Current Clinical Concepts: Blood Flow Restriction Training

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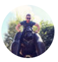

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ABSTRACT

Muscle weakness and atrophy are common impairments following musculoskeletal injury. The use of blood flow restriction (BFR) training offers the ability to mitigate weakness and atrophy without overloading healing tissues. This approach requires consideration of a wide range of parameters and the purpose of this manuscript is to provide insights into proposed mechanisms of effectiveness, safety considerations, application guidelines, and clinical guidelines for BFR training following musculoskeletal injury. BFR training appears to be a safe and effective approach to therapeutic exercise in sports medicine environments. While training with higher loads produces the most substantial increases in strength and hypertrophy, BFR training appears to be a reasonable option to bridge between earlier phases of rehabilitation when higher loads may not be tolerated by the patient and later stages that are consistent with return to sport performance.

Key Words: BFR, clinical rehabilitation, hypertrophy, occlusion training, resistance training

Key Points:

- Blood flow restriction training can be used to augment strength and hypertrophy gains during early phases of rehabilitation when higher loads may not be tolerated by the patient.
- The risk for injury or adverse event is thought to be consistent with traditional exercise models, provided that clinicians utilize appropriate training parameters.
- There is some evidence that blood flow restriction training can improve function and pain outcomes beyond traditional resistance training in individuals with joint pathology.

INTRODUCTION

Muscle weakness and atrophy are common impairments addressed in sports medicine following musculoskeletal injury and surgery. A common example is seen following anterior cruciate ligament reconstruction where deficits in quadriceps strength can persist for years despite rehabilitation.[1] Efforts to mitigate weakness should start early in the rehabilitation process. The development of both strength and hypertrophy depends on progressive tensile loading of the muscle, typically modified in the clinic through the amount of weight lifted (i.e. external load) and the number of sets and repetitions performed.[2] Resistance training guidelines for the enhancement of strength suggest the use of higher loads (>60% 1 repetition maximum [1 RM]; 8-12 repetitions).[2] However, training at this intensity immediately following injury or surgery may adversely stress damaged and healing tissues (e.g. cartilage, ligament, tendon, muscle). The use of lower loads, with repetitions to failure, can minimize excessive stress on healing tissues, but has limited ability to increase strength when compared to training with heavier loads.[3] There is a critical need to utilize clinical strategies that better transition from lower load exercises performed in the early stages of injury rehabilitation to higher load exercises consistent with training for athletic performance.

Given substantial evidence for persistent strength deficits, clinicians should consider all available methods to address weakness. The use of blood flow restriction (BFR) training to enhance strength gains in healthy individuals, as well as those with pathology, has gained substantial interest in the past 15 years.[4,5] This method is synonymous with other terms such as Kaatsu (specific device), occlusion training, and hypoxic training. BFR therapy utilizes a strap or pneumatic cuff to partially restrict arterial blood inflow, while occluding venous outflow until the cuff pressure is released. Training loads are usually lower (20-30% 1 RM; 15-30 repetitions per set) which offers the sports medicine professional a method to mitigate weakness and atrophy after musculoskeletal injury or surgery without overloading healing tissues.

Previous systematic reviews have demonstrated mixed efficacy for the use of BFR in clinical populations.[4,5] The use of low-load BFR training typically results in more positive adaptations (e.g. increased strength or muscle cross-sectional area) when compared to work matched low-load resistance training[4,5] but results are mixed when compared to higher load resistance training.[6,7] These results are generally consistent with healthy populations.[3,8] The use of BFR in a clinical environment requires consideration of a wide range of parameters that influence use and rehabilitation outcomes. These include pathology, patient medical history, time since injury/surgery, cuff selection, arterial occlusion pressure (i.e., limb occlusion pressure), exercise parameters (sets, repetitions, load), and length of time BFR is applied. Since there is mixed efficacy for outcomes in clinical populations,[4,5] and little consensus regarding treatment parameters,[9,10] clinicians may not be confident utilizing this treatment approach. Therefore, the purpose of this current clinical concepts manuscript is to provide the sports medicine practitioner with information regarding the practical application of BFR in clinical settings following musculoskeletal injury. Specifically, insights will be provided regarding proposed mechanisms of effectiveness, safety considerations, application guidelines, and clinical guidelines. The strength of evidence supporting each clinical recommendation was graded using the Strength of Recommendation (SOR) Taxonomy (Table 1).[11]

PROPOSED MECHANISMS OF EFFECTIVENESS

Muscular adaptations from exercise are due to the combined effect of mechanical tension, muscle damage, and metabolic stress.[12] A variety of physiological mechanisms are thought to cause the increased muscular size and strength seen with BFR training, although the exact mechanisms remain unknown. The general consensus suggests muscular changes occur through the indirect effect of metabolite accumulation and the hypoxic environment which causes greater muscle activation, fatigue, and anabolic signaling when compared to the same intensity of exercise done without BFR.[13-15] Muscle hypertrophy occurs when the intracellular environment shows a positive protein balance achieved through increased muscle protein synthesis and/or decreased muscle protein breakdown.[12] The opposite is seen with muscle atrophy which occurs due to increased rates of muscle protein breakdown.[16] BFR applied without the addition of exercise results in some acute increases in muscle thickness, along with comparable reductions in plasma volume, but it appears necessary to combine BFR with exercise to show the increased muscle protein synthesis rates seen when compared to load matched controls without restriction.[13]

The role played by metabolites pooling within the working muscle is not well understood. While some have attributed the muscular adaptations observed with BFR to this, these claims have been strongly debated.[13] It has also been suggested that the increased accumulation of metabolites (lactate and hydrogen ions) and a decrease in intramuscular pH, seen during BFR training stimulates group III and IV afferent fibers, thus driving earlier neuromuscular fatigue than what is seen in non-BFR exercise at the same load.[13-15] Taken together, group III/IV muscle afferents play a substantial role in exercise capacity and susceptibility to fatigue.[17] The impairment of the force generating capacity of a muscle after activity, is defined as muscle fatigue.[15] It may be that this increase in fatigue causes higher threshold motor units to be recruited earlier in the exercise set in order to maintain the required force output from the muscle to complete the prescribed number of repetitions. This would result in a hypertrophic stimulus for a greater proportion of muscle fibers during BFR training when compared to an equivalent exercise dosage done without BFR.[5]

The hypoxic environment associated with BFR may also induce fatigue and promote anabolic signaling within the muscle.[13-15] The availability of oxygen to the muscle is severely reduced during BFR training,[18] contributing to increased fatigue and decreased force production, which may be compensated for by progressive recruitment of additional motor units.[9] Additionally, increased production of reactive oxygen species such as nitric oxide can be seen due to the fluctuations in oxygen availability which, in turn, can stimulate muscle growth by activating muscle satellite cells.[14] Furthermore, the increase in metabolites also contributes to an increase in growth hormone (GH) and promotes an inflammatory response, which increases myokine production such as interleukin 6 (IL-6), also activating muscle satellite cells.[13-15] In addition, this hypoxic environment is purported to stimulate angiogenesis through the proliferation of vascular endothelial growth factor (VEGF), in a manner similar to that seen in conventional resistance training.[13,15]

Overall, there is limited data supporting the various proposed mechanisms behind BFR training, but there is strong evidence of clinically significant changes in strength and hypertrophy and angiogenesis when utilizing this treatment method. While the mechanisms for this are still being identified, BFR training appears to allow for an increased ability to load high threshold motor units and elicit relevant adaptations. *Strength of recommendation: C*

SAFETY CONSIDERATIONS

The safety of BFR training, especially in a clinical setting, raises concern for side effects and serious complications. Common side effects seen with BFR training include pain/discomfort during exercise, delayed onset muscle soreness, cardiac stress (increased heart rate, increased blood pressure, decreased stroke volume), while more serious, less common, side effects include numbness/nerve injury, bruising/ ischemic injury, dizziness/fainting, thrombus formation, muscle damage, and rhabdomyolysis.[9,19] Contraindications for use include history or potential for deep vein thrombosis, blood clotting disorders, poor circulation, hypertension, inadequate lymphatic system, history of endothelial dysfunction, varicose veins, peripheral vascular disease, diabetes, easy bruising, active infection, cancer, renal compromise, pregnancy, and intervention intolerance.[20] No definitive timeline post-surgery has been identified when it is safe to begin BFR training, but studies have used BFR training as early as 2-3 weeks post-surgery.[6,20,21] It should be noted that previous studies have not specifically compared adverse event rates between BFR training and traditional resistance training. The risk for injury or adverse event is thought to be consistent with traditional exercise models, provided that clinicians utilize appropriate BFR training parameters,[22] training volume progressions (i.e. rhabdomyolysis), cuff/device selection, and conduct screening for contraindications. *Strength of recommendation: C*

Risk of Blood Clot

While risk does exist for the formation of a blood clot due to external pressure and vascular occlusion, studies that have investigated blood markers indicative of coagulation (D-dimer, C-reactive protein, prothrombin fragment) have not demonstrated changes in these values beyond those equivalent to exercise and have indicated BFR therapy may actually help reduce the risk of DVT.[22] The use of BFR therapy has been used across a variety of musculoskeletal pathologies, including post-surgical cases (as early as 2-3 weeks post-op), and has not resulted in reported serious adverse events for participants who met study inclusion criteria (i.e., no contraindications for resistance training exercise or BFR training).[6,20,21,23] *Strength of recommendation: B*

Certifications and Use of Food and Drug Administration (FDA) Approved Devices

Clinicians should have knowledge of safety and effectiveness of any intervention and this knowledge may come from entry-level training or continuing education. Unfortunately, continuing education courses and marketing can be substantially influenced by financial conflicts of interest only creating greater confusion regarding device selection, training, and safety. While some entities offer opportunities for BFR certification, it is not specifically required. Medical device manufactures do need to provide directions for safe and effective use and ensure the end-user is adequately trained, but there is some leeway regarding appropriate training (instruction manual to intensive in-person training). It is also the responsibility of the clinician to be familiar with mechanisms, precautions/contraindications, target populations, and associated risks. Regarding the use of FDA approved devices, a pneumatic tourniquet is considered a Class I device (low-risk device) and intended to reduce or totally occlude circulation during surgery (21 CFR 878.5910). The FDA has exempted almost all class I devices (510K exemption), indicating that devices only need to be listed with the FDA since they are already approved. At this time, there is no BFR device that is “FDA approved” for use in an exercise or rehabilitation setting, but clinicians should strongly consider utilizing BFR training devices that are listed with the FDA. Decisions regarding certification or device selection should be a discussed between the clinical and administrative stakeholders and informed by administrative policies, malpractice insurance carriers, or specific state practice act.

APPLICATION GUIDELINES

Safe and effective BFR application requires the clinician to assess various elements of the treatment process and device, including but not limited to; cuff width and placement, cuff pressure, and device selection.

Cuff Design and Implications

BFR training devices are an evolution of surgical tourniquets, but surgical tourniquets are applied at much higher pressures and for longer periods of time with continuous monitoring of the patient. Research on surgical tourniquets has shown that a narrower cuff requires a higher level of pressure to achieve arterial occlusion and that neurological injury most often occurs at the edge of the tourniquet where the pressure gradient is highest.[24] Two studies have examined the impact of wide versus narrow cuff width specifically with BFR training.[25,26] When the same arterial occlusion pressure is used the percentage of blood flow occluded does not change based on cuff width (5, 10, vs 12 cm)[26] and results in similar increases in strength and muscle size.[25] These results suggest that a wider cuff can achieve arterial occlusion for BFR training at a lower pressure when compared to a narrower cuff and is preferred for patient safety. As BFR has evolved, manufacturers have added contoured cuff design systems and automated versus manual control of pressure. Although there may be anecdotal evidence for increased comfort and manufacture suggestion regarding the superiority of automated systems, studies have not demonstrated a difference in safety, efficacy, effectiveness, or comfort. *Strength of recommendation: C*

Cuff Placement

The standard recommendation for cuff placement is the most proximal location of the exercising limb, regardless of the targeted muscle group (Figure 1).[9] This proximal location allows for occlusion to occur in the majority of the muscle belly being worked (e.g., quadriceps) without interfering with normal joint excursions. The more proximal cuff placement also minimizes the potential for damage to more superficial nerves which are more common in distal extremities (e.g. superficial fibular nerve). It is recommended that a barrier, such as a limb protection sleeve, be placed on the limb prior to cuff application, to minimize the risk of pinching, friction burns, or blisters. *Strength of recommendation: C*

Cuff Pressure

BFR therapy utilizes a strap or pneumatic cuff to partially restrict arterial blood inflow, while occluding venous outflow. Arterial occlusion pressure (i.e., limb occlusion pressure) describes the pressure needed to completely occlude arterial blood flow and serves as an upper limit reference point for training and patient safety. The five most common methods to determine cuff pressure utilize: an arbitrary pressure selection (e.g., 150-200 mmHg), a percentage of systolic blood pressure (e.g., 130% systolic), limb circumference, an intensity scale of tightness, or a percentage of arterial occlusion pressure.[19,26-28] It is not clear if one approach lends to superior outcomes compared to other approaches or enhances safety.[29,30] Reproducibility and safety are the two main concerns when selecting pressure, in particular with respect to whether arterial flow is completely occluded. In order to understand how to safely apply BFR it is important to take into account the various factors that affect arterial occlusion pressure. Certain fixed factors like systolic blood pressure, diastolic blood pressure, limb circumference, sex, and race have all been shown to impact arterial occlusion pressure.[31] There are also modifiable factors like body position and cuff width that affect occlusion pressure.[32,33] Pressure selection based on a percentage of arterial occlusion pressure is recommended by the authors to best standardize the pressure used for each individual patient, regardless of limb or cuff size. It is further recommended that clinicians determine arterial occlusion pressure in the same position as the exercise is performed since body position can impact occlusion pressure.[32,33] While this approach may provide a more precise dosage pressure it remains to be shown if this approach improve outcomes or better addresses safety concerns[32,33] or if personalized pressures fall within arbitrary ranges (e.g., 150-200 mmHg). Arterial occlusion pressure can be identified in a variety of ways including an automated, higher cost, personalized tourniquet systems or manually using a handheld Doppler ultrasound unit (Figure 2) or pulse oximeter which are both lower cost methods with acceptable reliability.[34-36] It is not clear if automated personalized tourniquet systems increase safety or effectiveness compared to Doppler ultrasound or a pulse oximeter.

In general, 40-80% of arterial occlusion pressure is suggested as the range with the greatest likelihood of achieving training goals while minimizing risk for potential complications.[9,29] The pressure used will also depend on limb size with larger limbs usually being trained at a higher relative pressure (closer to 80%) than smaller limbs (closer to 40-50%). Higher pressures are usually associated with higher levels of discomfort and perceived exertion[37,38] but lower pressures may require a higher relative load to achieve desired results at the same volume.[39-41] Thus, clinicians should utilize a pressure that minimizes discomfort, but allows training at lower load to minimize stress on healing tissues.[38]

While it is recommended that pressure selection is based on arterial occlusion pressure it is appreciated that not all clinical settings may have this capacity or that patients may perform training outside of clinical settings with personal devices. In instances where arterial occlusion pressure cannot be established the rehabilitation professional should at a minimum ensure that arterial occlusion has not occurred by manual palpation of the pulse (e.g., posterior tibial artery, dorsalis pedis artery, or radial artery). Pressure ranges utilized in the clinic (e.g., 40-80% arterial occlusion pressure), benchmarked against known arterial occlusion pressures, can be suggested if using BFR training as part of a home exercise program. Instances where pressure is not specifically regulated by the device (i.e., weightlifting knee wraps) a rating of perceived pressure of 7/10 or less (numeric pain rating scale) can be used.[28] Regardless of the approach, it is advisable to ensure that distal pulses can be palpated to ensure wrap pressure or an individual's perception of perceived tightness does not exceed arterial occlusion pressure. This method has been shown to provide equivalent training results[29] but should be approached with a level of caution since actual arterial occlusion pressure is not established. It is not clear if patient outcomes vary based on arbitrary pressure selection or individualized cuff pressure[29,30] when using established methods.[19,26-28] *Strength of recommendation: C*

Device Selection

The clinician has a wide variety of cuffs or devices available in the market that breakdown to either static or dynamic pressure controls. Clinicians have the ability to make a decision based on the preceding recommendations regarding cuff width, ability to measure arterial occlusion pressure, and automatically adjust pressure. Broadly BFR cuff systems fall into two categories, static cuff (standard sphygmomanometer) or dynamic cuff (pneumatically regulated system). While each approach has proposed advantages and disadvantages to the implementation of pressure control during exercise current evidence suggests clinical outcomes are not different.[5] While pressure in a static cuff is initially set to a specific amount, the actual pressure may vary during exercise due to limb movement and muscle contraction under the cuff. A dynamic cuff has the capacity to maintain a specified pressure through a sensor and pneumatic pump but regulates pressure based on fluctuations in cuff pressure which may differ from changes in arterial pressure or percent of occlusion, especially during dynamic movement. It should be noted that studies have not specifically investigated arterial pressures (in vivo) during exercise so the validity of this suggestion is unknown. Other factors such as cost, quality, ease of use and ability to clean should also be considered. It is not clear if the rate of adverse events or patient outcomes vary based on cuff/device selection. *Strength of recommendation: C*

CLINICAL GUIDELINES

Strength & Hypertrophy

The sports medicine professional prescribes exercise to those who are injured or post-surgery with consideration of tissue healing processes, recognizing that in early rehabilitation phases it may not be possible to use the higher loads (>60% of 1RM) typically used to elicit changes in strength and hypertrophy.[2,4] It is for this reason that options such as BFR, which may offer an alternative to traditional approaches, have generated so much interest and are finding a place in the practice of sports medicine.[5-7] It is important to note that the effects BFR training has on adaptations will vary. For instance, hypertrophy will likely be similar to what is seen with traditional progressive resistance exercise while changes in strength may be less than what is achievable with traditional progressive resistance exercise.[40] Current evidence suggests that when effort matched, changes in hypertrophy seem to be equivalent across loads regardless of the methods used.[3] A recent meta-analysis demonstrated no comparable difference in muscle mass (i.e., hypertrophy) between high-load resistance training (>65% RM) and low load BFR training (20-50% RM).[40] There is even evidence to indicate that hypertrophic changes may occur at a more rapid rate during BFR training than with traditional training but these observed effects could be due in part to local cell swelling as well as the ability to train at a higher frequency.[9]

In contrast to hypertrophy, this same meta-analysis[40] found that strength adaptations do seem to favor high load resistance training regardless of the cuff size, absolute occlusion pressure, or method of measuring this pressure. While this result has been questioned by a follow-up review[42] that used very different inclusion criteria, the overall body of evidence still seems to support the use of high load resistance training when strength is the primary goal. As such, when absolute strength is desired heavier loads are ideal, however when these loads are contraindicated BFR can be utilized instead to improve strength with lower loads. Whereas for hypertrophy, BFR will yield results equivalent to any other approach which offers the clinician a way to strategically achieve these results with a reduced volume load and minimized stress on healing tissues.[15,29,40,43,44] *Strength of recommendation: C*

When applying low load BFR training in the clinic it may be possible to address both strength and hypertrophy with the same treatment parameters (Table 2). The number of sets and repetitions vary across studies, with the most common prescription being either 3-5 sets done to failure or 30 initial repetitions followed by 3 sets of 15 repetitions with approximately 30 seconds of rest between sets.[9,29,40] Since the results do not vary much between these approaches the authors suggest a clinical approach of 2-3 sets to failure with an additional 1-2 sets if more volume is desired. This approach is suggested due to its ease of implementation and clinical applicability. It has been suggested that there is a minimum intensity that is necessary in order to stimulate hypertrophy with traditional resistance training models, but precise values are yet to be determined.[44,45] In general, loads lower than 40% RM are used for BFR exercises.[9,40] However, since there does need to be some mechanical tension in order to elicit an adaption, these loads should not drop below a threshold of 20% RM.[41,44] In a practical sense, these percentages are not easily calculated since a maximum strength test may be contraindicated or not performed immediately following injury or surgery to minimize potential for tissue damage. An estimated 1RM can be determined by obtaining a 1RM on the uninvolved limb or selecting a load that allows at least 20 repetitions, but no more than 40-50 repetitions to be performed during the first set.[43,46] Subsequent sets can approach or be at failure, with a total of 75 repetitions per exercise likely being sufficient.[9,43,46] This also ensures that the lower volume benefits that BFR offers in comparison to low load training to failure are realized. Short rest intervals allow for metabolite accumulation and contribute to hypoxia that is achieved during exercise and BFR training further increases metabolic stress when compared to low intensity exercise.[47] Maintaining pressure during the rest period enhances metabolic stresses and inflating the cuff 5 minutes before exercise can further increase metabolic stress.[48] *Strength of recommendation: C*

Pain and Function

While strength and hypertrophy are often clinical goals to address impairments and improve function, these outcomes are often clinical in nature and do not reflect patient-oriented evidence. The use of BFR training (6-12 weeks) has been shown to result in greater improvements in function (e.g., SF-36 scores, IKDC subjective scores, timed-up-and-go), dynamic balance, and decreased pain when compared to traditional high load resistance training alone in individuals with arthritic conditions or following ACL reconstruction.[6,7,20] Outcomes regarding decreased pain have also been shown to occur in individuals with patellofemoral or anterior knee pain[49,50] as well as patellar tendinopathy.[51] While most studies tend to focus on physiological outcomes such as hypertrophy, strength, and reduced atrophy,[52] there is emerging evidence that BFR can improve outcomes related to function and pain. *Strength of recommendation: B*

Aerobic Conditioning/Exercise

BFR is a viable option for eliciting improvements in both aerobic conditioning and hypertrophy when used with walking or cycling.[8,53,54] Much like BFR used for strength and hypertrophy, expected gains can be realized in as little as 2-3 weeks.[53,54] BFR for aerobic exercise can be implemented within the sports medicine setting in a number of ways. It could be used to enhance a warm-up/cool-down session, increase intensity of aerobic exercise, or simply to introduce variability into an otherwise mundane workout session. In lieu of resistance training, BFR can be utilized during walking or cycling can help mitigate any strength and hypertrophy losses, but this has not been specifically investigated in individuals with pathology. Cuff pressures and widths as well as restriction time are relatively the same compared to other treatment objectives with some minor differences. Restriction time for resistance training exercise is typically 5-10 minutes per exercise with reperfusion between exercises, while aerobic conditioning varies between 5-20 minutes.[9] Differences in restriction time may be due to the relative intensity of exercise. For resistance exercise intensity is typically 20-40% of 1RM while intensity for aerobic conditioning is <50% VO2 max or the heart rate reserve.[9] Frequency is 2-3x/week or 1-2x/day for 1-3 weeks.[9] *Strength of recommendation: C*

CONCLUSION

In summary, BFR training provides the sports medicine professional an alternative method of approaching exercise intensity. Current research strongly supports its inclusion in situations without contraindications where the goal is hypertrophy and strength, but exercise volume and/or load is constrained. By judiciously applying BFR training when indicated, the sports medicine professional is able to achieve a minimum effective dosage at a volume and load that would otherwise be insufficient. In populations where occlusion is not contradicted and traditional progressive resistance training is indicated, BFR training appears to be a safe and effective adjunctive approach to therapeutic exercise in sports medicine environments.

FIGURES

Figure 1. Cuff placement on the A) upper extremity, B) lower extremity. The cuff should be placed proximally on the limb which allows for occlusion to occur in the majority of the muscle without interfering with movement.

Figure 2. Determining arterial occlusion pressure using a A) pulse oximeter or B) handheld Doppler ultrasound. A pulse oximeter can be placed on a finger. The doppler ultrasound is placed on a distal artery (B) upper extremity, radial artery; C) lower extremity, dorsalis pedis) Once the pulse has been identified, the cuff is slowly inflated (e.g., start at 50 mmHg with 10 mmHg increments every 10 seconds) to the point where full occlusion occurs (i.e., pulse absent)

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Table 1. The Strength of Recommendation Taxonomy (SORT)[10]	
Strength of Recommendation	Definition
A	Recommendation based on consistent and good-quality patient-oriented evidence.
B	Recommendation based on inconsistent or limited-quality patient-oriented evidence.
C	Recommendation based on consensus, usual practice, opinion, disease-oriented evidence, or case series for studies of diagnosis, treatment, prevention, or screening.

Table 2. Strength and Hypertrophy BFR Prescription Guidelines[4,5,9,55]	
Cuff Placement	Applied proximally on working limb(s)
Occlusion Pressure	40-80% arterial occlusion pressure using lower pressures with smaller limbs or for comfort. Arterial occlusion pressure identified via Doppler ultrasound (e.g., dorsalis pedis, tibial, or radial) or pulse oximetry.
Total Occlusion Time	<10 minutes total between periods of re-perfusion
Load (as %RM)	20% to 40% of 1RM (~20-40 repetition maximum)
Sets	Minimum of 2-3 sets and up to 5 sets total per exercise
Repetitions	45-75 repetitions per exercise (1-2 seconds concentric: eccentric per repetition), with the lower end assuming 1-2 sets

	are completed to failure. More than 75 repetitions per exercise appears to be unnecessary and less may be sufficient especially if sets are taken to failure.
Effort Level	Either concentric failure or approaching fatigue as determined by a significant drop in execution velocity and/or utilization of compensatory strategies.
Rest Period	30-60 seconds between sets
Frequency	2-3 times weekly for approximately 4-6 weeks Can also be done 1-2 times daily for brief (<3 week) periods
Exercise Selection	To ensure stress is applied to specific muscles and maximize motor unit recruitment, use isolated, single limb approaches when possible. Bilateral, multi-joint exercises can be used to maximize training program efficiency given that more muscles will be utilized in the same amount of time but may reduce efficacy and stress shield the target tissue.


25
25
Occlusion Cuffs
Occlusion Cuffs


8 MHz