**Blood flow restriction training--A novel approach to augment clinical rehabilitation: How to do it.**

*Corresponding author:*

Dr. Stephen D Patterson, School of Sport, Heath and Applied Science, St. Mary’s University, Waldegrave Road, Twickenham, London, TWI 4SX, United Kingdom. Stephen.patterson@stmarys.ac.uk, 020 8240 4000

*Co-authors:*

Mr. Luke Hughes, School of Sport, Heath and Applied Science, St. Mary’s University, London, United Kingdom.

Mr Paul Head, School of Sport, Heath and Applied Science, St. Mary’s University, London, United Kingdom.

Dr Stuart Warmington, Deakin University, Centre for Physical Activity and Nutrition Research, Burwood, Australia.

Dr Christopher Brandner, Aspire Academy for Sports Excellence, Doha, Qatar.

*Short running title:* Blood flow restriction training in rehabilitation

*Manuscript type: Editorial*

*Key terms: Strength*, rehabilitation

*Manuscript word count:* 727(excluding title page, abstract, references, figures and tables)

*Tables:* 0

*Figures:* 0

**Blood flow restriction training--A novel approach to augment clinical rehabilitation: How to do it.**

Strength training forms a pivotal part of rehabilitation. Heavy-load strength training (60-70% 1 repetition maximum) has been traditionally prescribed to improve muscle strength, body mass, and function [1], but may be unattainable and/or confer increased risk of adverse consequences in individuals with a musculoskeletal (MSK) impairment. The challenge faced by clinical practitioners is how to effectively and safely adapt training loads throughout rehabilitation.

In the past decade, research has proven that blood flow restriction [BFR] during light-load training (e.g. 20-30% 1RM) can produce significant gains in muscle strength and size in healthy populations, in contrast to non BFR load-matched controls [2] In this novel training method, limb blood flow is restricted via a cuff throughout the contraction cycle and rest period. This results in partial restriction of arterial inflow to muscle, but, most significantly restricts venous outflow from muscle. Given the light-load nature and strengthening capacity of BFR training, it can provide an effective clinical rehabilitation stimulus without the high levels of joint stress and cardiovascular risk associated with heavy-load training.

**Current practice in rehabilitation**

The use of BFR in MSK rehabilitation is in its infancy. However, our recent meta-analysis[3] identified studies that included individuals with; knee osteoarthritis (n=3), ligament injuries (n=3), sporadic inclusion body myositis (n=1), and older adults susceptible to sarcopenia (n=13). Light-load BFR training produced greater strength improvements and was more tolerable than light-load training alone in these clinical populations. We are currently using BFR to rehabilitate patients in clinic with various MSK disorders including; patello femoral pain syndrome, meniscal tears, ligamentous strains, low back pain and post-surgical rehabilitation. BFR training is showing promise in terms of reducing pain and improving function, and quality of life.

There are several registered clinical trials underway investigating BFR in rehabilitation from a range of injuries (anterior cruciate ligament [ACL], wrist fracture, femur fracture and total knee arthroplasty). In addition, within our own groups we are investigating BFR during rehabilitation with patients undergoing haemodialysis, military, patients in ICU, as well as in patients following ACL reconstruction and ankle fractures. Furthermore, there are many examples of the use of BFR for rehabilitation within elite sport, with many practitioners and leading sporting organizations currently applying this technique when rehabilitating their athletes. [4]

**Equipment and protocols used with BFR**

With that in mind there is some disparity over the equipment and the way in which individuals use BFR for rehabilitation. Many practitioners are using a range of equipment as well as BFR protocols that do not match usage within published literature.[4] The current approaches that focus on applying BFR during exercise consists of automatic pneumatic tourniquet systems or hand-held manual blood pressure cuffs, and more recently elastic wraps, at a range of different pressures and durations, particularly in the emerging rehabilitation literature.

Research demonstrating the influence of thigh circumference and cuff width [5] on occlusion pressure has accentuated a likely need for an individualised approach to BFR, particularly with regard to the setting of the restriction pressure. More recently a technique to calculate and prescribe the occlusive stimulus as a percentage of total limb occlusion pressure is just one example of efforts to account for the above factors and provide an individualised approach to prescribing BFR training that is relatively quick and inexpensive*.*

While the relationship between BFR pressure and the underlying tissue compression during exercise is not yet fully understood, BFR training utilising 40-80% of limb occlusion pressure is safe and effective when supervised by experienced practitioners; ,[6] therefore, lower pressures may provide less risk without the need for higher pressure. Establishing limb occlusion pressure is quick and easy to perform with a handheld Doppler and may minimize any cardiovascular risk from the application of BFR during exercise [7], alongside pre exercise screening.

**Risk of BFR training**

BFR training has been deemed to incur low risk of many possible adverse responses [4, 8] There have been case study reports of adverse responses to acute sessions of BFR, such as rhabdomyolysis and delayed onset muscle soreness, however it is likely that these responses are independent of BFR training and simply a response to individuals being unaccustomed to exercise. Therefore, we would currently recommend using 40-80% of limb occlusion pressure, when conducting BFR training in clinical populations. If increasing strength is the aim of training, and heavy-loads cannot be tolerated or are contraindicated, then light-load BFR training is an evidence based option.

**Competing interests: None
Acknowledgements: None**

References

[1] – Garber C E, Blissmer B, Deschenes M R, et al. American College of Sports Medicine

position stand. Quantity and quality of exercise for developing and maintaining

cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults:

guidance for prescribing exercise. *Med Sci Sports Exerc* 2011;43:1334-1359.

[2] – Slysz J, Stultz J, Burr JF. The efficacy of blood flow restricted exercise: A systematic review and meta-analysis. *J Sci Med Sport* 2015 19(8): 669-675.

[3] – Hughes L, Paton B, Rosenblatt B et al. – Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis. *Br J Sports Med* Published Online First: [13th January 2017]. doi:10.1136/ bjsports-2016-097071

[4]. Patterson SD, Brandner CR. The role of blood flow restriction training for applied practitioners: A questionnaire-based survey. *J Sports Sci* (01 Feb 2017) http://dx.doi.org/10.1080/02640414.2017.1284341

[5] Loenneke JP, Fahs CA, Rossow LM, et al. Effects of cuff width on arterial occlusion: implications for blood flow restricted exercise. *Eur J Appl Physiol* 2011; 112(8): 2903-12

[6] Lixandrão ME, Ugrinowitsch C, Laurentino G, et al. Effects of exercise intensity and occlusion pressure after 12 weeks of resistance training with blood-flow restriction. *Eur J Appl Physiol* 2015;115(12):2471–80.

[7]. Spranger MD, Krishnan AC, Levy PD, et al. Blood flow restriction training and the exercise pressor reflex: a call for concern. *Am J Physiol - Hear Circ Physiol* 2015; 309(9):H1440–52.

[8]. Loenneke JP, Wilson JM, Wilson GJ, et al. Potential safety issues with blood flow restriction training. *Scand J Med Sci Sports* 2011 21(4), 510-518.