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The Effect of Blood Flow Restriction (BFR) on Muscle Activation and Hypertrophy in Individuals with Chronic Ankle Instability (CAI): A Critically Appraised Topic

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Abstract

Clinical Scenario: Lateral ankle sprains (LAS) are among sports' most common musculoskeletal injuries and frequently lead to chronic ankle instability (CAI).[1-3] Blood flow restriction (BFR) used in conjunction with therapeutic exercises improves musculature's overall strength, endurance, and hypertrophy.[1,4-7] Current literature suggests that using BFR to improve muscular strength, endurance, and activation positively affects recovery from soft tissue injuries in the knee. BFR has been studied following anterior cruciate ligament tears, Achilles ruptures, and patellofemoral pain.[1,8,9] However, the research on BFR use in CAI patients is limited. ***Focused Clinical Question:*** What is the effect of blood flow restriction training on muscle strength and activation in individuals with chronic ankle instability? ***Summary of Key Findings:*** All three analyzed articles aligned with the current published BFR literature and found increases in muscular activation, hypertrophy, and strength in individuals with CAI.[1,11,12] The cause for these improvements is still unknown, although some suggest that increased muscular activation observed during BFR treatment may account for the increase in strength and hypertrophy.[11] Two of the articles found an increase in muscular activation during isometric contractions of dorsiflexion and eversion, as well as the vastus lateralis and soleus during dynamic stabilization exercises.[1,12] There is limited evidence on the chronic benefit of the observed improvements, but current theories suggest chronic adaptations can be made with prolonged BFR therapy.[1] ***Clinical Bottom Line:*** Increases in muscular activation, strength, and hypertrophy can be observed in BFR therapy for individuals with CAI and may be beneficial in a clinical setting in addition to traditional rehabilitation exercises.[1,8,10] The combination of BFR training and therapeutic exercise is theorized to have chronic muscular adaptations that may benefit the patient.[1] ***Strength of Recommendation:*** Grade A evidence shows statistically significant results supporting the use of BFR in treating CAI.

Clinical Scenario

Lateral ankle sprains (LAS) are among the most common musculoskeletal injuries during physical activity and sports.[1-3] Approximately 40% of individuals suffering from a LAS may progress to suffering from chronic ankle instability (CAI).[1,8,13] CAI can be described as recurring ankle sprains, self-reports of the ankle joint "giving way," and feeling "unstable," and prolonged symptoms following the initial LAS, such as pain weakness, decreased ankle ROM, and self-reported reduced functionality.[4,14,15] There is a current push to find supplemental treatment options for individuals with CAI to improve their overall quality of life and functionality.[1]

Blood flow restriction (BFR) is a possible additional treatment option that has been shown to increase muscular strength, endurance, and hypertrophy when used in conjunction with therapeutic exercise.[1,4-7] BFR accomplishes these gains by limiting blood delivery to the muscles being targeted for treatment with a tourniquet cuff that is applied and used during the performance of submaximal exercises and produces more strength gains than submaximal exercises alone.[1,4-8] The use of BFR results in local hypoxia, metabolic stress, and recruitment of type 2 muscle fibers which promotes strength and hypertrophy gains.[1,8,9,16-17]

In the current published literature, many studies have been conducted on the effectiveness of BFR training with rehabilitation programs on the treatment of postoperative anterior cruciate ligament (ACL) reconstruction, knee osteoarthritis, patellofemoral pain, postoperative knee arthroscopy, and Achilles tendon reconstructions.[1,8-9] There are limited published articles exploring the effectiveness of BFR training with therapeutic exercises. Therefore, this critically appraised topic sought to analyze the effect of blood flow restriction training on muscular activation and hypertrophy in individuals with chronic ankle instability.

Methods

A computerized search was completed in November 2022 (Figure 1).

- Terms used to guide Search Strategy:
  - **Patient/population group:** healthy individuals with chronic ankle instability OR CAI
  - **Intervention:** Blood flow restriction (OR BFR)
  - **Comparison:** conventional rehabilitation OR no treatment
  - **Outcome:** muscle activation OR hypertrophy
- Sources of Evidence Searched
  - PubMed Central, Google Scholar, and Cochrane Library
- Inclusion Criteria
  - Limited to studies that were conducted with individuals with CAI
  - Written in English
  - Published in the last ten years
  - Includes human subjects
  - Peer reviewed
- Exclusion Criteria
  - Additional treatment in addition to BFR
  - Comparison studies
  - Animal trials or research

Figure 1. Search Strategy

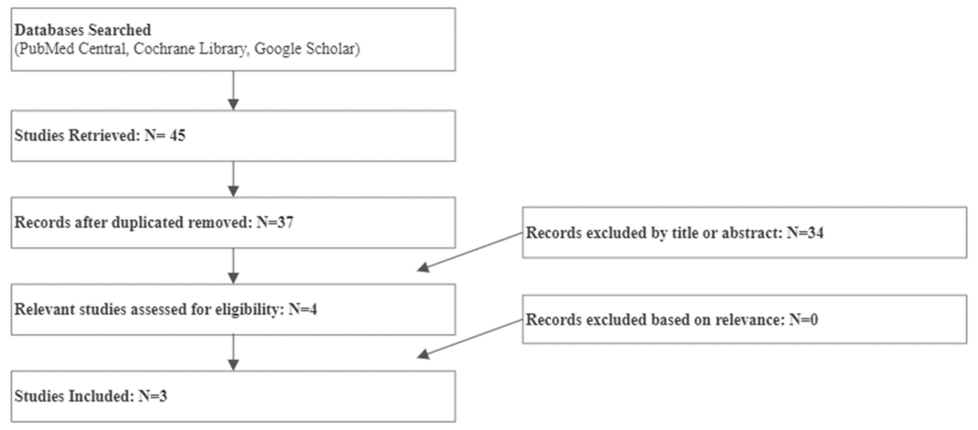

Table 1. PEDro Score Results

	Burkhardt et. al.[10]	Killinger et. al.[1]	Werasirirat et. al.[10]
Eligibility criteria specified (yes/no; not included in overall score)	Yes	Yes	Yes
Subjects randomly allocated to groups (yes/no)	Yes	Yes	Yes
Allocation was concealed (yes/no)	No	No	Unclear
Groups similar at baseline (yes/no)	Yes	Yes	Yes
Subjects were blinded to group (yes/no)	No	No	Yes
Therapists who administered therapy were blinded (yes/no)	No	No	No
Assessors were blinded (yes/no)	No	No	No
Minimum 85% follow-up (yes/no)	Yes	Yes	Yes
Intent to treat analysis for at least 1 key variable (yes/no)	Yes	Yes	Yes
Results of statistical analysis between groups reported (yes/no)	Yes	Yes	Yes
Point measurements and validity reported (yes/no)	Yes	Yes	Yes
Overall Score (out of 10)	6/10	6/10	7/10

Table 2: Characteristics of the Three Selected Studies

Author	Burkhardt et al.[10]	Killinger et al.[1]	Werasirirat et al.[8]
Title	Effects of blood flow restriction on muscle activation during dynamic balance exercises in individuals with chronic ankle instability	The effects of blood flow restriction on muscle activation and hypoxia in individuals with chronic ankle instability	Effect of supervised rehabilitation combined with blood flow restriction training in athletes with chronic ankle instability: a randomized placebo-controlled trial
Study Design	Cross Over Design with Counterbalanced Conditions	Cross Over Design with Counterbalanced Conditions	Randomized Control Trial
Participants	25 subjects ages 20.3±1.5 (10 females, 15 males) with an average of 4.2±2.3 ankle sprains.	19 subjects aged 21.8±2.8 (9 males, 10 females) with an average of 4.5±3.9 ankle sprains.	16 athletes that had a presence of unilateral CAI. The participants were 22±1.03 years of age, varsity athletes, and represented both genders.
Inclusion and Exclusion Criteria	Inclusion: Presented with a history of CAI in at least one ankle, self-reported history of a significant ankle sprain more than 12 months prior to participation, scored >11 on the Identification of Functional Ankle Instability, had multiple episodes of the ankle "giving way," and a history of multiple sprains on the same ankle. Exclusion: History of an acute fracture requiring realignment to the lower extremity, history of clinically diagnosed hypertension, blood clots or clotting disorder, peripheral artery disease, cardiovascular conditions, sickle cell trait, or diabetes mellitus.	Inclusion: Patients self-reported a history of at least one significant lateral ankle sprain over 12 months prior to participation in the study, recurring lateral ankle sprains, reports of the ankle "giving way" or feeling insatiable, scoring > or equal to 11 on the Identification of Functional Ankle Instability. Exclusion: A history of acute musculoskeletal surgery or a fracture that required realignment, history of clinically diagnosed diabetes mellitus, hypertension, compromised vascular circulation, or sickle cell trait.	Inclusion: Reported history of unilateral LAS occurring at least 12 months prior to involvement in the study, self-reported feeling of the ankle giving way or ankle instability during activities of daily living and sports for at least 6 months, a score less than or equal to 24/30 on the CAIT. Exclusion: A history of bilateral ankle instability, pathological joint laxity (a positive talar tilt or anterior drawer test), a history of an ankle fracture, surgery performed on the hip, knee, or ankle, a history of musculoskeletal disorders.
Interventions Investigated	Participants enrolled in the study acted as both the control group and the treatment group. Participants were randomly assigned which condition they would complete first. Participants completed 2 testing days within 24-48 hours of rest between conditions. A 5-minute cycling warmup was performed prior to the testing. During each session, participants completed 2 trials of dynamic balance exercises with 5-minutes of rest between the two trials. 4 sets of each exercise were performed with repetitions of 30x15x15x15 and a 30 seconds of interest rest. The patients stood at the center point of three lines which ran anteriorly, posteromedially, and posterolaterally. Patients stood on their CAI leg and reached out as far as they could on their raised leg to lightly touch the ground.	Participants enrolled in the study acted as both the control group and treatment group. Participants were randomly assigned which condition they would complete first. Participants completed 2 testing days with 24-48 hours of rest between the conditions. A 5-minute cycling warmup was performed prior to the testing. 4 sets of eversion exercises were then performed with 5 minutes of rest followed by 4 sets of dorsiflexion exercises. The BFR was applied with 80% occlusion during the BFR condition. EMG muscle activation levels and SmO2 levels were calculated in a seated position with the leg fully extended during the 4 sets. RPE was gathered following each set and condition.	BFR + R Group: A 5-minute dynamic stretching warmup was performed prior to a 30-minute supervised rehabilitation program. This program was performed 3 times weekly for 4 weeks. Patients progressed to more difficult variations of each exercise every week. Variations of heel raises, squats, Bosu ball balances, and Y-balance functional reaching were performed each session. The BFR cuff was inflated to the individual's predetermined 80% occlusion. R Group: A 5-minute dynamic stretching warmup was performed prior to a 30-minute supervised rehabilitation program. This program was performed 3 times weekly for 4 weeks. Patients progressed to more difficult variations of each exercise every week. Variations of heel raises, squats, Bosu ball balances, and Y-balance functional reaching were performed each session. The R group completed these exercises with a deflated BFR cuff.
Outcome Measures	Muscle activation was measured using surface EMG and the participant's perceived exertion and postural instability was measured using the OMI-Resistance Exercise Scale and the Rate of Perceived Stability Scale.	Surface electromyography muscle activation of the lower leg during ankle eversion and dorsiflexion was measured with surface EMG electrodes at 30% of maximum voluntary isometric contraction, local muscle oxygen saturation was measured using a Moxy muscle oxygen monitor system, and the patient's perceived exertion level was measured with the rate of perceived exertion (RPE).	Average peak torque to body weight ratio was calculated with an isokinetic dynamometer, cross-sectional area was determined with diagnostic ultrasound, dynamic balance was measured with the Y-balance Test, and the side hop test was used to measure the functional limitation of the involved limb.
Main Findings	The finding of this study presents that individuals with CAI present with higher levels of muscle activation of the vastus lateralis and soleus when utilizing BFR during dynamic stabilization exercises.	The findings of this study align with the current published literature. Participants presenting with a history of CAI performed greater muscle activation, hypoxia, and RPE when completing submaximal isometric resistance exercises with BFR than without BFR.	BFR in addition to a 4-week rehabilitation program was found to improve strength gains, hypertrophy, and cross-sectional area more than the rehabilitation group. Following the 4-week training period, the post testing for the BFR + R group was found to be statistically significant within groups for all outcome measures as opposed to the R group. Statistical significance between groups was also found in the cross-sectional area and side hop test.
Level of Evidence	1b	1b	1b
Quality Score	PEDro 6/10	PEDro 6/10	PEDro 7/10
Conclusion	BFR produced large to small increases in muscle activity in the vastus lateralis and soleus and large increases in patient perception of exhaustion and postural control. Small to no increases in muscle activity were found in the tibialis anterior and fibularis longus.	The data gathered concluded that BFR caused a moderate to large increase in muscle activation for dorsiflexion exercises and a small to moderate increase in muscle activation for eversion exercises. Increased muscle activation and hypoxia during the completion of BFR exercises should be examined further.	The data collected determined that the addition of BFR to supervised 4-week rehabilitation programs was more effective in improving strength, hypertrophy, and functional performance in individuals with CAI than traditional rehabilitation alone.
Abbreviation Definitions	CAI: chronic ankle instability EMG: electromyography BFR: blood flow restriction	RPE: rate of perceived exertion SmO2: muscle oxygen saturation	CAIT: Cumberland ankle instability tool BFR + R: blood flow restriction plus therapeutic program R Group: therapeutic program group

Results and Clinical Bottom Line

<u>**Results**</u>:

- The literature search identified 45 studies, and three studies were identified that met the inclusion and exclusion criteria (Table 1).
- The three studies found increased muscle activation and hypertrophy in individuals with CAI (Table 2).

<u>**Limitations**</u>:

- CAI is a subjective diagnosis.
- The nature of BFR therapy provides difficulty in blinding subjects, assessors, and therapists.
- Hormonal cycles, nutrition, previous exercise history, and lifestyle conditions of patients.

<u>**Clinical Bottom Line**</u>:

- Increases in muscular activation, strength, and hypertrophy can be observed in BFR therapy for individuals with CAI and may be beneficial in a clinical setting in addition to traditional rehabilitation exercises.[1,8]
- One study found statistically significant increases in strength and hypertrophy when BFR is used in conjunction with a rehabilitation program.[8]
- The current literature suggests BFR, in conjunction with rehabilitation programs, could potentially improve isokinetic strength and hypertrophy in ACL injuries, osteoarthritis, Achilles ruptures, patellofemoral pain syndrome, and hip/knee arthroscopies due to the decreased tissue demand placed on the body during BFR training.[9] Therefore, it is theorized that these effects could be seen in individuals with CAI.
- A significant implication for BFR training is cross-education. Cross-education is characterized by transfers of strength gains to the injured limb following the strengthening of the non-injured limb due to neural adaptations.[18] Therefore, there is potential use in chronic conditions and surgical interventions.

Future Work

1. Current research on the effects of BFR therapy on individuals with CAI is limited. Therefore, further research is required.
2. Determine the long-term effects of BFR on CAI.
3. Determine the acute and long-term effect of BFR on muscular strength and endurance.

References and Acknowledgments

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