OSTEOPRACTIC

PHYSICAL THERAPY

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Blood Flow Restriction Training: Physiological Mechanisms & Effects in the Management of Osteoporosis

Osteoporosis is a disease characterized by low bone mass, that occurs when the body loses too much bone, makes too little bone, or both.[1,2] As a result, bones suffer microarchitectural deterioration and become weak and frail. [1,2] Osteoporotic bones are more likely to break from falls or even minor incidents.[1,2]

A 2018 survey reported a 12.6% prevalence of osteoporosis and a 43.1% prevalence of low bone mass in the United States.[3] Over the next 4 decades the number of individuals 65 years and older will double in the United States, increasing from over 40 million in 2010 to more than 88 million by 2050.[4] Thus, the burden of osteoporosis and age-related fractures is estimated to increase by almost 50%, growing from 2.1 million in 2005 to over 3 million in 2025.[4,5] The increase in the cumulative cost of osteoporosis is projected to rise from $209 billion (2006-2015) to $228 billion (2016-2025).[5]

WHAT IS BFR TRAINING?

Blood flow restriction (BFR) has its roots in Japan, originating in the 1960s as "Kaatsu training" ("training with pressure").[6,7,8] BFR training utilizes a tourniquet-style cuff to the proximal aspect of the targeted limb in order to occlude venous flow and allow arterial inflow. [8,9] BFR has been called a developing clinical tool which can be used to attain physiological adaptations in populations who may not be able to tolerate or perform high resistance training.[8] BFR can be applied during voluntary resistance exercise (BFR-RE), aerobic exercise (BFR-AE), and passively without exercise (BFR-P). Notably, much of the recent research has focused on the effects of BFR during whole-body vibration and neuromuscular electrical stimulation.[10]

PHYSIOLOGICAL MECHANISMS & EFFECTS of BFR TRAINING

BFR with low mechanical load has been found to achieve significant gains in muscle hypertrophy and strength within a short-term exercise period. [11] Several mechanical changes have been found in the BFR training group, including: elevated Serum GH concentration, increased hematocrit, increased mean VO2 max, increased muscle-bone cross-sectional area (CSA), increased mid-thigh quadriceps and hamstrings muscle CSA, and increased leg press and leg curl 1-Rep Max (RM) strength.[12] It has been proposed that elevated metabolic stress is an essential factor in achieving hypertrophy outcomes; in addition, "enhanced intramuscular metabolic stress triggers muscle adaptations".[11]

Some of the suggested mechanisms for Low-Load BFR (LL-BFR) include a metabolic "overload" which is typically achieved with high resistance training.[13,14] More recently, it has been proposed that the gains related to BFR resistance exercise may be associated with a decrease in the mRNA gene expression of MURF-1, atrogin, and myostatin.[15,16]

The range of physiological mechanisms for BFR's capacity to provoke hypertrophy are likely yet to be fully identified and understood. Notably, two primary physiologic mechanisms for the effects of BFR training have been proposed: 1. biochemical responses that stimulate muscle hypertrophy [17, 18, 19, 20, 21,22,23,24] and 2. heightened muscular functioning due to shifts in fiber type recruitment associated with hypoxia.[24, 25, 26]

The American College of Sports Medicine (ACSM) recommends strength training at 60% of 1RM for novice individuals, 80% 1RM for trained individuals,[27] and 85% 1RM for athletes.[28] Moreover, according to ACSM, resistance training at 80% 1RM achieves the highest gains in muscular strength and endurance.[29]

It is common for patients in rehabilitation settings to not tolerate heavy resistance training due to pain, injury, illness, or safety concerns. BFR with low load training (LL-BFR) has been found to attenuate the effects of sarcopenia along with possible benefits of improving bone health.[30] BFR without exercise can be used in early rehabilitation to diminish atrophy and facilitate strength, along with a progressive effect on muscle size.[30]

A 2011 meta-analysis concluded that low intensity resistance training (without muscular failure) was not sufficient to stimulate muscle hypertrophy.[6] However, it was determined that LL-BFR stimulated significant increases in strength and muscle hypertrophy.[6] Similarly, a 2008 clinical trial found BFR with simple aerobic exercise (i.e., slow walking) was beneficial for muscle hypertrophy without signs of muscle damage, indicating a likely useful tool for a large range of populations including the frail and elderly.[12] Many injuries and illnesses can give way to disuse atrophy and dysfunction. More specifically, patients suffering from disuse atrophy secondary to immobilization, bed rest, unilateral limb unloading, or casting, may benefit from BFR training to attenuate atrophy, recuperate muscle strength, and improve endurance.[31]

SAFETY CONCERNS with BFR TRAINING

The safety of BFR training has been extensively studied. [8,10,12,24,32-49] One proposed risk is excessive muscle damage; however, it turns out BFR has been found to pose minimal risk of muscle damage with similar effects as LL-RT.[8,10,12,24,35,40] Nevertheless, practitioners should be mindful of those patients who may inherently be at higher risk of sarcoidosis.[8,10,12,24,35,40] Thrombus formation (i.e. a blood clot) has been raised as a theoretical risk for BFR training; however, the incidence of adverse events is very low and numerous studies have found no significant changes in blood markers for thrombus formation.[8,10, 37-39, 48]

Cardiovascular responses to BFR training have been extensively analyzed. [8,10,32-34,36,41-

[48] Overwhelmingly, these the large majority of studies found, that when applied properly, BFR is not associated with increased cardiovascular risk. [8,10,32-34,36,41-48] Notably, "proper application" include the cuff size, pressure, duration, rest, and intensity; moreover, these factors should be tailored specifically to each patient and account for their specific health presentation to best avoid adverse events. [8,10,32-34,36,41-48]

A potential side effect of BFR is numbness;[8,38] however, the incidence is low and most likely associated with excessive cuff pressure which can likely be prevented by the selection and application of an appropriate cuff size and pressure.[8,38] Notably, numbness during BFR training has been reported as transient in nature and is most often relieved with adjustments to the cuff application or pressure level.[8,38]

BFR TRAINING in the MANAGEMENT OF OSTEOPOROSIS

Increased muscle strength and muscle mass are associated with increased bone mass and decreased bone fragility.[50,53-57]Therefore, increasing muscle mass and muscle strength may be a valuable tool in the prevention, deceleration, or even reversal of the bone loss associated with osteoporosis.[50, 53-56] It has been recommended that older adults maintain higher muscle strength to slow down the loss of muscle mass and prevent balance impairments.[50] Furthermore, it is beneficial to include activities which improve body balance and proprioception as well and osteogenic exercises to prevent falls and fractures associated with osteoporosis.[50-57]

While research on BFR in older populations is still emerging, the existing literature does support the use of BFR training for muscle strength, muscle hypertrophy and increased functional performance in older populations.[34, 58-62] BFR is an effective training strategy which uses less mechanical stress and produces similar improvements in muscle strength and muscle mass as high resistance training.[34, 58-62] Notably, older adults are commonly found to suffer muscle atrophy and are at a higher risk of falling; therefore, improving muscle strength and muscle mass can produce vital benefits.[58]

Bone mass is determined by two metabolic processes which are highly influenced by the body's functional environment; most notably, loading stimulates bone building and bed rest or inactivity can induce bone loss.[63-71] Numerous studies have found aerobic and anaerobic exercise with BFR can stimulate enhanced bone biomarkers and can therefore be part of the management for improving bone diseases such as osteoporosis.[63,65-71]

DOES BFR STIMULATE BONE PRODUCTION?

There are several physiological mechanisms that may explain why BFR training stimulates bone production. The following are possible mechanisms: improved bone metabolism (as noted by analysis of alkaline phosphate and amino-terminal telopeptides), increased intramedullary pressure and interstitial fluid within the bone, activation of hypoxia-induced transcription factor (HIF), increased expression of vascular endothelial growth factor (VEGF), the formation of micro-blood vessels in bone, increased secretion of growth hormone (GH), enhanced endocrine responses, and improved bone-ALP concentrations indicating increased bone production activity.[24, 63-71]

While many studies have reported the benefit of BFR training for muscle hypertrophy, muscle mass, and bone mass in young and elderly populations,[6-71] the evidence to support BFR training in patients with osteoporosis is emerging. Following the addition of BFR low load training, a 2015 clinical trial found a significant improvement in maximal dynamic strength of women with osteoporosis at 6 and 12 weeks.[72] In postmenopausal women with low bone density, LL-BFR was recently found to be superior to low intensity resistance training for improving muscle strength, lactate concentration, bone formation markers and balance.[73] BFR training appears to be a beneficial intervention for those with osteoporosis, while avoiding the risks associated with heavy resistance training.[70-74]

CONCLUSIONS

In a recent literature review of the varied interventions for osteoporosis, many pharmacological options were presented; notably, bisphosphonates remain the *first line treatment* option for osteoporosis.[75] Within this 13-page review article, it is rather odd that the word 'exercise' is only mentioned in one sentence; however, the conclusion states, "osteoporosis is preventable with proper management of diet, lifestyle and fall prevention interventions".[75]

If medical physicians are to continue pushing bisphosphonates, then it is up to physical therapists to advise patients in physical exercise as the first line of defense for the treatment of osteoporosis and osteopenia. Interestingly, the American College of Sports Medicine reports that physical activity is the only intervention that can potentially increase bone mass/strength and reduce the risk of falling in older populations.[53] BFR training is an emerging intervention in patients with osteoporosis that uses less mechanical stress and produces similar improvements in muscle strength and muscle mass while avoiding the risks associated with high resistance training.

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