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This field is constantly evolving as new research and experience broadens our knowledge. As a result, changes in application may be necessary.

Trainers should rely on their own expertise in evaluating and using any information included in this book. They should be mindful of their own safety as well as the safety of others in their care, and if in doubt seek the advice of a qualified professional.

With respect to any techniques identified, readers are advised to research the most current information available on procedures, dosage, method and duration of treatment, and contraindications.

It is the responsibility of reader to take into account all the necessary safety precautions.

CONTENTS

Blood Flow Restriction Exercise

Size	Measurement (Inches)	Body part
Medium	24.5”	Arms
Large	36”	Legs

BEAR GRIP®

WHAT IS BLOOD FLOW RESTRICTION (BFR)?

- A training method that restricts blood flow in working musculature with low intensity exercise.
- BFR aims to achieve the same results of a high intensity training but with low intensity exercise and reduced blood flow.
- The technique primarily works by restricting arterial blood flow and venous outflow within the muscle.

HISTORY

- The root of BFR training is in a Japanese training method called “Kaatsu.”
- Dr. Yoshiaki Sato developed this patented training method.
- Kaatsu means “training with added pressure.”
- Kaatsu training is now performed worldwide and achieved using a pneumatic tourniquet system.

HOW BFR WORKS USING THE PNEUMATIC TOURNIQUET SYSTEM?

BFR technique involves applying an external pressure using a tourniquet cuff to the upper and/or lower limbs. The cuff becomes inflated as a result, while gradually compressing the blood vessels underneath it. This hampers the normal blood flow within the cuff by partially restricting the arterial blood flow and severely affecting the venous outflow. The end results of BFR include poor oxygen supply (hypoxia) within the muscle tissue and blood pooling (venous Insufficiency) within the capillaries. Generally, the blood pooling occurs in occluded limbs.

- Performing exercise with BFR further disturbs blood flow, as such activity increases the intramuscular pressure beneath the cuff.

APPLICATION OF BFR

1. Actively with exercise:

BFR with resistance exercise (BFR-RE)
BFR with aerobic exercise (BFR-AE)

2. Passively without exercise (P-BFR)

3. Experimental: BFR with non-traditional exercise modalities (e.g. whole-body vibration techniques and neuromuscular electrical stimulation)

BFR-RE

BFR-RE increases muscle hypertrophy and strength.

Recent systematic reviews and meta-analyses have also shown its effect on muscle strength and/or hypertrophy in young and older populations, as well as load compromised patients needing rehabilitation.

BFR-RE induced improvement in muscle strength have been shown using various measures:

i) dynamic isotonic, isometric and isokinetic strength

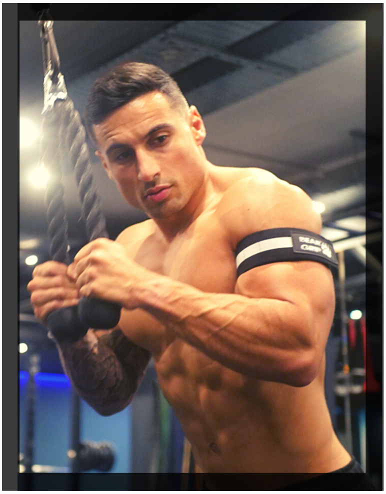
ii) rate of force development/explosive strength capacity

- **BFR-RE can produce greater results than low-load resistance exercise (LL-RE) in muscle hypertrophy and strength adaptations. We may observe such adaptations after only 1–3 weeks.**

- **Like BFR-RE, high-load resistance exercise (HL-RE) also achieves early increases in strength; however, muscle mass adaptations following HL-RE is typically slow.**

WHY BFR-RE ALLOWS MORE GAIN IN EARLY MUSCLE MASS COMPARED TO HL-RE?

- **Increases in muscle size with BFR-RE have been observed even after 2-10 days post-training.**
- **The early muscle growth after BFR-RE training is likely due to the use of a high training frequency, which is not always possible with HL-RE.**
- **BFR-RE takes lower mechanical demands than HL-RE, which likely allow for a higher training frequency.**
- **Muscle hypertrophy with conventional training frequency often results from longer training durations (3 weeks to ≥8 weeks).**



OTHER ADVANTAGES

- **BFR-RE allows more gain in muscle strength than LL-RE alone. However, it is less effective than HL-RE in muscle strength gains.**

- **Both BFR-RE and HL-RE seemed to be equally effective in muscle mass growth.**

RECOMMENDATION

- **BFR-RE is more effective than LL-RE alone and can be used when HL-RE is not advisable (e.g., post-operative rehabilitation, cardiac rehabilitation, inflammatory diseases, and frail elderly).**

- **BFR-RE may also severe as a potential alternative to HL-RE in clinical populations with disuse atrophy.**

DETERMINING CUFF PRESSURE

- **Several limb characteristics influence the arterial occlusion pressure[1] (AOP):**

- **tourniquet shape;**
- **width and length of the limb;**
- **the size of the limb; and**
- **blood pressure.**
- **A bigger limb often requires a greater cuff pressure to fully restrict arterial blood flow.**

- **Researchers recommended that the pressure be made relative to the exercised limb.**

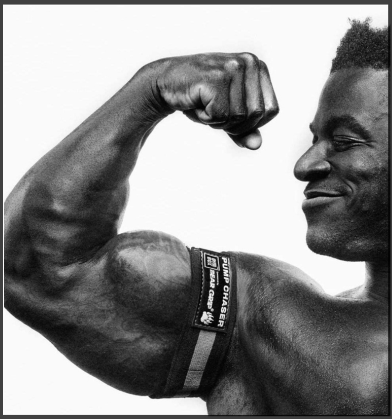
- **Therapists should avoid applying pressure relative to brachial systolic blood pressure (SbP).**

- **SbP correlates poorly with measurements of AOP and may not provide a consistent reduction in blood flow.**

- **Pressure during BFR exercise should be set based on measurement of AOP.**

- **Experts recommend pressures ranging from 40 to 80% of AOP.**

CUFF WIDTH



- Cuff width of the limb plays a major role in determining AOP.
- A wider cuff often requires a lower pressure due to the greater surface area.
- Cuff widths of 3–18 cm is frequently used in the BFR literature.
- Point to be noted: applying a relative pressure of 40% AOP does not mean that there will be a 40% reduction in blood flow.
- Researchers agree that growth may attenuate directly under the cuff location.
- Researchers approves the use of a wide variety of cuff widths, but the therapists should set the pressure using AOP.
- Researchers suggested avoiding the use of extremely wide cuffs as this may limit movement during exercise.

CUFF MATERIAL

- Both elastic and nylon cuffs are utilized in the literature.
- Both materials have shown beneficial muscular adaptations.
- Cuff materials appear to have little or no impact on the BFR-RE outcomes.
- Therapists may correct any difference in cuff material by applying pressure as a % of AOP to each cuff.

EXERCISE LOAD, VOLUME, REST PERIODS, DURATION, AND FREQUENCY

TABLE 1

MODEL OF EXERCISE PRESCRIPTION WITH BFR-RE.

	Guidelines
Frequency	2–3 times a week (>3 weeks) or 1–2 times per day (1–3 weeks)
Load	20–40% 1RM
Restriction time	5–10 min per exercise (reperfusion between exercises)
Type	Small and large muscle groups (arms and legs/uni or bilateral)
Sets	2-4
Cuff	5 (small), 10 or 12 (medium), 17 or 18 cm (large)
Repetitions Pressure	(75 reps) – 30 × 15 × 15 × 15, or sets to failure 40–80% AOP
Rest between sets	30–60 s
Restriction form	Continuous or intermittent
Execution speed	1–2 s (concentric and eccentric)
Execution	Until concentric failure or when planned rep scheme is completed

EXERCISE LOAD

• The relative load lifted during resistance exercise may dictate the applied pressure to some degree. Individuals may maximize muscle growth and strength by exercising with loads corresponding to 20–40% of their maximum strength level (e.g. 1-RM).

• Therapists may need to apply a higher pressure (∼80% AOP) if the loads fall below the above recommendation (e.g. ∼20% of 1-RM).

• Targeting muscle groups proximal to the cuff may require a higher applied pressure for maximal adaptation.

• Experts recommend utilizing exercise loads of 20-40% 1RM.

VOLUME

• The most commonly used set and repetition scheme is:

- 75 repetitions across four sets of exercises (30, 15, 15, 15)

  - 30 repetitions in the first set;
  - 15 repetitions in each subsequent set.

• It is also common to complete 3–5 sets to concentric failure during BFR-RE.

• Repetitions to failure may not be needed in practical settings (e.g. patients requiring post-surgery rehabilitation).

REST PERIODS

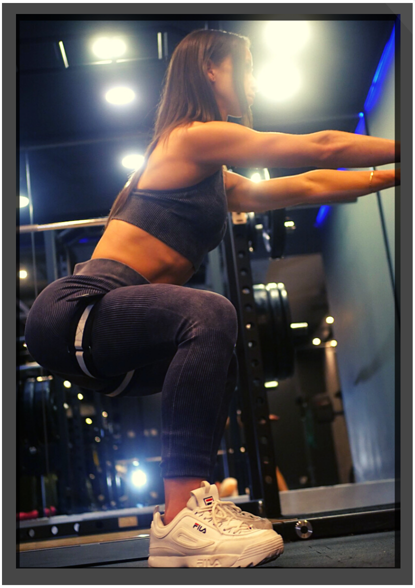
• Short inter-set rest periods should be used during BFR-RE.

• Therapists should also maintain the restriction throughout this period.

• Strength adaptations have been observed with both 30 and 60 s inter-set rest periods.

• Researchers recommend that rest periods should constitute 30–60 s.

• Intermittent BFR, however, may be more helpful in reducing swelling/metabolic stress than continuous.



FREQUENCY

• The traditional recommendation for BFR-RE is 2–4 times per week.

• Therapist may also implement twice daily training in a clinical rehabilitation setting. They may utilize high frequency approaches (1–2 times per day) for short periods of time (1–3 weeks).

• The ideal frequency during normal programming is 2–3 sessions per week.

DURATION OF TRAINING PROGRAMMES

- BFR-RE can stimulate muscle hypertrophy and strength adaptations within a 3-week period.

- Most studies, however, advocate longer training durations (> 3 weeks).

BFR-AE

- BFR-AE has shown to increase strength and hypertrophy in young and older populations.

- BFR-AE can be applied during walking or cycling.

- Individuals performing BRF-AE may observe changes in skeletal muscle strength and hypertrophy as early as 3 weeks.

- The BRF-AE training is most effective after at least 6 weeks.

- Research has shown an increase in muscle strength by 7–27% and hypertrophy by 3–7% following BFR-AE.

- BFR-AE also improves functional ability in a range of tasks relevant to daily living, health and wellbeing.

DOWNSIDES

- The applied BFR-AE is usually of low intensities (45% heart rate reserve or 40% VO2 max), which restrict performers to utilize the training to its full potential.

- There has been a lack of standardization of pressure during BFR-AE.

- More understanding is needed regarding muscle adaptations to training with BFR-AE.

TABLE 2

MODEL OF EXERCISE PRESCRIPTION WITH BFR-RE.

	Guidelines
Frequency	2–3 times a week (>3 weeks) or 1–2 times per day (1–3 weeks)
Intensity	<50% VO2 max or HRR
Restriction time	5–20 min per exercise
Type	Small and large muscle groups (arms and legs / uni or bilateral)
Sets Pressure	Continuous or intervals 40–80% AOP
Cuff	5 cm (small), 10 or 12 cm (medium), 17 or 18 cm (large)
Exercise mode	Cycling or walking

PROTOCOLS FOR PREVENTION OF STRENGTH LOSS AND ATROPHY

P-BFR

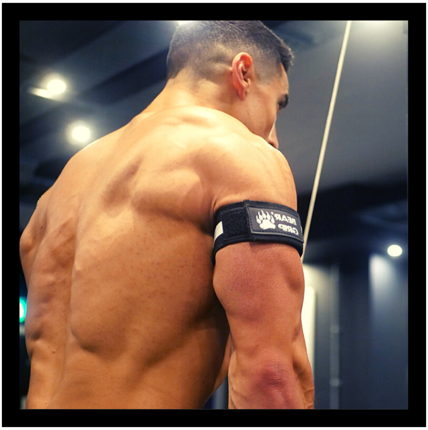
• P-BFR involves no exercise: only applying the cuffs to limbs.

• P-BFR has so far received little research attention.

• Available data suggest that applying P-BFR intermittently may offset muscle atrophy and strength loss during bed rest or immobilization.

• P-BFR may reduce the muscle mass and strength loss in several conditions:

- following anterior cruciate ligament (ACL) surgery;
- following total knee arthroplasty;
- during cast immobilization; and
- patients in intensive care.



BFR-AE

- P-BFR has also shown to enhance local skeletal muscle oxidative capacity and cardiovascular improvements within 7 days.
- Takarada et al. (2000) developed a standard protocol for implementing P-BFR.
- The protocol involves 5 min of restriction followed by 3 min of reperfusion applied for 3–4 sets.
- Therapist may implement this protocol once or twice daily for 1–8 weeks.
- The pressures used during P-BFR have varied widely in the literature, from 50 mmHg to 260 mmHg.
- High pressures may help protect against disuse atrophy.
- More investigation is needed to determine definitive pressure and examine other protocols.

TABLE 3

MODEL OF EXERCISE PRESCRIPTION WITH BFR-RE.

	Guidelines
Frequency	1–2 times per day (duration of bed rest/immobilization)
Restriction time	5 min intervals
Type	Small and large muscle groups (arms and legs/uni or bilateral)
Sets	3–5
Cuff	5 (small), 10 or 12 (medium), 17 or 18 (large)
Rest between sets Pressure	3–5 min Uncertain – higher pressure may be needed (70–100% AOP)
Restriction form	Continuous

BFR WITH ELECTRICAL SIMULATION (BFR-ES)

- Evidence is still limited in support of the use of BFR-ES.

- Twice daily BFR-ES for 2 weeks has shown an increase in muscle thickness and strength in untrained men.

- The intensity of BFR-ES may have a dose-response relationship with muscular adaptation.

- Low-intensity BFR-ES for 6 weeks has shown to increase the CSA of the extensor carpi radialis longus by 17%.

- Some patients have also shown to improve vascular function with BFR-ES.

- BRF-ES is a potential area of research and needs more investigations.

SAFTY ASPECT OF BFR-RE

Cardiovascular Response to BFR-RE

Note: Mechanisms regulating blood flow involve modulation of sympathetic tone and peripheral feedback arising from venules, arterioles and capillary beds.

- BFR-RE can mediate an altered cardiovascular response.

- Such response often results from the external pressure applied during BFR-RE.

- Both central and peripheral vascular responses match the increased oxygen demand from the skeletal muscles during BFR-RE.

- BFR-RE affect various metabolic, mechanical and endothelial factors involved in local control of vasomotor tone.

- BFR-RE usually lead to a balanced vasodilation within active muscle by limiting autonomic sympathetic control of vasomotor tone.

CENTRAL VASCULAR RESPONSE TO BFR-RE

- BFR-RE induced central cardiovascular response depends on several factors:

- Level of BFR
- Mode of exercise (i.e., BFR-RE vs. BFR-AE)
- Mode of application (i.e., continuous vs. intermittent BFR)

- BFR-RE acutely affects central hemodynamic parameters.
- The increased cardiovascular response during BFR-RE usually returns to baseline (5–10 min) after the training.
- BFR-RE seems not to affect the cardiac output.
- BFR-RE causes less changes in central hemodynamic response than HL-RE, especially if the BFR is combined with aerobic exercise.
- BFR induced changes in peripheral flow during light walking augments both peripheral and aortic systolic pressure than similar exercise without occlusion.
- BFR exerts influence only on the outgoing, but not reflected, pressure waves.
- Pressure handling affects the cardiovascular response to BFR-RE.
- Higher relative restrictive pressures induce higher cardiovascular responses to BFR-RE.
- Increased relative restrictive pressures may increase the potential risk associated with BFR-RE.
- BFR-RE can keep the blood pressure elevated if pressure cuffs are kept during rest intervals.
- BFR-RE causes higher post-exercise hypotension than HL-RE.

PERIPHERAL VASCULAR RESPONSE TO BFR-RE

- BFR exercise can affect arterial compliance and endothelial function.
- BFR-RE affects both large and small artery compliance.
- BFR-RE increases large artery compliance to the same extent as LL-RE and HL-RE.
- HL-RE affects small artery compliance more intensely than BFR-RE and LL-RE.
- BFR-RE may also transiently improve endothelial function.

- BFR-AE can acutely affect flow mediated dilatation (FMD).
- BFR-AE has also shown to increase FMD in the long term.

- Syncope episodes are common among practitioners and clinical settings; however, such incidences are seldom reported in BFR-RE literature.
- Applying BFR without any other stimulus can concomitantly increase SVR and decrease CO.
- SVR has shown to increase or to remain unchanged following BFR-RE or BFR-AE and to be reduced following exercise.
- CO and SVR pose no cardiovascular threat in BFR exercise; however, a steady CO coupled with an increased SVR may produce adverse individual responses.

BFR-RE AND VENOUS THROMBOEMBOLISM: ACURE MEASURE

- The formation of a deep vein thrombus (DVT) is an inherent concern as the occlusive cuff compresses the vasculature during BFR-RE.
- Current BFR-RE literature reveals minor adverse events pertaining to venous thromboembolism (VTE).
- Direct blood markers for coagulation is the most commonly used measure for VTE following BFR-RE application.
- Acute studies have shown insignificant changes in blood coagulations using D-dimer.
- Some studies have also reported non-significant elevation of C-reactive protein (CRP) and fibrin degradation product (FDP).
- Future acute studies should focus on relative pressures, the upper extremities, clinical populations and female subjects.

BFR-RE AND VENOUS THROMBOEMBOLISM: CHRONIC MEASURE

- Several BFR-RE papers addressing VTE concerns have suggested the following:

- No changes in D-dimer, fibrinogen or CRP with lower extremities exercise for 4 weeks at 30% 1RM.
- No significant increase in FDP, D-dimer or creatine kinase (CK) values after 12 weeks of BFR-RE at 20–30% 1RM (2 days/week).
- No significant increase in D-dimer, FDP, or CK levels after 12 weeks of bilateral elbow extension and elbow flexion elastic band exercises.

- The likelihood of DVT following BFR-RE poses a very low population risk (0.2–0.26% in Asia).

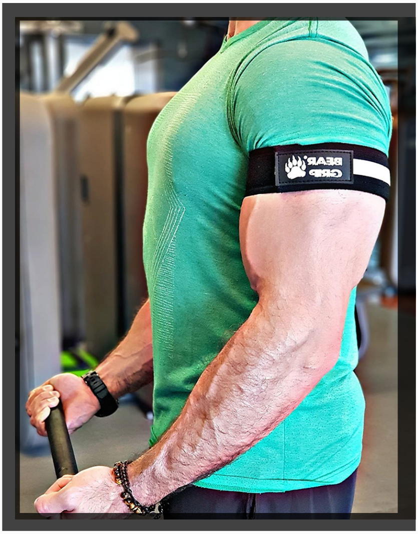
- Duplex ultrasound scans revealed no signs of thrombus formation following 12 sessions of BFR-RE after knee surgery.

BFR-RE AND THE FIBRINOLYTIC SYSTEM

- Resistance training (RT) has shown to up-regulate the fibrinolytic pathway after just one exercise session.
- The beneficial effects of RT on the fibrinolytic system has been shown in both healthy young adults and aged heart disease patients.
- BFR-RE seems to stimulate the fibrinolytic system.
- Lower extremity BFR-RE has shown to increase tissue plasminogen activator (tPA) in healthy participants.
- Vascular occlusion without exercise has also demonstrated an increase in fibrinolytic factors.
- Several variables may, however, alter the fibronolytic response to exercise (e.g. age, sex, and obesity).

BFR-RE AND AT-RISK POPULATION FOR VTE

- Studies has so far reported no adverse effects related to VTE in elderly people after BFR-RE.
- Research has shown no increase in blood coagulation factors with BFR-RE in aged heart disease population.
- Clinicians should utilize established clinical prediction rules before applying BFR-RE to assess VTE probability in at risk population.



BFR-RE AND REACTIVATE OXYGEN SPECIES

- **Oxidative stress occurs when the production of reactive oxygen species (ROS) imbalances the antioxidant system's ability to reduce the molecules.**
- **A deflated tourniquet cuff can give rise to ROS and is linked to ischemic reperfusion injuries after orthopedic surgery.**
- **RT can also induce the ROS production.**
- **Blood markers of oxidative stress include:**
  - protein carbonyls,
  - lipid peroxides,
  - blood glutathione, and
  - antioxidants systems.
- **Applying BFR-RE (20% 1RM) to bilateral lower extremities has not shown to significantly raise lipid peroxide levels.**
- **BFR has demonstrated to increase protein carbonyls and blood glutathione.**
- **BFR-RE at 30% 1RM, however, has shown to reduce protein carbonyls and glutathione status.**
- **Moderate intensity (70% 1RM) exercise can elevate oxidative stress with or without BFR.**
- **Oxidative stress formation may be load, rather than BFR-dependent.**

MUSCLE DAMAGE

- **Traditional HL-RE can cause muscle damage to inexperienced individuals.**
- **Both direct and indirect markers can detect this damage.**
- **Such muscle damage often occurs at the eccentric phase of the exercise.**
- **Experts believe overstretching of the sarcomere cause the initial damage response.**
- **The inflammatory response often causes a secondary muscle damage.**
- **Muscle biopsy and symptoms quantifying can be used to determine the muscle damage.**
- **Common markers of muscle damage include:**

  - muscle soreness
  - edema
  - reduced force production
  - decreased range of motion
  - level of CK and/or myoglobin

- **Exercise can also cause exertional rhabdomyolysis in extreme cases, which often leads to secondary pain, swelling and potential end organ damage.**
- **Exertional rhabdomyolysis cases are typically associated with:**

  - extreme exercise load,
  - high thermal loads,
  - dehydration, or
  - the use of certain medications

- BFR training may exaggerate the risk of rhabdomyolysis as it magnifies the metabolic stress despite the use of low-loads.

- Some isolated case reports have indeed described rhabdomyolysis incidences with BFR-RE.

- The risk of rhabdomyolysis with BFR-RE, however, remains very low (0.07–0.2%).

- The Kaatsu training also has a, similarly, low incidence of rhabdomyolysis (0.008%).

- Current evidence does not suggest that the risk of rhabdomyolysis is inflated with BFR-RE than traditional exercise.

- A common concern: applying BFR may lead to or even augment muscle damage by ischemic-reperfusion injury.

- BFR with muscle contraction exercises can elevate the risk of muscle damage.

- BFR with LL-RE is reported to elevate muscle soreness above baseline in the days following the training.

- BFR-RE causes changes in torque production and muscle edema; however, such changes often return to baseline by 24–48 h.

- Studies investigating changes in range of motion with BFR-RE found no differences across time.

SUMMARY

- BFR-RE appears not to cause muscle damage with single exercise protocols of up to 5 sets to volitional failure.
- Therapists should be watchful while admitting individuals into the exercise program.
- They should utilize indirect markers to identify those who are more susceptible to muscle damage.
- The effects of applying a relative pressure is currently unknown.
- Current evidence infers no apparent muscle damage with strenuous, high-frequent BFR training for 1-3 weeks (1–2 sessions/week).
- It remains unknown whether BFR with low intensity aerobic exercise may cause a damage response.

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