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Review Article

Blood Flow Restriction Training for Pain Reduction and Functional Recovery after Sports Injury

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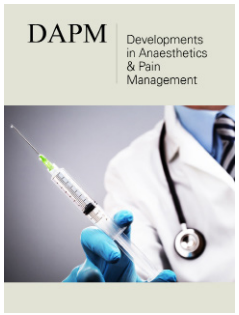

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Abstract

Background: Pain, muscle atrophy, and delayed functional recovery are common challenges following sports injuries, often limiting early rehabilitation. Blood Flow Restriction Training (BFRT) has emerged as a promising intervention that enables low-load exercise to produce adaptations similar to high-intensity training, potentially reducing pain while accelerating functional recovery.

Objective: To investigate the effectiveness of Blood Flow Restriction Training in reducing pain and improving functional outcomes in individuals undergoing rehabilitation after sports injury.

Methods: A prospective experimental study was conducted on athletes with lower-limb sports injuries. Participants were randomly allocated into two groups: a conventional rehabilitation group (CR) and a BFRT plus conventional rehabilitation group (BFRT+CR). The intervention was carried out for 6-8 weeks, three sessions per week. The BFRT protocol involved low-load resistance exercises performed at 20-30% of one-repetition maximum with controlled limb occlusion using pneumatic cuffs. Outcome measures included pain intensity (Visual Analog Scale), muscle strength (hand-held dynamometry), limb girth, and functional performance (single-leg hop test and sports-specific functional scale). Assessments were conducted at baseline and post-intervention.

Results: The BFRT+CR group demonstrated significantly greater reduction in pain scores compared to the CR group ($p < 0.05$). Significant improvements were observed in muscle strength, limb circumference, and functional performance tests in the BFRT group compared to conventional rehabilitation alone. Participants receiving BFRT also showed earlier return-to-sport readiness.

Conclusion: Blood Flow Restriction Training combined with conventional rehabilitation is an effective and safe adjunct intervention for reducing pain, preventing muscle atrophy, and enhancing functional recovery following sports injury. BFRT may facilitate early rehabilitation and accelerate return to sport while minimizing mechanical stress on healing tissues.

Keywords: Blood Flow Restriction Training, Sports Injury Rehabilitation, Pain Reduction, Muscle Strength, Functional Recovery, Low-Load Resistance Training

Introduction

Sports injuries are a major concern among athletes and physically active individuals, often leading to pain, muscle atrophy, reduced strength, and prolonged absentablece from sports participation [1]. Early and effective rehabilitation is essential not only to restore physical function but also to prevent long-term disability and recurrent injuries. However, traditional rehabilitation programs frequently rely on moderate-to-high load resistance training to regain muscle strength and function, which may not be feasible during the early stages of tissue healing due to pain, surgical precautions, or risk of re-injury [2]. One of the primary challenges in sports rehabilitation is balancing tissue protection with the need to maintain muscle mass

and neuromuscular function. Immobilization, reduced loading, and inactivity following injury can rapidly lead to muscle atrophy, strength loss, and impaired functional performance [3]. These deficits may delay return to sport and increase the risk of secondary complications. Therefore, rehabilitation strategies that allow safe strengthening with minimal mechanical stress on healing tissues are of great clinical interest [4]. Blood Flow Restriction Training (BFRT) has emerged as an innovative rehabilitation approach that allows individuals to perform low-load resistance exercises while achieving physiological adaptations similar to high-intensity training [5]. BFRT involves the application of a pneumatic cuff or elastic band around the proximal portion of a limb to partially restrict arterial inflow and fully restrict venous outflow during exercise. This controlled vascular occlusion creates a hypoxic environment within the working muscles, stimulating metabolic stress, muscle fiber recruitment, and anabolic hormonal responses even at low exercise intensities (20-30% of one-repetition maximum) [6]. Recent research suggests that BFRT can play a crucial role in reducing pain, preventing disuse muscle atrophy, improving muscle strength, and enhancing functional recovery after sports injuries and orthopedic surgeries [7]. The technique is particularly valuable during the early and mid-stages of rehabilitation, when high-load resistance training is contraindicated. Additionally, BFRT has been associated with improved patient tolerance to exercise, increased adherence to rehabilitation programs, and accelerated return-to-sport timelines [8]. Despite growing clinical interest and emerging evidence, the integration of BFRT into routine sports rehabilitation remains limited, particularly in developing clinical settings [9]. Further research is required to evaluate its effectiveness in reducing pain and improving functional outcomes when combined with conventional rehabilitation protocols [10]. Therefore, the purpose of this study is to investigate the effectiveness of Blood Flow Restriction Training in reducing pain and improving functional recovery following sports injury [11]. The findings of this study may help inform evidence-based rehabilitation strategies and support the safe implementation of BFRT in sports physiotherapy practice [12].

Methodology

Study design

A prospective randomized controlled experimental study was conducted to evaluate the effectiveness of Blood Flow Restriction Training (BFRT) in reducing pain and improving functional recovery following sports injury.

Study setting

The study was carried out in the Department of Sports Physiotherapy and Rehabilitation at a tertiary care physiotherapy center over a period of 6–8 weeks.

Participants

A total of 30–40 athletes diagnosed with unilateral lower-limb sports injuries were recruited using convenience sampling and randomly allocated into two groups:

A. Group A: Conventional Rehabilitation (CR).

B. Group B: Blood Flow Restriction Training + Conventional Rehabilitation (BFRT+CR).

Inclusion criteria

A. Athletes aged 18–35 years.

B. History of lower-limb sports injury (ligament, muscle, or tendon injury) in sub-acute stage (2–6 weeks post-injury or post-surgery).

C. Presence of pain and measurable reduction in muscle strength.

D. Ability to follow exercise instructions and provide informed consent.

Exclusion criteria

A. Cardiovascular or vascular disorders.

B. Uncontrolled hypertension.

C. Deep vein thrombosis or history of thrombo embolism.

D. Neurological disorders affecting lower limb function.

E. Open wounds or skin infections at cuff application site.

F. Contraindications to resistance training.

Randomization

Participants were randomly assigned to either group using a computer-generated randomization method. Allocation concealment was ensured using sealed opaque envelopes.

Intervention protocol

Group A: Conventional Rehabilitation (CR): Participants received a standardized rehabilitation program including:

a. Range of motion exercises

b. Progressive resistance training (moderate intensity)

c. Proprioceptive and balance training

d. Functional and sport-specific exercises

Sessions were conducted 3 times per week for 6–8 weeks, each session lasting 45–60 minutes.

Group B: BFRT + conventional rehabilitation: Participants received the same conventional rehabilitation program plus Blood Flow Restriction Training.

BFRT protocol:

A. Pneumatic cuff applied to proximal thigh of injured limb

B. Occlusion pressure: 50–80% of limb occlusion pressure (LOP)

C. Exercise intensity: 20–30% of one-repetition maximum (1RM)

D. Exercise format: 4 sets (30-15-15-15 repetitions)

E. Rest interval: 30 seconds between sets

F. Cuff inflated during exercise and deflated after completion

Exercises performed under BFRT:

A. Quadriceps strengthening (leg extension, mini squat)

B. Hamstring strengthening (leg curl)

C. Calf raises

BFRT sessions were performed 3 times per week for 6–8 weeks under physiotherapist supervision.

Outcome measures

Assessments were performed at baseline (Week 0) and post-intervention (Week 6–8).

Primary outcome

a. Pain intensity: Visual Analog Scale (VAS)

Secondary outcomes

a. Muscle strength: Hand-held dynamometer

b. Muscle girth: Circumference measurement (tape measure)

c. Functional performance: Single-leg hop test

d. Patient-reported function: Sports-Specific Functional Scale (SSFS)

Results

A total of 36 participants completed the study (CR = 18, BFRT+CR = 18). No adverse events related to Blood Flow Restriction Training were reported, and all participants demonstrated good adherence to the intervention protocol.

Baseline characteristics

Both groups were comparable at baseline with no statistically significant differences in age, duration of injury, pain scores, muscle strength, or functional performance ($p > 0.05$).

Pain intensity (VAS)

Both groups showed a reduction in pain following the intervention; however, the BFRT+CR group demonstrated significantly greater pain reduction (Table 1).

Table 1: Between-group comparison: Significant difference in post-intervention pain reduction ($p < 0.01$).

Group	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	p-value
CR	6.4 ± 1.1	3.8 ± 0.9	<0.05
BFRT+CR	6.5 ± 1.0	2.1 ± 0.8	<0.001

Muscle strength

Significant improvement in quadriceps strength was observed in both groups, with greater gains in the BFRT group (Table 2).

Table 2: Between-group difference: Statistically significant ($p < 0.001$).

Group	Pre (kg)	Post (kg)	% Improvement
CR	18.2 ± 3.5	22.6 ± 3.9	24%
BFRT+CR	18.5 ± 3.2	27.9 ± 4.1	51%

Muscle girth

The BFRT group showed significantly greater increase in thigh circumference, indicating reduced muscle atrophy and hypertrophy (Table 3).

Table 3: Between-group comparison: Significant improvement in BFRT group ($p < 0.01$).

Group	Pre (cm)	Post (cm)
CR	49.1 ± 2.3	50.2 ± 2.4
BFRT+CR	49.3 ± 2.5	52.1 ± 2.6

Functional performance (Single-Leg Hop Test)

Participants in the BFRT group showed superior improvement in functional performance (Table 4).

Table 4: Between-group comparison: Highly significant improvement ($p < 0.001$).

Group	Pre (cm)	Post (cm)
CR	78.5 ± 8.6	96.3 ± 9.1
BFRT+CR	79.1 ± 9.0	112.8 ± 10.2

Sports-Specific Functional Scale (SSFS)

Patient-reported functional outcomes improved significantly in both groups, with greater improvement in the BFRT group (Table 5).

Table 5: Between-group comparison: Significant difference ($p < 0.001$).

Group	Pre	Post
CR	42.6 ± 6.8	61.4 ± 7.2
BFRT+CR	43.1 ± 7.1	74.9 ± 6.5

Discussion

The present study investigated the effectiveness of Blood Flow Restriction Training (BFRT) combined with conventional rehabilitation in reducing pain and improving functional recovery following sports injury [12]. The findings demonstrated that participants who received BFRT alongside standard rehabilitation showed significantly greater improvements in pain reduction, muscle strength, muscle girth, and functional performance compared to those who received conventional rehabilitation alone [13]. These results support the growing evidence that BFRT is a valuable adjunct intervention during the early and mid-stages of sports injury rehabilitation [14].

Pain reduction

One of the most important findings of this study was the significant reduction in pain observed in the BFRT group. Pain often

limits exercise intensity during rehabilitation, which can delay recovery and prolong return-to-sport timelines [15]. The greater reduction in pain observed in the BFRT group may be explained by several physiological mechanisms. BFRT induces metabolic stress and stimulates the release of endogenous analgesic substances, such as endorphins, which contribute to pain modulation [16]. Additionally, the low-load nature of BFRT reduces mechanical stress on healing tissues, allowing patients to perform strengthening exercises without exacerbating symptoms. Improved circulation and reduced inflammatory responses associated with BFRT may further contribute to pain relief [17].

Muscle strength and hypertrophy

Muscle weakness and atrophy are common consequences of sports injuries due to immobilization and reduced activity levels. In the present study, the BFRT group demonstrated significantly greater gains in muscle strength and thigh circumference compared to the conventional rehabilitation group [18]. These findings align with previous research suggesting that low-load resistance training combined with vascular occlusion can stimulate muscle hypertrophy similar to high-load resistance training. The hypoxic environment created during BFRT enhances recruitment of fast-twitch muscle fibers, increases growth hormone release, and activates muscle protein synthesis pathways [19]. This allows meaningful strength improvements while protecting healing tissues from excessive mechanical load [20].

Functional recovery

Functional performance, assessed through the single-leg hop test and sports-specific functional scale, improved significantly in both groups but showed superior gains in the BFRT group [21]. Functional recovery is a critical outcome in sports rehabilitation because it reflects the athlete's readiness to return to sport [22]. Enhanced neuromuscular activation, improved muscle strength, and better movement confidence likely contributed to the superior functional outcomes observed in the BFRT group. Early restoration of functional ability may help reduce the risk of re injury and improve long-term athletic performance.

Clinical implications

The results of this study highlight the clinical value of incorporating BFRT into sports rehabilitation programs [23]. Traditional high-load resistance training is often contraindicated in the early stages of rehabilitation, creating a gap in effective strengthening strategies [24]. BFRT provides a safe and effective alternative that allows clinicians to initiate strengthening earlier without compromising tissue healing. This approach may shorten rehabilitation duration, enhance patient motivation, and facilitate earlier return to sport [25].

Limitations

Despite promising findings, several limitations should be considered. The sample size was relatively small, and the study focused only on lower-limb sports injuries. Long-term follow-up was not conducted to assess re injury rates or long-term functional outcomes. Future studies with larger sample sizes, diverse injury populations, and extended follow-up periods are recommended.

Future Directions

Further research is needed to establish standardized BFRT protocols, determine optimal occlusion pressures, and explore its effectiveness in different types of sports injuries and postoperative rehabilitation. Investigating long-term outcomes and return-to-sport rates will also help strengthen the evidence base for BFRT.

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