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EFFECTIVENESS OF PRACTICAL BLOOD FLOW RESTRICTION TRAINING ON MUSCLE STRENGTH, PAIN AND PHYSICAL FUNCTIONALITY IN ACL RECONSTRUCTION REHABILITATION

Authors Name

Prachi Bhal,[1] Niraj Kumar,[2] Tabassum[3]

Affiliation

1. Postgraduate Student, Department of Physiotherapy
School of Paramedical and Allied Health Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand,

2. Ph. D. (Physiotherapy), MPT, MHA, Physiotherapy Department, Shri Guru Ram Rai School of Paramedical & Allied Health Sciences, Shri Guru Ram Rai University, drnirajkumar25@gmail.com,

3. Assistant Professor, Department of Physiotherapy, School of Paramedical & Allied Health Sciences, SGRRU University, (Dehradun)

Corresponding Author- Prof. (Dr.) Niraj Kumar Ph. D. (Physiotherapy), MPT, MHA, Physiotherapy Department, Shri Guru Ram Rai School of Paramedical & Allied Health Sciences, Shri Guru Ram Rai University, drnirajkumar25@gmail.com

ABSTRACT

Introduction: Anterior Cruciate Ligament (ACL) injuries frequently cause knee instability, resulting in pain, muscular weakening, and functional restrictions. Traditionally, the postoperative rehabilitation procedures frequently need high-load resistance exercise, which is not always practicable during the initial recovery period. Practical Blood Flow Restriction (pBFR) training, which uses elastic bands to partially restrict blood flow, has developed as a cost-effective method for improving muscle strength and functional recovery. The purpose of this study was to assess the efficacy of pBFR on muscle strength, pain, and physical functionality in patients after ACL reconstruction.

Method: A comparative study was conducted on 46 patients who had undergone ACL reconstruction. Participants were randomly divided into two groups: Group A (control, n=23) performed standard resistance training using resistance bands, while Group B (pBFR, n=23) performed the similar exercise with the addition of pBFR using elastic bands. Both groups received the treatment twice per week for eight weeks. Outcome measures used were muscle strength (handheld dynamometer), pain (Numerical Pain Rating Scale), and functional scores (IKDC and Lysholm knee scores) and were assessed at the baseline, week 4, and week 8.

Result: Both groups demonstrated significant improvements in muscle strength, pain reduction, and functional scores over the intervention period ($p<0.001$). However, Group B (pBFR) exhibited significantly greater improvements in all the outcome measures compared to the control group at 8 weeks. Improvement in muscle strength, functions and reduction of pain were significantly higher in the Group B.

Conclusion: Practical Blood Flow Restriction training is an effective and accessible rehabilitation strategy following ACL reconstruction. Compared to conventional resistance training, pBFR significantly improves muscle strength, reduces pain, and improves knee functionality emphasizing its use in early rehabilitation phase.

Keywords: ACL Reconstruction, Practical Blood Flow Restriction Training, Muscle strength, Pain, Knee function, Resistance exercise, Rehabilitation

INTRODUCTION

The anterior cruciate ligament (ACL) is a critical stabilizer of the knee joint, essential for maintaining biomechanical function. Composed of densely packed collagen fibers, the ACL exhibits remarkable stiffness and flexibility, averaging 38 mm in length [(1)]. Anatomically, it originates from the anterior tibial plateau and inserts into the posteromedial aspect of the lateral femoral condyle. Functionally, the ACL divides into two bundles the anteromedial (AMB) and posterolateral (PLB) bundles which synergistically prevent excessive anterior tibial translation and rotational instability across knee motions [(2,3)].

The anterior cruciate ligament (ACL) derives its blood supply primarily from the middle genicular artery (MGA), which branches from the popliteal artery and penetrates the posterior knee capsule to form a periligamentous network. Additional contributions arise from the inferior genicular arteries, particularly to the distal ACL, though vascular connections to the infrapatellar fat pad diminish in adulthood. The femoral and tibial bony attachments lack direct vascular penetration, relying instead on synovial and subsynovial vascular networks . Notably, an avascular zone exists in the ACL's fibrocartilaginous region near the tibial insertion, likely due to compressive stress during knee extension [(4,5)]. Innervation of the ACL involves myelinated and unmyelinated nerves entering via subsynovial connective tissue, terminating in mechanoreceptors such as Ruffini corpuscles (slow-adapting, detecting tension and joint position) and Pacinian corpuscles (rapid-adapting, sensing acceleration), as well as free nerve endings for nociception [(6)].

The anterior cruciate ligament (ACL) is a primary stabilizer of the knee joint, functioning to limit anterior tibial translation and rotational movements [(7)]. Beyond mechanical stability, the ACL contributes significantly to proprioception and neuromuscular control, both of which are essential for maintaining dynamic stability during complex athletic activities like cutting, pivoting, and landing. Its role is particularly critical in high-demand sports settings, where multiplanar stresses and rapid deceleration place substantial loads on the knee joint [(8)].

ACL injuries most frequently occur through non-contact mechanisms, particularly during high-risk maneuvers such as sudden deceleration, change of direction, and single-leg landing. These movements often generate excessive knee valgus, internal tibial rotation, and anterior tibial shear forces, which exceed the structural tolerance of the ACL. The meta-analytic evidence reinforces that female athletes are disproportionately affected due to biomechanical and neuromuscular factors such as increased knee abduction angles, greater quadriceps activation relative to hamstrings, and reduced trunk control which contribute to higher rates of ligament loading and failure [(7,8)].

An anterior cruciate ligament (ACL) injury typically presents with acute symptoms following a sudden twisting motion, direct trauma, or awkward landing. The most common signs include a loud "pop" or snapping sensation at the time of injury, followed by immediate pain and rapid swelling within hours due to hemarthrosis (bleeding into the joint). Patients often report knee instability, particularly during pivoting movements, and a sensation of the knee "giving way" when attempting weight-bearing activities (9). In chronic cases, recurrent instability and muscle weakness may develop, increasing the risk of secondary meniscal or cartilage damage (10).

The diagnosis of an anterior cruciate ligament (ACL) injury relies on a systematic physical examination, beginning with inspection and palpation to identify signs of effusion, localized tenderness, or soft tissue swelling. Provocative maneuvers are subsequently employed to evaluate ligament integrity. The Lachman test, performed with the knee in 20-30 degrees of flexion while applying an anteriorly directed force to the tibia, demonstrates the highest sensitivity and specificity for detecting ACL insufficiency. In contrast, the anterior drawer test, executed at 90 degrees of knee flexion, assesses anterior tibial translation but may yield inise-negative results due to compensatory hamstring activation. The pivot shift test, which dynamically reproduces pathologic tibiofemoral subluxation during valgus and internal rotation, is highly specific for ACL deficiency but requires both patient relaxation and clinician proficiency for accurate interpretation(11).

Anterior cruciate ligament (ACL) reconstructions universally recognized as the optimal treatment for complete ACL tears in active individuals, effectively restoring knee stability and preventing secondary joint degeneration (12). The postoperative period presents three primary challenges: restricted range of motion due to arthrofibrosis, persistent quadriceps and hamstring atrophy, and neuromuscular control deficits, all of which contribute to prolonged recovery timelines (13).

Immediate postoperative rehabilitation following ACL reconstruction is critical for optimal recovery, with some protocols even initiating pre-surgical conditioning (14). The initial phase focuses on passive range of motion (PROM) exercises to gradually restore joint mobility while simultaneously introducing weight-bearing activities to stimulate early muscular activation (15). During the first two postoperative weeks, rehabilitation progresses systematically to include controlled weight-bearing and non-weight-bearing exercises, proprioceptive training for balance and neuromuscular control, and early-stage strengthening all carefully titrated to patient tolerance to avoid graft stress while promoting tissue healing (16).

Current rehabilitation protocols recommend strength training at 60-100% of one repetition maximum (1RM) to optimize muscle recovery and functional performance (17). This high-intensity training is crucial for rebuilding maximal strength (through 80-100% IRM loads), developing explosive power, and restoring muscular endurance (via high-repetition submaximal loading). However, clinical studies show that approximately 65% of postoperative patients cannot safely achieve these intensity thresholds during early rehabilitation phases (18). To address this challenge while protecting the healing graft, contemporary programs now incorporate: 1) velocity-based training to maintain neuromuscular demand at reduced loads, 2) extended periodization (6-9 months) of strength progression, and 3) careful monitoring of tendon-loading parameters during explosive movements (13).

Traditional blood flow restriction (BFR) therapy, typically administered through pneumatic cuff systems, has faced significant barriers to widespread adoption due to its clinical complexity, cost-prohibitive equipment, and requirement for specialized supervision (19). These limitations have spurred innovation in BFR methodologies, leading to the development of simplified, portable devices that maintain therapeutic efficacy while improving accessibility for non-clinical populations (20). Contemporary research demonstrates that novel elastic BFR bands and automated pressure-regulating systems can achieve comparable hemodynamic effects to traditional cuffs, enabling safe implementation in home-based and recreational training environments(21).

Practical Blood Flow Restriction (PBFR) training represents a significant innovation in rehabilitation technology, replacing traditional pneumatic cuffs with simple elastic bands that maintain comparable occlusion pressures(22). When applied to proximal limbs during exercise, these bands create the characteristic hemodynamic response of BFR - including venous pooling and cellular hypoxia - while eliminating the need for complex pressure monitoring systems(23). This simplified approach preserves approximately 85% of the hypertrophic benefits observed in traditional BFR protocols, as demonstrated in electromyography studies of muscle activation(24).

Aim of the study

To evaluate the effectiveness of practical Blood Flow Restriction Training in improving muscular strength and pain in the patients of ACL Reconstruction.

Objectives of the study

- To assess the effects of practical blood flow restriction (BFR) training on pain levels and functional outcomes in patients of ACL Reconstruction.
- To evaluate the impact of practical BFR on muscle strength around the knee joint in patients of ACL econstruction.
- To compare the functional improvements in patients undergoing practical BFR training with those using standard exercises without BFR.

MATERIALS AND METHODS

ETHICAL CONSIDERATIONS: This study was approved by the Institutional Ethics Committee of Shri Guru Ram Rai Institute of Medical and Health Sciences (Ref. No. SGRR/IEC/24/25) and a No Objection Certificate was obtained. It was prospectively registered with the Clinical Trials Registry of India (REF/2025/04/103176) in compliance with national standards. Participants received a detailed explanation, provided written informed consent, and were informed of their right to withdraw at any time without consequences. Identities were anonymized using codes, and data was stored securely. The thesis is registered for copyright protection with the Copyright Office, Government of India (Diary No. LD-23840/2025-CO).

STUDY SETTING AND DESIGN: The randomized experimental study was conducted in the Department of Physiotherapy, Shri Guru Ram Rai University, and Shri Mahant Indiresh Hospital, Dehradun. A total of 46 participants fulfilling the inclusion and exclusion criteria were recruited and randomly allocated into two equal groups: Group A (n=23) served as the control group, while Group B (n=23) received Practical Blood Flow Restriction (pBFR) training. Participants were included if they had undergone anterior cruciate ligament (ACL) reconstruction with an autologous tendon graft, were 1–4 months post-surgery, could perform unsupported unilateral weight-bearing without pain for at least 5 seconds, were able to perform repeated straight leg raises without knee extension lag, had no contralateral leg injury within the past 12 months, and had a minimum active knee range of motion of 100 degrees in the operated limb. Exclusion criteria included pregnancy, history of deep vein thrombosis, congenital heart disease, varicose veins, rheumatoid arthritis, chronic obstructive pulmonary disease (COPD), hypothyroidism, and unwillingness to provide informed consent.

Group A- Control Group

Participants performed a standardized resistance exercise protocol using resistance bands without the application of blood flow restriction. Each session began with a 5-minute cycling warm-up to enhance peripheral circulation and prepare the lower limb muscles for exercise. For the exercise protocol, the participants were seated upright on a firm surface with hips and knees flexed at 90°. They first performed a warm-up set consisting of 10 repetitions of unilateral knee extension. This was followed by three sets of 10 repetitions of unilateral knee extension at approximately 70% of the predicted 1 Repetition Maximum (1RM) using resistance bands of suitable intensity. The band was anchored securely behind the participant, with the free end looped around the ankle to provide resistance during active extension. Each repetition was performed through the full range of motion, with a rest interval of 30 seconds between sets.

Figure 1: Performing 5 mins of warm-up cycling

Figure 2: Performing leg extension exercise with resistance band

Group B- Practical BFR Group

Participants in this group followed a resistance training protocol similar to Group A but with practical blood flow restriction (pBFR) applied using elastic bands. Each session began with 5 minutes of cycling, followed by 10 warm-up repetitions of unilateral knee extension. The main protocol consisted of four sets of unilateral knee extension at approximately 30% of the predicted 1 Repetition Maximum (1RM), with 30 repetitions in the first set and 15 repetitions in the remaining three sets. The elastic band was secured as in Group A, with 30 seconds rest between sets.

Blood flow restriction was achieved by wrapping an elastic restraint around the proximal thigh at about 20% of the limb circumference, providing safe, moderate occlusion. The band remained in place throughout the exercise and was removed immediately after. Participants were monitored continuously for any discomfort or circulatory issues.

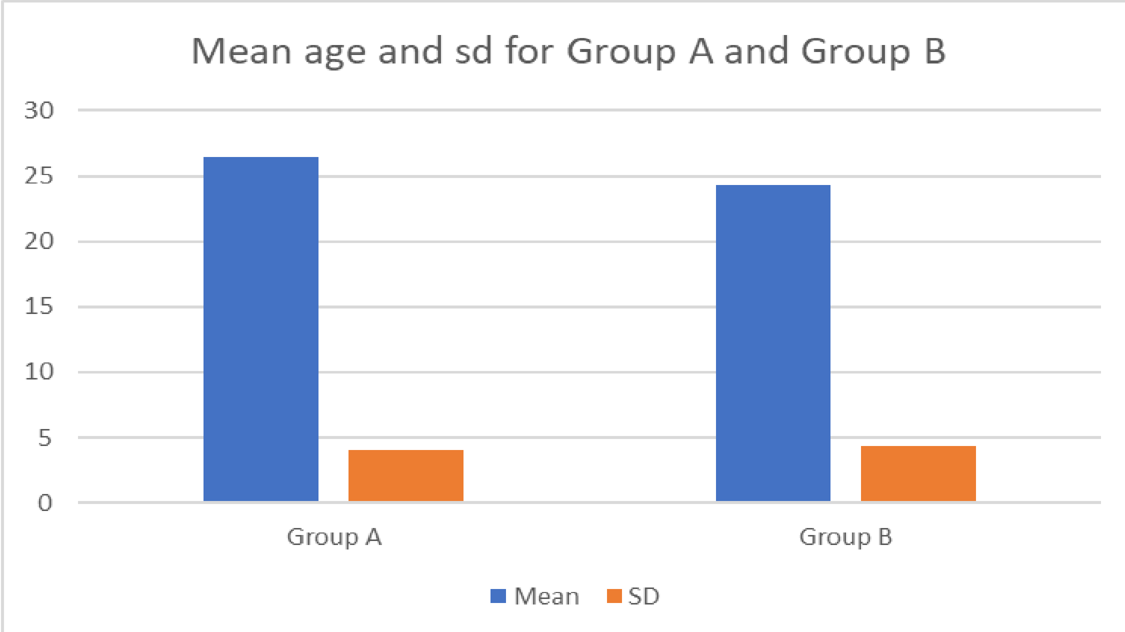
Figure 3: Measuring the thigh circumference for the limb circumference method

Figure 4: Resisted leg extension exercise with pBFR band

RESULTS

To analyze the age distribution between the two groups, the mean and standard deviation were calculated. Group A had a mean age of 26.5 ± 4.05 years, while Group B had a mean age of 24.3 ± 4.38 years. This indicates that participants in both groups were comparable in terms of age, with only a slight difference between the two groups.[Table and Graph 1]

Table 1 Mean and standard deviation of age of Group A and Group B



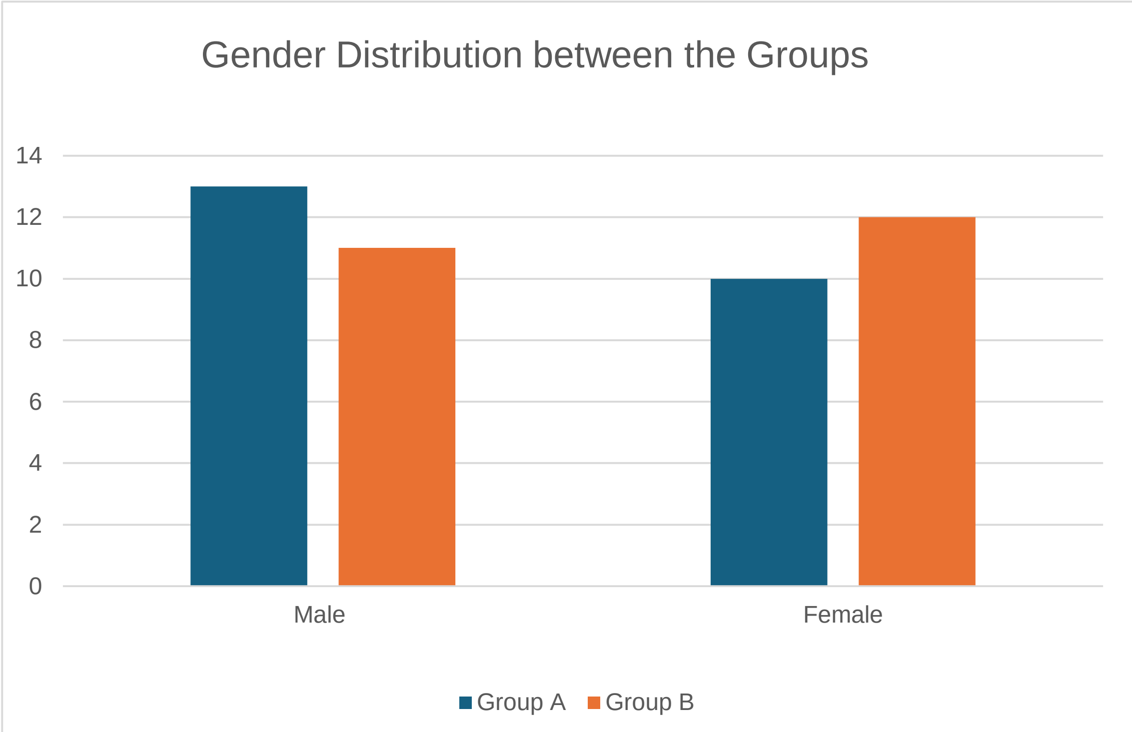
Groups	Mean	SD
Group A	**26.5**	**4.05**
Group B	**24.3**	**4.38**

Graph 1 Graphical representation of mean age and standard deviation of Group A and Group B

The gender distribution of participants across the two groups, Group A consisted of 23 participants, including 13 males and 10 females, while Group B comprised 23 participants as well, with 11 males and 12 females. Both groups had a relatively balanced representation of genders, ensuring minimal gender bias in the comparative analysis of outcomes between the two groups. [Table and Graph 2]

Group	Male	Female
Group A	**13**	**10**
Group B	**11**	**12**

Table 2 Gender distribution between the Group A and Group B



Scale	0 Week (Mean ± SD)	4 Week (Mean ± SD)	8 Week (Mean ± SD)	F-value	P-value	Result
HHD	184.52 ± 9.21	196.47 ± 8.62	232.36 ± 7.65	193.727	0.0001	Significant
IKDC	45.91 ± 4.15	53.04 ± 3.52	64.00 ± 3.28	141.449	0.0001	Significant
Lysholm	51.27 ± 3.75	57.86 ± 2.97	68.13 ± 2.07	183.939	0.0001	Significant
NPRS	6.39 ± 0.499	3.52 ± 0.510	2.00 ± 0.603	92.76	0.0001	Significant

Graph 2 Graphical representation of gender distribution between the Group A and Group B

The within-group analysis for Group A demonstrated statistically significant improvements across all measured outcomes over the 8-week rehabilitation period. For the Hand-Held Dynamometer (HHD), which assessed quadriceps strength, the mean scores increased from 184.52 ± 9.21 at baseline (0 week) to 196.47 ± 8.62 at 4 weeks, and further to 232.36 ± 7.65 at 8 weeks. The corresponding F-value was 193.727 with a p-value of 0.0001, indicating a significant gain in muscle strength. Similarly, functional improvements were evident in the International Knee Documentation Committee (IKDC) scores, which rose from 45.91 ± 4.15 at baseline to 53.04 ± 3.52 at 4 weeks, reaching 64.00 ± 3.28 at 8 weeks (F-value: 141.449, p-value: 0.0001). The Lysholm Knee Score, another functional scale, showed a consistent upward trend from 51.27 ± 3.75 at 0 week to 57.86 ± 2.97 at 4 weeks and 68.13 ± 2.07 at 8 weeks, with an F-value of 183.939 and a p-value of 0.0001, again suggesting statistically significant progress. In contrast, the Numerical Pain Rating Scale (NPRS) scores, which measure perceived pain, decreased from 6.39 ± 0.499 at baseline to 3.52 ± 0.510 at 4 weeks and 2.00 ± 0.603 at 8 weeks. This reduction in pain was also statistically significant, with an F-value of 92.76 and a p-value of 0.0001. Overall, these findings confirm that participants in Group A showed substantial improvements in muscle strength, knee function, and pain reduction over the course of the intervention. [Table 3]

Table 3 Comparison of all the outcome measure within Group A

The within-group analysis for Group B (Practical Blood Flow Restriction—pBFR group) revealed statistically significant improvements in all outcome measures over the 8-week intervention period. The Hand-Held Dynamometer (HHD) scores, indicating quadriceps strength, increased markedly from 182.17 ± 7.17 at baseline (0 week) to 212.391 ± 7.88 at 4 weeks and further to 264.95 ± 8.77 at 8 weeks. This change was highly significant, as reflected by an F-value of 635.2 and a p-value of 0.0001. Similarly, functional improvements were observed in the International Knee Documentation Committee (IKDC) scores, which rose from 49.30 ± 4.116 at 0 week to 60.52 ± 3.32 at 4 weeks and 74.60 ± 3.48 at 8 weeks (F-value: 276.03, p-value: 0.0001). The Lysholm Knee Score followed a comparable trend, increasing from 53.26 ± 4.48 at baseline to 64.26 ± 3.29 at 4 weeks and 77.60 ± 2.60 at 8 weeks, with an F-value of 271.77 and a p-value of 0.0001, indicating significant enhancement in knee function. On the other hand, the Numerical Pain Rating Scale (NPRS) scores showed a substantial reduction in pain levels, decreasing from 6.60 ± 0.499 at 0 week to 2.30 ± 0.470 at 4 weeks and further down to 0.913 ± 0.603 at 8 weeks. The F-value for NPRS was 127.54 with a p-value of 0.0001, confirming a statistically significant decrease in pain. These results collectively suggest that practical blood flow restriction training led to marked and statistically significant improvements in strength, function, and pain reduction among participants in Group B. [Table 4]

Scale	**0 Week (Mean ± SD)**	**4 Week (Mean ± SD)**	**8 Week (Mean ± SD)**	**F-value**	**P-value**	**Result**
HHD	182.17 ± 7.17	212.391 ± 7.88	264.95 ± 8.77	635.2	0.0001	Significant
IKDC	49.30 ± 4.116	60.52 ± 3.32	74.60 ± 3.48	276.03	0.0001	Significant
Lysholm	53.26 ± 4.48	64.26 ± 3.29	77.60 ± 2.60	271.77	0.0001	Significant
NPRS	6.60 ± 0.499	2.30 ± 0.470	0.913 ± 0.603	127.54	0.0001	Significant

Table 4 Comparison of all the outcome measure within Group B

The between-group analysis compared the outcomes of Group A (Control) and Group B (pBFR) across HHD, IKDC, Lysholm, and NPRS at 0, 4, and 8 weeks. Results indicated significantly greater improvements in Group B across all parameters.

For HHD, Group B showed a higher increase in strength (264.95 ± 8.77 at 8 weeks) compared to Group A (232.36 ± 7.65), with a t-value of 9.012 and p-value of 0.001. IKDC scores also improved more in Group B (74.60 ± 3.48) than in Group A (64.00 ± 3.28), with a t-value of 10.23, confirming better knee function. Lysholm scores followed a similar trend, showing higher improvements in Group B (77.60 ± 2.60) versus Group A (68.13 ± 2.07), with a t-value of 12.321. For NPRS, pain reduced more significantly in Group B (0.913 ± 0.603) compared to Group A (2.00 ± 0.603), with a t-value of 5.321 and p-value of 0.021.

Overall, Group B demonstrated significantly better outcomes in strength, function, and pain reduction, supporting the effectiveness of practical blood flow restriction training over conventional rehabilitation. [Table 5]

Scale	Group A - 0 Week (Mean ± SD)	Group B - 0 Week (Mean ± SD)	Group A - 4 Week (Mean ± SD)	Group B - 4 Week (Mean ± SD)	Group A - 8 Week (Mean ± SD)	Group B - 8 Week (Mean ± SD)	t-value	P-value	Result
HHD	184.52 ± 9.21	182.17 ± 7.17	196.47 ± 8.62	212.391 ± 7.88	232.36 ± 7.65	264.95 ± 8.77	9.012	0.001	Significant
IKDC	45.91 ± 4.15	49.30 ± 4.116	53.04 ± 3.52	60.52 ± 3.32	64.00 ± 3.28	74.60 ± 3.48	10.23	0.001	Significant
Lysholm	51.27 ± 3.75	53.26 ± 4.48	57.86 ± 2.97	64.26 ± 3.29	68.13 ± 2.07	77.60 ± 2.60	12.321	0.001	Significant
NPRS	6.39 ± 0.499	6.60 ± 0.499	3.52 ± 0.510	2.30 ± 0.470	2.00 ± 0.603	0.913 ± 0.603	5.321	0.021	Significant

Table 5 Comparison of all the outcome measure between Group A and Group B

DISCUSSION

The study evaluated the effectiveness of Practical Blood Flow Restriction (pBFR) training in improving muscle strength, pain levels, and physical function among patients recovering from Anterior Cruciate Ligament Reconstruction (ACLR). A total of forty-six participants were randomly divided into two groups: a control group performing conventional resistance exercises at 70% of 1RM, and an experimental group performing low-load exercises (30% 1RM) combined with elastic blood flow restriction bands. Both groups followed the intervention twice per week for eight weeks. Outcome measures included muscle strength assessed with a handheld dynamometer, pain evaluated using the NPRS scale, and knee function measured with IKDC and Lysholm scores, recorded at baseline, four weeks, and eight weeks. Although both groups showed significant improvements over time, the pBFR group achieved superior gains, particularly in muscle strength and pain reduction.

The aim of the study was to determine whether a simplified, low-cost pBFR approach could match or surpass the outcomes of conventional resistance-based rehabilitation in ACLR patients. The hypothesis proposed that pBFR would lead to greater enhancements in pain, strength, and function. Findings supported this hypothesis, with the pBFR group demonstrating substantial increases in quadriceps strength (182.17 ±7.17 kg to 264.95 ± 8.77 kg) compared to the control group (184.52±9.21 kg to 232.36 ± 7.65 kg). Pain levels also decreased more notably in the pBFR group (6.60 ± .49 to 0.913 ± .603) than in the control group (6.39 ± .499 to 2.00 ± .603). Similarly, functional outcomes assessed by IKDC and Lysholm scores improved in both groups but were more pronounced in the pBFR group, reflecting better joint function and subjective recovery.

These findings align with those of Jung et al. (2022), who also reported significant gains in muscle strength and dynamic balance in ACLR patients undergoing BFR-based rehabilitation. Their research emphasized the benefits of incorporating BFR into early rehabilitation phases, as it enhances functional outcomes without exposing the knee to high mechanical loads, which are often contraindicated during early recovery. Importantly, the study highlights practical BFR (pBFR) using elastic bands as a feasible and cost-effective alternative to traditional pneumatic BFR cuffs, delivering similar physiological benefits while simplifying clinical application.

Supporting this, Freitas et al. (2020) conducted a comparative study that evaluated electromyographic (EMG) responses and lactate accumulation in untrained individuals using both traditional pneumatic and elastic BFR systems. Their findings demonstrated "no significant differences between the two groups in terms of muscle activation and metabolic stress, suggesting that elastic BFR bands are a valid, low-cost alternative for inducing neuromuscular adaptations. This equivalence is particularly relevant for clinical populations, where accessibility, patient compliance, and ease of administration play a crucial role in treatment success.

Further reinforcing these points, Hughes et al. (2021) emphasized that simplified BFR systems, such as elastic bands, improve accessibility for both clinicians and patients. They are portable, cost-effective, and require minimal training, making them highly suitable for use in home-based settings or low-resource environments. This is especially valuable during the early rehabilitation phase post-ACLR, where supervised high-load resistance training may not be feasible due to pain, inflammation, or surgical precautions. The ability to stimulate strength gains with lower mechanical loads reduces stress on the healing graft, minimizing the risk of re-injury or delayed recovery.

Our results are also consistent with the randomized controlled trial conducted by Luke Hughes et al. (2019), which showed that low-load resistance training combined with BFR produced strength gains comparable to traditional high-load training while significantly reducing pain and joint effusion. This finding is particularly important for ACLR rehabilitation because introducing high-load exercises too early can compromise graft integrity and increase the risk of complications. Therefore, the ability of pBFR to promote hypertrophy and strength at lower, safer intensities offers a clear clinical advantage.

In addition, our approach supports the findings of Wernbom et al. (2008), who reported that low-intensity resistance exercise with BFR significantly enhanced muscle protein synthesis and hypertrophy. These adaptations are typically associated with high-intensity training, which further validates the use of BFR, particularly practical elastic-based systems, as a valuable intervention during the early and intermediate stages of recovery.

Furthermore, Ladlow et al. (2022) highlighted the importance of preserving muscle mass, neural drive, and motor unit recruitment in the immediate postoperative phase following ACL reconstruction. This observation aligns with our findings, where the pBFR group not only maintained muscle integrity but also demonstrated greater strength improvements compared to the control group by week 8. These gains were achieved without the adverse effects often associated with high-load training, confirming the dual benefit of pBFR in protecting healing tissues while promoting early functional recovery.

In a similar vein, Wilk et al. (2020) advocated for the use of low-load BFR training in early rehabilitation stages to facilitate muscular and functional recovery while minimizing joint strain and inflammation. Their recommendations support our intervention model, which employed elastic pBFR bands as part of a structured rehabilitation program. The results confirm the clinical utility of such systems, particularly in ACL rehabilitation, where achieving strength gains without jeopardizing joint integrity is essential.

Taken together, our study "contributes to a growing body of evidence supporting the" application of practical BFR as a safe, effective, and accessible tool in musculoskeletal rehabilitation. Its use in the context of ACLR not only promotes early functional gains but also offers logistical advantages that can enhance patient adherence, continuity of care, and scalability across diverse healthcare settings.

Overall this study demonstrates that Practical "Blood Flow Restriction training is not only effective but also" superior to standard resistance exercise in early-phase ACLR rehabilitation. The results suggest that pBFR can bridge the gap between patient safety and performance by offering a low-risk, cost-effective, and functionally impactful intervention. This method holds promise for broader application in physiotherapy, especially in resource-limited settings or for patients unable to tolerate high training loads.

LIMITATIONS OF THE STUDY

Short-term follow-up (8 weeks) limits understanding of long-term effects and sustainability of functional gains.
Lack of blinding (participants and assessors) may introduce measurement bias..
Single-center study with a specific population may limit generalizability to broader ACLR populations or different age/activity groups.

CONCLUSION

This study provides strong evidence that practical blood flow restriction (pBFR) training can significantly enhance rehabilitation outcomes following ACL reconstruction. Participants who engaged in low-load exercises combined with pBFR showed more rapid and greater improvements in muscle strength, pain reduction, and functional mobility compared to those performing traditional resistance training alone. The results suggest that pBFR is not only an effective rehabilitation strategy but also a practical alternative for patients "who may be unable to tolerate high-intensity exercise" in the early stages of recovery. Its simplicity, affordability, and clinical impact make it a promising addition to current physiotherapy practices.
While the outcomes are encouraging, the study was limited by its relatively short duration and the specific patient population. Further research with larger sample sizes, longer follow-up periods, and broader demographic groups is recommended to validate these findings and explore their application in diverse clinical settings.
As the demand for accessible, home-based, and cost-effective rehabilitation methods continues to grow, pBFR emerges as a valuable option that aligns with the future of personalized care. Integrating pBFR into standard post-operative rehabilitation protocols could reduce recovery times, enhance patient adherence, and improve long-term functional outcomes especially in community and resource-limited environments

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CONFLICT OF INTEREST

Conflicting Interest (If present, give more details): - Nil

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