



Invited Editorial

Blood Flow Restriction Training: Implementation into Clinical Practice

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ABSTRACT

International Journal of Exercise Science 10(5): 649-654, 2017. To improve muscular strength and hypertrophy the American College of Sports Medicine recommends moderate to high load resistance training. However, use of moderate to high loads are often not feasible in clinical populations. Therefore, the emergence of low load (LL) blood flow restriction (BFR) training as a rehabilitation tool for clinical populations is becoming popular. Although the majority of research on LL-BFR training has examined healthy populations, clinical applications are emerging. Overall, it appears BFR training is a safe and effective tool for rehabilitation. However, additional research is needed prior to widespread application.

KEY WORDS: Occlusion training, tourniquet training, rehabilitation, safety, KAATSU

OVERVIEW

Resistance training at an intensity of 60-80% of an individual's 1-repetition maximum strength (1-RM) is recommended to achieve improvements in muscular strength and hypertrophy (4). Unfortunately, this intensity is often impossible or contraindicated in clinical populations (e.g., post-acute injury, post-operative, certain chronic diseases). Therefore, clinicians often implement low load (LL) resistance training which, unless performed to muscular fatigue, is ineffective at eliciting increases in muscular strength and/or hypertrophy (8). However, muscular strength and hypertrophy can be improved with LL resistance training if combined with blood flow restriction (BFR). LL-BFR training entails applying a tourniquet-style cuff on the proximal aspect of a limb just prior to exercise. The cuff is manually tightened or pneumatically inflated to a pressure that occludes venous flow yet allows arterial inflow.

BFR training was originally conceived and developed in Japan in the late 1960's by Yoshiaki Sato and termed KAATSU training. Prior to 2008 LL-BFR training equipment was scarce outside of Japan. However, multiple units are now readily available worldwide, facilitating expansion of research in this area. Thus far, research results regarding the efficacy of LL-BFR have been consistent and promising (8).

SAFETY

Thrombus Formation

Although speculative, an initial safety concern regarding LL-BFR training included thrombus formation (i.e., blood clot). Research examining LL-BFR training with healthy individuals and older adults with heart disease found no change in blood markers for thrombin generation or intravascular clot formation (1, 9). Furthermore, data from two surveys of nearly 13,000 individuals utilizing BFR training found that the incidence of deep venous thrombosis was <.06% and pulmonary embolism was <.01% (11, 12).

Muscle Damage

Data from the aforementioned surveys found the incidence of excessive muscle damage (i.e., rhabdomyolysis) to be <0.01% (11, 12). The amount of muscle damage associated with BFR training is conflicting; however, a comparison between maximal eccentric actions and LL-BFR training to exhaustion in untrained individuals revealed comparable amounts of exercise-induced muscle damage (14, 16). However, we do not recommend performing LL-BFR training to exhaustion in clinical populations and, therefore, it appears the risk of LL-BFR training resulting in excessive muscle damage is minimal. In general, it is well established that unaccustomed exercise results in muscle damage and delayed onset muscle soreness (DOMS), especially if the exercise involves a large amount of eccentric actions (2). DOMS is normal after unaccustomed exercise, including after LL-BFR training, and should subside within 24-72 hours.

Abnormal Exercise Pressure Reflex

An additional concern raised with LL-BFR training is the possibility of an intensified exercise pressure reflex (EPR), a reflex that contributes to cardiovascular modifications during exercise from the autonomic nervous system. It is hypothesized that reduced blood flow to the working muscles could lead to EPR-mediated cardiovascular complications and result in excessive blood pressure elevation. Although an abnormal EPR could occur in the apparently healthy, the hesitation is heightened for at-risk populations such as individuals diagnosed with heart failure, hypertension, or peripheral artery disease (PAD). These individuals are predisposed to an exaggerated increase in sympathetic nervous system activity during exercise (15). We agree that an awareness of this potential complication is justified. However, the risk of an adverse event can be mitigated by using relative cuff inflation pressures and by reducing the BFR pressure (6).

Nerve Conduction

Lastly, a side effect associated with LL-BFR training is numbness (11). This is likely due to inappropriately high tourniquet pressures, thus resulting in peripheral nerve compression. The incidence is low (<2%) and cases are transient in nature (11). However, appropriate selection and application of the cuff (i.e., size, site, pressure) is essential for preventing peripheral nerve irritation.

EXERCISE PRESCRIPTION

LL-BFR Resistance Training

One of the main tenets of resistance exercise prescription is intensity of exercise or load. LL-BFR resistance training at intensities as low as 20% of an individual's 1-RM strength results in significant improvements in muscular strength and hypertrophy. The largest effects have been observed training 2-3 days per week. However, a frequency greater than this appears to be less effective, possibly due to overtraining (8). High volume is ideal; a standard structure for LL-BFR training is 75 repetitions over 4 sets (i.e., 30/15/15/15) with 30-second rest periods between sets. The goal of this training volume scheme is metabolite accumulation (i.e., lactate), which stimulates an increase in serum growth hormone (GH) thus promoting collagen synthesis for tissue repair and recovery. A surge in GH increases insulin-like growth factor-1 (IGF-1) production, a protein linked to muscle growth. IGF-1 has powerful anabolic effects by enhancing satellite cell proliferation and therefore increased muscle mass (10). Interestingly, early hypertrophy (≤ 4 weeks) is a consistent finding, whereas significant increases in strength are typically not observed until ≥ 10 weeks of training. This indicates that the traditional paradigm of early strength gains due to neural adaptations followed by muscular hypertrophy is potentially reversed with LL-BFR training (8).

Low Intensity BFR Aerobic Training

Low intensity (LI) BFR aerobic training results in significant improvements in cardiorespiratory endurance (i.e., VO_2^{peak}). These changes have been observed with walk and cycle training at intensities as low as 30% of heart rate reserve, durations of 10-15 minutes at a frequency of 2-3 times a week for 6 weeks (2). The physiological explanation of this enhanced cardiovascular function after aerobic training with BFR training is not well understood. However, a potential reason could be enhanced levels of vascular endothelial growth factor (VEGF) concentrations. VEGF is a protein associated with the formation of new capillaries and improvements in oxygen delivery to exercising skeletal muscle (13).

One of the most interesting findings of BFR aerobic training is significant improvements in muscular strength and hypertrophy using the aforementioned exercise parameters. Although the magnitude of increases in muscular strength and hypertrophy is less than that of resistance training, this is a significant finding considering that conventional "aerobic exercise" typically does not improve muscular strength and hypertrophy.

Additional Considerations

Beyond frequency, intensity, and duration there are other unique considerations that can impact BFR training effectiveness (e.g. cuff width, cuff pressure, continuous versus intermittent pressure application). Cuff pressures are typically prescribed at 40-90% of the individual's arterial occlusion pressure (i.e., relative pressure). However, absolute pressure varies depending on cuff width (4, 5). Leonneke and colleagues applied both wide and narrow cuffs to the lower body to observe total arterial occlusion pressures (AOP) at the distal artery (posterior tibial artery). The results of this study found that the wider cuff had a lower absolute AOP than did the narrow cuff (7). Overall, utilizing the lowest possible pressure to achieve a training response is considered the safest tourniquet BFR training application and it is also advantageous as it is perceptually less stressful to the individual performing the training, which in turn can improve exercise/therapeutic treatment adherence.

FUTURE DIRECTIONS

Although there is a significant amount of research regarding the effects of BFR training on the muscular system, there is less evidence regarding the effects of BFR training on the cardiovascular and skeletal systems. Clinical application of BFR is an exciting frontier, but as previously mentioned, an exaggerated EPR is a concern, especially for at risk populations. To that end, we are initiating an investigation to observe the acute cardiovascular responses (electrocardiography and non-invasive continuous blood pressure) of healthy, middle-aged individuals' during BFR lower extremity (LE) cycling. In addition, we are beginning a study measuring potential changes in walking distance for patients with PAD-related intermittent claudication after 4 weeks of BFR LE cycling. In this case, LE cycling is viewed as a potentially more tolerable activity than walking for individuals with PAD-related intermittent claudication. Under typical training methods we would not expect to see significant changes in walking distance after LI cycle training (i.e., specificity of training). However, the emergence of research regarding BFR training has sparked our interest about the possibility of a cross-over effect from one exercise modality to another. Lastly, there is limited evidence regarding the effects of BFR on musculature proximal to the cuff.

Additional research is needed to examine the impact of BFR training on individuals with musculoskeletal dysfunction, which affects hundreds of millions worldwide and accounts for billions of dollars in direct and indirect costs (17). Fortunately, current evidence supports BFR training as a way to improve muscular strength and hypertrophy for individuals with musculoskeletal dysfunction (e.g., post-operative anterior cruciate ligament reconstruction, pre-sarcopenia, knee osteoarthritis) (5). In addition, there may be benefits to utilizing BFR training with other clinical populations, such as individuals with compromised bone mineral density or those with neurological conditions (e.g., stroke and cerebral palsy).

Overall, BFR training can be viewed as an emerging clinical modality to achieve physiological adaptations for individuals who cannot safely tolerate high muscular tension exercise or those who cannot produce volitional muscle activity. However, continued research is needed to establish parameters for safe application prior to widespread clinical adoption. We encourage

the readers of IJES to learn more about BFR training and we encourage researchers to examine the use of this technique for improving health and fitness in clinical populations.

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