Blood Flow Restriction Training – basic overview

Report compiled by Chris Gaviglio.

I have compiled a literature review around BFR use;

- Introduction: background of BFR training and its advantages
- Mechanisms behind it effectiveness
    - Motor unit recruitment
    - Endogenous hormone response
    - Other factors
- Safety
    - Review of literature
    - Considerations around reporting of negative use of BFR
    - Cuff pressure
- Other models for consideration
    - *Suggestions for improving processes around BFR training*
- Conclusion and personal thoughts
- Further information

**Introduction**

Resistance exercise is a major part of an athlete's training regime. Depending on the type of resistance exercise, benefits include improvements in power, strength, muscular endurance and hypertrophy [1]. Literature agrees that the load lifted by the athlete should be at least 60% of their 1 repetition maximum (RM) in order to stimulate increases in strength and that optimal strength gains result from loads in excess of 80% of 1RM [2]. Furthermore training below this level of intensity rarely produces increases in muscle size or strength [3].

Occlusion training is a unique training modality that has been shown to produce positive training adaptations at low intensities [4]. Occlusion training is a method of strength training "with the addition of pressure" and is also known as Blood Flow Restriction, KAATSU (figure 1) or Ischemic Training. This additional pressure is applied to the arms or legs through the use of a special belt. The consequent restriction of blood flow creates a highly specialised environment for muscle training. The use of a modern day tourniquet is one method of providing a controlled and safe occlusion environment for the user.

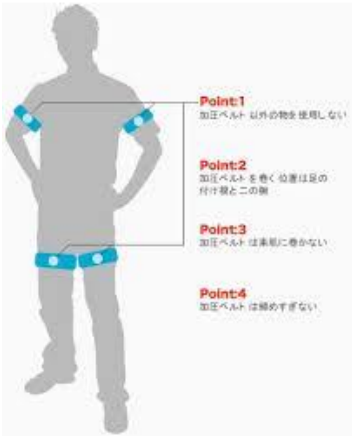


Figure 1. Schematic diagram of placement of tourniquets performed during KAATSU training.

The advantages of tourniquet training are numerous but the major findings are:

- Gains in muscle strength and hypertrophy at low to moderate loads of between 20-50% of 1RM [5,6];
- Type II fibre (fast-twitch) recruitment during low-intensity training [7];
- Improvement in endogenous endocrine markers (e.g. growth hormone, testosterone and IGF-1) [8]; and
- Performing exercises at lower loads after a regime of high-intensity sets (70-80% 1RM) has showed greater increases in whole muscle area and muscle fibre area compared with a pure high-intensity routine [4,9].

The exact mechanism for the efficacy of this method of training in not totally clear but it appears that there is both an improvement in endogenous hormone markers and motor unit recruitment whilst training with occlusion cuffs. Therefore the purpose of this article is to summarize the current literature regarding the physiology of blood flow restriction training and to discuss some of the practical aspects of this type of training.

## Mechanisms behind it effectiveness

*Motor unit recruitment*

The size principle of motor unit recruitment indicates that small units (i.e. slow & fatigue resistant fibers) are recruited first and with increasingly larger unit demands for force or power, larger units are recruited [10]. Thus, units with type I fibers are generally recruited first and with increasing intensity of exercise, units comprised of type IIa fibers and finally also units with type IIx fibers are recruited [11]. It has also been reported [12,13] that the recruitment thresholds for the motor units decrease during fatiguing exercise at submaximal loads so that type II fibers are increasingly recruited as the point of torque failure draws closer. Blood flow restriction has been demonstrated to decrease the endurance and increase the electrical activity (as measure by electromyography, EMG) of the working muscle during low-intensity exercise. Yasuda et al. (2005) for example reported type II fiber hypertrophy (biopsy), increase in strength (squat 1RM) and whole muscle cross-sectional area (CSA) after a period of low-intensity strength training (3x15 @ 20% 1RM – squat and leg extension) combined with blood flow restriction [7].

*Hormone response*

Acute changes in the plasma levels of several hormones and growth factors are typically seen as a result of heavy-resistance exercise. Acute elevations in endogenous hormones (e.g. testosterone) increase the likelihood of receptor interactions [1], offering short-term benefits for training performance and long-term adaptations [14]. It has also been suggested that acute changes in hormone concentrations across resistance workouts reflect a stress response rather than a hypertrophy signal [15]. This work demonstrated that acute changes in testosterone did not correlate with hypertrophy but rather focused on the potential of testosterone to motivate effort in training as a driver to improve performance and morphological changes [15]. Large increases in plasma growth hormone concentrations (GH) have also been reported with low-load occlusion training [16]. Significant correlations have also been reported between acute increase in GH and increase in type I and type II fiber area in the bicep brachii [17] and quadriceps CSA [18] in response to strength training. Like testosterone, increased GH levels are rather thought to be a reflection of a greater level of effort, which in itself would likely be sufficient to cause increased muscular growth [2]. Furthermore, the elevated levels of GH also may be reflective of local processes that may be more important for the hypertrophic response.

*Other exercise-related factors*

Numerous other factors in the environment apart from hormones, growth factors and mechanical stimuli have also been suggested as possible stimuli in blood flow restriction training; blood flow changes [3], increases in muscle protein synthesis [19], heat stress [20], hypoxia-hyperoxia [21] and nitric oxide (NO) [22].

**Safety**

Wernbom et al (2008) performed a literature review of 13 studies using blood flow restriction with a tourniquet [8]. These studies typically lasted between 2 and 8 weeks except for two studies [16,20] that lasted for 16 weeks. A total of 116 subjects trained a total of 4376 training sessions. Occlusion generally lasted between 5 and 10 min, and except for acute muscle pain, no adverse effects were reported. Another published survey on the safety of occlusion training reported on over 12 600 individuals who used tourniquets in combination with different modes of exercise (walking, cycling, weight training etc) [23]. The most common side effects were subcutaneous hemorrhage (incidence: 13.1%) and temporary numbness (1.3%). More serious side effects were rare: venous thrombosis (0.055%), deterioration of ischemic heart disease (0.016%), cerebral infarction (0.008%), rhabdomyolysis (0.008%) and pulmonary embolism (0.008%).

Loenneke et al (2010) performed a review on several measures of safety with respect to BFR training and in comparison to those responses to regular exercise[24]. This is quite a comprehensive review and I have attached this article if you require an in-depth read. The review highlighted the following areas:

1. Cardiovascular
    a. Peripheral blood flow changes.
    b. Central responses of the cardiovascular system
    c. Blood coagulation
2. Oxidative Stress
3. Muscle damage
4. Nerve conduction velocity
5. Pressure recommendations for future research

The review reports that the areas of studies in these areas are sparse and equivocal in their findings. As with all studies the disparity in the results revolves around study design.

Their closing perspective on BFR training states that the research, while positive, is limited and more research should be completed to better determine under what conditions this type of training can be safely used. In addition, the width of the belt and limb circumference should be accounted for when applying the restrictive stimulus to each subject. In conclusion, the current research on blood flow restriction training with respect to safety outcomes confirms earlier reports that blood flow restriction exercise, when used in a controlled environment by trained and experienced personnel, provides a safe training alternative for most individuals regardless of age and training status[24].

*Considerations around reporting of negative use of BFR*

The above summary highlights possible concerns around the use of BFR training. When reading literature it is imperative that the following information be considered:

- Subject (training and chronological age, previous injuries, medical conditions)
- Width of cuff (narrow – 5cm vs. wide – 8→ 10.5cm)
- Pressure (75 → 220mmHg – the pressure **must** be taken into consideration with the cuff width)
- Exercise selection
- Rep and set scheme (this **must** be taken into consideration with the exercise used)
- Intermittent vs. continuous pressure.

My take on most studies that have reported negative side effects have used subjects that are not well trained, employ a continuous pressure, narrow cuff, high pressure and utilize a very high rep scheme (typically to failure). On the contrary the protocols that I use include a wider cuff, pressure relevant to the athlete (to be discussed), intermittent pressure, reps and sets scheme as per typical strength training programs. Furthermore the subjects at the QAS are athletes who are well trained and any medical conditions are highlighted through their medical and physical screening conducted during the yearly induction process.

*Cuff pressure*

Despite the observed benefits with BFR, there is little consensus in the literature as to what the BFR pressure should be based upon[25]. Table 1 highlights the range of cuff pressures used for restricting blood flow.

Table 1: Summary of recently published BFR studies in the upper and lower body[25]

| Author | Cuff width (cm) | Final pressure (mmHg) |
|---|---|---|
| Upper body studies | | |
| Hunt et al. (2012) | 13 | 80 |
| Luebbers et al. (2014) | 7.6 | Unknown |
| Ozaki et al. (2013) | Unknown | 160 |
| Thiebaud et al. (2013b) | 3 | 120 |
| Vieira et al. (2014) | Unknown | 110 |
| Weatherholt et al. (2013) | 3 | 180 |
| Yasuda et al. (2012) | 3 | 160 |
| Yasuda et al. (2014) | 3 | 170–260 |
| Yasuda et al. (2011) | Unknown | 160 |
| Yasuda et al. (2013) | Unknown | 160 |
| Lower body studies | | |
| Cook et al. (2014) | 6 | 1.3 × SBP |
| Cumming et al. (2014) | 13.5 | 90/100 |
| Fahs et al. (2014) | 5 | 80 % arterial occlusion (up to 240 mmHg) |
| Fitschen et al. (2013) | 5 | 160 |
| Hunt et al. (2013) | 13 | 110 |
| Karabulut and Perez (2013) | Unknown | 1.44 × SBP |
| Karabulut et al. (2013) | 5 | 240 |
| Labarbera et al. (2013) | 5.4 | 180 |
| Luebbers et al. (2014) | 7.6 | Unknown |
| Manimmanakorn et al. (2013) | 5 | 230 |

The discussion around the use of absolute pressures is that it may not necessarily restrict the same amount of blood flow in every individual since the amount of tissue surrounding the blood vessels may influence the pressure exerted on the vasculature and therefore, the degree of blood flow restriction[26]. Scott et al (2014) reported that a BFR pressure equivalent to 50-80% of the pressure required to occlude arterial flow is appropriate during low-load resistance exercise[27]. Loenneke et al (2014) determined a method to calculate upper and lower body arterial occlusion[25] incorporating limb circumference, and relevant systolic blood pressure (SBP) and diastolic blood pressure (DBP).

The respective formulas for upper and lower body are as follows (based upon 5cm narrow cuffs):

Upper Arterial Occlusion (mmHg) = 0.667 (SBP) + 0.339 (DBP) + 1.461 (Arm Circumference) + 17.236

Notes:

- arm circumference - measured at a distance 50% distal to the acromion process
- SBP & DBP – applied and measured to the most proximal portion of each arm

Lower Arterial Occlusion (mmHg) = 5.893 (thigh circumference) + 0.734 (DBP) + 0.912 (SBP) – 220.046

Notes:

- thigh circumference - measured at 33% of the distance from the inguinal crease to the top of the patella
- SBP & DBP - pulse at the ankle was detected on the posterior tibial artery.

From this work, Loenneke et al (2014) reported BFR pressure stimuli equivalent to 60% of arterial occlusion (5cm cuff width), estimated from thigh circumference as follows: <45-50cm = 120mmHg; 51-55cm = 150mmHg; 56-59cm = 180mmHg; and >60cm = 210mmHg[28]. Previous work with subjects at the QAS (prior to cessation of BFR use) set at a pressure stimuli equivalent to 50% of arterial occlusion using a wider cuff (8.5cm; wider cuff = need for lower pressure) highlighted the following estimation from thigh circumference: 58.5cm = 150mmHg, 61.2cm & 63.9cm = 165mmHg; and 68.8cm = 190mmHg. With my own extensive personal experience I do not allow pressures of >200mmHg to be used. As stated earlier I also utilize an intermittent pressure protocol. Previous pressure protocols I have also used incorporated absolute pressures up to 150mmHg. Irrespective of the pressure prescribed I have always adjusted the pressure according to the comfort and tolerability of the user.

**Use within the different environments**

The application of BFR training specifically for athletic populations is numerous. Table 2 outlines a few uses of BFR in the daily training and competition environment according to the large body of peer reviewed articles and personal experience and feedback from athletes who I have worked with.

Special mention must be given to the discussion on the role of BFR as a modality to induce bone adaptation, which was previously thought to only occur with higher intensity/impact exercise[29]. Despite the limited research on BFR and bone markers, preliminary research has identified increased interstitial fluid shifts throughout the bone and the activation of the hypoxia inducible transcriptional factor (HIF) pathways and its downstream activation of vascular endothelial growth factor (VEGF). A growing body of evidence supports the role of angiogenesis-osteogenesis coupling during skeletal formation and repair[30].

Table 2. Application of BFR in the training and competition environment

| | When | Why | How |
|---|---|---|---|
| Injury | Post-operative | Atrophy attenuation | Passively with & without activation exercises |
| | Warm-up | Activation, | Stationary aerobic equipment |
| | Strength exercises | Activation, Hypertrophy, Strength | Rehabilitative-based and low level strength exercises as per appropriate progression |
| Strength Training | Warm-up (general) | Activation Hormonal Priming | Stationary aerobic equipment Low-level activation based exercises |
| | i. Warm-up (leading into main set) ii. Main session | Activation Hormonal Priming Strength Hypertrophy (if applicable) | Primarily lower body strength exercises (double and single leg) – performed with a controlled tempo. |
| Competition | Warm-up | Activation Hormonal Priming | Used passively or actively through using select exercises within a structured routine (low & moderate intensity) |
| Bone Stress Injury | Prevention &/or implement according to diagnosis | Improve bone response | Use during normal strength training exercises regimes |

Typically in high training load sports (e.g. triathlon) we have already seen a high incidence of bone stress injuries. Although this cohort of athletes include resistance exercise in their training regime they do not typically lift high loads commonly needed to take advantage of performance benefits associated with resistance exercises. Therefore the inclusion of BFR training into their gym-based routines may provide a double benefit of improving both muscular and bone response.

**Other models for consideration**

Scott et al (2014) created a simple flowchart regarding how the practitioner should assess the functional capabilities of an individual to determine the most appropriate BFR strategies (figure 1) [27]. Nakajima et al (2011) outlined key considerations with the implementation of KAATSU training, which is specific methodology of BFR utilizing a narrow cuff (5cm)[31]. They included tables that gathered basic information (Table 3) required for general exercise including; 1) subjective symptoms, 2) previous medical history; 3) existence of lifestyle related diseases; 4) family medical history; 5) lifestyle habits. Careful examination based on exercise tolerance tests will also be required as appropriate.

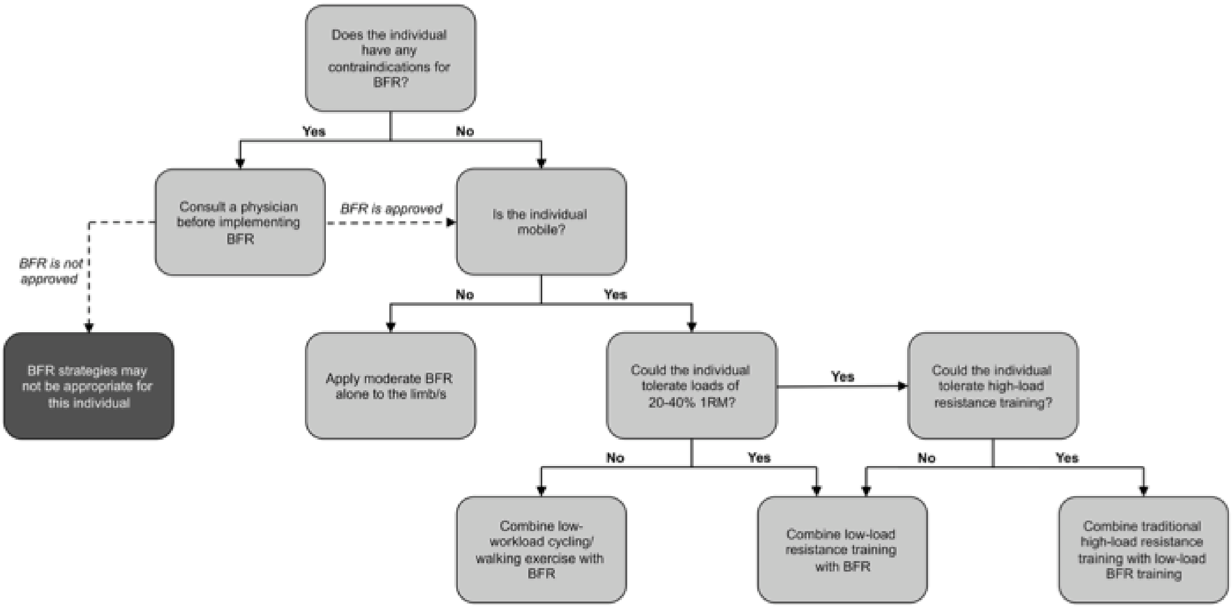


**Fig. 1** Simplified flowchart for the practical implementation of blood flow restriction strategies for clinical, healthy and athletic populations. Contraindications for blood flow restriction have been described by Nakajima et al. [6]. *BFR* blood flow restriction, *1RM* 1-repetition maximum

Table 3. Basic treatment information required for exercise therapy[31]

| Basic treatment information | Necessity of an exercise tolerance test | Other action |
|---|---|---|
| Subjective symptoms | | |
| Chest pain / chest discomfort / palpitation / shortness of breath | Yes | |
| Dizziness / fainting / intermittent claudication | Yes | |
| Spondylosis symptoms / joint symptoms | | Orthopedic examination and guidance |
| History of disorder | | |
| Cardiovascular disease | Yes | |
| Orthopedic disorder | | Orthopedic examination and guidance |
| Existence of lifestyle-related diseases | | |
| High blood pressure | Assessed severity | |
| Diabetes | Assessed severity | |
| Hyperlipidemia | Assessed severity | |
| Obesity | Assessed severity | |
| Family medical history* | | |
| Myocardial infarction and sudden deaths in first degree relatives | Yes | |
| Lifestyle habits | | |
| Exercise / diet / smoking / alcohol | | Lifestyle guidance |
| Resting electrocardiogram | | |
| Myocardial infarction | Yes | |
| ST-T segment abnormality | Yes | |
| Ventricular arrhythmia | Yes | |
| Other important observations | Yes | |

* A family medical history of relatively young sufferers such as father or first degree male relative aged under 55 or mother or first degree female relative aged under 65 who have undergone myocardial infarction and coronary revascularization or died suddenly.

Table 1 and 2 are cited from the following papers, and changed: (1) Edited by Japanese Circulation Society et al. Guidelines for diagnosing and treating cardiovascular disease. 2000-2001 Joint Research Group Report. Guidelines for exercise therapy for cardiovascular disease (JCS 2002) (Group head: Saito) (2) Manual for prescribing exercise therapy. Journal of the Japan Medical Association, 116 (3), 1996.

Table 4 shows indications and contraindications of normal exercise therapy for lifestyle-related diseases. Although this is used for training of patients who are obese or have a metabolic syndrome it could form a comprehensive screening tool for potential BFR users.

Table 4**.** Indications and contraindications for exercise therapy for lifestyle-related diseases

| Disease | Indication | Conditional indication | Contraindication |
|---|---|---|---|
| High blood pressure | 140-159/90-94 mmHg | 160-179/95-99 mmHg<br>Men aged over 40 or women aged over 50 that are in treatment and don't have a contraindication value should undergo an exercise tolerance test if possible. | 180/100 mmHg or more<br>CTR of 55% or more visible on a chest roentgenogram<br>Life-threatening arrhythmia or ischemic change shown by an electrocardiogram (excluding times when safety was confirmed by an exercise tolerance test)<br>Uric protein of 100 mg/dl or hypertensive change in the fundus oculi (more than IIb) |
| Diabetes | Fasting blood glucose - 110 - 139 mg/dl | Fasting blood glucose - 140 - 249 mg/dl<br>Men aged over 40 or women aged over 50 that are in treatment and don't have a contraindication value should undergo an exercise tolerance test if possible. | Fasting blood glucose – 250 mg/dl or more<br>Urinary ketone body (+)<br>Diabetic retinopathy (+) |
| Hyperlipidemia | TC：220 - 249 mg/dl<br>or<br>TG：150 - 299 mg/dl | TC: 250 mg/dl minimum or<br>TG: 300mg/dl or more<br>Men aged over 40 or women aged over 50 that are in treatment should undergo an exercise tolerance test if possible. | |
| Obesity | BMI：24.0 - 29.9 | BMI：24.0 - 29.9 and lower limb joint damage<br>Orthopedic examination and exercise restriction | BMI：30 or more |

TC: Total cholesterol; TG: Triglycerides; BMI: Body Mass Index (body weight (kg) / height $(m)^2$)

Table 5 highlights risk factors in determining KAATSU training indication to serve as a useful reference when conducting KAATSU training.

Table 5. Point system to identify suitability of KAATSU training using risk factors

| Points | Indication |
|---|---|
| 5 | History of deep-vein thrombosis (DVT); hereditary thrombotic tendency; antiphosholipid antibody syndrome |
| 4 | Pregnant women |
| 3 | 1. Varicose vein of legs<br>2. Prolonged immobility (incapable of 8 hours thromboprophylaxis rehab);<br>3. Atrial fibrillation or heart failure |
| 2 | 1. people > 60 years old;<br>2. BMI > 30<br>3. Hyperlipidemia;<br>4. Malignancy<br>5. Using lower limb tourniquet<br>6. Using oral contraceptive or adrenocortical steroids<br>7. Quadriplegia<br>8. High hemoglobin level |
| 1 | 1. people aged 40 to 58 years old;<br>2. women<br>3. 25 < BMI < 30 |

The higher the number of points the greater the risk and the higher the combined number of point for several risks the greater the risk. The suitability for KAATSU training for people corresponding to the above point system:

- 5 points (history of deep- vein thrombosis; hereditary thrombotic tendency; and antiphospholipid antibody syndrome) should be avoided.
- Caution is required when dealing with pregnant women, who have impairment of the coagulation system in the latter stages of pregnancy. We do not conduct training for these pregnant women in principle.
- While there have been no reports of KAATSU affecting varicose veins of legs, a review of this is needed in the future.
- Older people and bedridden patients are considered to be suitable for KAATSU training, but it is necessary to exercise care when providing KAATSU training for people that originally had thrombosis.
- Some patients get thrombosis in the early postoperative period and extreme caution needs to be exercised for such patients.

*Suggestions for improving processes around BFR training*

Pre-activity questionnaires:

1. Lifestyle questionnaire (e.g. Table 3)
2. Indications and contraindications questionnaire
    a. lifestyle-related diseases (e.g. Table 4)
    b. risk factors – point system (e.g. Table 5)
3. Voluntary consent form

**Conclusions and personal thoughts**

The body of evidence would suggest that blood flow restriction training could provide a unique and beneficial training mode for promoting muscle hypertrophy and/or strength around resistance exercise. Furthermore the associated hormonal benefits may also provide further avenues for performance enhancement around training and competition. As with the addition of any modality to a training program it is important to trial such an intervention to identify the best protocol specific to each athlete. My own personal experiences have been very positive across multiple sports and all athlete levels (male/female, injured/uninjured, developmental/elite, training/competition). Although few, the only negative side effect (n=2) I have experienced from my own athletes have been acute muscle tightness around the hamstring region during use and DOMS following use. However as with all well structured training programs, the inclusion of an occlusion cuff must be introduced and incorporated appropriately. Also limb length, muscle bulk and training age of the athlete also dictates how best the occlusion cuff can be used.

Working in other professional sporting environments (Rugby - Bath Rugby and AFL - Gold Coast Suns) I have been able to successfully implement the use of occlusion cuff training into the gym and rehabilitation environment in the following ways:

1. Post-operative & injured athletes (eg ACL) – especially in the acute phases of strength training where it is imperative to maintain muscle mass whilst keeping the loads lifted low;

2. Hard gainers who need to increase the workload without excessive levels of fatigue that is usually associated with continual high intensity training (>65% 1RM);

3. Athletes with non-critical chronic injuries. Using patella tendinopathies as an example, the maintenance of quadriceps bulk is typically difficult due to pain associated with gym-based movements. Using lower loads (with an occlusion cuff) decreases mechanical stress on joints and tendons, which is usually associated with heavy resistance training. Anecdotally, the perceived pain during these movements significantly decreases whilst using an occlusion cuff;

**Further information**

This information is further summaries of literature.

*Narrow vs. wide tourniquets*

The width and pressures used within the studies vary. In the context of limb surgery, it has been recommended that wide tourniquet should be used as wide cuffs have been shown to achieve occlusion at considerably lower pressure than more narrow cuffs [32]. The use of wide tourniquets and lower pressure also may reduce the harmful effects of high compression and shear forces on soft tissues [32].

Studies using narrow cuffs (30-50mm) are typically used at higher pressures of between 160 – 240 mmHg. These narrow cuffs tend to originate within the origins of KAATSU practice. Wider cuffs (100-140mm) have been reported at lower pressures between 75-100mHg, despite more recent studies investigating the effects at higher pressures around 200mmHg [33].

*Frequency of occlusion training*

Strength training programs are governed using principles of frequency, intensity, volume and mode of training. Conventional resistance training is typically performed on two to three occasions per week and most rehabilitative programs up to five sessions. Standard training frequencies (2-3 times per week) using blood flow restriction have been shown to result in marked hypertrophy of the quadriceps [34–36] where the rates of hypertrophy observed in these four studies were between 0.04% and 0.22%/day. This increase in within the range reported for conventional heavy resistance training (0.03-0.26%/day) at similar frequencies [37].
Yasuda et al (2005) [7] reported significant increases in strength and CSA also whilst training twice a day for 12 consecutive days whilst using blood flow restriction. Although this is an unusually high frequency, the authors suggested that because of the low mechanical stress

(20% of 1RM), a shorter recovery time between sessions was needed in comparison to traditional strength training protocols. Abe et al [6] studied the effects of walk training on a treadmill whilst wearing occlusion cuffs. The 3-week study involved subjects walking twice a day for 5 x 2 minute bouts at a speed of 50 m/min (3km/h). Subjects who wore the occlusion cuff reported a significant increase in thigh muscle CSA and leg strength (1RM leg press and leg curl) whereas subject who did not wear the cuffs experienced no change.

A more recent study [33] investigated the effects of moderate load strength training with and without blood flow restriction (160-180mmHg) on strength, power, repeat sprint ability and salivary hormonal parameters. Strength training sessions were performed three times a week for three weeks with 5 sets of 5 repetitions of bench press, squat and pull-ups at 70% of 1RM. Greater improvements in bench press (5.4 vs. 3.3kg), squat (7.8 vs. 4.3kg), maximum sprint time (40m: −0.03 vs. −0.01s) and leg power (countermovement jump: 168 vs. 68W) were observed following the occlusion intervention (Figure 2). Salivary testosterone and cortisol were also acutely elevated following the occlusion intervention sessions. Furthermore, baseline salivary testosterone was also significantly elevated across the 3 week training blocks with the blood flow restricted training. The occlusion cuffs were only worn on the thigh suggesting a possible systemic mechanism that is not limited to localized hypoxia or metabolite accumulation [33].

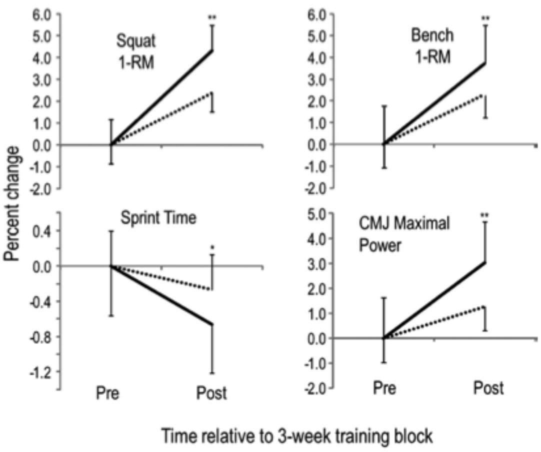


Figure 2. Improvements observed in strength, power and sprint ability through using blood flow restriction during strength training sessions over a period of 3 weeks.

Solid line: 180mmHg occlusion applied to the lower-limbs during exercise; Dotted line: no occlusion stimulus applied during training; ** p <0.01; * p<0.05.

*Preconditioning before an event*

Ischemic preconditioning (IPC) has been shown to acutely enhance muscle function [33]. This involves the use of repeated bouts of ischemia induced in skeletal muscle through the use of a cuff or tourniquet, interspersed with period of reperfusion. It has been suggested that IPC increases muscle blood flow resulting in improved oxygen delivery and clearance and/or up-regulation of intramuscular cellular movement. IPC may also improve muscle force and contractility via increased efficiency of excitation-contraction coupling (process by which a muscular action potential causes a muscle fiber to contract). A recent study by Bailey et al [38] reported significant reductions in blood lactate accumulation and a subsequent 34-second improvement in 500m run performance in a group of healthy males where blood flow restriction was performed before a standardized warm-up involving 4 x 5-minute bout of bilateral occlusion at 220mmHg.

Blood flow restriction could also be used as hormonal priming tool prior to key training sessions and competitions. Aside from the benefits of elevated testosterone to physical performance (e.g. positive correlation between baseline testosterone levels and ability to produce power [39] recent literature has identified a potential link between endogenous testosterone and aspects of athletic behavior related to motivation and confidence to compete [40].

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