Blood Flow Restriction Following ACL Reconstruction

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Background: Blood flow restriction (BFR) therapy is a technique that uses partial occlusion of arterial blood flow in tandem with low-load resistance training to promote an environment of metabolic stress within muscle tissue. It is hypothesized that such therapy can facilitate protein synthesis and muscle hypertrophy even in the setting of age, injury, or postoperative rehabilitation—conditions which are marred by muscle atrophy and progressive loss of function. Therefore, BFR may be a successful option to facilitate strength gains even in patients unable to perform traditional high-load resistance training.

Indications: BFR therapy has been shown to be efficacious when used in healthy athletes, the elderly, or in postoperative patients undergoing rehabilitation after upper or lower extremity procedures. More specifically, BFR application in patients undergoing knee surgery has been shown to reduce muscle atrophy post operatively.

Technique Description: BFR involves application of a tourniquet or occlusion cuff at 70% of the determined arterial occlusion pressure (commonly 150-180 mm Hg). The arterial occlusion pressure is calculated by observing the loss of Doppler ultrasonography signal at the pedal pulses with sequential inflation of a blood pressure cuff. This cuff should be applied as proximal as possible at the affected extremity. The patient subsequently performs 5 exercises, including 3 sets of 15 repetitions of each exercise, with 30 seconds of rest in between sets. The cuff remains inflated for all 5 exercises.

Results: BFR in tandem with low-load resistance training has been shown to be effective in improving lower extremity muscle torque and mass of the quadriceps and hamstring muscles when used after knee surgery, specifically anterior cruciate ligament (ACL) reconstruction. The most commonly reported adverse outcomes after BFR include muscle soreness and sensory paresthesias; however, BFR is generally believed to be safe and acceptable for use in a broad spectrum of patients.

Discussion/Conclusion: Muscle atrophy and loss of strength are hallmarks of aging, injured, and postoperative patients. Traditional means of high-intensity strength training is not feasible in these patient populations, and the use of BFR in tandem with lower intensity strength training shows promise in its ability to promote improvements in muscle strength and hypertrophy. However, more high-level research into the long-term effects, complications, and optimal BFR training regimen is warranted.

Patient Consent Disclosure Statement: The author(s) attests that consent has been obtained from any patient(s) appearing in this publication. If the individual may be identifiable, the author(s) has included a statement of release or other written form of approval from the patient(s) with this submission for publication.

Keywords: ACL reconstruction; rehabilitation; vascular occlusion training; muscle hypertrophy; blood flow restriction therapy

VIDEO TRANSCRIPT

This is a review of blood flow restriction (BFR) and its application in sports medicine with a particular focus on its use in anterior cruciate ligament (ACL) rehabilitation. This talk was prepared at the Rothman Orthopedic Institute. A special thank you to my colleagues Dr Sommer Hammoud and Bright Wiafe as well as Nathan Johnson and Tyler Huggins for their contributions to this work.

Some authors do have disclosures, though these are not relevant to this topic. These can be accessed via the AAOS Disclosure program online.

Here is an outline of our talk.

We have long known that in order for muscles to gain size and strength through resistance training, the target muscle must be subjected to increased loads.[8] The American

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Submitted August 27, 2022; accepted December 7, 2022.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Video Journal of Sports Medicine (VJSM®), 3(1), 26350254221148215
DOI: 10.1177/26350254221148215

College of Sports Medicine recommends that loads should exceed 70% of the 1 Repetition Max during strength training to achieve maximum muscle hypertrophy.[4]

However, some of our patients—whether it be age or injury—are not able to perform high-intensity strength or resistance training.

Particularly, postoperative patients after knee surgery are often unable to effectively load the joint due to various reasons such as protection of a repair or reconstruction or even pain. This precludes strength and resistance training to maintain muscle mass and function. Therefore, muscle atrophy is a significant challenge during rehabilitation after knee surgery that can lead to prolonged recovery and diminished patient outcomes.

Due to extensive periods of joint unloading and muscular inhibition secondary to pain and joint effusion, the rate of muscle mass reduction of the quadriceps muscles is higher in patients who have undergone knee surgery when compared with healthy subjects—this can occur even within 5 days of disuse.[3,12,17] Furthermore, this atrophy and loss of overall muscle mass and strength can persist for years postoperatively.[3]

This poses both a dilemma and also an opportunity for improvement. What can be done in our postoperative patients to reduce the rate of muscle atrophy while stimulating muscle hypertrophy in order for patients to decrease recovery time and promote earlier return to activities.

One proposed method to combat this challenge is BFR therapy. BFR works by occluding venous outflow while allowing for sustained arterial inflow through the application of a tourniquet to the affected extremity.[2] While the patient performs postoperative exercises, this induces an anaerobic environment with a reduction of oxygen delivery to muscle cells.[13]

We know that low-load resistance training alone does not promote strength gains, but low-load training and BFR can lead to strength gains.[16]

Although the exact mechanism of BFR has not yet been fully elucidated, it is believed that BFR works through inducing a combination of metabolic and mechanical stressors. This results in tissue hypoxia, buildup of metabolites that ultimately alter the local growth hormone concentrations, and cell signaling cascades, which leads to increases in protein synthesis, preferential activation of fast-twitch, and large diameter type 2 muscle fibers when accompanied with low-level resistance exercise.[14,16]

Two of the more notable studies using BFR postoperatively for rehabilitation following ACL reconstruction have demonstrated that BFR could potentially help improve knee flexor and extensor strength and reduce postoperative muscle atrophy when compared with non-BFR control groups.[10,15]

Here is an example and demonstration of BFR in action.

Hello. My name is Nathan Johnson, and this is Tyler Huggins, and we are physical therapist with Select Medical at Rothman Orthopaedics here in Media, Pennsylvania. We are going to show you how we do BFR here in our office. There are multiple different cuffs that we have used. Right now, we have got the B strong (B Strong Blood Flow Restriction Training; Park City, UT) cuffs. They are very comfortable for the patient, flexible, and they move around well with the patient doing their exercises.

Go ahead and lay down on your back. We're going to put this on. You put the cuff on as high up on the thigh as possible.

And these cuffs are nonspecific in regard to pressure, so they come with a recommended pressure to start with, and then you can adjust the pressure based on the patient's perceived level of fatigue. For this particular cuff, the recommended pressure is 300. So, we are going to pump it up right about there. How does that feel? Good.

And then you can release the valve. The pressure stays, and then the patient can begin doing their exercises. We usually start with 3 sets of 15 repetitions of 5 exercises, keeping the cuff on the whole time, with a 30-second rest between each set. We also use a larger cuff and that allows us to set a patient-specific level of occlusion.

So, we got a cuff from Hokanson (Hokanson Vascular; Bellevue, WA). It is a wider cuff, so it will completely occlude the artery, and that will allow us to set a patient-specific criteria.

We will use a Doppler ultrasound on the posterior tibial artery here, get the pulse, and then pump the cuff up to where the pulse stops, and then that is the level of occlusion. Once we get the level of occlusion, we release the cuff, and then set the therapeutic pressure to 70% of the level of occlusion. So the puff will be set at 70% for the duration of the exercises. Again, usually 5 exercises, 3 sets of 15 repetitions, 30-second rest in between, and that usually takes about 22 minutes to complete. If the patient experiences any numbness or tingling, any localized discomfort, we can relax the pressure, give them 30 seconds for the symptoms to subside, and then we can pump it back up, stay at 65% of the level of occlusion, and have the patient continue on with their exercises.

Similar to application of a tourniquet for other indications, the tourniquet is applied to the most proximal aspect of the affected extremity, for example, the thigh in a patient with a prior knee procedure. The arterial occlusive pressure is defined as the pressure in which the Dorsalis Pedis pulse signal is lost on Doppler, and there have been studies suggesting efficacy of BFR therapy with pressures anywhere between 40% and 90% of the arterial occlusion pressure.[1] There are different types and styles of tourniquets or bands that can have a tourniquet-like effect.

Blood flow restriction could be especially useful when used in conjunction with low-load resistance training, body weight training, cycling, and even walking. A recent meta-analysis by Wengle et al[18] published in AJSM demonstrated the utility of BFR in maintaining quadriceps femoris cross-sectional muscle mass following knee surgery. However, there is currently no gold standard protocol for BFR therapy following ACL reconstruction, and this is a topic that needs to be further studied.

The ACL reconstruction rehabilitation protocol used at Rothman begins at 2 weeks postoperatively and continues to 4 months, consisting of 3 major phases. During these 3 phases, there are 5 core exercises for which BFR is used. The routine consists of 3 sets of 15 repetitions, with 30 seconds in between sets. The cuff is to remain inflated for all 5

exercises, but should not remain inflated for more than 30 minutes.

As you can see, the 5 key exercises used in the early postoperative period are the straight leg raise, side lying straight leg raise, terminal knee extension, hamstring curls, and leg press.

As we progress to weeks 7 to 12, the 5 core exercises include long-arc quads, body squats, step-ups, Romanian dead lift, and lateral heel taps.

In the final phase of the ACL rehab protocol, the 5 core exercises include Romanian dead lifts, lateral heel taps, walking lunges, BOSU squats, and split squats.

Blood flow restriction should not be considered to be risk-free. There are risks for adverse events—some that are theoretical and some that are born out in the literature. Specifically, delayed onset muscle soreness and sensory paresthesias have been shown to be fairly common, although these are both thought to be transient changes. There are also concerns for thromboembolic events such as deep vein thrombosis or pulmonary embolism with the use of BFR, although you can see the risk of these complications is very low.[9,11]

In addition, there are certain patient populations in whom we believe BFR should be avoided. Specifically, these are patients who have peripheral vascular disease, significant history of thromboembolic disease, or are thought to be at high risk of blood clots or poor circulation. Ultimately, further research needs to be done to consistently demonstrate the efficacy of BFR as well as to further elucidate its safety and side-effect profile.

Thank you.

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