Level V Evidence

The Role of Blood Flow Restriction Therapy Following Knee Surgery: Expert Opinion

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Abstract: Blood flow restriction (BFR) therapy is becoming increasingly popular in musculoskeletal injury rehabilitation. In particular, this form of therapy is being utilized more often in the postoperative setting following knee surgery, including anterior cruciate ligament reconstruction. BFR therapy provides patients and clinicians an alternative treatment option to standard muscle strengthening and hypertrophy guidelines in the setting of postoperative pain, weakness, and postoperative activity restrictions that contribute to muscle atrophy. The ability to complete exercise in a low load environment and achieve similar physiological adaptations as high-intensity strength training makes this modality appealing. With poor patient-related outcomes associated with continued muscle atrophy, pain, and muscle weakness, some researchers have investigated BFR training postoperatively following arthroscopic knee surgery with promising results. However, owing to the current paucity of research studies, inconsistency among reported protocols, and mixed results, it may be some time before a mass adoption of BFR therapy is made into the world of orthopaedic rehabilitation. Although the current data is inconclusive, we choose to utilize BFR in postoperative knee patients, regardless of weight-bearing status, for whom maintenance of existing muscle mass or improvement of decreased postoperative strength levels is important. Therefore, the purpose of this expert opinion is to review the background of BFR, describe the clinical evidence of BFR following knee surgery, and report the authors' current recommendations for application of BFR postoperatively.

Historical Background

The first study on blood flow restriction (BFR) training was published in 1998.[1] However, the concept of BFR appears to have originated from Japan in the 1970s by Dr. Yoshiaki Soto with the inception of *Kaatsu* resistance training, or ischemic exercise in which a tourniquet is applied to a limb and restricts muscular venous blood flow. However, the modes of vascular occlusion in the beginning were not sophisticated and included ropes and bands. In 1984, first-generation electronic tourniquet systems were invented, and it was not until the development of third-generation tourniquet systems in the early 2000s before BFR could be performed with precision and safety. This led to the clinical implementation and investigation of using BFR in select patients who could not exercise with heavy resistance due to various restriction (elderly, sedentary, etc.) but needed some means to resist muscle atrophy. In recent years, BFR has been adopted as an adjunct to traditional therapy for musculoskeletal injuries and orthopaedic-related trauma. Popularized by Johnny Owens, M.P.T., BFR was initially implemented in his clinic for building muscle strength and hypertrophy in military limb salvage patients.[2] Within just a few years, the potential for BFR in other subspecialties was recognized and there was a transition from trauma patients to treating sports medicine injuries. Twenty years after the first publication, clinical evidence has allowed for a potential paradigm shift in sports medicine rehabilitation and the scientific literature continues to expand on this topic.

Current Concepts

Muscle atrophy is a significant challenge during rehabilitation after knee surgery that can lead to

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The authors report the following potential conflicts of interest or sources of funding: R.F.L. receives consultancy fees, grants, and other support from Arthrex, Ossur, and Smith & Nephew, outside the submitted work. Full ICMJE disclosure forms are available for this article online, as supplementary material.

Received April 12, 2018; accepted May 22, 2018.

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0749-8063/18464/$36.00

https://doi.org/10.1016/j.arthro.2018.05.038

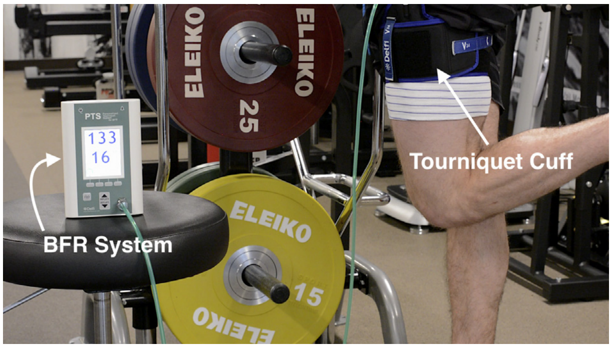

Fig 1. Blood flow restriction (BFR) therapy application. Delfi Personalized Tourniquet System for BFR with pneumatic cuff (third-generation tourniquet), utilized for minimal- to no-resistance, weight-bearing, and non–weight-bearing exercises.

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.[3,4] Difficulty in regaining muscle mass, strength, and volume has been reported, in addition to the potential for atrophy to persist for several years postsurgery.[5-8] Therefore, reducing the rate of muscle atrophy and stimulating muscle hypertrophy is desired for patients to decrease recovery time and promote earlier return to activities.

Current exercise prescription protocols suggest that increased muscular strength and size is achieved by enduring loads of 60% to 100% of the patient's 1-repetition maximum.[9] Postoperatively, these loads are unable to be attained owing to the time required for sufficient structure repair or reconstruction graft healing, pain, and protection of the knee.[10,11] To combat this challenge, BFR has been suggested as an alternative to traditional strength rehabilitation.[9,12-14]

BFR occludes venous outflow while maintaining arterial inflow[15] by the application of an extremity tourniquet (Fig 1). This ultimately reduces oxygen delivery to muscle cells during low-resistance exercises. The induced anaerobic environment has been reported to promote muscle hypertrophy by initiating cell signaling[16] and hormonal changes[15,17] that stimulate protein synthesis,[16,18] proliferation of myogenic satellite cells,[19] and preferential activation and mobilization of type II muscle fibers.[17,20,21] When using BFR as an adjunct to postoperative rehabilitation, it has been suggested that exercises performed at lower loads (20%-50% of 1-repetition maximum) can promote muscle hypertrophy similar to traditional strengthening protocols while reducing pain and adverse joint loading.[21,22]

Clinical Evidence

Despite the promising claims surrounding BFR as an adjunct to standard physical therapy, there is a paucity of literature regarding its use following arthroscopic knee surgery. To date, 2 Level I randomized controlled trials and 1 Level II controlled trial have reported on the use of BFR following anterior cruciate ligament reconstruction (ACLR). All 3 studies utilized hamstring tendons (autograft and allograft; number of each not reported) for graft selection in all patients (BFR and control).[15,23,24] Of the 3 studies on ACLR, no studies have reported on the weight-bearing status of the patients immediately postoperatively. Furthermore, no studies have reported on concomitant injuries and/or procedures performed at the time of surgery—including meniscal pathology, chondral injuries, or multiligament knee reconstructions. Currently, only 1 Level I randomized controlled trial has reported on the use of BFR following knee arthroscopy.[25] Their exclusion criteria were any ligamentous, bony, or other soft tissue reconstruction performed at the time of the knee arthroscopy. However, their specific indications for arthroscopic treatment, including procedures performed, were not reported. Patients in both the control and BFR groups were allowed to bear weight immediately after the knee arthroscopy.[25] A more detailed overview of these studies is provided below.

Takarada et al.[15] investigated BFR without exercise in patients immediately following ACLR with hamstring tendon autografts. After 2 weeks of knee immobilization and BFR therapy, patients demonstrated significantly less muscle atrophy than immobilized controls with non-inflated occlusion cuffs (sham).[15] Similarly, Ohta et al.[24] reported significant increases in both muscle circumference and strength following ACLR with hamstring tendon grafts. Training interventions were conducted from weeks 2 to 16 postoperatively and consisted of combined resistance training with BFR compared with a matched protocol without BFR.[24] Between the control and BFR groups, there were no significant differences in knee range of motion or anterior knee stability between preoperative and postoperative training, thus supporting the use of BFR following ACLR without compromising ligamentous healing or graft integrity.[24] In a study of patients treated with ACLR using hamstring tendons, Iversen et al.[23] investigated the combination of low-load resistance and BFR compared with patients participating in a similar resistance training program without BFR; respective interventions began 2 days postoperatively. Results showed a significant reduction in quadriceps cross-sectional area from measures taken preoperatively to 2 weeks postoperatively in both groups.[23] Thus, the authors concluded that the application of BFR during the first 2 weeks following ACLR did not reduce muscle atrophy of the quadriceps.[23]