

Blood Flow Restriction Training—An Overview and Implication in New Generation Physical Therapy: A Narrative Review

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Blood Flow Restriction Training (BFRT) is a novel strengthening technique utilitarian in many conditions. But there is lack of exploration on this clinical intervention. The training can prove to be a boon in many conditions such as muscle weakness, degenerative among others. It can serve to be an essential treatment in prevention of disuse atrophy occurring on the initial days of bed-rest on post surgical patients and improve circulation. BFRT with aerobic activities can improve cardiovascular fitness and holistically help in rehabilitation. The electronic databases such as PubMed, ScienceDirect, Scopus and Google Scholars were reviewed including the reference lists to retrieve relevant information regarding the topic. The result of the review states that BFRT is a novel strength training program that has not been explored in India but is very effective, less expensive and innovative way of rehabilitation. The utility of BFRT is evident in post-operative disuse atrophy in the initial days of bed-rest. The evidence depict that BFRT is a very effective training modality that can efficiently improve the muscle function, strength and mass.

Key Words: Blood flow restriction training, Physical therapy, Strengthening technique, Musculoskeletal conditions, Neurological conditions, Post-surgery

INTRODUCTION

Muscle strength and cross-sectional area are inter-linked and are primary components of muscle conditioning. The exclusive property of the skeletal muscle is that it acclimatizes with change in mechanical domain. Muscle Hypertrophy

(MH) is a consequence of the balance of the protein synthesis. When the protein synthesis exceeds the protein breakdown and a net positive protein balance is maintained over a period of time, the size of the muscle increases [1]. Hormonal, mechanical and metabolic processes are involved in inducing MH by the resistance training [2]. Hypertrophy can be further classified into two types: sarcoplasmic hypertrophy and myo-fibrillar hypertrophy. Various principles were put forward to adequately train the muscle like the Overload Principle and the Principle of Progression. Resistance Training is the intervention of choice to promote muscle hypertrophy used mainly by the body-builders and recreational strength trainees. The American College of Sports Medicine (ACSM) prescribes that for muscle strengthening optimally resistance exercise training with weights of 60-100 per cent

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of 1 Resistance Maximum (RM) shall be used over a period of time with customized frequency, intensity, time and type [2]. Mechanical stress adaptation is the muscle promotes MH while immobilization rapidly leads to decrease in muscle size i.e., atrophy.

Blood Flow Restriction Training (BFRT) is defined as the training in which there is a partial vascular occlusion induced in the most proximal muscles by the help of pneumatic tourniquet system. It emanated in Japan, by Dr. Yoshiaki Sato where it was popularly known as ‘KAATSU Training’ [3] denoting ‘adding pressure to training’. It became popular and effective in athletic population as well as in healthy and elderly individuals and in rehabilitative medicine. It works on the principle of peripheral vascular occlusion created by the help of pneumatic compression that can be induced by theraband, blood pressure cuffs or tourniquet [3].

HOW DOES BFRT WORK?

The muscle fibres are basically of 3 types, namely Type I, Type IIa and Type IIb. The Type I are slow twitch fibres require an aerobic environment and get recruited during initial phases of exercise although they fatigue easily. They are used during endurance activities. The type IIa fibres are fast twitch fibres requiring anaerobic environment and come into action on moderate work out. Their fatigue rate is moderate. While type IIb fibres are fast twitch glycolytic muscle fibres recruited in short distance, high intensity activity. Normally, in strength training the Type IIb fibres are recruited at termination of the work-out and are mainly responsible for the muscle hypertrophy. But when practiced along with blood flow restriction the Type IIb fibres get early recruited due to an anaerobic environment and result in hypertrophy much earlier than anticipated. The supra-physiological benefits of exercise with BFR may be partially explained by the proliferation of satellite cells within connective tissue responsible for regeneration and growth [4]. Hence, BFRT is a very effective and efficient way of strength training in both the population, healthy and diseased.

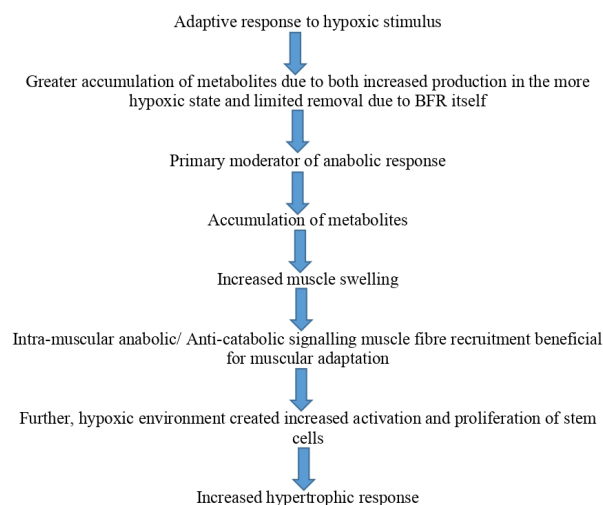


Fig. 1. Physiological response of BFRT.

BODILY RESPONSES of BFRT

1. Physiological Response of BFRT

There are various physiological responses proposed to prove the mechanism of action of BFRT namely [5],

- a. Fibre recruitment
- b. Metabolic response
- c. Cellular swelling
- d. Anabolic hormone response
- e. mTOR pathway (activation of protein synthesis)

The exact mechanism is yet to be discovered although the Fibre recruitment model is most acceptable explained in Fig 1.

2. Hormonal Response of BFRT

Blood flow restriction creates an anaerobic environment resulting in decreased pH within the blood. It further triggers the sympathetic nervous system peripheral mechanoreceptors (III and IV efferents) to send signals to the hypothalamus. Hypothalamus sends signals to the anterior pituitary gland to release Growth Hormone (GH). Activation of the GH and IGF1 takes place enhancing the strength and power in the muscles via protein synthesis. The protein synthesis in the muscle helps in hypertrophy as shown in Fig. 2.

3. Tourniquet System in BFRT

Different types of cuffs can be used to practice BFRT like tourniquet, inflatable cuff, elastic wraps, therabands or

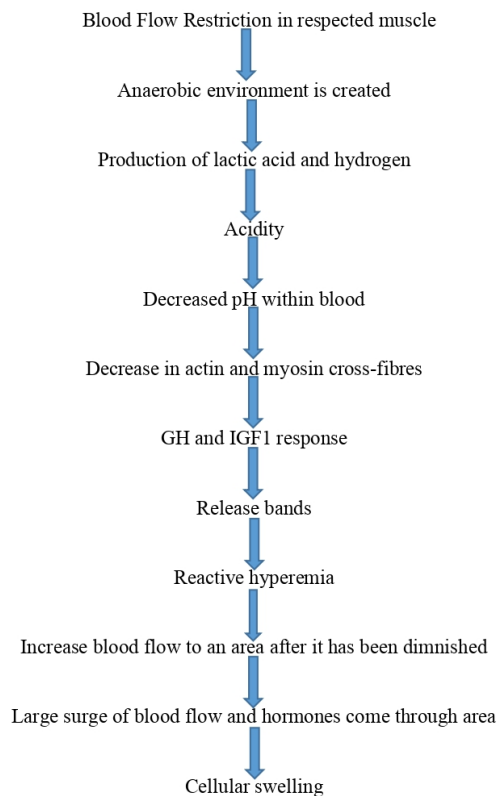


Fig. 2. Hormonal response of BFRT.

Blood Pressure (BP) cuffs (mostly used). The BP cuff is most widely used as it is cheap and easily accessible. Width of the cuff plays a vital role; they may be narrow or wide cuffs according to the area of application. Evidently, the width range for arm is 3-12 cm and for legs is 4.5-18.5 cm [6]. The pressure exerted by the cuff on the soft-tissue leading to occlusion varies from person-to-person and area of application as they have different adaptive implications. Researchers state that wider cuffs restrict blood flow at arteries at lower pressure. But the major short-coming of wider cuffs are that they restrict range of motion in participants more on upper extremity resulting in negative impact on the overall training. The Arterial Occlusion Pressure (AOP) is directly proportional to the circumference of the limb. When opting for lower limb where the bulk of the muscle is more, higher occlusion pressure is required, hence wide cuffs are used preferably. For arms, narrow cuffs are more preferable. The AOP is assigned according to person [6]. Literature estimates a pressure greater than the diastolic brachial blood pressure is the ideal compressive pressure.

One of the most specific things about the BFRT protocol is that whether at rest or during the exercise the cuff is kept inflated. It's recommended to assess the individual Limb Occlusion Pressure (LOP), in other words the minimal pressure required to occlude arterial blood flow before the start of training as to perform BFRT with 40-80 per cent of LOP [6].

BFRT in VARIOUS DOMAINS

BFRT Training can be practiced depending on different conditions as shown in Table 1 and 2. The training protocol depends on three principles namely the Principle of Progression, the Overload Principle and Principle of Specificity. 8-12 repetitions are recommended for each large muscle group for about 8-10 exercises and 10-15 repetition for elderly [7].

Recent literature about depicts that BFRT has been applied in combination with various modalities such as Neuromuscular Electrical Stimulation (NMES) and vibration techniques as depicted in Table 3.

BFRT in the recent years have been a highlight for its implications in combination with strength training used in patients for limb salvage and volumetric muscle loss in service members. Musculoskeletal conditions (MSK) are the most prevalent conditions clinically responsible for Muscular Weakness (MW) [8]. These conditions irrespective of being acute or chronic resulting from immobilization due to fractures or ligament tears may lead to muscle atrophy.

1. BFRT in ACL Reconstruction

Apart from the healthy population suffering from conditions, there are athletic population that are more prone to ACL tears or menisci tears, which may be life turning as they may have a hard time going back to vigorous training post reconstructive surgery. There is atrophy of muscles around the knee; especially knee extensor muscle accompanied by reduced muscle strength is early post-operative period. Prevention of muscle atrophy and early recovery of muscle strength have been reported to be associated with an early return to athletic activities [9].

Table 1. Studies depicting various conditions and effects with application of BFRT

Study aim	Author	Year	Participants	Findings	Conclusion
To induce strength gain and hypertrophy in combination of BFR and low-load (LL) exercises.	Natsume et al [14]	2015	Untrained young males (n = 8)	Increase in muscle thickness (+3.9%) after 2 weeks of training. There is a maximal knee extension strength isometric (+14.2%), isokinetic (+7.0%) at voluntary contraction.	NMES in combination with BFR results in an increase in muscle hypertrophy.
To determine the progress in muscle strength with moderate BFR and LL training in ACL reconstruction.	Ohta et al [9]	2003	Patients post- ACL reconstruction surgery trained with BFR (n = 22) Control group (n = 22)	Significant increase.	Low-load resistance training with moderate BFR during early days of rehabilitation promotes muscle strength and hypertrophy.
To identify the change in Cross-Sectional Area (CSA) of knee extensors following disuse atrophy after ACL reconstruction surgery.	Takarada et al [11]	2000	Patients with ACL reconstruction (n = 8)	Post-occlusion there was 9.4 ± 1.6% and 9.2 ± 2.6% increase in the CSA.	Occlusion of the proximal thigh helps to regain knee extensor strength and function. There was a significant increase in the cross-sectional area of the muscle.
To determine the role of BFR on the Quadriceps muscle strength on elderly patients with knee Osteoarthritis (OA).	Segal et al [10]	2015	Patients with knee OA (n = 22) Control group (n = 22)	There was increase in leg press.	There was no significant increase in knee extensor strength for elderly patients.
To compare the strength of quadriceps muscle with and without BFR training on patella-femoral pain.	Giles et al [15]	2017	Patients trained with BFR (n = 35) Without BFR (n = 34)	There was a significant decrease in pain of about 93% with application of BFRT.	BFRT produced more improvement in pain and contributed in quadriceps strength.

Table 2. Represents the application of BFRT

No.	Application	Dosage	Pressure	Usage	Reference
1.	Cast immobilization	5 sets of 5 minutes with 3 minutes of free flow between sets	50 mm Hg	Prevents disuse weakness induces chronic unloading.	[12]
2.	Post-operative disuse atrophy	5 sets of 5 minutes with 3 minutes of free flow between sets	180-260 mm Hg	Prevents post-operative disuse atrophy in ACL surgical reconstruction.	[6]
3.	Bed-rest/immobilization	5 minutes cuff inflated, 3 minutes cuff deflated	50 mm Hg	Prevents muscle atrophy of the knee extensors and flexors.	[6]
4.	Upper-limb strength training	3 sets of 10 repetitions at 75% of 1RM	160-180 mm Hg	Promotes muscle hypertrophy.	[4]

2. BFRT in Knee Osteoarthritis (OA)

Degenerative effects like loss of strength, reduced function, loss of muscle mass and difficulty in Quality of Life (QoL) seen in Osteoarthritis (OA) [10]. When correlated

with increasing age of population more than 250 million adults globally are affected. MW is the most common complain which is seen not only in the affected population but even in the healthy population, mostly in elderly population. The etiology behind it may be sarcopenia (loss of physical

Table 3. Various types of BFRT exercises for muscle strength training

Training	Protocol	Prescribed exercise
BFR-RE	BFR-RE in combination with dynamic exercises (Isometric, Isotonic, Iso-kinetic).	Frequency 2-3 times a week (> 3 weeks) Intensity 1-2 times/day Repetition 75 reps (30*15*15*15) Sets 2-4 sets Set pressure 40-80% AOP Restriction time 5-10 min/exercise Rest between sets 30-60 seconds
BFR-Aerobic exercise	BFR in combination with walking and cycling.	Frequency 2-3 times a week (> 3 weeks) Intensity < 50% VO ₂ max/ HRR Set pressure 40-80 % AOP Restriction time 5-20 min/exercise
Passive-BFR	5 minutes of restriction followed by 3 minutes of reperfusion between 3-4 sets.	Frequency 1-2 times/day Sets 3-5 sets Restriction time 5 minutes Rest between sets 3-5 minutes Set pressure 70-100% AOP

BFR: Blood Flow Restriction, BFR-RT: Blood Flow Restriction-Resistance Exercise.

function due to decrease in muscle mass, strength, vascular function due to decrease bone mineral density that occurs with ageing) [10].

3. BFRT in Rheumatoid Arthritis (RA)

Auto-immune disease such as Rheumatoid Arthritis (RA) result in reduced muscle strength and mass when progressively loaded and patients suffering have a poor QoL. Due to chronic inflammation, physiologically there is acceleration in cellular catabolism which further lead to loss of muscle mass and dysfunction in muscular activity [5].

4. BFRT in post-operative patients

In post-operative patient rehabilitation BFRT plays a crucial role. Literature has proven that post-fracture cast removal application of BFRT can alone augment the recovery of patient when used in an intermittent way (5 sets of 5 minutes inflation of cuff and 3 minutes deflation of cuff) [11]. To attenuate disuse atrophy during periods of chronic muscular unloading BFRT can be applied [12]. An aggressive approach for early rehabilitation is to perform BFRT twice daily for faster recovery.

5. BFRT in Diabetes Mellitus (DM) patients

DM is a collection of a variety of other pathologies one of the major symptom may be vascular complications, mi-

tochondrial function alteration in several tissues, including skeletal muscles corresponding to MW [13]. Preservation of muscle function is essential for metabolic health especially in individuals with Type 2 DM, a group of patients who are affected by increased cardiovascular risk and exacerbated progression of sarcopenia because diminished muscle mass and function are reduced glucose disposal capacity. Hence, exercise became the only treatment option available for treating the root cause [4].

DISCUSSION

This review throws light on the emerging importance of BFRT that has not been explored much. The utility of BFRT has been depicted in some recent studies. BFRT is a strength training program that helps patients to gain strength and attain hypertrophy of the muscles. Even in cases of amputations, BFRT may play a significant role to reach up to the level of prosthesis for better quality of life. The muscle strength and muscle cross-section are inter-linked and both play a crucial role in muscle reconditioning. The atrophy of muscles majorly depends on the loading and un-loading. Resistance training is the intervention of choice solely. The guidelines of ACSM states that for optimum strength training a weight of 70 per cent of 1 RM is required to note hypertrophy. Although new researches on the

same have concluded that instead of the conservative intervention BFRT is enough to observe noticeable hypertrophy in all the population, healthy or athletic or bed-ridden patients.

CONCLUSION

The author after analyzing majority of the literature available concluded that under proper assessment and guidance BFRT may prove to be game-changer in clinical settings. It may be used under phases in ICU settings. BFRT has various implications and is a novel strength training protocol creating windows for a new generation of physical therapy.

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