I J C R M
International Journal of Contemporary Research In Multidisciplinary

*Research Article*

# Role of Low-Load Blood Flow Restriction Training in ACL Reconstruction Rehabilitation: A Literature Review

**Dr. Gayathri Devi (PT) [1*], Dr. K.A. Anandhi (PT) [2], Dr. Himabindu (PT) [3]**
[1-3] Dept of physiotherapy, Shridevi College of Physiotherapy, Tumkur, Karnataka, India

**Corresponding Author:** *Dr. Gayathri Devi (PT)

**DOI:** https://doi.org/10.5281/zenodo.18979246

## Abstract

After anterior cruciate ligament (ACL) reconstruction, patients often experience knee muscle weakness and atrophy. Blood flow restriction (BFR) training offers a way for therapists and patients to build strength using low-load exercises, helping to protect against this muscle loss and support musculoskeletal recovery. This review aimed to assess how effective BFR therapy is for improving quadriceps strength, size, range of motion, and overall function during ACL rehab. Relevant studies from 2020 to 2024 were identified through PubMed and ResearchGate. Because the studies varied widely and carried some risk of bias, the findings should be viewed cautiously. Future randomised trials are needed to clarify the best frequency and duration of BFR training for these patients, so it can be applied more confidently in clinical practice.

## Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 13-01-2026
- **Accepted:** 26-02-2026
- **Published:** 12-03-2026
- **IJCRM:**5(2); 2026: 231-236

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

## How to Cite this Article

Devi G (PT), Anandhi K.A (PT). Himabindu (PT). Role of Low-Load Blood Flow Restriction Training in ACL Reconstruction Rehabilitation: A Literature Review. Int J Contemp Res Multidiscip. 2026;5(2):231-236.

**Access this Article Online**

www.multiarticlesjournal.com

**KEYWORDS:** Blood flow restriction therapy, ACL reconstruction, low load training, ACL rehabilitation, physical therapy, functional recovery.

## 1. INTRODUCTION

Anterior cruciate ligament (ACL) injuries are the most prevalent, affecting strength, physical function, and daily activities in active individuals. They are caused by road traffic accidents, work injuries, and sports activities, and require surgical intervention and extended rehabilitation. The biggest worry following surgery is quadriceps weakness and atrophy. Loss of muscular strength, imbalance, and knee Extensor lag result in an unsuccessful return to sports, job, and/or reinjury. Loss of bone mineral density (BMD) in an immobilized limb can also result in a post-operative patellar/periarticular fracture caused by immobilisation soon following surgery. To develop quadriceps strength and bulk in people aged 18–50 and active individuals, the American college of sports Medicine recommends that the muscle be stressed for 60–100% of one repetition maximum (1RM). Conversely, in older adults, the co-existence of many medical conditions such as hypertension, diabetes, and coronary heart disease may exacerbate the risks associated with high-load resistance exercise. Extended recuperation periods might also result in increased tissue damage and exacerbation of preexisting injuries. Exercises involving external loads more than 60% of 1RM after ACL Graft. Early in the healing process, a person may find it difficult to follow traditional rehabilitation protocols like high-load resistance training (HL-RT), which restore muscle mass and enhance function.

Blood flow restriction training, or BFR, enables patients and doctor's to work in a low-load bearing environment while still achieving the essential strengthening of the musculoskeletal system. This helps prevent muscle atrophy, which is a common side effect after reconstructive knee surgery. Consequently, low-load blood flow restriction training (LL-BFRT), which uses external loads of 20%–30% of 1RM, has been proposed as an alternative to traditional rehabilitation. It has also been shown to increase strength and fatigue resistance in healthy adults in a manner similar to that of high-intensity resistance exercise.

Blood flow restriction training, also known as KATTSU training or vascular occlusion training, entails wrapping a band or cuff around the proximal aspect of the knee joint or thigh to restrict venous blood flow out of the working muscle group while allowing arterial blood flow into the muscle. The combination of this venous occlusion and weight exercise is thought to increase muscular growth, protein synthesis, and activation of type II muscle fibers .however ,BFR exercise creates local metabolic effect by physical compression which encourages the brain to secrete growth hormone to enhance anabolism, improve muscle strength. And due to lack of data and established protocol, BFR has not been extensively adopted. As a result, it is critical to asses the importance and value of this treatment.

Historical background consists as Dr. Yoshaiki Soto first recorded the conceptual and history of BFR therapy in japan in the year 1970's. Soto noticed that KATTSU used bands and ropes to form tourniquets that restricted muscular venous blood flow. While KATTSU was primitive, soto lead the path for the creation of electronic tourniquets as well as modest BFR therapy. The first study. In BFR therapy was published in 1998, with the use and creation of electronic tourniquets. In the early 2000's with the use of third generation tourniquets, BFR therapy was done safely and accuratly.

Mechanism of action includes Venous block age causes anaerobic conditions inside the targeted muscle region. At this low oxygen level, the body uses muscular fibers that are normally reserved for demanding activity. Such as type II muscle fiber. Stress on these muscle fibers regulates muscular growth by increasing protein synthesis.

## 2. AIMS AND OBJECTIVES:

**Aims:**

- To systematically evaluate the effectiveness of Blood flow restriction therapy in ACL reconstruction rehabilitation in improving quadriceps strength, mass, range of motion and functional recovery.

**Objectives:**

- To critically review the current studies on the impact of low load BFR training on ACL recovery.
- To determine the efficacy of low-load BFR training in improving muscle strength, hypertrophy, and functional recovery in people undergoing ACL rehabilitation
- To analyse and evaluate the safety of low load BFR training protocols.

## 3. METHODOLOGY

**Study design**: literature review.
**Source of data**: PubMed, google scholar.
**Inclusion criteria:**

- Articles from 2020 to 2024.
- English full text Articles.
- Articles focusing on Blood flow restriction therapy in ACL rehabilitation.
- Type of articles: systematic review, randomized control trial and meta analysis, cohort studies.

**Exclusion criteria:**

- Articles before 2019
- Abstracts
- Other language articles
- Narrative review excluded

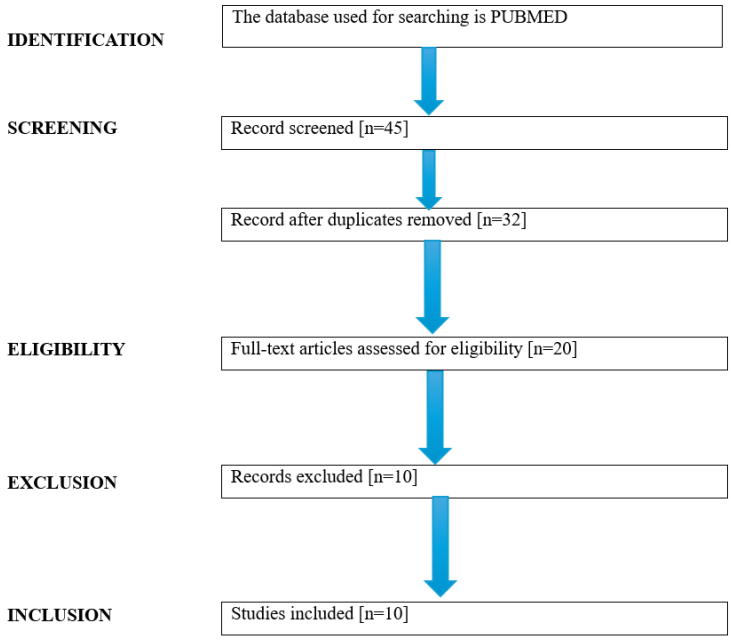


**Figure 1**: Selection methodology for included studies

**Procedure:** Using keywords and Boolean operators search strategy was done with the help of PubMed and 45 articles were reviewed, and 32 records were duplicated, full text articles assessed for eligibility was 20 and 10 articles were reviewed.

## 4. REVIEW OF ARTICLES

**1. Robert A. Jack 2nd et al.** Completed a randomized control trial in May of 2023. To see if BFR reduces loss of lean muscle mass, bone mass, and bone mineral density while enhancing function after ACL surgery when compared to normal therapy. A total of 32 patients who had ACL rehabilitation bone patellar tendon bone auto graft were considered and randomly assigned to two groups. (CONTROL: N = 15 [male = 7, female = 8; age = 24.1 ± 7.2 years; BMI = 26.9 ± 5.3 kg/m2]; BFR: N = 17 [male = 12, female = 5; age = 28.1 ± 7.4 years; BMI = 25.2 ± 2.8 kg/m2]) After surgery, rehabilitation lasted 12 weeks with an average follow-up of 2.3 ± 1.0 years. Both groups followed the same rehabilitation plan. Only the control group had a decrease in lower extremity lean mass at week 6 (−12.87 ± 3.02 g, −2.11 ± 0.47%; P < 0.01) and week 12 (−16.95 ± 4.32 g, −2.58 ± 0.64%; P < 0.01). The CONTROL group lost more site-specific bone mineral density (P < 0.05). At week 12, only the CONTROL group showed reductions in proximal tibia (−8.00 ± 1.10%; P < 0.01) and proximal fibula (−15.0 ± 2.50%, P < 0.01) compared to presurgery
measurements. There was no complication. Functional measurements were comparable among groups. As a result, it was determined that after ACL rehabilitation, BFR may reduce muscle and bone mass for up to 12 weeks postoperatively, improving time to return to sports with functional outcomes comparable to those of normal rehabilitation.

2. **Mark Colapietro et al**. Did a systematic review between March and April of 2023. To review the research on the benefits of BFR training versus standard therapy on knee muscle morphology and strength in ACL reconstructed patients. The PubMed, SPORTDiscus, CINAHL, and Cochrane central register databases were searched for relevant articles between January 1991 and April 2021. Articles provided at least level 3 evidence focusing BMI knee muscle morphology as well as extensor and flexor strength outcomes in ACL-reconstructed patients with all graft types. Six articles (four Randomized control studies, one nonrandomized research, and one case-control study) were considered. Exercises combined with BFR training included open kinetic chain, closed kinetic chain, and passive applications. As a result, he concluded that there is inconsistent and limited patient oriented evidence to support the use of BFR training improve or maintain thigh muscle size as week as knee extensor
and flexor strength in ACL-reconstructed patients. The effect size revealed no consistent clinically relevant difference as compared to conventional therapy. Subsequent analyses should be done if new information becomes available to update practice guidelines.

**3. Baris B Koc et al.** A comprehensive study in 2022 to explore the effect of LL-BFR training on quadriceps strength, quadriceps mass, knee joint pain, and ACL graft laxity following ACL reconstruction when compared to non-BFR training. On February 19, 2021, a literature search was performed using PubMed, EMBASE, Cochrane, and web of Science. Studies that compared LL-BFR training and No-BFR training following ACL reconstruction in terms of pre and post intervention quadriceps strength, quadriceps mass, knee joint pain, or ACL graft laxity

were considered. Systematic reviews, editorials, case reports, and studies that did not appear in a scientific peer-reviewed journal were excluded. Two studies found that LL-BFR training increased quadriceps mass significantly more than non-BFR training, while the other two found no significant difference in quadriceps mass. Three studies looked at knee joint pain, and LL-BFR training resulted in much less pain than non-BFR training. Two investigations on ACL graft laxity found no significant differences between LL-BFR and non-BFR training. This review concluded that LL-BFR training after ACL reconstruction may improve quadriceps strength, mass and knee joint discomfort compared to non-BFR training, with no negative effects on ACL graft laxity. More randomized controlled trials with standardized intervention protocols and outcome assessments are required to add evidence to the clinical benefit of LL-BFR training.

**4. Lawrence Wengle** and colleagues did a Systematic review and meta-analysis in August 2022. The goal of this study was to look at the effectiveness of BFR training in individual's undergoing knee surgery. The databases PubMed, EMBASE, and Cochrane were used to conduct literature searches. Eleven studies met the eligibility criteria, including anterior cruciate ligament reconstruction and knee arthroscopy. The findings revealed that using BFR in the postoperative phase can result in a considerable increase in cross sectional area when measuring muscle atrophy. However, he concluded that future research should look at the effects of BFR preconditioning prior to surgery. Finally, BFR techniques must be further researched to identify which produce the best patient outcome.

**5. Kelechi R Okoroha et al.** Carried out a randomized control trial in the year 2023. The goal of this study was to determine postoperative isometric quadriceps strength in individuals who received ACLR with a preoperative BFR training. Patients diagnosed with ACLR were divided into two groups and given two weeks of rehabilitation. The BFR group did activities with a pneumatic cuff set at 80% limb occlusion pressure placed over the proximal thigh. The study included 46 patients, with 22 in the BFR group and 24 in the control group. At 6 weeks postoperatively, the BFR group exhibited considerably better strength than the controls. Three patients elected to drop out of the BFR group secondary to cuff intolerance during exercise. Hence he concluded that no differences in strength or patient report outcome were found at 3 and 6 months between the 2 groups.

**6. Joshua M Spada et al.** Carried out a systematic review in the year 2022. This study aims to establish if BFR training can limit the loss of knee extension and knee flexion muscular torque during early recovery following ACL surgery. Three databases(PubMed, Embase, and scopus) were searched to find level 1 randomized controlled trials that used knee flexion and knee extension muscle torque as primary outcome measurements. The highest-quality level 1 trials examining knee extension and knee extension strength using isokinetic torque all concur that blood flow restriction training reduces post-operative knee flexion and extension strength deficits. There were no adverse events reported in either study. However additional research comparing BFR training techniques is required before an optimal protocol can be firmly advised.

**7. Dylan P Roman et al**. Did a cohort research in the year 2023. To examine the effect of BFR training on adolescent knee strength following ACL rehabilitation at two postoperative time points: three months and the time of return to sport. Patients aged 12 to 18 years who had primary ACL rehabilitation with quadriceps tendon autograft were included. A prospective intervention (BFR) training group was compared to a retrospective control group with the same age, gender, and body index. The BFR training group comprised of sixteen patients. The BFR training group showed considerably higher isometric knee extension torque than the control group. As a result, he found that in teenagers, adding a standardized BFRT treatment to a regular rehabilitation protocol following ACL rehabilitation significantly increased knee strength and patient reported function when compared to a traditional rehabilitation program alone.

8. Sai K Devana et al. Has conducted a cohort study in the year 2024. To compare the overall time to return to sports (RTS) and (2) identify a postoperative time interval for which BFRT has the maximum therapeutic benefit. Total of 55 student Athlete's who underwent ACLR between 2000 and 2023 while participating in NCAA division I sports at a single institution were included in this study. Athletes were allocated to 1 of 2 groups (BFRT group;n = 22) (non-BFRT group;n = 33). Primary outcome measure was time to RTS. Secondary outcome measure handheld dynamometry quadriceps strength testing at various postoperative time points, converted to a limb symmetry index. Statistically significant delay was observed in RTS with BFRT compared with standardised physical therapy alone after undergoing ACLR. where BFRT had a beneficial impact on quadriceps strength.

**9. Eduardo Fraca-Fenandez et al.** Has conducted a systematic review in the year 2024. To investigate the impact of BFR training on muscle strength, cross sectional area, and knee-related function in patients underwent ACL reconstruction. Pubmed, Cochrane, web of science, and Scopus databases were used to search. Ten studies were included of 287 participants. There were alterations in knee extensor isometric strength and knee related function. As a result, he found that there is very little evidence to suggest that BFR training on isokinetic strength and quadriceps cross-sectional area in patients having ACLR.

**10. Varun Gopinath et al.** Has conducted a comprehensive review and meta-analysis on randomized control trial in the year 2024.To compare the neuromuscular and clinical effects of BFR training following ACL rehabilitation to non-BFR rehabilitation. The search terms included PubMed, Medline, Scopus, and the Cochrane databases. Eight RCTs with 245 patients met the inclusion criteria, with 115 patients undergoing non-BFR

rehabilitation versus 130 patients undergoing BFR after ACLR. As a result, he found that using BFR following ACL rehabilitation improved pain and isokinetic muscular strength, volume, and thickness when compared to non-BFR rehabilitation.

## 5. DISCUSSION

The incorporation of LL-BFR training into ACL reconstruction rehabilitation presents a novel and promising approach foe enhancing recovery outcomes. This discussion will explore the implications of LL-BFR on muscle strength, hypertrophy, rehabilitation timelines and overall patient outcomes, while also addressing potential challenges and areas for future research.

Research indicates that LL-BFR can produce comparable hypertrophic and strength outcomes to high-load training, despite the lower mechanical loads involved. This makes it a valuable tool for maintaining muscle mass and strength during the early stages of ACL rehabilitation, when higher loads may be contraindicated. Additionally, the ability to achieve these outcomes with low loads may help improve patient compliance by reducing pain and discomfort associated with rehabilitation.

However, it is important recognize that patient responses to LL-BFR can vary. Factors such as the patients baseline fitness level, the extent of the injury, and individual differences in muscle physiology can all influence the effectiveness of LL-BFR. As a result, while LL-BFR shows great promise, it may not be suitable for all patients, and its use should be tailored to the individual needs and circumstances.

Despite the potential benefits, using LL-BFR in ACL rehabilitation has a number of obstacles. One of the main concerns is the potential of inappropriate application, which can result in nerve injury, thrombosis or sever pain. As a result, LL-BHR should only be performed by trained specialists capable of precisely assessing and adjusting the pressure applied during the treatment.

Another issue is a lack of long-term data on the efficiency of LL-BFR in ACL rehabilitation. While short term trails have yielded promising results, additional study is needed to understand the long- term ramifications, such as the possibility for sustained muscle strength, the danger of re-injury, and patients general quality of life after rehabilitation.

## 6. CONCLUSION

The result of this literature review, found that the use of BFR after ACL reconstruction led to improvement in pain, muscle strength with variable outcomes on the basis of quadriceps strength, volume and thickness when compared with non-BFR rehabilitation and also found that very low degree of certainty suggests that BFR training provides additional benefits compared to the same unrestricted training on isokinetic knee extensor and flexor strength. These additional benefits likely emerge when BFR is applied after ACL reconstruction rather than before it, but further research is needed. These results should be interpreted cautiously due to heterogeneity and risk of bias among studies. Further randomized trials should be examined the optimal frequency and duration of BFR training after ACL reconstruction in this population to assist with clinical integration.

## REFERENCES


1. Jack RA 2nd, Lambert BS, Hedt CA, Delgado D, Goble H, McCulloch PC. Blood flow restriction therapy preserves lower extremity bone and muscle mass after ACL reconstruction. *Sports Health*. 2023;15(3):361–371. doi:10.1177/19417381221101006.
2. Colapietro M, Portnoff B, Miller SJ, Sebastianelli W, Vairo GL. Effects of blood flow restriction training on clinical outcomes for patients with ACL reconstruction: a systematic review. *Sports Health*. 2023;15(2):260–273. doi:10.1177/19417381211070834.
3. Koc BB, Truyens A, Heymans MJLF, Jansen EJP, Schotanus MGM. Effect of low-load blood flow restriction training after anterior cruciate ligament reconstruction: a systematic review. *Int J Sports Phys Ther*. 2022;17(3):334–346. doi:10.26603/001c.33151.
4. Wengle L, Migliorini F, Leroux T, Chahal J, Theodoropoulos J, Betsch M. The effects of blood flow restriction in patients undergoing knee surgery: a systematic review and meta-analysis. *Am J Sports Med*. 2022;50(10):2824–2833. doi:10.1177/03635465211027296.
5. Okoroha KR, Tramer JS, Khalil LS, Jildeh TR, Abbas MJ, Buckley PJ, et al. Effects of a perioperative blood flow restriction therapy program on early quadriceps strength and patient-reported outcomes after anterior cruciate ligament reconstruction. *Orthop J Sports Med*. 2023;11(11):23259671231209694. doi:10.1177/23259671231209694.
6. Spada JM, Paul RW, Tucker BS. Blood flow restriction training preserves knee flexion and extension torque following anterior cruciate ligament reconstruction: a systematic review. *J Orthop*. 2022;34:233–239. doi:10.1016/j.jor.2022.08.031.
7. Roman DP, Burland JP, Fredericks A, Giampetruzzi N, Prue J, Lolic A, et al. Early- and late-stage benefits of blood flow restriction training on knee strength in adolescents after anterior cruciate ligament reconstruction. *Orthop J Sports Med*. 2023;11(11):23259671231213034. doi:10.1177/23259671231213034.
8. Devana SK, Solorzano CA, Vail J, Jackson N, Pham D, Jones KJ. Outcomes of blood flow restriction training after ACL reconstruction in NCAA Division I athletes. *Orthop J Sports Med*. 2024;12(5):23259671241248589. doi:10.1177/23259671241248589.
9. Fraca-Fernández E, Ceballos-Laita L, Hernández-Lázaro H, Jiménez-Del-Barrio S, Mingo-Gómez MT, Medrano-de-la-Fuente R, et al. Effects of blood flow restriction training in patients before and after anterior cruciate ligament reconstruction: a systematic review and meta-analysis. *Healthcare (Basel)*. 2024;12(12):1231. doi:10.3390/healthcare12121231.

10. Gopinath V, Garcia JR, Reid IK, Knapik DM, Verma NN, Chahla J. Blood flow restriction enhances recovery after anterior cruciate ligament reconstruction: a systematic review and meta-analysis of randomized controlled trials. *Arthroscopy*. 2024. doi:10.1016/j.arthro.2024.05.032.



**About the corresponding author**

**Dr. Gayathri Devi** (PT) is associated with the Department of Physiotherapy at Shridevi College of Physiotherapy, Tumkur, Karnataka, India. She is involved in physiotherapy education, clinical training, and research, contributing to the development of rehabilitation sciences and mentoring students in the field of physiotherapy.