Blood Flow Restriction (BFR) Rehabilitation

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Owens Recovery Science Delphi System

What is BFR?

Use of a tourniquet to occlude arterial blood flow to a limb to enhance strength and hypertrophy gains, achieving results with low intensity exercises comparable to heavy loading.

Tourniquet system (Delfi) allows for improved safety and application of treatment by allowing for automatic measurement of limb occlusion pressure (LOP) with doppler, ability to adjust/set the maximum tourniquet pressure, and automatic timer for accuracy of inflation time.

Safety:

- Contraindications and Risks (see list)- cancer, DVT, impaired circulation, sickle cell anemia, severe hypertension, skin grafts, cancer (ANY HISTORY OF CANCER)
- Use of limb protective sleeve (2 layers of non-shedding stockinette) or barrier between tourniquet and skin
- Use of wide, tapered cuff
- No increased risk of clotting with use of tourniquet (without other clotting risks)
    - Deflation of tourniquet, body releases "clot buster" (fibrolytic potential)

Risks (general tourniquet use):

- Nerve injury
- Skin injury
- Pain
- Arterial injury
- Chemical burns
- Respiratory, cardiovascular, cerebral circulatory and hematologic effects caused by prolonged ischemia
- Temp. changes
- Prolonged post-operative swelling of the affected limb

Patient Evaluation for BFR

Clinical Chart[9-10] - **No BFR > 4 points**	
History of DVT Acute sickness or fever Blood pressure > 180/100 mmHg Early postoperative period Higher class arrhythmia or coronary ischemia	**5 points**
Pregnancy	**4 points**
Varicose veins Prolonged inactvity A-Fib or heart failure Blood pressure 160-179/95-99 mmHg	**3 points**
Age > 60 years BMI > 30 kg/m^2 Malignancy Hyperlipidemia Estrogen therapy	**2 points**
Age 40-59 years Women BMI 25-30 kg/m^2	**1 point**

THE SCIENCE:

Anabolic resistance (muscle atrophy)

- *"Anabolic resistance can be defined as a situation where the skeletal muscle is unable to respond appropriately to these anabolic stimuli by stimulating protein synthesis. Anabolic resistance contributes to muscle mass loss in elderly, during immobilization as well as in response to inflammation and cancer"* The Stress Response of Critical Illness: Metabolic and Hormonal Aspects pp 45-60

- Within 2 weeks of injury- muscle protein synthesis decreases by 27-31%
- With BFR can decrease atrophy to 10% loss vs. 30% without BFR

Muscle Protein Synthesis/MTORC1

- BFR increases protein synthesis by 46% in work matched group without BFR
- MTORC1 (mammalian target of rapamycin complex 1)= signaling pathway responsible for protein synthesis= with BFR at 20% 1RM increases 41.5% at 3 hours and 69.4% at 24 hours vs. matched controls
- Encourage protein intake every 4 hours (at every meal) for 24 hours
    - Young 20 grams (20s) and older 40 grams (late 30s)
    - Leucine is key, encourage whey based protein with leucine bolus, liquid/powder > meat

Cell swelling

- NOT just venous congestion, as this would subside quickly
- Cellular hydration state tied to protein metabolism
- Plasma volume shift into muscle
- Can decrease atrophy without exercising (just application of tourniquet with occlusion)
    - "Cell swell" protocol: 5 rounds of 5 minutes with a 3 minute rest between sets

Metabolite theory

- Lactate & muscle activity
    - Increased tourniquet pressure will increase lactate
        - 80% occlusion for LE, 50% occlusion for UE
    - Anaerobic= fast twitch
    - Forced recruitment based on necessity as glucose stores are used
- Growth hormone (GH)
    - Brain releases GH in response to acidic environment created by lactic acid
    - BFR with exercise increases GH release 1.7x higher than high intensity training (HIT)
        - Bigger response in younger population
        - 20% load BFR vs. 80% HIT= similar GH response in older population
        - Larger effect in LE vs. UE
        - BLE BFR (multi-joint muscle) largest effect (even with UE injury)
    - GH directly related to collagen synthesis= repair
    - GH leads to IGF 1 (insulin-like growth factor)
- IGF1 & Satellite cells
    - IGF1 (insulin-like growth factor) released from kidney in response to GH
    - IGF1 directly linked to muscle growth/mass
    - BFR leads to increased IGF1, hypertrophy seen in 2-3 weeks with BFR
    - GH activates satellite cells (muscle stem cells) to fill void to repair damage, IGF1 fuses the cells to the muscle
        - # cells per muscle fiber is rate limited for growth/hypertrophy

        - BFR based exercise with decreased muscle breakdown= less repair, so as satellite cells are recruited they lead to hypertrophy since the cells don't need to devote the time/energy for repair
        - Hypertrophy with BFR 30-40%, HIT 15-20%
        - *Hypertrophy maintains if continue to load until failure after finish BFR
- Metabolite Build-up protocol= BFR 2-3x/week, work at 20-30% 1RM, 30/15/15/15 reps, 4 sets with 30 second rest period between sets, 2 second concentric and 2 second eccentric

Myostatin & TGF-B

- Myostatin block protein synthesis, needs to be down regulated for muscle growth
- Down regulated with BFR and HIT, not seen in light load exercise
- Myostatin is in the TGF-B (transferring growth factor-B) family, linked to fibrosis and scarring

Tendon

- BFR increases GH, GH increases collagen synthesis, MAYBE BFR increases tissue repair
- Analgesic response/gate theory?
- Tolerable load to tendon, 50% less pain during and up to 1 hour after BFR

Bone

- Early vs. delayed WB for fractures or fixators?
- Bone won't heal (or heal well) unless covered by muscle
- Osteoblasts have receptors for GH, BFR increases GH
- Myostatin inhibitor boosted the concentration of bone specific alkaline phosphatase
    - BFR leads to increased down regulation of myostatin = increased bone remodeling
    - Cell swell protocol (goat study)= increased fracture union

Proximal & Distal Gains

- Proximal gains: downstream fatigue, proximal muscles kick in to help
    - Back-up of blood flow trying to get in
- Systemic response: prime environment for growth
    - Back flow effect, currently just theory
    - BFR groups vs control demonstrate increased noradrenaline, GH, cortisol, and testosterone levels
    - Can train UEs to get effects in LEs and vice versa
    - Can train on limb and see effects in contralateral limb (R UE BFR, LUE results)

Endurance

- Walking and cycling have shown increase in VO2max
- Total 15-20 minutes of steady state or intervals (start 8-10 minutes), 2-5x/week
- Could also use recumbent bike, elliptical, UBE, or stairmaster

	Recommendation	Factors to consider
Cuff application	Proximally around the limb to be trained	Trunk muscles can also benefit from BFR during multi-joint exercises
Cuff type	Wide cuffs (~6–13.5 cm) for the legs, and narrow cuffs (3–6 cm) for the arms	Inflatable cuffs and elastic knee wraps may be most practical
Occlusive pressure	Inflatable cuffs: 50–80 % of pressure to occlude arterial flow at rest Elastic wraps: should feel snug but not substantially restrict completion of desired repetition scheme	Limb circumference: Larger limbs require higher pressure Cuff width: Wider cuffs achieve occlusion at lower pressures
Exercise stimulus	BFR alone: Attenuated ↓ in muscle mass and strength BFR + walking/cycling: Moderate ↑ or maintenance of muscle mass and strength Low-load resistance exercise + BFR: substantial ↑ in muscle mass and strength	The type of exercise that can be tolerated should be considered before deciding on an appropriate BFR strategy (Fig. 1). The progressive model proposed by Loenneke et al. [67] should be followed for clinical populations
Type of exercise	Both single- and multi-joint exercises can provide benefit	Hypertrophy between limb and trunk muscles following multi-joint BFR training may be disproportionate
Exercise loads	Low-load exercise (~20–40 % 1RM or MVC)	Multiple sets of low-load BFR exercise provides similar metabolic stimulus to high-load training, but may not replicate neural demands
Training volume	50–80 repetitions per exercise (sets do not need to be performed to muscular failure)	Standard scheme of 30–15–15–15 repetitions equates to 75 total repetitions
Inter-set rest	30–45 s	To ensure sufficient venous pooling, occlusion should be maintained during inter-set rest periods
Training frequency	Clinical populations: 2–3 training sessions per week is sufficient Athletic populations: 2–4 sessions per week, in addition to normal high-load resistance training	May be possible to train twice per day with BFR

BFR blood flow restriction, *MVC* maximum voluntary contraction, *1RM* 1-repetition maximum, ↓ indicates decrease, ↑ indicates increase

	HIGH INTENSITY (HIT)	(BFR) +LOW INTENSITY	LOW INTENSITY
Training range	70 – 85% %1 RM	20 – 35% 1 RM	20 – 35% 1 RM
Strength	Recruitment of fiber II	Recruitment of fiber II	Recruitment of fiber I
Muscle Damage requiring recovery (Creatine Kinase)	Present	Not significant	Not significant
Lactate production (mmol)	Similar	Similar	Not present
Neuromuscular (Type II recruitment)	Type II activation near maximal effort	Type II activation at sub max effort	No additional recruitment
Growth Hormone	100 fold increase	1.7 X greater than HIT	No change from baseline
IGF-1	Increase	Significant Increase	No change from baseline
MTOR1C	Increase	Significant Increase	No change from baseline
Myostatin	Down regulation	Down regulation	No change from baseline
Time to adaptation	12 weeks	2 weeks	