What is blood flow restriction (BFR)?

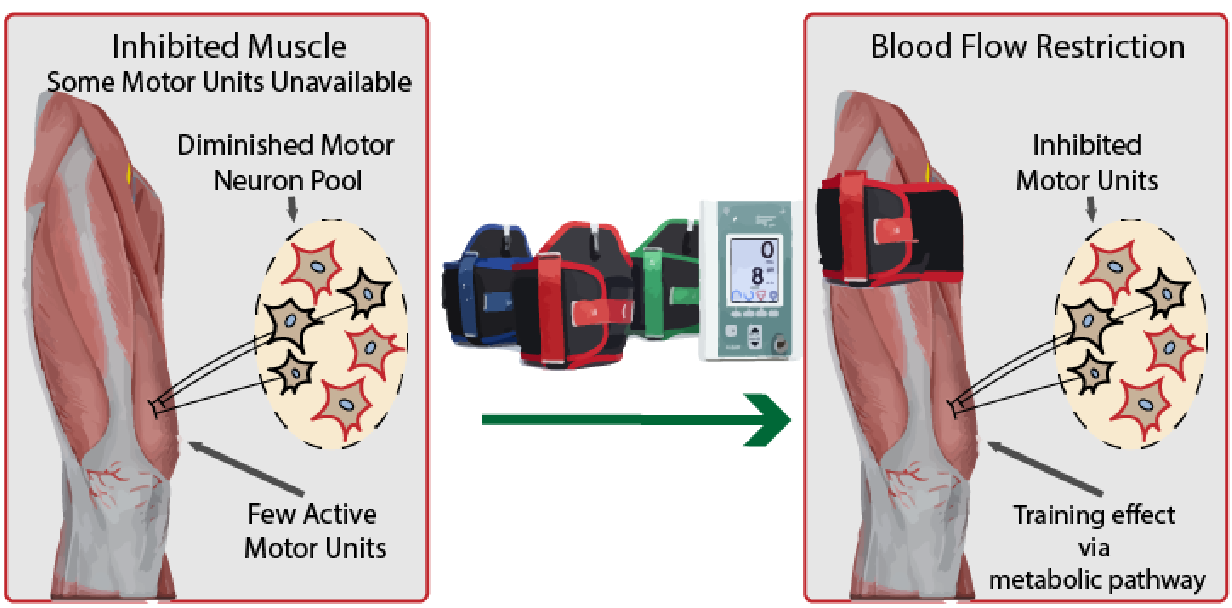
Since successful application in wounded warriors, blood flow restriction (BFR) has been popularized in post-surgical rehabilitation for mitigating disuse atrophy. BFR involves a pneumatic tourniquet at the proximal limb that creates mechanical compression of the vasculature underneath the cuff. The key, is to get this external pressure to result in partial restriction of arterial blood flow (40-80% as we'll discuss), which more fully occludes venous outflow from the limb. Together (reduced arterial flow and occluded venous flow) results in muscle hypoxia, pooling of blood in the capillaries, and **increased intramuscular pressure** during muscle contraction.

How does it work? (Mechanisms)

Blow flow restriction works through two main mechansims: 1) mechanical tension of muscle fibers (think: lifting heavy weights) and 2) metabolic stress. By applying a partial tourniquet to the limb, venous pooling and intramuscular tension allows patients to achieve high levels of mechanical tension during low-load exercise (20-40% 1 rep max [1RM]). In parallel, increased levels of metabolic stress drive systemic hormone production and fast-twitch (anearobic) muscle fiber recruitment. Together, these stimuli promote gains in muscle hypertrophy and strength despite training with low-loads.

Does it address muscle inhibition?

Not directly. Neural inhibition persists, but BFR does encourage selective activation of high-threshold fast-twitch muscle fibers. This means effects similiar to high-training loads despite low-resistance in rehabilitation -- albiet inhibited muscle fibers theoretically remain unrecruited). *I wonder what would happen if we combined this with cryotherapy?!*



High-load resistance training is better than BFR

Before we begin. The bottom line is this:

If your patients/clients can tolerate high-load resistance training, skip BFR. High-load resistance training is consistently better than BFR at building hypertrophy and strength.

With high-load resitance training healthy populations -- i.e., 80% 1-RM 3x/week for 6 weeks -- in general, we can expect 6% increase in muscle size and 22% increase in strength.

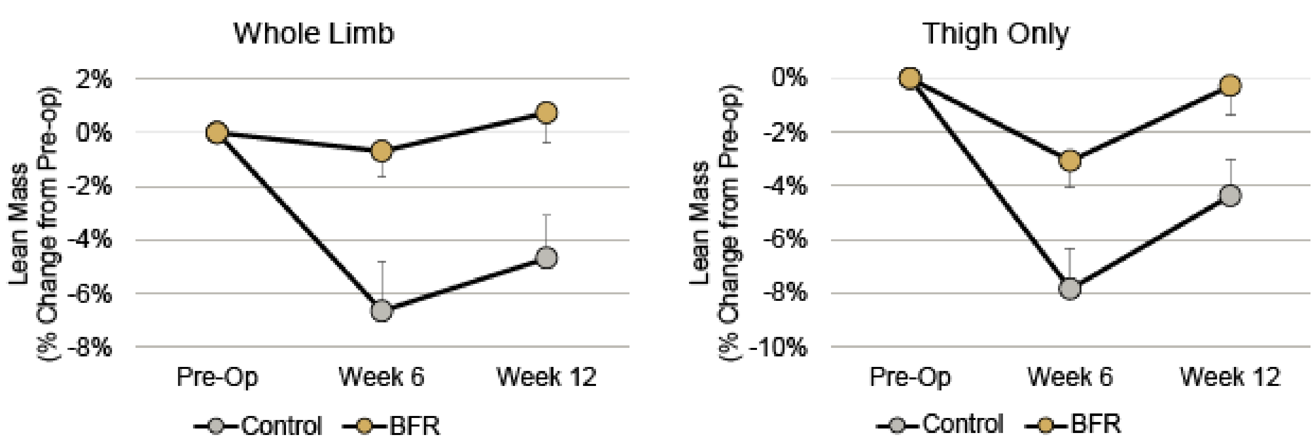
With low-load resistnce training with BFR -- i.e., 20-40% 1-RM 3x/week for 6 weeks -- in general, we can expect 5% increase in muscle size and 12% increase in strength.

Where BFR really shines, is **when our patients cannot tolerate high-loads**. In this scenario, as is the case with arthrogenic muscle inhibition, we can drive more effective training sessions by using low-loads with BFR compared to low-load training alone.

Using blood flow restriction after ACL reconstruction.

A systematic review in IJSPT (Charles et al, 2020) included four randomized controlled trials using BFR early after ACL reconstruction. The results are rather consistent showing better strength and preservation of muscle mass for individuals using BFR training compared to low-load resistance training alone.

Jack et al, recently published in Sport Health showed a LARGE preservation effect in terms of lean muscle (muscle mass) in the involved limb compared to control groups. Essentially, the involved thigh of the no-BFR group had 5% less muscle mass at 3 months than they did at baseline, where the BFR group was normal. (note: 0% is pre-op mass, not pre-*injury* mass).



Jack et al., Sports Health, 2022. RCT. n = 32. Both groups completed same post-op exercise routine. BFR group did so using 80% AOP at 20% 1-RM of uninvolved limb. Lean mass was measured using DEXA scan pre-op, 6 wks post-op, and 12 wks post-op. Precription was 4 sets at 30-15-15-15 reps, 30 seconds rest. 2x/week for 12 weeks. Exercises performed were progressive.

Sets and reps are shown in the figure caption and can be weighed against the recommendations in the user guide below.

User Guide to Blood Flow Restriction

The following tables are extensions of a review paper by Patterson et al., 2019. Non-blurry versions can be found in the cliff notes downloadable here.

Set-up of BFR

Table 1 describes the set-up of BFR, regarding where to place the cuffs, how to determine the appropriate pressure, and how long to keep them on for. I've expanded on some clinical considerations in the context of the key evidence as well.

Table 1: Set-Up of Blood Flow Restriction

Parameter	Guidelines	Considerations	Evidence
Laterality	Unilateral or Bilateral	-	-
Location	Proximal Limb (As proximal as possible)	-	-
Cuff Pressure	40-80% AOP (**not % systolic BP***)	40% for exercise intensities at 20-40% 1-RM Up to 80% if loads are < 20% 1-RM Do **not** set based on absolute pressure!	Patterson 2017 Loenneke 2012 McEwen 2018 Mouser 2017
Cuff Width	"small" (< 10 cm) "medium" (10-12 cm) "large" (>17 cm)	If setting cuff pressure (as % AOP), then cuff material and width won't matter for effectiveness.	Mouser 2017 Loenneke 2013 Loenneke 2014 Fahs 2015 Kim 2017
Cuff Material	Elastic or Nylon		
Restriction Time	5-10 minutes	5-10 minutes per exercise (reperfusion between exercise)	-
Restriction Method	Intermittent or Continuous	"Continuous" refers to keeping occlusion within exercise during rest periods. Increased accumulation. More effective. "Intermittent" refers to reperfusion during each rest, can be used for patients who are cardiovascular compromised.	-

Abbreviations: AOP, Arterial Occlusion Pressure; BP, Blood Pressure.
* % AOP and % BP are not equivalent. It is not appropriate to set to % Systolic Blood pressure, only because units of measure and reliability of measure across devices will be different—i.e., measurement error between BFR cuffs and BP cuff.

One key thing to note: cuff pressure must be set to % of arterial occlusion pressure (AOP), not % systolic blood pressure. Whats the difference? Essentially it comes down to measurement error between the devices. The best way to do this is using the BFR cuff to determine AOP and then setting it to 40% of that.

AOP is the absolute pressure of the cuff that results in cessation of pulse. Once found, adjust cuff pressure to 40% of AOP for training.

Exercise prescription with BFR

Table 2 describes how to go about determining exercise prescription in terms of sets and reps, load, rest periods, and training frequency to get the best result.

Table 2: Prescription of Blood Flow Restriction

Parameter	Guidelines	Considerations	Evidence
Frequency	2-3x/week	Similar to high-load resistance exercise. Can do short bouts of high-frequency for most impaired patients—e.g., 1-2x/day 5x/week for 1 week	Fleck 2004, Kraemer 2004; Ohta 2003, Ladlow 2018
Duration	>3 weeks		
Load	20-40% 1-RM	Consistently produce muscle adaptations with BFR. Lighter loads should be accompanied by higher % AOP.	Lixandrao 2015 Counts 2016
Sets	2-4	Training volume of 75 repetitions across four sets of exercise is most reported. Performance until concentric failure is also effective but is <u>not required</u>.	Yasuda 2006, 2010, 2011, 2012 Loenneke 2016
Reps	75 (30 x 15 x 15 x 15)		
Rest	30-60 seconds	Inter-set rests are typically short (<60s). Longer rests do not significantly increase metabolic stress.	Loenneke 2012
Tempo	1-2 seconds Con/Ecc	-	-
End Point	Planned rep, or failure	-	Loenneke 2011; Martin-Herandez 2013

Abbreviations: Con, concentric; Ecc, eccentric

For the most part, training regiemen needs to be similiar to that of high-load training (3x/week for at least 6 weeks). In rare cases, high-frequency training (2x/day) has been applied as well, but only for short periods (1 week).

Other Effects (AKA Side-Effects), Risks, and Other Considerations

Table 3 describes the other effects of blood flow restriction. Everything from common (muscle soreness) to exceedingly rare (syncope and clotting).

Table 3: Other Effects, Risks, and Contraindications of Blood Flow Restriction

Effects	Risks + Considerations	Evidence
Muscle Damage	Resistance training results in muscle damage. In extreme cases, exertional rhabdomyolysis can result. This risk is increased with inappropriate training loads, dehydration, or certain medications. There is no evidence to suggest BFR increases risk of rhabdomyolysis.	Zimmerman and Shen 2013 Nakajima 2006
Muscle Soreness	Muscle soreness is consistent elevated above baseline in the days following BFR with low-load resistance training. The associated decline in torque output and range of motion are similar to those observed in high-load resistance training.	Umbel 2009 Wernbom 2012 Loenneke 2014
Increased Systolic Blood Pressure	The arterial and interstitial effects of BFR stimulate the exercise pressor reflex (EPR). This reflex acutely increases HR and BP. It may make exercise with BFR dangerous for individuals with cardiovascular disease. Although not necessarily a contraindication, keep in mind that systolic BP will increase 10-30 mmHg higher when using BFR vs no BFR. Intermittent cuff pressure (reperfusion during rest) may mitigate this effect.	Rossow 2012 Vieira 2013 Downs 2014 Staunton 2015 Neto 2016
Improved Arterial Compliance	Similar to low load and high load training, BFR has the peripheral vascular benefit of improved large artery compliance in the extremities. However, small artery compliance is better treated with high load resistance training than by BFR.	Lixandrao 2015 Counts 2016
Oxidative Stress	Reactive oxygen species are increased following all types of exercise (including use of BFR). However, there is no evidence to suggest BFR increases oxidative stress over resistance training along.	Garten 2015 Patterson 2019
* Syncope?	The application of BFR in the absence of exercise stimuli can result in systemic vascular resistance with a concomitant decrease in CO – possibly resulting in hypotensive syncope. Clinicians should be aware of these effects when using with patients.	Hogan 2009 Patterson 2017
* Clotting?	Although seemingly related, there are no documented increases in venous thromboembolism (deep vein thrombosis or pulmonary embolism) with either acute or chronic use of BFR. It is recommended that clinician <u>use published clinical prediction rules</u> to identify patients at high risk for venous thromboembolism and avoid use in those patients.	Patterson 2019 Wells 2000

Abbreviations: BFR, Blood Flow Restriction, EPR, exercise pressor reflex; HR, heart rate; BP, blood pressure, mmHg, millemeters of mercury;
* Not reported in the literature, but may be more common with less regimented use in clinical practice.