Blood Flow Restriction, Tendon Hypertrophy, and Strength Gain in the Biceps Brachii

Direct Original Research

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Abstract

Introduction: Blood flow restriction (BFR) can improve muscular strength under lower loads versus traditional resistance training. Little research has been completed on the upper extremity and almost no targeted research on BFR and the tendon. Therefore, we aim to investigate the effects of BFR on the biceps brachii muscle and tendon compared to traditional resistance training.

Methods: Randomized controlled trial of healthy participants over seven weeks of completing bicep curls. Participants were randomly allocated to the BFR or control group (C). Ultrasound measurement of the tendon occurred at baseline, midpoint, and completion of study, while adjusted one repetition maximum (adj1RM) was examined at baseline and post intervention.

Results: Forty-two participants (18 BFR; 24 control) completed the protocol. The adj1RM showed no difference between the BFR and Control groups (p = 0.56), however, a significant effect of exercise was found with participants lifting more post-intervention compared to baseline (23.5 ± 1.3 vs. 28.9 ±1.2 respectively; p < 0.00). Similarly, ultrasound measurements did not vary by the group (p = 0.82). However, a difference in intervention was found for all participants (p < 0.00) with pairwise comparisons revealing increased tendon size at each point (8.3 ± 0.3 vs. 8.9 ± 0.3 vs. 9.8 ± 0.3 respectively)

Conclusion: Low-load BFR can induce similar effects of tendon hypertrophy and strength gains as a high-load exercise program.

Key Words: blood, ultrasound, upper extremity

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Introduction

Blood flow restriction (BFR) has often been used as a tool with resistance training for the purpose of improving muscular strength and hypertrophy under lower loads compared to traditional resistance training. BFR involves partial occlusion of arterial blood inflow while fully restricting venous outflow in working musculature during exercise.[1] A tourniquet cuff is applied and gradually inflated usually at the most proximal region of the limb. This results in the arterial blood flow to the distal to the cuff being partially restricted while fully impeding venous return.[1] Traditional training routines generally use loads greater than 70% of an individual's one repetition maximum to stimulate muscle development while BFR may use only 20-40%.[2]

Physiologically, vascular occlusion increases metabolic stress combined with mechanical tension leads to muscular hypertrophy and an increase of strength.[2,3,4,5,6,7] Hypoxic and ischemic conditions during BFR exercise amplify metabolites and satellite cells which are known to be mediators of hypertrophy and produce early fatigue resulting in greater motor unit recruitment.[3] In this way, further mechanical tension is directed through the tendon thereby stimulating hypertrophy.

The use of BFR as of recent has become widely popular in anterior cruciate ligament reconstruction (ACLR) patients during rehabilitation[3] and literature has widely researched the benefits of BFR in the lower extremity but failed to take the same approach for the upper extremity or tendons. Tendon injuries at the elbow are increasingly common (Greif, 2021) are frequently implicated in chronic conditions such as epicondylitis. Improved information about the role of BFR in tendon in the elbow can only benefit performance for patients.

From the small sample of BFR upper extremity literature, researchers have examined benefits at the shoulder and wrist.[8,9,10,11,12,13] Further research is required to gain a clearer understanding of the specific benefits associated with BFR in the upper extremity and specifically tendons. Therefore, the purpose of this study is to investigate the effects of blood flow restriction with low load resistance training at the biceps brachii tendon compared to traditional resistance training.

Scientific Methods

Participants

The study was approved by the host institution's Institutional Review Board. Participants between 18-30 years of age were recruited. Exclusion criteria included: current shoulder injury or surgery, active/prior history of clotting and/or circulation disorders, currently pregnant, on blood thinners or medications known to increase clotting risk. After screening, informed consent was obtained. Participants were randomly allocated via coin flip to either the experimental group (BFR) or the control group (C). An *a priori* power analysis found a required minimum size of 34 participants.

Protocol

Prior to initiating the exercise program, participants underwent ultrasound imaging of the distal biceps brachii tendon. Participants were positioned supine with their shoulder in 90 degrees of abduction and elbow in 90 degrees of flexion. Only the long-axis view of the distal biceps brachii tendon was obtained (Siemens Acuson X300 Ultrasound Special; Siemens Medical Solutions, USA). The transducer of the ultrasound was placed on the distal ⅓ of the humerus and moved while rotating 90 degrees to be perpendicular with the ulna thus bringing the musculotendinous junction of the biceps brachii muscle into view. The thickness of the tendon was measured at 3 points (3, 5, and 7mm) from the musculotendinous junction. At the midpoint and endpoint of the 7-week protocol participants again underwent ultrasound imaging to assess potential growth.

The second portion of the baseline testing was to determine the adjusted 1 repetition maximum (adj1RM) while doing a "bicep curl" or full elbow flexion and extension with the arm parallel to the body. Each participant began using a 5lb dumbbell and completed 10 repetitions of full flexion and extension with a metronome set at 60 beats per minute on a count of 2 seconds extension and 2 seconds flexion. After the 10 reps the participant was given a 30 second break and the weight was increased by 5lbs. This pattern was repeated until the participant was (1) unable to keep pace with the metronome, (2) unable to perform full range of motion, or they were (3) unable to complete the lift with the weight given. The final weight of the last 10 successful repetitions was input to the Brzycki Predicted adj1RM equation.[14] At the end of the seven weeks participants completed a post-intervention testing in the same protocol.

After the pre-testing participants underwent a lifting protocol. The BFR group exercised at 40% of their individually predicted adj1RM with the BFR cuff inflated to moderate pressure of the individualized limb occlusion pressure as determined by the Smart Tools Cuff (Smart Cuffs 2.0; Ohio, USA). They completed 4 rounds of one set of 30 repetitions followed by three sets of 15 repetitions with a 30 second break in between. After the midpoint an additional set of 15 was added.

The control group exercised at 80% of their individually predicted adj1RM completing 4 rounds of one set of 10 repetitions, one set of 8 repetitions, and two sets of 6 repetitions with a 30 second break in between each set. After the midpoint an additional set of 6 was added. A metronome was used for both groups set at the same pacing as the baseline testing. All participants completed exercises 2 times per week for 7 weeks with the investigators.

Statistical Analysis

Outcome variables included tendon size (mm) and adj1RM (lbs.) averaged by group (BFR, C) for analysis using SPSS software (IBM Corporation, Version 27.0. Armonk, NY). A repeated measures ANOVA with 2 groups (BFR and C) and two levels of adj1RM (pre- and post-) were completed. A separate repeated measures ANOVA was completed with two groups (BFR and C) and three levels of US measurement (pre, mid, post). Alpha level was set *a priori* to $p < 0.05$.

Results

A total of 47 participants were recruited for this study with 42 completing the entire intervention. There were 18 in the BFR group (mean age 22.4years ±3.7; 10F; 8M) and 24 in the C group (mean age 21.2years ± 2.4; 20F; 4M). Only 6 participants reported regular weightlifting habits.

Interaction of group and intervention for adjusted adj1RM was found to be not significant (p=0.52) nor was the main effect of group (p= 0.56). However, there was a significant effect of intervention with post-intervention participants lifting significantly more than pre-intervention (P< 0.00; Table 1) for all participants.

Table 1. Mean and Standard Deviation for the adjusted one repetition maximum measured in pounds at Baseline and after completion of the resistance training intervention.

	Mean ± SD	95% Confidence Interval	
		Lower Bound	Upper Bound
Pre-Intervention	23.5 ± 1.3	21.0	26.0
Post-Intervention	28.9 ±1.2*	26.5	31.3

*Significantly greater that pre-intervention, p< 0.001.

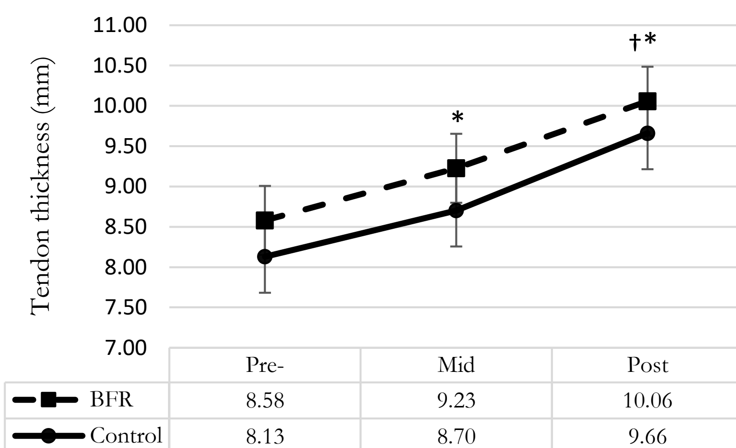
Similarly, there was no significant interaction (p=0.82) between groups and intervention time point (pre, mid, post) or main effect of group (p=0.38) in tendon size. However, a main effect of intervention was found for all participants in tendon size (p <0.00). Pairwise comparisons revealed increased tendon size at each point (Table 2).

Table 2. Mean and Standard Deviation for all participants of the ultrasound measurement at pre-, mid-, and post-resistance training intervention measured in millimeters.

	Mean ± SD	95% Confidence Interval	
		Lower Bound	Upper Bound
Pre-Intervention	8.3 ± 0.3	7.8	8.8
Mid-Intervention	8.9 ± 0.3*	8.4	9.5
Post-Intervention	9.8 ± 0.3*†	9.3	10.4

* Significantly greater that pre-intervention, p< 0.001. † Significantly greater that mid-intervention, p< 0.001

Figure 1. Ultrasound measurements in millimeters of the biceps brachii tendon for each group at pre-, mid-, and post-intervention.



Data are Mean SD * Significantly greater than pre-intervention, p< 0.001. † Significantly greater that mid-intervention, p< 0.001

Discussion

In healthy participants, both the low-load BFR and control groups demonstrated increases in biceps brachii tendon hypertrophy and elbow flexor strength with no differences between-groups. The current study showed that low-load BFR produced similar effects as high-load resistance training. The finding that BFR induces similar stress to the muscle and tendon is similar to other examinations of the effects of BFR compared to high-load resistance [4,15].

Of the currently available literature on BFR and the upper extremity, this study is one of the few discussing the effects of BFR on tendon. A meta-analysis was conducted by Dankel and colleagues[15] that analyzed the effectiveness of low-load BFR on increasing muscle size and strength in the upper body. Similar to the current findings they found evidence that biceps brachii muscle size and strength improvements were similar between high-load resistance training versus low-load BFR.[15] However, the 1RM percentage (%1RM) varied from 20-60% with most studies showing the greatest increases of muscle strength at 50-60% with low-load BFR. The current study found increases in muscle strength and hypertrophy with only 40% of their adj1RM.[14] However, Dankel and colleagues[15] did exclude studies that examined high load as a control group and did not examine tendon hypertrophy, limiting generalizability.

Increases in tendon size were found at the mid-intervention ultrasound measurements, indicating that hypertrophy gains can be accomplished with BFR in as little as 3 weeks. There is no current literature to our knowledge that reports hypertrophy gains in tendons in relatively short periods of time. Centner and colleagues[4] did examine tendon hypertrophy of the Achilles tendon and found results similar to ours, however, there was no midpoint measurement and their protocol extended to 14 weeks.[4] Kubo and colleagues[16] investigated 12 weeks of training and found that low-load BFR did not change patellar tendon cross sectional area. Differences in these findings can be attributed to the methodological differences in the progression of the applied stresses and therefore the anabolic response [4,16]

These findings are significant in providing evidence for the use of low-load BFR in healthy populations but may also support the use for patients with orthopedic conditions. Those who cannot withstand the higher loads during traditional exercise may benefit from using a lower load with BFR to produce similar physiological effects but with less stress placed on joints and healing tissue. Patients with biceps brachii tendonitis, rupture and repair, for example, could utilize BFR throughout their rehabilitation process to optimize strength gains when pain and surgical healing are limiting factors.

Limitations include the inability to control for any additional upper extremity exercise outside the study and the overall healthy young sample. While numbers were adequate for this analysis, future research should have greater sample size and include those with upper extremity injuries in order to compare low-load BFR and high-load resistance training in patients who have orthopedic conditions, specifically related to the biceps brachii tendon and its effects on perceptual pain, strength, and hypertrophy gains.

Conclusions

The lower load with BFR produces the same strength and hypertrophy effects as high-load exercise. Clinicians planning therapy to the upper extremity when traditional strength-training loads would be inappropriate may utilize low-loads combined with blood flow restriction when tendon hypertrophy is a goal.

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