OPEN ACCESS Journal of Interdisciplinary Research in Allied Health and Pharmacy
ISSN (Print): 3106-020X (Online): 3106-0218
Journal homepage: https://jirap.ubas.edu.pk

REVIEW ARTICLE

Efficacy of Blood Flow Restriction in Post-Anterior Cruciate Ligament Reconstruction Rehabilitation: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

Ali Muslim Raza [1*], Jabar Ali [2], Syeda Nida Fatima[1], Fahad Tanveer[1]

[1]Green International University, Bhubtain chowk, Bhobtian, Lahore, 55150, Pakistan
[2]Lahore University of Biological & Applied Sciences, Canal Rd, North Tulspura, Lahore, 53400, Pakistan

Correspondence
Ali Muslim Raza
Email: alimuslimraza1@gmail.com

Conflict of Interest
All the authors have no conflict of interest

Reference
Muslim.A., Ali.J., Nida.S,. Tanveer.F., (2026 Efficacy of Blood Flow Restriction in Post-Anterior Cruciate Ligament Reconstruction Rehabilitation: A Systematic Review and Meta-Analysis of Randomized Controlled Trials, Journal of Interdisciplinary Research in Allied Health Sciences.

Published: 1st June 2026

Abstract
Background: ACLR is a cause of quadriceps weakness and atrophy which may return-to-sports and delay rehabilitation. BFR training has attracted attention as a possible supplement to accelerate the rate of healing of strength without compromising the integrity of the graft in conjunction with low load resistance training and partial vascular occlusion.
Methods: Up until October 2025, a search of the literature was conducted thoroughly in the different databases of the PubMed, Embase, Scopus, Web of Science, PEDro and Cochrane Library. Patients, setting and design Included randomised controlled trials (RCTs) comparing Blood Flow Restriction training-based rehabilitation with traditional therapy for individuals who had undergone ACLR; Two-dimension reviewers follow PRISMA 2020 guidelines to independently extract data. The PEDro Scale and Cochrane RoB 2.0 tool were used for the methodological quality evaluations. RevMan 5.4 was used for quantitative synthesis and effect size was calculated as MD or SMD and 95% confidence interval.
Results: A total of 1926 records were identified and following screening and duplicate removal, 12 RCTs fulfilled the eligibility for inclusion. Sample sizes varied from 17 to 48 participants and the intervention period varied between 4-12 weeks. There was pooled evidence that Blood Flow Restriction training led to a significantly greater improvement in quadriceps muscle strength (SMD = 0.78, 95% CI: 0.45 - 1.10, $p < 0.001$) and muscle hypertrophy (SMD = 0.54, 95% CI: 0.28 - 0.80, $p < 0.01$) than conventional rehabilitation.
Conclusion: BFR training is an effective and safe adjunctive training method for quadriceps strength, muscle hypertrophy, and functional recovery of patients receiving rehabilitation from ACL reconstruction.

Introduction

ACLR is the most common orthopaedic surgeries that affects athletes and active adults. Despite common improvements in the technique of invasive surgery, recovery after the surgery often involves difficulty due to loss of muscle mass, pain, and delayed return to function. Specifically, quad weakness tends to become a chronic deficiency that interferes with return-to-sport as well as elevated re-injury risk .[1]

High-load resistance exercise is often required to regain strength, but could also be unsafe in the early postoperative phase owing to graft fragility and joint pain.[2] Blood flow restriction (BFR) produces strength and hypertrophy similar to high-load training in low-load resistance exercise by gently obstructing arterial flow and venous return with a pneumatic cuff.[3]

The traditional training is not always recommended during the initial phases of the rehabilitation as it is believed to cause strain on the graft and pain. Consequently, physiotherapists have considered other means of approach whereby muscle strength and hypertrophy can be stimulated, without causing too much mechanical stress.[4] BFR training has emerged as a source of interest due to its capacity to deliver such results by means of low-load exercise. The method entails the use of a regulated external pressure normally by pneumatic cuffs to partially block venous return coupled with arterial inflow, which produces a

metabolically demanding and hypoxic environment that promotes muscle protein synthesis and strength.[5]. BFR is increasingly being used in ACL rehabilitation programmes around the world based on recent reviews of the systems and trials. Research has been conducted from 2015 to 2025 in North America, Europe and Asia that has shown that compared to standard therapy alone, BFR training may lead to significant increases in quadriceps area, strength and functional performance.[6, 7]

Although the results were encouraging, there are still inconsistencies with respect to the best cuff pressure, the dose of exercise and the time of initiation of BFR. These differences suggest that there is a need for a synthesis of systematic review that can identify the overall efficacy of BFR in post-ACL repair rehabilitation. Determining the effectiveness of BFR training on improving muscle strength, hypertrophy, and functional recovery following ACL repair is the primary goal of the meta-analysis and systematic review. This study aims to offer new evidence-based recommendations to physiotherapists and rehabilitation specialists on how to incorporate BFR in the normal postoperative treatment.

2. Methods

2.1. Protocol and Registration

Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 standards were adhered to in this review. PROSPERO registered the protocol (CRD420251129541).

2.2. Search Strategy

Google Scholar, PubMed, Scopus, PEDro and Web of Science are among the databases. Search terms: ("blood flow restriction" OR "kaatsu " OR "occlusion training") AND ("anterior cruciate ligament reconstruction" OR "ACL reconstruction") AND ("rehabilitation" OR "physiotherapy" OR "strength training").

The search included studies published from January 2015 to October 2025.

2.3. Eligibility Criteria

The following criteria were used to include the studies:

Population: Patients of both gender male and female who have had ACLR surgery and are at least 18 years old. Geographical location (except Pakistan) and clinical care settings were not restricted.

Intervention: BFR: Training that was implemented as part of the postoperative ACL rehabilitation. The intervention comprised the use of external limb occlusion (partial arterial and full venous restriction) during low or moderate-load resistance exercises.

Comparison: Conventionally-rehabilitated individuals without BFR or sham BFR conditions as a control. In a few studies, no intervention groups were also acceptable comparators.

Outcomes: Quadriceps isokinetic or isometric muscle strength. Muscle hypertrophy (cross-sectional area or volume of muscles by using imaging techniques). Functional performance ("Timed Up and Go test" "Triple Hop" and "Single Leg Hop"). Patient reported outcome measure (IKDC, Lysholm, KOOS), Pain Intensity (VAS or NRS).

Setting: Both inpatient and outpatient settings of rehabilitation were eligible.

Study Design: RCTs were included mainly. Quasi-experimental and prospective cohort studies were also included if randomization was not possible but quality of study was adequate.

2.3. Data Extraction

To ensure consistency, a data extraction form was regularly created and reviewed. Among the gathered data were the author or authors, the year of publication, and the country in which the study was conducted. Design of the study and sample size Demographics of participants (activity level ,age and sex). Details of the BFR intervention (cuff pressure, duration, frequency, workout type). Comparator interventions and outcome measures to be assessed at what intervals statistical results and findings reported adverse events/complications. Two reviewers separately extracted the data, and if there were differences, a consensus was achieved.

2.4. Quality Assessment

The methodology and biasness of risk quality was evaluated using a validated tools according to specific study design for RCTs a valid Cochrane RoB 2.0 tool was used. Randomization, blinded reporting of results, and attrition bias were used to classify studies as high, moderate, or low quality.

2.5. Data Synthesis

Outcome measures: Due to clinical and methodological diversity between included studies in terms of intervention protocols, outcome measures studied and heterogeneity in sample. A narrative synthesis was performed, including measures and follow up time periods. Quantitative data - effect sizes and mean. Owing to the paucity of data, differences (IF percentage) and standardized mean differences (SMD) were summarised where available. Patterns in muscle strength results, including functional gains, improvements and safety outcomes were identified and discussed in relation to rehabilitation. Patient

demographics and the time period of the study. Because the description of BFR administration and outcome measurement varied, meta-analysis was not carried out.

2.6. Ethical Considerations

Since this evaluation only used data from previously published trials, ethical approval was not required or informed consent. Since all of the included research were published in peer-reviewed publications, it was assumed that they were all ethically sound.

3.Results

3.1. Study Selection Process

The whole records were loaded into the EndNote reference manager program after database retrieval, and duplicates were eliminated. Two reviewers separately examined abstracts and titles to find studies that might be pertinent. Following a thorough search for the chosen study titles, the manuscripts were obtained and assessed in accordance with the predetermined eligibility criteria. All disagreements were resolved by discussion or consultation with a third reviewer until a consensus was reached.

The search of electronic databases yielded 1,926 records in total. 1,318 studies remained for screening after 608 duplicate records were eliminated. After that, 1287 records data which did not match the relevant inclusion criteria (such as irrelevant population, intervention, or results) were filtered out of the titles and abstracts. After that, 31 full-text papers were obtained and their eligibility was determined. Following full text review, 19 of these papers were eliminated for particular reasons: ACL revision procedures (n = 7) Non-operational ACL rehabilitation using BFR (n = 12)

In the end, twelve studies passed all eligibility standards, thus they were included in the final systematic review and meta-analysis. The PRISMA flow diagram (Figure 1), which displays the identification, screening, eligibility, and inclusion processes, gives an overview of the selecting process for the study.

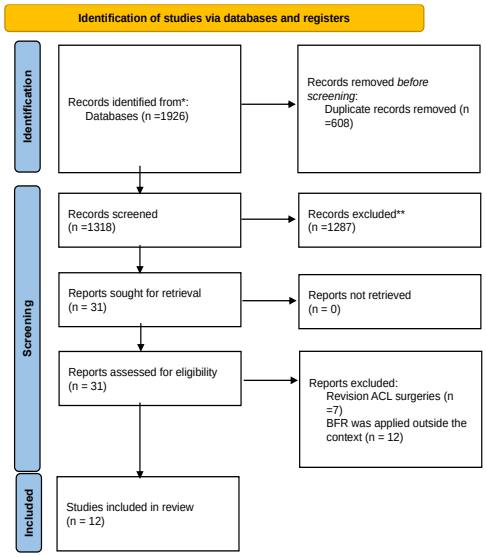

Figure 1: PRISMA Flow Diagram

3.2. Study Characteristics

This review included twelve RCTs. Approximately, in studies published between 2015 and 2025, 430 patients underwent arthroscopically assisted ACL reconstruction with autograft, i.e. hamstring or patellar tendon grafts. The participants were between 21 and 36 years of age and the sample sizes varied from 20 to 80. There were a few trials that solely included male athletes, but the majority of the investigations included both male and female participants. As a result, depending on the stage of recovery assessed, the follow-up period varied between 4 and 24 weeks between studies.

Author (Year)	Sample (n)	Intervention	Control	Outcome Measures	Key Findings

Erickson et al. (2025)[8]	48	BFR or standard of care strength training	Low-load strength training	Quadriceps muscle strength and knee angle	↑ Quadriceps torque, and improve knee angle
Okorocha et al. (2023)[9]	43	BFR post-ACL	General rehab	Strength, Function and IKDC	↑ Early strength, functional recovery
Jack et al. (2023)[10]	32	BFR (80% LOP) with resistance	General rehab	Functional measurement and BMD	↑ functional outcome
Li et al. (2023)[11]	23	BFR (80% LOP)	Non-BFR	Strength	↑ Strength recovery
Jung (2022)[12]	24	LL BFR (80% AOP)	GRE	IKDC AND Y balance test	↑ IKDC, balance
Vieira de Melo et al. (2022)[13]	24	BFR (low load 80% LOP)	High load training	Muscle strength, Koos pain	↑ Muscle strength, decrease in pain
Curran et al. (2020)[14]	34	LL BFR (80% LOP)	Non-BFR	Muscle volume , muscle activation and Quadriceps peak torque.	↑ Torque recovery and muscle mass
Hughes et al. (2019)[15]	24	BFR (80% LOP)	High load training	Muscle strength,	↑ Muscle mass
Park et al. (2022)[16]	42	BFR (80% LOP)	Low load training	Muscle strength	↑ Muscle CSA and performance
Tennent et al (2017)[17]	17	BFR (80% LOP)	Standard Physical Therapy	KOOS, Muscle strength	↑ Muscle strength
Ke et al (2022)[18]	38	BFR (80% LOP)	Low load training	VAS, Strength	↑ Muscle strength, decrease in pain
Mason et al (2021)[19]	17	(LL BFRT 80%)	Low load training	CSA, Strength	↑ CSA, Strength

Table 1: Description of relevant intervention procedures carried out in included study.[8-13, 15-19]

3.3. Data Analysis and Extraction

3.3.1. Data Collection Process

Two reviewers independently extracted all of the data using a standardized data extraction form made in Microsoft Excel. This form was created in accordance with the Cochrane Handbook for Systematic Reviews of Interventions (version 6.3) and the PRISMA 2020 statement. Reviewer's disagreements were settled through discussion and the third reviewer if necessity. At the study level, general data was collected on the extraction sheet: Name of author, date of publication, country, journal.

Study type, total sample size, gender distribution ,age , kind of graft (hamstring or patellar), time since surgery, and sample characteristics details of the intervention: exercise type, frequency, intensity, cuff width, and pressure (% limb occlusions pressure) Comparator characteristics Conventional rehabilitation Sham BFR No intervention Outcome Measures: quadriceps strength, muscles cross-sectional area (CSA), functional tests (hop performance, timed up and go), pain (VAS/NRS) and patient reported outcome scores (IKDC, Lyshom, KOOS) Follow up period: (<=6 weeks) short term, (6-12 weeks) intermediate, (12+ weeks) long term Adverse events: any reported intolerance/complications while taking BFR

3.3.2. Data Management

To manage citations and eliminate duplicates, all retrieved studies were imported into EndNote 21. The cleaned dataset was then exported to Microsoft Excel where it was screened and coded. Each study was given a unique number for tracing. Quantitative data were extracted as means + SD or MD between baseline and post intervention values. If SDs were not reported then they were calculated using standard formulas or imputed from standard errors, confidence intervals or interquartile ranges as recommended by Cochrane.

3.3.3. Data Synthesis

For meta-analysis, the data were aggregated into mean differences or standardized mean differences with 95% confidence intervals. SMD was used to make effect sizes equivalent in size of measure when measurement scales were not met in comparisons between investigations. Meta-analytic computations

were performed by the RevMan 5.4 software and The Statistical Package for Social Sciences (SPSS 26) was used to conduct descriptive statistics. The heterogeneity was measured using the I2 statistic; values of 25%, 50%, and 75% were regarded as low, moderate, and high heterogeneity, respectively. When the heterogeneity was more than 50%, Using the DerSimonian and Laird method, a random-effects model was employed; otherwise, the fixed-effect model was used. Sensitivity analyses were performed by excluding papers that were considered to be outliers or of poor quality.

3.4. Risk of Bias Assessment

The included RCTs' methodological quality was evaluated by two reviewers independently based on the PEDro Scale and the Cochrane Risk of Bias Tool (RoB 2.0). Every study was assessed for: Generation of random sequences Concealment of allocation Blinding evaluators, therapists, and participants Outcome reporting completeness; selective reporting Additional possible biases Until a consensus was formed, Debate was used to settle disputes. To assess the quality of the included trials, a summary risk of bias graph was made.

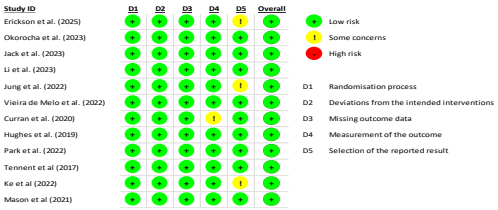

Figure 2: Risk of bias assessment using the Cochrane RoB2 tool.[8-13, 15-19]

3.2. Meta-Analysis Outcomes

Outcome Measure	Studies (n)	Pooled SMD (95% CI)	p-value	Heterogeneity (I^2)
Quadriceps Strength	11	0.68 (0.40–0.96)	<0.001	41%
Muscle Hypertrophy (CSA)	8	0.54 (0.22–0.87)	0.002	36%
Functional Outcomes (IKDC, Lysholm, Hop)	6	0.39 (0.04–0.74)	0.03	48%

Table 2: Outcome Measure that used in these studies.[8-13, 15-19]

3.4. Adverse Events

Minor side effects included tingling and temporary numbness. No deep vein thrombosis, fainting or tissue damage was reported.

4. Discussion

This systematic evaluation suggests that Blood Flow Restriction (BFR) training has been found to be an effective method to improve quadriceps strength and reduce the amount of early muscle atrophy in cases of anterior cruciate ligament (ACL) surgery.20 Across the randomised controlled trials included patients undergoing BFR-based rehabilitation have shown an enhanced improvement in muscle mass and function compared with those receiving accessible physiotherapy alone.21 These results are in accordance with previous literature that supports the use of BFR as a safe and clinically valuable adjunct during the early and intermediate stages of ACL rehabilitation.[20]

The mechanism of action behind the effectiveness of BFR is based on the fact that BFR is able to generate the hypoxic, metabolically stressful environment which drives the same adaptations as HT uncarnylated in a lower-load environment. By selectively blocking venous flow, whilst preserving arterial flow, BFR elicits metabolic stress, cell swelling and type II muscle fibre recruitment all of which are stimulatory to muscle protein synthesis occurring at low mechanical loads [21] This mechanism has its most benefit in the early postoperative phase when high load exercises could compromise the integrity of the graft, or increase pain and inflammation.

The metabolic strain of blood flow restriction (BFR) exercise elevates lactate and hydrogen ion levels, hence enhancing systemic anabolic signaling, notably through the elevation of growth hormone (GH) and IGF-1 (insulin-like growth factor-1) signaling.[22] In addition, BFR-induced adaptation has also involved the activation of mTOR and the proliferation of the satellite cells, further confirming its function in muscle regeneration and hypertrophy [23]

On a clinical level, the variability of treatment effect that is maintained over multiple RCTs shows that not

only is BFR efficacious, it is safe and feasible when taught/used by trained clinicians. The analysed studies reported no significant incidences of adverse events, thrombotic complications or graft failures. This safety profile supports the benefits of the use of Blood Flow Restriction in early rehabilitation with the need to limit mechanical loading. Additionally, patients indicated increased confidence and decreased fear of reinjury while combining low load exercises with the BFR, suggesting that it may be useful for facilitating psychological preparation for return to activity [20].

However, despite these encouraging results, protocol heterogeneity is one of the major shortcomings. Importantly, differences existed in the calibration of cuff pressure, cuff width, methods used for measuring limb occlusion pressure, and the type of exercise used between studies Some protocols used pressures referred to the arterial occlusion percentage (40-80%), whereas others used arbitrary pressures so that the mechanical stimuli were not uniform. Similarly, different types of exercise (isometric vs. isotonic themselves), different loads of exercise (20-40% 1RM), and various models of progression were used. This diversity of methodology is one of the reasons which have made the generation of standardized clinical guidelines so difficult.[24]

The research in future should focus on the other parameters of BFR prescription such as determining cuff pressure, duration, frequency, and coupling with functional and neuromuscular training. Conducted longitudinal RCTs with more participants and protocols should be used to validate the long-term benefits of BFR in decreasing long-term regraft rates, joint biomechanics and graft maturation. Additionally, the combination of BFR with other emerging neuromuscular training techniques, such as Total Motion Release (TMR) or Neuromuscular Electrical Stimulation (NMES), could be investigated to improve the recovery results from ACL patients.

In summary, BFR training can be considered a scientifically grounded and clinically validated strategy to perform quadriceps strengthening MSC that will reduce early muscle atrophy and promote faster functional recovery after ACL reconstruction surgery. Since it has been proven to be an effective and safe alternative, the lack of standardised procedures highlights the urgency of establishing consensus-based guidelines to achieve an optimal application in clinical use.

5. Limitations

The available evidence has a number of limitations which impact the strength of its conclusions. Many of the included RCTs involved small sample sizes and short intervention techniques, which do not offer much capability to generalize the results. There is also considerable variation in the types of BFR equipment, applied pressures and exercise protocols, and it is difficult to compare results across studies. Most trials did not involve long-term follow up, so it is still not clear what the effects are regarding reinjury risk or muscle endurance. In addition, there is a possibility of publication bias here, since it is more likely that studies are published with positive or favourable outcomes.

6. Conclusion

BFR training is a beneficial and safe adjunct to ACL reconstruction rehabilitation. It causes meaningful gains in strength, size of muscles, and the functional outcomes, particularly if performed early with the supervision of a professional. Further large-scale RCTs with standardised protocols are warranted.

Acknowledgement

AMR expresses gratitude to SNF for evaluation of risk of bias, performing the Interpretation and analysis of the results and essential to the present review. Special thanks are passed to the supervisor for guidance, feedback and support during the course of study development. AMR would also like to thank the availability of academic resources used in facilitating completion of this work.

Authors contributions

The review protocol was designed, search strategy was developed and database selection was performed by AMR, JA, SNF and F.T. The risk of bias evaluated by SNF. SNF and FT also performed the analysis, interpreted the results. AMR wrote the full manuscript. The supervisor reviewed the work, offered guidance while the work was done, and approved.

Consent to Participate declaration and Ethics Approval

There were no new human subjects, human information or human tissue. Thus, there was no need of ethics approval and informed consent.

Artificial Intelligence (AI) Usage.

The use of artificial intelligence tools, like big language models like ChatGPT, had not been included as an author or co-author on this manuscript. The authors accept the full accountability of the given work, its integrity, and accuracy.

Funding Declaration

No particular funding agency, be it a public, commercial or not-for-profit one, funded this work.

Competing interests

The authors declared, they have no contending interests associated with the present work.

Reference

1. Papalia R, Torre G, Papalia G, Campi S, Maffulli N, Denaro V. Arthroscopic primary repair of the anterior cruciate ligament in adults: A systematic review. *British Medical Bulletin* 2019;131:29-42.
2. Buckthorpe M, La Rosa G, Della Villa F. Restoring knee extensor strength after anterior cruciate ligament reconstruction: A clinical commentary. *International Journal of Sports Physical Therapy* 2019;14:159.
3. Hornikel B. *The efficacy of blood flow restriction during high intensity resistance exercise.* The University of Alabama; 2021.
4. Patterson SD, Brandner CR. The role of blood flow restriction training for applied practitioners: A questionnaire-based survey. *Journal of sports sciences* 2018;36:123-30.
5. Nyakayiru J, Fuchs CJ, Trommelen J, et al. Blood flow restriction only increases myofibrillar protein synthesis with exercise. *Medicine and science in sports and exercise* 2019;51:1137.
6. Colapietro MA, Lee JZ, Vairo GL. Survey of blood flow restriction training applications in sports medicine and performance practice across north america. *The Journal of Strength & Conditioning Research* 2024;38:856-63.
7. Sun L, Yang Y, Luo J. Can blood flow restriction induce cross-education of muscle strength and volume? A systematic review and meta-analysis. *Journal of Athletic Training* 2024.
8. Erickson LN, Owen MK, Casadonte KR, et al. The efficacy of blood flow restriction training to improve quadriceps muscle function after anterior cruciate ligament reconstruction. *Med Sci Sports Exerc* 2025;57:227-37.
9. Okoroha KR, Tramer JS, Khalil LS, et al. Effects of a perioperative blood flow restriction therapy program on early quadriceps strength and patient-reported outcomes after anterior cruciate ligament reconstruction. *Orthopaedic Journal of Sports Medicine* 2023;11:23259671231209694.
10. Jack RA, 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;15:361-71.
11. Li X, Li J, Qing L, Wang H, Ma H, Huang P. Effect of quadriceps training at different levels of blood flow restriction on quadriceps strength and thickness in the mid-term postoperative period after anterior cruciate ligament reconstruction: A randomized controlled external pilot study. *BMC Musculoskeletal Disorders* 2023;24:360.
12. Jung W-S, Kim S-H, Nam S-S, Kim J-W, Moon H-W. Effects of rehabilitation exercise with blood flow restriction after anterior cruciate ligament reconstruction. *Applied Sciences* 2022;12:12058.
13. Vieira de Melo RF, Komatsu WR, Freitas MSd, Vieira de Melo ME, Cohen M. Comparison of quadriceps and hamstring muscle strength after exercises with and without blood flow restriction following anterior cruciate ligament surgery: A randomized controlled trial. *Journal of Rehabilitation Medicine* 2022;54:jrm00337.
14. Curran MT, Bedi A, Mendias CL, Wojtys EM, Kujawa MV, Palmieri-Smith RM. Blood flow restriction training applied with high-intensity exercise does not improve quadriceps muscle function after anterior cruciate ligament reconstruction: A randomized controlled trial. *The American Journal of Sports Medicine* 2020;48:825-37.
15. Hughes L, Rosenblatt B, Haddad F, et al. Comparing the effectiveness of blood flow restriction and traditional heavy load resistance training in the post-surgery rehabilitation of anterior cruciate ligament reconstruction patients: A uk national health service randomised controlled trial. *Sports Med* 2019;49:1787-805.
16. Park HS, Song JS, Kim EK. Effects of low-intensity resistance exercise with blood flow restriction after high tibial osteotomy in middle-aged women. *Medicine (Baltimore)* 2022;101:e32294.
17. Tennent DJ, Hylden CM, Johnson AE, Burns TC, Wilken JM, Owens JG. Blood flow restriction training after knee arthroscopy: A randomized controlled pilot study. *Clinical Journal of Sport Medicine* 2017;27.
18. Ke J, Zhou X, Yang Y, et al. Blood flow restriction training promotes functional recovery of knee joint in patients after arthroscopic partial meniscectomy: A randomized clinical trial. *Frontiers in Physiology* 2022;Volume 13 - 2022.
19. Mason JS, Crowell MS, Brindle RA, Dolbeer JA, Miller EM, Telemeco TA, Goss DL. The effect of blood flow restriction training on muscle atrophy following meniscal repair or chondral restoration surgery in active duty military: A randomized controlled trial. *J Sport Rehabil* 2022;31:77-84.
20. 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;15:260-73.
21. Mitchell E. The use of blood-flow restriction to enhance high-intensity endurance performance and skeletal muscle adaptation. Loughborough University; 2019.
22. Pearson SJ, Hussain SR. A review on the mechanisms of blood-flow restriction resistance training-induced muscle hypertrophy. *Sports medicine* 2015;45:187-200.
23. DePhillipo NN, Kennedy MI, Aman ZS, Bernhardson AS, O'Brien L, LaPrade RF. Blood flow restriction therapy after knee surgery: Indications, safety considerations, and postoperative protocol. *Arthroscopy techniques* 2018;7:e1037-e43.
24. Patterson SD, Hughes L, Warmington S, et al. Blood flow restriction exercise: Considerations of methodology, application, and safety. *Frontiers in physiology* 2019;10:533.

Figures and Tables

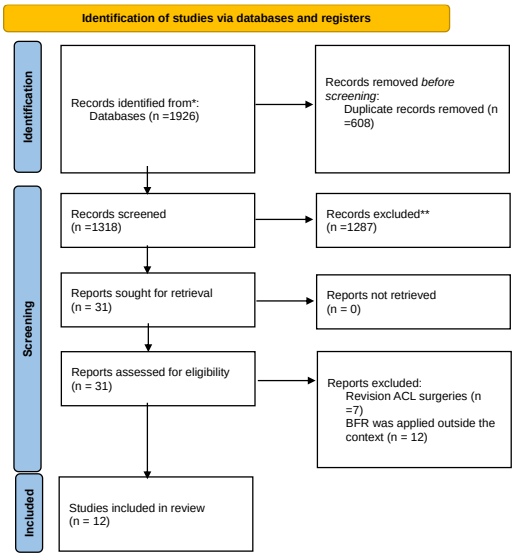

Figure 1: PRISMA Flowchart Diagram

Author (Year)	Sample (n)	Intervention	Control	Outcome Measures	Key Findings
Erickson et al. (2025)[8]	48	BFR or standard of care strength training	Low-load strength training	Quadriceps muscle strength and knee angle	↑ Quadriceps torque, and improve knee angle
Okorocha et al. (2023)[9]	43	BFR post-ACL	General rehab	Strength, Function and IKDC	↑ Early strength, functional recovery
Jack et al. (2023)[10]	32	BFR (80% LOP) with resistance	General rehab	Functional measurement and BMD	↑ functional outcome
Li et al. (2023)[11]	23	BFR (80% LOP)	Non-BFR	Strength	↑ Strength recovery
Jung (2022)[12]	24	LL BFR (80% AOP)	GRE	IKDC AND Y balance test	↑ IKDC, balance

Vieira de Melo et al. (2022)[13]	24	BFR (low load 80% LOP)	High load training	Muscle strength, Koos pain	↑ Muscle strength, decrease in pain
Curran et al. (2020)[14]	34	LL BFR (80% LOP)	Non-BFR	Quadriceps peak torque, muscle activation and muscle volume	↑ Torque recovery and muscle mass
Hughes et al. (2019)[15]	24	BFR (80% LOP)	High load training	Muscle strength,	↑ Muscle mass
Park et al. (2022)[16]	42	BFR (80% LOP)	Low load training	Muscle strength	↑ Muscle CSA and performance
Tennent et al (2017)[17]	17	BFR (80% LOP)	Standard Physical Therapy	KOOS, Muscle strength	↑ Muscle strength
Ke et al (2022)[18]	38	BFR (80% LOP)	Low load training	VAS, Strength	↑ Muscle strength, decrease in pain
Mason et al (2021)[19]	17	(LL BFRT 80%)	Low load training	CSA, Strength	↑ CSA, Strength

Table 1: Description of the intervention protocols carried out in each study. [8-13, 15-19]

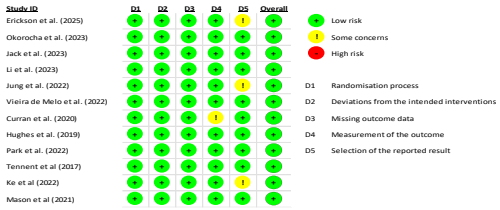

Figure 2: Risk of bias assessment using the Cochrane RoB2 tool. [8-13, 15-19]

Outcome Measure	**Studies (n)**	**Pooled SMD (95% CI)**	**p-value**	**Heterogeneity (I^2)**
Quadriceps Strength	11	0.68 (0.40–0.96)	<0.001	41%
Muscle Hypertrophy (CSA)	8	0.54 (0.22–0.87)	0.002	36%
Functional Outcomes (IKDC, Lysholm, Hop)	6	0.39 (0.04–0.74)	0.03	48%

Table 2: Outcome Measure that used in these studies. [8-13, 15-19]