity musculature has been completed using loads greater than 70% of a 1RM. However, recent research shows that when low loads are coupled with blood flow restriction (BFR) training, improvements in muscle strength and hypertrophy can still be observed [7].

Blood Flow Restriction consists of placing a wrap or cuff around a muscle to restrict venous return and prevent the arterial blood supply from reaching the muscle [8]. After the cuff is placed around the muscle, it is inflated until the blood supply to that muscle is fully occluded. The cuff will then deflate, and a percentage of that pressure is taken to give a new occlusion pressure. The cuff will be inflated again to this new occlusion pressure, and exercise can then be performed.

Mechanisms have been proposed to explain why low intensity resistance exercise coupled with occlusion would lead to an increase in muscle strength and hypertrophy. The most likely mechanism is that the decrease in oxygen places the muscles under greater metabolic stress, which increases production of proteins and hormones that aid in muscle growth [9,10]. Another proposed mechanism for increasing strength and hypertrophy is the recruitment of Type II fibers under low oxygen conditions [9,10]. Type II fibers are normally utilized in power activities that require quick bursts of energy and do not require much oxygen to fuel the muscles. In contrast, oxygen is necessary for improvement in type I fibers, which are utilized for long duration, low intensity activities. Even though BFR training uses the low intensities that are normally considered endurance exercise, the lack of blood flow and oxygen allows for the recruitment of Type II muscle fibers.

Blood Flow Restriction has been shown to be an effective training method for improving whole body muscle strength and mass [2]. Although traditional moderate-heavy resistance training may still be a superior training method, Brandner, et al. [11] demonstrated that whole body resistance training concurrent with BFR is effective in improving muscle strength and mass. These muscle gains were also maintained after a 4-week detraining period [2].

Many studies have looked at the effects of the muscle directly being occluded, but few have observed the effect of BFR on the muscles proximal to the occlusion pressure. Browman, et al. [9] found that lower extremity muscles on the proximal side of the occlusion cuff did increase in strength when compared to a non-BFR group. In contrast, Yasuda, et al. [12] looked at muscles on the proximal side of the occlusion cuff in the upper extremity. In addition to looking at hypertrophic changes in the chest and arm, changes in bench press 1RM were also analyzed. The BFR group had a significant change in triceps brachii and pectoralis major size and strength compared to the non-BFR control group. There was also a significant increase in bench press 1RM in the BFR group.

The purpose of this study was to place the BFR tourniquet on the proximal arm (biceps muscle) to assess the effects of BFR on the proximal musculature of the upper extremity, specifically the muscles of the chest and shoulder. We hypothesized that both proximal muscle strength and 1RM would increase in a BFR trained group compared to a non-BFR control group.

Methods

Subjects

The study was approved by the Institutional Review Board (IRB) on the campus where the study was conducted. Eleven physically active males between the ages of 20 and 29 volunteered to participate in the study; no females volunteered to participate in the study. While those in the BFR group reported that they exercised an average of 5.4±0.8 days per week, those in the CON group reported that they exercised an average of 5.25±0.83 days per week. The workout regimen of the subjects used a mixture of endurance and resistance training. Subjects were excluded from the study if they met any of the following criteria: upper or lower extremity injury within the past year, currently receiving physical therapy for any musculoskeletal injury, uncontrolled hypertension, sickle cell anemia, history of deep vein thrombosis, diabetes, active infection, less than normal range of motion or muscle strength, or current diagnosis of cancer. Prior to the subjects participating in the study, each subject was informed of the benefits and risks of the study. Each subject was required to sign an IRB approved informed consent document before he began participating in the study. Subjects were randomly assigned to either the BFR group (n=6) or the CON group (n=5).

Experimental Approach to the Problem

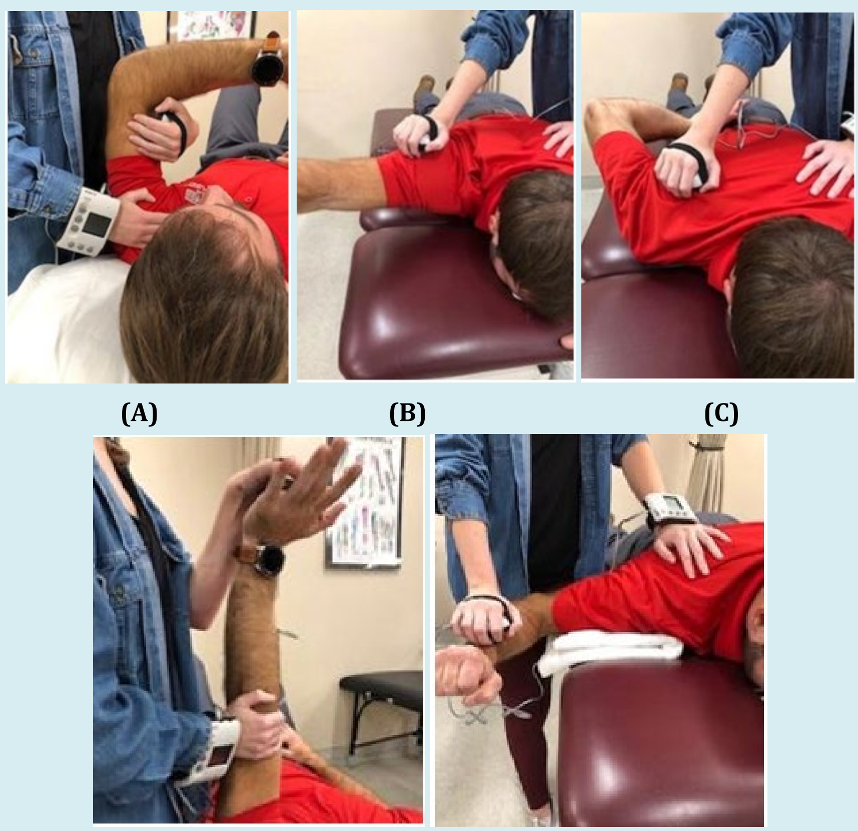
Participants were randomly selected to completed exercise sessions twice per week for four weeks at the student recreation center. Participants continued to complete their regular exercise outside of the study. The first session consisted of an assessment of the 1RM of four different exercises and dynamometer strength testing of six different muscles. Assessments were completed on both the dominant and non-dominant extremities. The participants were randomly assigned to either the BFR or CON group. With the cuff being placed around the proximal bicep of their dominant arm, the BFR group performed exercises unilaterally at 20% of their 1RM. The CON group followed the American College of Sports Medicine (ACSM) strength and hypertrophy protocol and completed exercises bilaterally at 70% of their 1RM [12]. After completing their respective strengthening protocol each session, subjects ingested a protein shake consisting of 30 grams of protein.

One Repetition Maximum Test

Before completing the 1RM testing, participants were given several minutes to complete their own individualized warm up. All testing was completed in the on campus student recreation center. Exercises for 1RM testing consisted of the following: bench press plus, scapular retractions, shoulder external rotation (ER), and bent over rows. Unilateral shoulder ER was completed using a cable machine; scapular retractions were performed on a lat pulldown machine with bilateral upper extremities. The following exercises were completed with dumbbells: bench press plus with bilateral upper extremities and bent over rows with unilateral upper extremity. Participants were instructed to complete each exercise until only one repetition was able to be performed. To maintain intra-rater reliability, each participant's 1RM was measured by the same tester for pre- and post-test results.

Strength Testing

For both groups, JTECH Commander Power track Handheld Muscle Dynamometer manual muscle testing (MMT) was used to measure bilateral strength pre- and post-testing. The participants were placed in standard MMT positions [13] measuring pectoralis major, lower trapezius, rhomboids, serratus anterior, and external rotator strength (Figure 1).



(A) (B) (C) (D) (E)

Figure 1: A: Dynamometer testing positions for pectoralis major; B**:** lower trapezius; C**:** rhomboids; **D:** serratus anterior and **E:** external rotators.

Hand position was altered for serratus anterior in order to apply proper force with the dynamometer. To maintain intra-rater reliability, each participant's bilateral strength was measured by the same tester for pre-and post-test results; exercise testing was not randomized.

Determining Occlusion Pressure

Occlusion was achieved using Delfi's Personalized Tourniquet System for BFR. The cuff was placed around the proximal bicep of the dominant arm. At the beginning of each session, subjects were instructed to lay still on a mat while the BFR machine calculated their personalized tourniquet pressure. Per the BFR protocol, the dominant upper extremity was occluded by 50% for a total of seven minutes [8].

Training Protocol

Both the BFR and CON groups completed the four 1RM exercises twice per week for four weeks for a total of 8 training sessions. With each subject reporting his hand dominance, the BFR group completed exercises unilaterally on their dominant arm at 20% of their 1RM. Each exercise was started by inflating the cuff on the dominant upper extremity and then completing a set of thirty repetitions, followed by completing three sets of 15 repetitions. The occlusion cuff was inflated for a total of seven minutes, and each exercise was performed within the seven minutes. Once the 30-15-15-15 rep scheme was completed, the cuff was deflated, and subjects were given a one-minute rest break before the cuff was inflated again to complete the next exercise. Each subject completed the 30-15-15-15 rep scheme for each exercise. Completing the four exercises bilaterally at 70% of their 1RM, CON subjects followed the ACSM strength and hypertrophy protocol. CON subjects completed 3 sets of 10 repetitions of each exercise and were encouraged to rest as needed between exercise sets.

Statistical Analysis

All statistical analyses were performed with SPSS software, Version 23. To determine the pre-test and post-test effects of strength and one repetition max within the CON and BFR groups, the Wilcoxon Signed Rank test was performed. To compare the strength and one repetition max for the BFR between groups, Mann-Whitney U test was performed. Statistical significance was set a priori at $p < 0.05$.

Wilcoxon Signed Rank Test was used to compare pre- and post-testing within the BFR group. Results showed a significant difference in pectoralis major (6.75$^{+/-}$4.07) and lower trapezius (25.17$^{+/-}$7.57) strength within the BFR group. Refer to Table 1. Results also showed a significant difference in 1RM for prone rows (96.67$^{+/-}$15.06) within the BFR group (Table 2).

Wilcoxon Signed Rank was also used to compare pre- and post- testing within the CON group. Results showed a significant difference in pectoralis major (56.40$^{+/-}$7.44), lower trapezius (31.60$^{+/-}$5.64) and external rotator (27.60$^{+/-}$5.03) strength (Table 1). Results also showed a significant difference in 1RM for pre-testing of scapula retraction (208.00$^{+/-}$22.80) within the CON group (Table 2). Between group comparisons were also made using Mann-Whitney U. Results showed a significant difference in pre-testing of pectoralis major muscle (56.40$^{+/-}$7.44) strength (Table 2).

Pre and post-training measurements were examined for differences within the BFR group and CON group. Post intervention for within group analysis revealed a significant difference for pectoralis major (p = .028) and lower trapezius strength (p = .046) for the BFR group. Post intervention for within group analysis revealed a significant difference for pectoralis major (p = .043), lower trapezius (p = .043), and external rotator strength (p = .043) for the CON group. A significant difference was also noted with 1RM for prone rows (p = 0.34) for the BFR group and scapula retraction for the CON group (p = 0.42). Pre and post-training measurements were examined for differences between the BFR and CON groups. A significant difference was noted between groups for pre-training for the pectoralis major muscle ($p < 0.05$) (Tables 1 & 2).

Results

	BFR		Control	
	Pre (Mean$^{+/-}$SD)	**Post (Mean$^{+/-}$SD)**	**Pre (Mean$^{+/-}$SD)**	**Post (Mean$^{+/-}$SD)**
Pectoralis Major	*36.75$^{+/-}$4.07	*49.58$^{+/-}$8.13	*56.40$^{+/-}$7.44	63.90$^{+/-}$7.14
Lower Trapezius	*25.17$^{+/-}$7.57	32.58$^{+/-}$5.51	*31.60$^{+/-}$5.64	37.50$^{+/-}$4.61
External Rotators	27.42$^{+/-}$8.03	39.58$^{+/-}$15.77	*27.60$^{+/-}$5.03	42.30$^{+/-}$9.23

*Significant difference $p < 0.05$

Table 1: Dynamometer Results for the BFR and Control Groups.

	BFR		Control	
	Pre (Mean+/-SD)	Post (Mean +/-SD)	Pre (Mean +/-SD)	Post (Mean +/-SD)
Prone Row	*96.67+/-15.06	104.17+/-18.55	97.00+/-13.96	105.00+/-16.58
Scapular Retraction	229.17+/-38.52	247.50+/-34.17	*208.00+/-22.80	247.00+/-25.88

*Significant difference *$p < 0.05$*
Table 2: 1RM Results for the BFR and Control Groups.

Discussion

The purpose of this study was to investigate the effects of BFR on proximal upper extremity musculature used in conjunction with weight training and protein after 4 weeks within the healthy, young adult population. We hypothesized that those who performed a low-intensity lifting protocol concurrent with BFR and protein would experience greater gains in muscular strength compared to those in the CON group. Based on the results, the hypothesis could not fully be accepted.

The primary results of the study were as follows: (a) BFR, in combination with protein, does improve the strength in the pectoralis major muscle and lower trapezius strength ($p<0.05$) for the BFR group. (b) Prone row 1RM was also increased in the BFR group compared to the CON group ($p<0.05$). (c) BFR intervention produces the same post-training strength gains in the pectoralis major muscle as the implementation of high intensity exercise.

The secondary results of this study were as follows: (a) External rotation strength ($p< 0.05$) improved significantly for the CON group. (b) A significant difference was noted between groups for pre-training for the pectoralis major muscle ($p<0.05$).

Although the literature overall generally indicates that the traditional high-intensity protocols are superior for gaining strength [2], there are recent studies that suggest using low-intensity protocols with higher repetitions concurrently with BFR may also be effective and perhaps even more effective at promoting strength [8,14].

Practical Applications

This study was conducted to compare the BFR protocol to ACSM's high intensity exercise protocol in the healthy, young adult population. The study compared the strength gained in the proximal shoulder musculature between two groups. Based on the results of this study, BFR is as effective as using high resistance exercise to increase strength in the proximal muscles of the shoulder. Implementing BFR into upper extremity strength training can be beneficial for athletes, especially the overhead athlete who has an upper extremity injury. By using BFR and lighter weights, not only can strength gains for the injured overhead athlete be achieved, but also the likelihood of further overhead injuries can be decreased. Future studies should focus on strength training for 6 to 8 weeks. Additionally, future studies should focus on a more diverse population in order to see how BFR affects the general population.

This study did not go without limitations. The power of our results from this pilot study would be greater with a larger sample size. In regard to 1RM, several participants were able to max out the equipment at pre-testing; therefore, skewing post-testing results. Since an intra-rater reliability analysis was not conducted for dyanamometer testing position, held dynamometer testing positions could have intra-rater reliability inaccuracy. Also, this study was only performed within a 4-week time period because of time constraints during the spring semester. Research has shown that muscles begin to hypertrophy at 6-8 weeks [15]. In addition, only male participants volunteered to complete this study; therefore, this study cannot be generalized to other populations. Considering this study was not a double-blind or single blind study, discriminative validity could also be considered a limitation for this study. Both the participants and the researchers were aware of group placement for the participants.

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The results of this study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation, and statement that results of the present study do not constitute endorsement by Annals of Physiotherapy & Occupational Therapy (APhOT).

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