



Personalized Blood Flow Restriction Therapy: How, When and Where Can It Accelerate Rehabilitation After Surgery?

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Abstract: Personalized (based on a percentage of a patient's limb occlusion pressure) blood flow restriction is emerging as a potential advancement in orthopaedic surgery. Safe application of the technology requires the use of medical devices capable of customizing the pressures applied to individual patients. In those circumstances, it is a low risk and noninvasive technique. By limiting muscle atrophy and aiding in the recovery of strength and function, it has the potential to significantly reduce the morbidity from limb trauma and surgery, and aid in achieving a substantially earlier return to full activity.

There is increasing evidence that personalized blood flow restriction, combined with low-load resistance exercise, may enhance and accelerate the recovery of muscle mass and strength after injury or surgery. It can be especially effective when targeting individuals who cannot tolerate the mechanical stress of heavy-load exercise.¹ Using conventional strengthening techniques, individuals typically require loads up to 70% or more of their 1-repetition maximum to achieve noticeable increases in muscle mass and strength over time.² However, such loads may not be achievable after injury or surgery. In such instances, low-load resistance exercise combined with personalized blood flow restriction, based on a percentage of a patient's limb occlusion pressure, is proving to be effective and safe in augmenting muscle morphologic and strength responses.³ Blood flow restriction therapy typically involves applying a tourniquet cuff proximally on a patient's limb and using a tourniquet instrument to maintain a personalized level of pressure that restricts

to a specific level, but does not fully occlude, arterial blood flow past the cuff into the patient's limb^{3,4} during low-load resistance exercise of 20% to 30% of the 1-repetition maximum.⁵ Applying such therapy without rehabilitative exercise after lower limb surgery or after limb immobilization has been shown to effectively diminish disuse atrophy and associated muscle weakness.⁶ Despite increasing evidence of its effectiveness and safety, and its increasingly rapid adoption within the military and professional sports,⁴ this therapy has not yet been widely adopted or studied within the field of arthroscopic surgery.

Mechanisms

The cellular mechanisms responsible for the physiological responses associated with both passive and active blood flow restriction training are still not well understood but are being investigated by several groups. Several cytokines, signaling molecules, and satellite cells are thought to be responsible for the control of muscle fiber growth, strength, and atrophy.⁷ One key study demonstrated marked proliferation of myogenic stem cells and myonuclei, accompanied by substantial myofiber hypertrophy.⁸ Another study found significantly increased levels of the cytokine myostatin in the early postoperative period following anterior cruciate ligament reconstructive surgery.⁷ Myostatin signaling was analyzed for high-intensity training compared with low-intensity blood flow restriction training, showing that both techniques were effective in down-regulating the levels of myostatin, with associated increases in muscle mass and strength.⁹

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Other possible factors may include enhanced mammalian target of rapamycin complex 1 signaling, increased growth hormone concentrations, heat shock protein expression, and cell swelling.¹⁰

Effectiveness

Low-load resistance exercise paired with blood flow restriction enables a more tolerable and effective rehabilitative therapy for patients who cannot normally tolerate the high-load rehabilitative exercises currently required to regain strength, either due to muscle weakness, postoperative recovery, osteoarthritis, or general patellofemoral pain.^{5,11} Patient compliance and acceptance is high,^{5,11} and multiple studies have demonstrated that control groups assigned high-load resistance exercises alone were often unable to complete their prescribed exercises because of the high levels of discomfort.^{5,11,12} In a key study of personalized blood flow restriction and arthroscopic knee surgery, the benefits included reduction of postsurgical pain, significant improvement of muscle girth, function (objectively assessed by sit-to-stand times, walking velocity, timed stair ascent), and quadriceps flexion and extension strength.¹² Case studies of patients whose initially prescribed rehabilitation programs were ineffective at returning full strength and function have similarly demonstrated significant improvements in quadriceps strength, peak torque, and knee flexion and extension, and successful return to their active daily living and work-related activities.^{13,14}

Safety

Safety issues and complications of this relatively new therapy have been studied as well. Although its effectiveness is well demonstrated,¹ there are potential risks if appropriate guidelines are not followed.¹⁵ This is in part because there are many inconsistencies in how the therapy is delivered. In some instances, equipment not meeting medical device standards is being used by non-healthcare practitioners with little or no training;

in other instances, nonproven instruments and cuffs, with non-personalized blood flow restriction pressures and inconsistent protocols, are employed.^{3,15,16} Although there are some reported side effects to blood flow restriction therapy (e.g., fainting/dizziness; numbness; perceived exertion, pain, and discomfort; bruising; skin discoloration), no severe adverse responses have been reported in published, randomized controlled trials.¹⁵ A recently published review of reported side effects and safety considerations concluded that the therapy can be used safely in most patient populations if surgical-grade tourniquet equipment is used, but that it is essential that the therapy is prescribed by a trained practitioner who uses clinical judgment, with knowledge of the appropriate protocols and possible contraindications, and who maintains personalized restrictive pressures.¹⁵

Implementation Into Clinical Practice

There is no official guideline for a blood flow restriction protocol; however, general practice has been demonstrated through several published controlled trials. The therapy should be prescribed by a trained practitioner using a surgical-grade tourniquet with personalized blood flow restriction capabilities (PTS Personalized Tourniquet System for Blood Flow Restriction, Delfi Medical Innovations, Vancouver, Canada) and personalized to each patient.^{15,17} Table 1 represents a typical protocol and patient populations recommended for blood flow restriction therapy as found in current literature. The table is provided only as a suggestion for how blood flow restriction may be prescribed and is not limiting.

Future Directions

Personalized blood flow restriction can potentially enhance and accelerate patient recovery after injury and surgery. Its effectiveness and safety have been demonstrated, as long as the safeguards and protocols discussed previously are followed. As with all new

Table 1. Suggestion for How Blood Flow Restriction May Be Prescribed

Possible Indications ^{1,5,11-14}	Arthroscopies; knee reconstructions; cartilage repairs; tendon repairs; extremity fractures; inflammatory myopathies; muscle strains; joint sprains; joint osteoarthritis; general debility, weakness, or sarcopenia; total joint replacement; musculoskeletal trauma; spinal pathology
Possible Contraindications ¹⁵	Open fractures of the limb, severe crushing injuries, severe hypertension, compromised vascular circulation, diabetes mellitus, secondary or delayed procedures after immobilization, varicose veins in the indicated limb
Suggested Training ^{1,17}	<ul style="list-style-type: none"> • 75 repetitions over 4 sets in the order of 30/15/15/15 with 30-second rest periods between sets • Training 2-3 days per week • Resistance training at 20% to 30% of 1-repetition maximum • Therapy period between 4 and 12 weeks
Blood Flow Restriction Techniques ^{1,17}	<ul style="list-style-type: none"> • Use of personalized pressures based on an individual's limb occlusion pressure • Blood flow restriction between 40% and 80% of the limb occlusion pressure based on the indicated limb, comfort level, patient ability

advances, there are unanswered questions and a need for further research and study. We need more precise quantification of the extent to which it accelerates and enhances rehabilitation after major and minor surgical procedures and injuries. The optimal time to initiate the therapy after surgery is also not clear. Additionally, there is a need for more precise protocols for specific injuries and procedures, and we must examine the possible benefits arising from combination with other modalities.¹⁸ Although most studies to date have focused on the application of this therapy in lower limb surgery and injuries, applications in the upper limb show considerable potential. A recent randomized controlled pilot study after nonoperative management of distal radius fractures demonstrated that it was safe, well tolerated, and reduced pain with activity, resulting in less perceived disability with daily activities.¹⁹ Another potential use is to accelerate recovery by improving prehabilitation, particularly when there may be an extended delay between diagnosis and surgery. Preoperative quadriceps strength has been shown to be a strong predictor of postoperative functional performance,²⁰ and thus the use of personalized blood flow restriction, with or without low-load exercise, may mitigate such disuse atrophy preoperatively.⁶

In conclusion, by limiting muscle atrophy and aiding in the recovery of strength and function, blood flow restriction has the potential to reduce the morbidity from limb trauma and surgery.

References

- Hughes L, Paton B, Rosenblatt B, Gissane C, Patterson SD. Blood flow restriction training in clinical musculoskeletal rehabilitation: A systematic review and meta-analysis. *Br J Sports Med* 2017;51:1003-1011.
- American College of Sports Medicine. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 2009;41:687-708.
- McEwen JA, Owens JG, Jeyasurya J. Why is it crucial to use personalized occlusion pressures in blood flow restriction (BFR) rehabilitation? *J Med Biol Eng*. April 2018 [Epub ahead of print.]
- McEwen JA, Jeyasurya J, Owens J. How can personalized tourniquet systems accelerate rehabilitation of wounded warriors, professional athletes, and orthopaedic patients? Presented at the 39th Conference of the Canadian Medical and Biological Engineering/La Societe Canadienné de Génie Biomédical, Calgary, AB, May 2016.
- Giles L, Webster KE, McClelland J, Cook JL. Quadriceps strengthening with and without blood flow restriction in the treatment of patellofemoral pain: A double-blind randomised trial. *Br J Sports Med* 2017;51:1688-1694.
- Kubota A, Sakuraba K, Koh S, Ogura Y, Tamura Y. Blood flow restriction by low compressive force prevents disuse muscular weakness. *J Sci Med Sport* 2011;14:95-99.
- Mendias CL, Lynch EB, Davis ME, et al. Changes in circulating biomarkers of muscle atrophy, inflammation, and cartilage turnover in patients undergoing anterior cruciate ligament reconstruction and rehabilitation. *Am J Sports Med* 2013;41:1819-1826.
- Nielsen JL, Aagaard P, Bech RD, et al. Proliferation of myogenic stem cells in human skeletal muscle in response to low-load resistance training with blood flow restriction. *J Physiol* 2012;590:4351-4361.
- Laurentino GC, Ugrinowitsch C, Roschel H, et al. Strength training with blood flow restriction diminishes myostatin gene expression. *Med Sci Sports Exerc* 2012;44:406-412.
- Fry CS, Glynn EL, Drummond MJ, et al. Blood flow restriction exercise stimulates mTORC1 signaling and muscle protein synthesis in older men. *J Appl Physiol* 2010;108:1199-1209.
- Ferraz RB, Gualano B, Rodrigues R, et al. Benefits of resistance training with blood flow restriction in knee osteoarthritis. *Med Sci Sports Exerc* 2018;50:897-905.
- Tennent DJ, Hylden CM, Johnson AE, Burns TC, Wilken JM, Owens JG. Blood flow restriction training after knee arthroscopy: A randomized controlled pilot study. *Clin J Sport Med* 2017;27:245-252.
- Gaunders CL, Hawkinson MP, Tennent DJ, Tubb CC. Occlusion training: Pilot study for postoperative lower extremity rehabilitation following primary total knee arthroplasty. *US Army Med Dep J* 2017;2-17:39-43.
- Yow BG, Tennent DJ, Dowd TC, Loenneke JP, Owens JG. Blood flow restriction training after Achilles tendon rupture. *J Foot Ankle Surg* 2018;57:635-638.
- Brandner CR, May AK, Clarkson MJ, Warmington SA. Reported side-effects and safety considerations for the use of blood flow restriction during exercise in practice and research. *Tech Orthop* 2018;33:114-121.
- Younger ASE, McEwen JA, Inkpen K. Wide contoured thigh cuffs and automated limb occlusion measurement allow lower tourniquet pressures. *Clin Orthop Relat Res* 2004;428:286-293.
- Vanwye WR, Weatherhold AM, Mikesky AE. Blood flow restriction training: Implementation into clinical practice. *Int J Exer Sci* 2017;10:649-654.
- Slysz J, Burr JF. The effects of blood flow restricted electrostimulation on strength and hypertrophy. *J Sport Rehabil*. May 22, 2018 [Epub ahead of print.]
- Cancio J, Rhee P. Blood flow restriction therapy after non-operative management of distal radius fracture: A randomized controlled pilot study. *J Hand Ther* 2018;31:161 (abstr).
- Mizner RL, Petterson SC, Stevens JE, Axe MJ. Preoperative quadriceps strength predicts functional ability one year after total knee arthroplasty. *J Rheumatol* 2005;32:1533.