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Review Article

Orthopaedics Section

Efficacy of Blood Flow Restriction Training as a Novel Treatment Approach for Musculoskeletal Conditions: A Narrative Review of Existing Literature

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ABSTRACT

Blood Flow Restriction Training (BFRT) helps reduce pain and improve muscle strength and hypertrophy at low intensity by partially occluding arterial inflow and fully restricting venous outflow. This is particularly beneficial for populations contraindicated for High Intensity Resistance Training (HRT). However, there is a lack of research on BFRT that can be used to treat musculoskeletal conditions. The aim of this review is to summarise the current available evidence on the efficacy of BFRT as a novel treatment approach for musculoskeletal conditions, as well as to identify gaps in the literature that may require further research. Databases such as PubMed, MEDLINE, PROSPERO, and PEDro were searched. Articles were included if they described BFRT as a primary intervention. BFRT is an effective treatment approach for musculoskeletal conditions and is indeed a novel strategy. The findings of this review suggest that BFRT can be included in the treatment of conditions like osteoarthritis, low back pain, Anterior Cruciate Ligament (ACL) injury, rheumatoid arthritis, and others. Low load BFRT is an essential treatment option that can be used for musculoskeletal conditions. Individuals contraindicated for high-intensity or high load training can adopt low load BFRT as a primary intervention.

Keywords: Low load training, Musculoskeletal diseases, Pain management, Rehabilitation, Resistance training

INTRODUCTION

BFRT involves the partial or complete restriction of arterial and venous inflow and outflow in active muscles within the human body. This technique utilizes external devices, such as pneumatic tourniquet systems, to exert pressure on the most proximal regions of the upper and lower limbs [1]. To achieve vascular occlusion, various methods are employed, including inflatable cuffs, elastic knee wraps, and automated cuff systems, which have been recently introduced and applied to the proximal parts of the arms and legs [2].

Normally, in strength training, Type IIb fibers are recruited at the termination of the workout and are mainly responsible for muscle hypertrophy. However, when practiced along with blood flow restriction, Type IIb fibers are recruited earlier due to the anaerobic environment, resulting in hypertrophy much sooner than anticipated. The supraphysiological benefits of exercise with BFRT may be partially explained by the proliferation of satellite cells within connective tissue, which are responsible for regeneration and growth [3,4].

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BFR RT, commonly referred to as "BFRT training," translates to "training with inclusion of pressure." Unlike traditional High load Resistance Training (HLRT), BFRT combines low intensity exercise (approximately 20-50% of one-repetition maximum [1-RM]) with an external pressure cuff applied to the working limb [5]. A key distinction between HLRT and BFRT is that HLRT improves muscle strength predominantly through neural adaptations, whereas BFRT primarily induces strength gains through muscle hypertrophy [6].

Existing research has demonstrated that real world BFRT protocols, which often resemble High-Intensity Interval Training (HIIT) and do not require specialised equipment, can yield comparable metabolic benefits to HLRT [7]. The literature suggests that performing multiple sets with a 20% 1-RM load while maintaining continuous BFRT during inter set rest periods produces results similar to those achieved with HLRT [8,9]. Typically, BFRT is implemented at low intensities, ranging from 20% to 40% of 1-RM for resistance training. The literature indicates that a higher occlusion pressure (80%) elicits greater muscle hypertrophy than a moderate occlusion pressure (40%) when exercising at low intensities (20% of 1-RM) [10,11]. Standard resistance training, often prescribed at 60-80% of 1-RM, is recommended for enhancing muscular strength and hypertrophy; however, this level of exertion may be challenging for individuals with contraindications to high load training. BFRT provides a viable alternative by achieving similar benefits with lower intensity through the restriction of arterial inflow and full occlusion of venous outflow [10,12-14].

Given the growing demand for improved rehabilitation and training methods, it is essential to refine traditional approaches and incorporate more effective techniques. This narrative review aims to assess the efficacy of BFRT as an innovative treatment for musculoskeletal conditions, particularly among individuals unable to engage in HLRT.

MATERIALS AND METHODS

This review employed a comprehensive methodological search across ten databases: PubMed, MEDLINE, EMBASE, Cochrane Library, CINAHL, PEDro, Web of Science, Scopus, SPORT Discus, and ClinicalTrials.gov, covering the period from January 2015 to April 2024. To reduce publication bias, grey literature sources such as ProQuest Dissertations, OpenGrey, and the World Health Organisation International Clinical Trials Registry Platform (WHO ICTRP) were also screened, along with the reference lists of included studies. Eligible studies were Randomised Controlled Trials (RCTs) or randomised crossover designs involving participants with musculoskeletal diagnosis, investigating BFRT or RT-BFR, and published in English within the specified date range. Studies were excluded if they focused on systemic conditions affecting the cardiovascular, neurological, gastrointestinal, or excretory systems;

involved combined interventions without independent assessment of BFRT; or were systematic reviews, meta-analyses, narrative reviews, RCT protocols, observational studies, published before 2015, or in languages other than English.

RESULTS

The search yielded a total of 1,682 articles from various databases, as mentioned in the methodology section. Among these, 98 full-text articles were further reviewed based on matched inclusion criteria, and only four articles met the eligibility requirements. All RCT studies utilised different types of BFRT and cuffs, with findings from various clinical conditions listed in [Table/Fig-1] [15-18]. BFRT has emerged as a highly effective modality across a range of musculoskeletal rehabilitation contexts, including conditions such as knee instability, patellofemoral pain, ACL reconstruction, and recovery following distal radial fractures. Clinical evidence consistently demonstrates that BFRT contributes to significant improvements in muscle strength, reductions in pain levels, and enhanced functional outcomes [15-18]. These benefits are particularly notable when BFRT is integrated into low load resistance training (RT) protocols, making it a valuable option for patients who may not tolerate high-intensity exercise due to injury or postoperative limitations.

Moreover, studies suggest that applying higher occlusion pressures, such as 80% of Arterial Occlusion Pressure (AOP), can lead to superior gains in muscle hypertrophy and strength compared to lower pressures or traditional rehabilitation methods [17]. This dose-response relationship highlights the importance of individualised pressure calibration to optimise therapeutic outcomes. Importantly, BFRT has also demonstrated a favourable safety profile. In post-fracture rehabilitation, for instance, BFRT has not been associated with adverse effects on bone healing or coagulation parameters, reinforcing its suitability for use in vulnerable patient populations [18]. Overall, BFRT represents a promising and adaptable strategy for accelerating recovery and restoring function in orthopaedic and sports rehabilitation settings.

DISCUSSION

The available research suggests that varying levels of AOP (ranging from 40% to 80%) combined with low-intensity RT can be beneficial. However, the precise physiological mechanisms through which BFRT enhances muscular strength and hypertrophy remain partially understood. Traditionally, BFRT is believed to involve the partial restriction of arterial blood flow while completely restricting venous outflow in the working muscles. During physical activity, blood flow to active muscles naturally increases. Even though BFRT induces partial arterial occlusion, the affected limb still receives greater blood circulation compared to a resting, non occluded limb. The subsequent accumulation of venous blood and hypoxic conditions trigger physiological responses at both the local and systemic levels, involving endocrine and metabolic pathways [15-18].

The hypoxic environment created by BFRT is thought to promote muscle hypertrophy by stimulating muscle protein synthesis, altering gene expression in muscle satellite cells, increasing muscle fiber recruitment, and enhancing muscular endurance. Additionally, the acidic environment resulting from hypoxia is believed to contribute to these adaptations. Hypoxia, in combination with metabolite accumulation, is suggested to increase the recruitment of muscle fibers and enhance the secretion of Growth Hormone (GH) and Insulin-like Growth Factor-1 (IGF-1), both of which are associated with muscle growth. However, this hormonal hypothesis remains debated, as some studies indicate that exercise-induced increases in GH have a minimal impact on muscle hypertrophy [19].

The accumulation of metabolites during BFRT is also linked to muscle hypertrophy through the generation of Reactive Oxygen Species (ROS), which influence protein metabolism and stimulate satellite cell proliferation. This signalling pathway has been shown to increase following BFRT. In individuals undergoing ACL reconstruction, BFRT at 80% occlusion has been found to significantly improve quadriceps strength and muscle thickness, demonstrating its potential for rehabilitation. Additionally, BFRT has been explored as an alternative to high load training for managing

Authors	Clinical condition of study participants	Study characteristics (study design/ participant	Type of BFRT intervention parameters	Type of cuff used	Procedure	Outcome measurement parameters	Key findings
Brightwell BD et al., 2022 [15]	Patellar instability	Randomised, double-blind, placebo-controlled trial 78 patients with patellar instability	Low load hip and knee exercises with BFR (30% 1-RM)	Sports Rehab Tourniquet™ cuffs (10 cm wide)	BFRT or sham BFRT during rehab therapy (3 sessions/week for 9 week) targeting quadriceps and hip strength; progression monitored via occlusion pressure and performance	Kujala anterior knee pain scale, worst/usual pain, Kinesio phobia, pain catastrophising, knee and hip isometric strength, pain-free flexion angle	BFRT group improved quadriceps strength and knee biomechanics, and reduced cartilage degradation vs sham; patient- reported outcomes improved significantly
Constantinou A et al, 2022 [16]	Patelllo femoral pain	Observer-blinded randomised trial 60 adults (18-40 years) with patellofemoral pain	Low load Resistance Training (RT) with BFR	Pneumatic cuffs	Group 1: Hip and knee exercises at 70% 1-RM; Group 2: same with BFR at 30% 1-RM; supervised thrice weekly for 4 weeks	Muscle strength (isokinetic testing), limb circumference before and after the intervention	Both groups improved pain and strength; BFR group had improved pain scores and greater knee extensor strength at follow-up
Li X et al, 2023 [17]	Post ACL reconstruction patients	Randomised Controlled Trial (RCT) 30 post ACL reconstruction patients	LL-BFRT {30% 1-RM with 70% Arterial Occlusion Pressure (AOP)}	Not specified	Randomised to 3 groups (control, 40% AOP BFR, 80% AOP BFR); all underwent 8 wks of progressive exercise training (2×/week)	Isometric knee strength, functional capacity, dyspnea perception, and physical activity levels	80% AOP BFR achieved the greatest improvement in quadriceps strength, muscle thickness, and knee function vs 40% AOP and control
Fan Y et al., 2023 [18]	Post distal radial fracture (DRF) surgery patients	Prospective randomised controlled study35 post-DRF surgery patients	BFR during post-op rehabilitation for DRF (120 mmHg)	Elastic bandage (5 cm wide, B-Strong brand)	Low-intensity BFR training to one forearm (16 sessions over 8 wks.), contralateral forearm as control; sessions supervised with EMG and individualised progression	Pain (VAS), limb circumference, wrist ROM, isometric strength (grip, wrist flexion, and extension), D-dimer levels, wrist function (Cooney modification), bone healing (RUSS)	BFR group had reduced pain and swelling, greater wrist strength and functionality improvements; no negative effect on bone healing or coagulation

[Table/Fig-1]: Characteristics of the included studies.

patellofemoral pain, showing benefits in both pain reduction and muscle strength improvement [19].

BFRT is applied using inflatable cuffs of varying widths (small, medium, or large) placed on the proximal region of the exercised limb. Before 2008, studies commonly used arbitrary pressure levels for BFRT application, failing to consider individual variations in limb circumference. This limitation potentially altered the physiological effects of the training. Individuals with larger limb circumferences require higher external pressure to achieve the same level of arterial occlusion compared to those with smaller limbs. Using a standardised, non individualised pressure within a study population may result in inconsistent physiological responses to BFRT. To address this, recent research advocates for adjusting BFRT pressure based on a percentage of AOP, ensuring a more personalised and effective approach [12].

This review highlights that BFRT, when combined with low load RT, can serve as an alternative to high-intensity resistance training (HIRT) for patients with musculoskeletal conditions. However, it also reveals a lack of qualitative research on BFRT as a physiotherapy intervention for these conditions. The strengths of this review include the broad scope of the literature search and the screening of studies across various musculoskeletal conditions. This narrative review reinforces the potential benefits of BFRT as a treatment modality for musculoskeletal conditions, with or without conventional physiotherapy interventions.

However, the scope of this review was limited to assessing the potential benefits of BFRT within musculoskeletal conditions. Only English language, peer-reviewed journal articles were included, which may have led to the exclusion of some relevant evidence, potentially impacting the comprehensiveness of the findings. Additionally, studies were not categorised based on study design, which may affect the clarity of the interpretations. Future research should explore the efficacy of BFRT in other health domains, including cardiorespiratory, neurological, paediatric, and geriatric populations.

CONCLUSION(S)

BFRT is an effective and emerging treatment approach for musculoskeletal conditions. The studies reviewed vary significantly in their methodologies, research objectives, and participant demographics. This narrative review suggests that BFRT can be integrated into the management of conditions such as osteoarthritis, low back pain, ACL injuries, rheumatoid arthritis, and other musculoskeletal disorders, both in preoperative and postoperative rehabilitation.

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