Clinical Applications of Blood Flow Restriction Training (BFR)

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Muscular Response to Injury

- Injury/surgery and disuse can lead to sequelae of neurologic inhibition, atrophy, weakness, & sarcopenia in addition to predisposition of aging
- Selective inhibition of fast-twitch early
- Imbalance of protein synthesis & protein degradation
<table>
<thead>
<tr>
<th>Goal/Level</th>
<th>Order</th>
<th>Loading</th>
<th>Volume</th>
<th>Rest Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength</strong></td>
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<tr>
<td>Novice</td>
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<tr>
<td>Intermediate</td>
<td>Large → small</td>
<td>60–70% of 1-RM</td>
<td>1–3 sets, 8–12 reps</td>
<td>2–3 min for core, 1–2 min for others</td>
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<tr>
<td></td>
<td>Multiple joint → single joint</td>
<td>70–80% of 1-RM</td>
<td>Multiple sets, 6–12 reps</td>
<td>2–3 min for core, 1–2 min for others</td>
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<tr>
<td>Advanced</td>
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<tr>
<td></td>
<td>70–100% of 1-RM</td>
<td></td>
<td>Multiple sets, 1–12 reps—periodized</td>
<td>2–3 min for core, 1–2 min for others</td>
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<tr>
<td><strong>Hypertrophy</strong></td>
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<tr>
<td>Advanced</td>
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<td></td>
<td>70–80% of 1-RM with emphasis on 70–85%—periodized</td>
<td>Multiple sets, 1–12 reps with emphasis on 6–12 reps—periodized</td>
<td>2–3 min—very heavy, 1–2 min—light to medium heavy</td>
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<tr>
<td><strong>Power</strong></td>
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<td>Novice</td>
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<tr>
<td>Intermediate</td>
<td>Large → small</td>
<td>Heavy loads (&gt;80% of 1-RM)—strength</td>
<td>Train for strength</td>
<td>2–3 min for core, 1–2 min for others</td>
</tr>
<tr>
<td></td>
<td>Light (30–60% of 1-RM)</td>
<td>velocity—periodized</td>
<td>1–3 sets, 3–6 reps</td>
<td>2–3 min for core, 1–2 min for others</td>
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<tr>
<td>Advanced</td>
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<td></td>
<td>High intensity → low intensity</td>
<td>3–6 sets, 1–6 reps—periodized</td>
<td>2–3 min for core, 1–2 min for others</td>
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<tr>
<td><strong>Endurance</strong></td>
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<td>Novice</td>
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<tr>
<td>Intermediate</td>
<td>Variety recommended</td>
<td>50–70% of 1-RM</td>
<td>1–3 sets, 10–15 reps</td>
<td>1–2 min for high-rep sets</td>
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<tr>
<td></td>
<td>50–70% of 1-RM</td>
<td>Multiple sets, 10–15 reps</td>
<td>1–2 min for high-rep sets</td>
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<td>Advanced</td>
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<td></td>
<td>30–80% of 1-RM—periodized</td>
<td>Multiple sets, 10–25 reps or more—periodized</td>
<td>&gt;1 min for 10–15 reps</td>
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Rehabilitation Conundrum

- Rehab following injury may require protection from heavy loads &/or weight-bearing that accentuates this process.
- Loss of muscle mass and strength deficits can persist for years following injury/surgery.
Traditional Management Options

- Wait & See
- Neuromuscular Stimulation
- High intensity resistance training (70% 1RM)
- High volume low load resistance training
Possible Solution?

Low Load Resistance Training with BFR
Is it safe?
Theoretical Safety Issues

- Impaired Hemodynamics
- Ischemic/Muscle Injury
- Cardiac Issues
- Nerve Injury
Thrombus Formation

► No increase in clotting factors with BFR
► DVT < 0.06%
► PE < 0.01%
► Case Report (2017)
  ▪ 29 year old female KAATSU instructor
  ▪ Diagnosed with Subclavian vein thrombosis/Thoracic Outlet
  ▪ Intermittent and progressive symptoms over 2 years
  ▪ unknown protocol
    • 30 min – 1 hr in duration; 3 times per week
Ischemic/Muscle Injury

► Rhabdomyolysis
  ▪ <0.01%
  ▪ Case Report (2016)
    • 30 year old Japanese Obese Male
    • 1 session of BFR on LE with 3 sets of 20 squats
    • Unknown Protocol
    • ER next day
    • Also diagnosed with an acute bacterial tonsillitis
Cardiac

- Abnormal excessive pressure reflex
- No current reports
- At risk = heart failure, hypertension, PAD (precaution)
  - Reduce % BFR pressure
Nerve Injury

- Transient
  - No permanent injury reported
- <0.2%
Safety in BFR Studies

- Lack of reporting in studies (either presence or absence)
- Study exclusions
- Clinical vs Healthy population?
Current Consensus/Recommendations

- Most common issue is bruising &/or discomfort
- No greater risk than other exercise modes
  - Assuming correct application
- Short duration of application
- Use caution in clinical populations
  - Possible use of lower occlusion pressures
- Avoid in potential high risk populations
  - prone to clot, Sickle cell, previous compartment syndrome, previous rhabdomyolysis, lymphedema, infection, diabetes, etc.
Continued Questions

- Acute vs Chronic use?
- Clinical populations at risk?
Has in been studied in typical clinical rehabilitation populations?
2016 Systematic Review of BFR in Musculoskeletal Rehabilitation

- 20 studies
  - 13 were focused on elderly (no apparent clinical diagnosis)
  - Only 7 represented use in clinical populations with pathologic conditions
    - 3 ACL
    - 3 knee OA/risk of OA
    - 1 myositis
Clinical populations studied...
ACL
Phases of BFR within rehab progression

- Early – passive
- Gait with BFR
  - No evidence specifically in ACLR
- Low load resistance BFR
- Heavy loading

No evidence pre-ACLR
No evidence re: functional improvements, return to sport
Early Phase

  - 8 patients used a 90mm width cuff to create a progressive pressure between 180 and 260 mmHg for 5 sets of 5 minutes with 3 minutes between sets twice a day on days 3-14 post-op
  - NO exercise - passive process
  - Decreased quad mm atrophy in BFR group compared to 8 person control group
Early Phase

  - 24 patients (12 BFR, 12 control)
  - 18-40 years old post-ACLR with HS graft
  - 14cm wide cuff provided progressive pressure between 130 and 180 mmHg for 5 sets of 5 minutes with 3 minutes between sets twice a day on days 2-14 post-op
  - 20 reps of quad isometrics, SAQ, or SLR during each 5 minute set
  - No difference in post-op mm atrophy between BFR & control
  - BFR group had more variability
  - BFR group avg. 2.5 mo since injury while control group avg. 5.4 mo since injury
Low Load Resistance with BFR

Ohta (2003)

- 44 patients (22 BFR, 22 control)
- 18-52 years old post-ACLR with HS graft
- 180mmHg of pressure (unknown cuff width) during a standardized exercise program from week 2-16 post-op
- BFR group demonstrated greater strength improvements and less mm atrophy compared to control group (same exercises, no BFR)
Knee OA
Risk of OA (Segal 2015) - Men

- Community dwelling, ambulatory, 45-90 y.o., volunteers (n=42)
- Radiographic knee OA without symptoms OR at least 1 risk factor
  - previous knee injury
  - previous knee surgery
  - pain/aching/stiffness >30days
  - overweight/obese
Risk of OA (Segal 2015) - Men

- BFR with 65mm width cuff
- Pressure progressively increased over 5 minute period
- Standard final pressures of 160 mmHg at week 1 progressing to 220 mmHg at week 4
- 4 sets of leg press (30, 15, 15, 15) with 30 sec rest periods between sets at 30% of 1RM
  - No adjustments made during training period
- Control group = same as intervention group, but without BFR
- 3 sessions per week for 4 weeks
Risk of OA (Segal 2015) - Men

- Outcome Measures = bilateral leg press 1RM, isokinetic knee extensor strength, KOOS
- 1 person dropped out due to “intolerance to the cuff”
- No significant differences between the 2 groups for any of outcomes
Risk of OA (Segal 2015) - women

- Same population as study in men except age was 45-65 years old (n=45)
- Same BFR protocol & exercise program as in men
- Same outcome measures with addition of quad volume & stair climb muscle power
- 1 person dropped out due to “inability to tolerate the intervention”
- Leg press 1RM & isokinetic strength improved in BFR > control
- No differences between groups in quad volume, stair climb, or KOOS scores
Why Gender Differences?

- Thigh girth NOT considered
- Pressure NOT individualized
- Age differences of groups
- Differences within included sub-groups
OA (Byrk 2016)

- Women with clinical & radiographic diagnosis of knee OA (n=34)
- Standard program of stretching, general strengthening of other LE mm, balance
- OKC knee extension at 30% 1RM 3 sets of 30 reps
  - BFR group used 200 mmHg pressure (unknown cuff)
  - Control group = exercise without BFR
  - 1RM updated weekly
- 3 sessions per week for 6 weeks
Outcomes
- 11-point NPRS (max pain in last week & during BFR ex)
- Lequesne questionnaire
- Timed Up-and-Go (TUG)
- Isometric dynamometer strength of quadriceps

Results
- Improved quad strength in BFR group compared to control
- Decreased pain during exercise for BFR group vs control
- No between group differences for Lequesne, TUG, or max pain
Anterior Knee Pain
Anterior Knee Pain (Giles 2017)

- 18-40 years old (n=79)
- Atraumatic anterior knee pain >8wks
- Pain with at least 2 activities
  - running, jumping, squatting, kneeling, stair ascent/descent, prolonged sitting
- Pain with 2 tests
  - patellar compression, peripatellar palpation, seated resisted isometric knee extension
Anterior Knee Pain (Giles 2017)

- BFR using 60% of arterial occlusion pressure (measured with Doppler)
- Leg press & Leg extension exercises
- 30% of estimated 1RM
- 4 sets (30, 15, 15, 15) with 30 sec between sets
- Control group = 70% of estimated 1RM 3 sets of 7-10 reps with sham BFR
- 3 sessions per week for 8 weeks
Anterior Knee Pain (Giles 2017)

- Both groups improved
- BFR group decreased pain with ADLs compared to controls at 8 weeks (BFR group had higher pain with ADLs at baseline)
- No difference between groups with function, pain at worst, muscle size, or muscle strength
- No differences between groups for any measure at 6 months
- Subgroup of patients who had pain with resisted isometric extension improved strength more with BFR than controls at 8 weeks
Anterior Knee Pain (Korakakis 2018)

- Non-experimental Design
- 30 male patients with anterior knee pain (post-op ACLR, PFJS, post-op meniscus, OCD, patellar tendinopathy)
- Measured pain with shallow single limb squat (SLS), deep SLS, and double limb squat (DLS)
- Measurements pre- and post- BFR exercise and again following 45 minute PT session
Anterior Knee Pain (Korakakis 2018)

- 10 cm cuff induced pressure to 80% of vascular occlusion (measured with Doppler)
- Performed OKC knee extension with BFR at a pain determined load 4 sets (max, 15, 15, 15) with 30 sec between sets
- Statistically significant decrease in pain following BFR for all tests and maintained at 45 minutes
- BFR early in session may help reduce pain with subsequent exercise or activity
Other Conditions...
Following Knee Scope (Tennet 2017)

- 17 patients 18-65 y.o.
- Non-reconstructive knee scope
- 12 visits of PT with BFR vs 12 visits of PT without BFR
  - initiated at 3 weeks post-op
- Standard post-op exercise protocol for both groups
“Additional” exercises for BFR group
- Leg press, Leg extension, “Reverse press” (standing bent knee hip ext)
- 30% of 1 RM; 4 sets (30, 15, 15, 15) with 30 sec rest between sets
- Pressure = 80% limb occlusion pressure (using Doppler)
Following Knee Scope (Tennet 2017)

- Increase thigh girth in BFR group compared to control (tape measure)
- Improved mental component score (not physical) of Veterans RAND-12 Health Survey in BFR compared to control
- Improved timed stair ascent in BFR group compared to control
- Knee extension & flexion strength improved in BFR group compared to control
Cast Immobilization (Kubota 2011)

- healthy, male patients (n=11)
- Immobilized lower leg in cast & used crutches with NWB for 2 weeks
- BFR group vs No treatment group
- 50 mmHg pressure
- 5 sets twice a day for 14 days (5 minutes BFR, 3 minutes rest)
- Less loss of calf muscle strength (at 60 deg/sec) compared to non BFR group
  - No difference between groups for other isokinetic tests
Athletes & Performance

- Not a detriment
- No improvements in strength, size, or functional performance compared to high intensity exercise
- Benefits for in-season strength training?
Osteochondral Fracture (Loenneke, et al 2013)

- 22 y.o. male, bodybuilder
- Injured knee & began self management/compensation with BFR (elastic wrap)
- Ortho visit (3 days post injury) = joint effusion, decreased knee flexion, mild limp
- MRI (5 days post injury) = significant osteochondral defect; surgery recommended
- Continued BFR training & postponed surgery due to upcoming competition
- Returned for pre-op visit (17 days post injury) – normal gait, pain free, no effusion
  - osteochondral fracture was healing and patient was continued to be managed conservatively
Case Studies

► Parkinson’s (Douris, et al 2018)
  ▪ 65 y.o. male, recreational boxer
  ▪ Walking program with BFR (120 – 160 mmHg)
  ▪ Improved Timed Up-and-Go, 6-minute walk test, 30-second chair stand test, and decreased restless leg symptoms
  ▪ Improvements every 2 weeks over the course of 6 week intervention
Case Studies

▶ Achilles Rupture (Yow, et al 2018)
  - 2 patients
    - 29 y.o. active-duty military; 38 y.o. male service member
  - Both had experience complications/unusual circumstances
  - Both increased strength at 5-6 weeks
  - Both returned to running program
Theoretical Proposals

- Low Back Pain
- TKA Prehab
- Chronic Ankle Instability
- In-patient Rehab
- End-stage Renal Disease with dialysis
Other thoughts...

- Cancer
- Obesity
- Fractures
- Neurologic
- Cardiovascular
Concussion?
Factors to Consider

- Cuff Width
- Thigh or Arm Girth
- Time to achieve maximal pressure
- Maximal pressure
- Risk vs Benefit in clinical populations & individual patients
- Intensity & Volume of resistance
- Length of program
- Timing of program during course of recovery
- Timing of program within a session
- Outcome measures
What we know...

- Current studies in clinical populations are generally low quality with methodological issues
- No worse than low intensity training alone
- No better than high intensity training
- Likely a reduction in pain compared to high intensity training
- Individualized determination of pressure
- Short duration of application
- Continued progression of resistance with gains
- 30% 1RM (30, 15, 15, 15)
Questions we still have...

- Do strength and muscle size translate to functional improvements?
- How long of a program is needed to be effective?
- Does BFR early in session facilitate other exercises/interventions?
- How does BFR interact with other interventions?
- Proximal effects?
- Improved bone healing?
- Clinical populations?
  - Upper Extremity?
  - Children/Adolescents?
Current Recommendations

- **Individualized approach**
  - 40% - 80% occlusion pressure

- **Resistance progression**
  - 20% - 30% 1RM
  - 4 sets (30, 15, 15, 15)
  - NOT to point of complete exhaustion/maximal volume

- **Consider rehab progression**
  - BFR alone during early stages of rest
  - BFR with low workload walking/cycling
  - BFR with low load resistance training
  - BFR with low level functional training

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Approximately 30 on-going clinical trials

- ACL
- OA
- Chronic Heart Failure
- TKA
- Meniscus
- Articular Cartilage
- Urinary Stress Incontinence
- Coronary Heart Disease
- Multiple Sclerosis
- Achilles Tendinopathy
- Fracture
- Low Back Pain
- Biceps Tenodesis
- Chronic Kidney Disease
Questions?
References


References


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References


- [www.clinicaltrials.gov](http://www.clinicaltrials.gov)

- Images obtained from search of Google Images