Manuscript Title: Using blood flow restriction strategies to manage training stress for athletes

Brief Running Head: Blood flow restriction for athletes

Manuscript Type: From the Field

Authors: Brendan R. Scott¹

Setting/Laboratory:
¹ Applied Sports Science and Exercise Testing Laboratory
School of Environmental and Life Sciences,
Faculty of Science and Information Technology
University of Newcastle, Ourimbah, AUSTRALIA

Corresponding Author: Mr. Brendan R. Scott
School of Environmental and Life Sciences
Faculty of Science and Information Technology
University of Newcastle
PO Box 127, Ourimbah,
NSW 2258 Australia
Ph: +61 2 43484149
Fax: +61 2 4348 4145
Email: brendan.scott@uon.edu.au

Financial Support: No external financial support was received for this study
BLUF STATEMENT

Low-load resistance training performed with moderate blood flow restriction to the working muscles can stimulate substantial muscle growth and strength improvements in athletes, while limiting the mechanical stress and negative effects of high-load training.
ABSTRACT

Traditional guidelines state that substantial muscular development requires resistance training using at least 70% of 1-repetition maximum (1RM). However, recent evidence suggests that low-load resistance training (20-40% 1RM) combined with moderate blood flow restriction (BFR) to the exercising musculature can also result in significant improvements in muscle size and strength. While BFR techniques have been predominantly researched using untrained or clinical populations, emerging evidence supports the use of low-load BFR training for muscular development in well-trained athletes. The purpose of this paper was to discuss how to implement BFR for athletes, and highlight how to design effective BFR training programs. Furthermore, BFR methods to either supplement or replace some traditional resistance training sessions are described. This has important applications for monitoring the total stress of training, especially when considering that BFR exercise does not appear to cause the muscle damage or prolonged decrements in contractile function that are commonly reported after heavy resistance training. Low-load BFR training can limit the mechanical stress on an athlete’s body, and potentially avoid overtraining symptoms. Additionally, low-load BFR training can be used to provide a physiological overload stimulus for anabolic responses when combined with an athlete’s normal resistance training program.

Keywords - Strength training, hypertrophy, training load, overtraining.
INTRODUCTION

Research in recent years has highlighted that low-load resistance exercise can result in muscular hypertrophy and strength gains when it is performed using blood flow restriction (BFR) techniques (22). These methods involve applying an inflatable cuff, tourniquet or elastic wrap at the top of a limb, with the aim of maintaining arterial inflow, and occluding venous outflow from the limb during exercise. As arterial walls are generally thicker and more resistant to compressive forces than the walls of veins, moderate restrictive pressures can collapse veins beneath the restrictive cuff (occluding venous return), whereas more ridged arteries retain their shape and thus maintain arterial inflow to the limb. Furthermore, the blood pressure in arteries is greater than in corresponding veins, meaning that higher restrictive pressures are required to occlude arterial than venous blood flow. The addition of BFR during resistance training enhances the adaptive potential of the exercising muscles, with muscle growth and strength increases being possible when using low-loads (20-40% 1-repetition maximum [1RM]) that would not normally facilitate these changes. This is particularly important for athletes looking to manage their total training stress, as it provides a potent anabolic stimulus without the need for highly demanding heavy loads. While the majority of BFR research has focused on clinical or untrained populations, substantial muscular adaptations have also been reported in athletes (13,25). This paper aimed to provide strength and conditioning coaches with information regarding how to use BFR methods for enhanced muscular development in athletes, and to present strategies for implementing BFR exercise to manage the total training stress of athletes.
METHODS

Searches of PubMed and Google Scholar databases were conducted for original investigations that have employed BFR resistance exercise to train athletes. The reference lists of articles retrieved were also screened for additional papers that had relevance to the topic. Investigations were included if they met the following criteria; 1) trained athletic participants using BFR resistance exercise, 2) included a work-matched control training group, and 3) reported on hypertrophic and strength changes over the training period. Following this search, seven separate investigations were identified, and are discussed throughout this paper. Additional relevant literature using untrained and clinical populations was also included to provide information pertaining to the mechanisms of BFR adaptation and how to apply the BFR stimulus.

BENEFITS AND MECHANISMS OF BFR EXERCISE

The use of BFR alone during periods of immobilisation can prevent disuse atrophy (6), and can improve muscular size and strength when combined with low-intensity walking (16). However, the most beneficial way to employ BFR for muscular development is during low-load resistance exercise. Numerous investigations have demonstrated that low-load resistance training performed with moderate BFR can induce significant improvements in muscle mass and strength (2,13,20). Furthermore, these adaptive responses have resulted in improved performance during athletic tasks, including countermovement jump power (3), maximal and repeated sprint performance (1,3,13), agility performance (13) and an aerobic shuttle run test (13). The main findings of these studies examining physical performance following BFR training in athletes are presented in Table 1.
While the mechanisms responsible for muscular responses to BFR exercise are not fully understood, it is likely that an increased accumulation of metabolites is an important factor (18). This accumulation of metabolites may increase muscle cell swelling (27), intramuscular signalling (5), and muscle fibre recruitment (19), which are all thought to be beneficial for muscular adaptation. Furthermore, localised hypoxia during BFR may increase the activation and proliferation of muscle stem cells, enhancing the hypertrophic response (15). Largely increased hormonal responses have also been observed, with an early investigation reporting growth hormone levels were elevated to ~290 times baseline levels following low-load BFR exercise (19). However, the role of acute exercise-induced hormonal responses in resistance training adaptation has been recently questioned (23), and therefore may not be the predominant mechanism of adaptation to BFR training.

HOW TO APPLY BFR
The first consideration for a strength and conditioning coach implementing BFR is to understand how best to apply the BFR stimulus to an athlete. Research investigations generally use inflatable cuffs during BFR exercise, which provide good control over the actual pressure applied to the limb. However, in situations where numerous athletes are training at once with BFR, a more practical method may be simply using elastic wraps around the limbs (7). This method has been previously used by researchers working with well-trained American football players to enhance muscular strength and hypertrophy (25). These athletes trained using four sets (30, 20, 20 and 20 repetitions) of the bench press and squat (20% 1RM and 45 s inter-set rest), 3
times each week following their normal strength training sessions for 4 weeks. Larger improvements in 1RM for the bench press and squat were observed in subjects who performed this additional training with BFR (7.0% and 8.0%, respectively) than without BFR (3.2% and 4.9%, respectively). There were also larger increases in upper and lower chest girths in the BFR group (3.7 and 2.6 cm, respectively) than the control group (1.0 and 1.2 cm, respectively). Therefore, it appears that using elastic wraps for BFR is viable even in athletes who have already developed a large degree of strength and muscle size.

While numerous factors related to the occlusive cuffs or wraps can impact on the actual BFR stimulus experienced, it is important to consider two primary points:

1. The pressure of the cuffs/wraps should be sufficient to somewhat maintain blood flow into the limb, but to stop blood flow out of the limb (i.e. they should feel snug, but not painful).

2. Larger limbs (legs or large athletes) require wider cuffs/wraps than smaller limbs (arms or small athletes) to produce the same occlusive stimulus at a given pressure.

Generally, using a narrow cuff or wrap (3-6 cm) is recommended for the arms, whereas wider cuffs or wraps (6-13.5 cm) are necessary for the legs. The occlusive stimulus should be applied near the top of the limb, making sure that it does not interfere with the desired range of motion during exercise (Figure 1). When using inflatable cuffs, research has employed BFR pressures based on the circumference of the thigh, as follows; <45-50 cm = 120 mmHg, 51-55 cm = 150 mmHg, 56-59 cm = 180 mmHg and ≥60 cm = 210 mmHg (9). This should equate to 60% of arterial
occlusion pressure (the pressure required to completely stop arterial inflow into the leg), therefore allowing blood flow into the limb, but occluding venous return. However, similar guidelines have not been reported for the arms, and other methods to estimate wrap pressure are needed.

***INSERT FIGURE 1 NEAR HERE***

***INSERT VIDEO 1 NEAR HERE***

For ease of use, particularly when using wraps, BFR has been applied using a perceived pressure scale from 0-10, with a score of 0 indicating no pressure and 10 indicating intense pressure with pain (24). Using this method, wraps (or inflatable cuffs) should be applied so that a score of 7 (moderate pressure with no pain) is achieved. However, ratings of discomfort may not be sensitive to changes in pressure in all athletes. It is therefore recommended to also monitor BFR pressure based on the total repetitions that can be completed. Participants should be able to complete 20-30 repetitions in the first set of a BFR training session using low-loads (20-30% 1RM); if they achieve substantially more or less than this goal number repetitions, the cuff/wraps may be too loose or tight, respectively, and should be adjusted. While there may be a degree of trial-and-error associated with establishing the correct occlusive pressure during the early stages of BFR training with wraps, athletes will quickly become accustomed to this form of training, and the BFR pressure will become more consistent.

Although early BFR research utilised occlusive pressures in excess of 200 mmHg (19), it is important to recognise that pressures this high are unlikely to provide
optimal training responses. Loenneke et al. (10) have recently proposed that BFR pressure may have a hormetic dose-response relationship with muscular adaptations, meaning that if the pressure is either too low or high, the effectiveness of training is decreased. At high pressures (at or near arterial occlusion pressure), arterial inflow to the limb will be substantially decreased or stopped completely. This has obvious implications for decreased venous pooling and muscular swelling in the restricted limb, which is suggested as an important mechanism for adaptive responses to BFR exercise (8). As such, if the BFR pressure is applied correctly, participants should be able to note a visual fluid shift and transient swelling in the limb during BFR exercise. Complete or near-complete arterial occlusion is also a safety concern for the formation of a thrombus, muscle damage and/or cell necrosis, and slowing of nerve conduction velocity (10).

**TYPES OF TRAINING PROGRAMS**

Although the BFR stimulus is localised to the limb being trained, research has demonstrated that muscles of the trunk can also benefit from this novel exercise strategy (26). This is important for athletes, as muscles are rarely trained in isolation to enhance athletic performance, with obvious exceptions being to correct muscular imbalance or during rehabilitation from an injury. Therefore, BFR training can include pivotal strength exercises such as the bench press or squats (Figure 2). However, it is possible that the adaptive responses over extended training periods may be disproportionate between the trunk and limb muscles, increasing the potential for muscular imbalance. As such, BFR exercise should not be used as the only training method for muscle size and strength in healthy athletes.
A popular repetition scheme that has demonstrated favourable results with BFR is performing four sets of 30, 15, 15 and 15 repetitions using 20-30% 1RM with 30 s inter-set rest periods. The BFR stimulus should be maintained during inter-set rest periods to encourage venous pooling and metabolite accumulation, and therefore provide an anabolic intramuscular environment. However, if localised numbness, excessive pain, or dizziness are experienced during the exercise or between sets, it is likely that the BFR pressure too high, and cuffs/wraps should be loosened or removed. It is not necessary to train to failure when using a BFR stimulus, though this repetition scheme may take some athletes close to the point of fatigue.

***INSERT FIGURE 2 NEAR HERE***

***INSERT VIDEO 2 NEAR HERE***

For well-trained athletes with extensive resistance training experience, such as those involved in contact sports, it is likely that the greatest benefits will arise from using BFR in combination with their normal heavy-load training. For example, following a lower-body strength training session, benefit may arise from performing additional BFR training using a weighted squat variant (i.e. back or front squats) using the 30, 15, 15, 15 repetition scheme. Due to the low-loads used, this additional training does not result in muscle damage or prolonged decrements in muscle function of the same magnitude as high-load training (11). Therefore, the addition of supplemental low-load BFR training following a normal training session can provide an increased anabolic stimulus for muscular development without the detrimental effects of significantly increased training volumes.
However, some research using athletes with extensive strength training experience has reported limited (25) or no (12) hypertrophy after traditional strength training combined with supplemental low-load BFR training. While it is possible that the girth measurements employed by these researchers were not accurate enough to detect small changes in muscle size (particularly when compared to magnetic resonance imaging techniques), it may also be that large increases in muscle size are not possible in very well-trained athletes following a brief period of BFR training (17). Further research to this point is therefore required.

**USING BFR TO MANAGE TRAINING STRESS**

BFR training is most commonly promoted for individuals who would benefit from muscular development, but cannot perform traditional high-load training (e.g. the elderly and post-surgery patients). However, considering the beneficial responses that have been reported in well-trained athletes following BFR training (12,13,25), there is potential to use this exercise strategy to manage the total training stress imposed on an athlete. Many athletes are required to develop several physiological and physical qualities during their training, including muscular strength and power, aerobic and anaerobic capacities, repeated sprint ability, speed and agility, not to mention skills specific to their sport. It is important that strength and conditioning coaches consider not only the time required to train for numerous adaptations, but also the stress that high training intensities can impart on an athlete’s body. Low-load training with BFR may be useful in these circumstances to provide an anabolic stimulus without the need for heavy mechanical loads.
Implementing BFR during appropriate stages of periodised athletic training plans may help counter the potential negative effects of high overall training loads. As mentioned previously, the low-loads used during BFR training do not appear to cause measureable muscle damage (11), yet they can still provide a physiological stimulus for muscular adaptation. This form of training may therefore be useful for athletes who have a decreased capacity for recovery from intense exercise (e.g. masters athletes), and even for those in a compromised immune state (e.g. following a period of high training stress or extensive travel). In these scenarios, substituting some high-load resistance training sessions with low-load BFR training can provide a physiological stimulus for muscular hypertrophy and strength improvements (or at the very least, maintenance). Training sessions using BFR are also notably shorter in duration than traditional high-load training, mainly due to the brief inter-set rest periods used (~30 s), therefore decreasing the time that athletes need to devote to strength training.

Another potential benefit of BFR exercise is during periods of extensive travel or when desired training facilities are unavailable. As heavy weights are not required when using BFR methods, other forms of external resistance such as elastic bands can be used for muscular development (28). While this research was performed using older adults, it is reasonable to propose that athletes may at least be able to maintain muscle size and strength during brief periods of similar training, if more appropriate equipment is not available. However, it should be noted that low-load BFR exercise does not elicit muscle activation of the same magnitude as traditional high-load strength training (4,14), and therefore is not likely to elicit neural adaptations to the same degree. For comprehensive athletic development, it is therefore important to not
rely on low-load BFR training as the sole method of muscular development. Furthermore, while research using well-trained and athletic participants has reported beneficial muscular responses to BFR training (1,3,12,13,21,25), additional research is required to comprehensively assess whether individuals with an extensive resistance training history who have already achieved very high levels of strength, can consistently benefit from BFR training strategies.

**CONCLUSIONS**

Similarly to untrained and clinical populations, well-trained athletes can experience muscular benefits from low-load resistance exercise combined with BFR. When implementing the actual BFR stimulus, it is important to remember that the restrictive pressure should be sufficient to maintain arterial flow into the limb while stopping venous return, and that both the size of the limbs being restricted and the width of the cuffs or wraps being used should be considered. Interestingly, muscles of the trunk can also benefit from multi-joint exercises performed with BFR to the limbs. The BFR scheme of 30, 15, 15 and 15 repetitions at 20-30% 1RM with 30 s inter-set rest appears to stimulate beneficial muscular adaptations, even in well-trained athletes. However, it is important to recognise that for healthy athletes, BFR training should not be used as the sole method for muscular development, and traditional high-load training should also be incorporated. Due to the low-loads used during BFR training, this novel training strategy can be used to manage the total training stress imposed by resistance exercise. Muscle damage and prolonged decrements in muscular function do not appear to occur following low-load BFR training, meaning that this type of training can provide a physiological stimulus for muscle adaptation without the potential negative effects of high training loads. Additionally, for athletes looking to
maintain their muscle size and strength low-load BFR training can be beneficial as a replacement for selected high-load training sessions, or during times where only body weight and elastic band exercises are possible due to equipment availability.
REFERENCES


28. Yasuda, T., Fukumura, K., Uchida, Y., Koshi, H., Iida, H., Masamune, K., Yamasoba, T., Sato, Y., & Nakajima, T. Effects of low-load, elastic band resistance training combined with blood flow restriction on muscle size and
FIGURE CAPTIONS

Figure 1. Application of elastic wraps (a) and inflatable cuffs (b) for BFR training of the legs. Wraps and cuffs are positioned at the top of the limb to ensure range of motion is not compromised during exercise (the same applies for the arms).

Figure 2. Examples of low-load back squat exercise performed with BFR using elastic wraps (a) and inflatable cuffs (b).

VIDEO CAPTIONS

Video 1. Application of elastic wraps to the legs and arms for practical BFR training.

Video 1. Examples of multi-joint low-load resistance exercises performed with practical BFR.