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Review

Impact of Blood Flow Restriction Training on Postoperative Rehabilitation Outcomes Following Knee Surgeries: A Review of Literature

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ABSTRACT

This review investigated the effectiveness of Blood Flow Restriction (BFR) training in postoperative rehabilitation following knee surgeries. Clinical trials were reviewed in PubMed between November and December 2024 using predefined keywords. Methodological quality was assessed using the PEDro scale. Key outcomes included muscle strength, morphology, pain, function, performance, balance, range of motion (ROM), thigh circumference, and return to sport/activity (RTS/A) times. Nineteen studies (635 patients, mean age 14.84–69.89 years) met the eligibility criteria, with an average PEDro score of 5.84. The primary surgical diagnoses were anterior cruciate ligament reconstruction, followed by total knee arthroplasty, meniscal repair and chondral restoration, arthroscopic partial meniscectomy, and high tibial osteotomy. BFR parameters varied, with most studies using personalized tourniquet systems, proximal cuff placement, and 40–80% limb occlusion pressure. Low-intensity BFR (20–30% 1RM) was commonly applied with 30 s–2 min rest intervals, 2–5 sessions per week for 2–16 weeks, initiated from 2 days to over a year post-surgery. Adverse events were minimal, mainly mild discomfort. In eight studies, BFR significantly improved muscle strength compared to non-BFR protocols, while seven studies found no between-group differences. Muscle morphology changes were inconsistent, with some studies reporting superior BFR effects. Pain reduction was greater in two studies, while knee function, performance, and balance improved significantly in several trials. ROM improvements and thigh circumference changes showed mixed results. RTS/A times varied across studies. BFR training is a promising rehabilitation method, offering comparable results with the traditional approach or superior benefits in various outcomes while maintaining a favorable safety profile. Future research should standardize protocols and assess long-term effects to optimize its application in knee surgery rehabilitation.

Keywords: Knee pathologies, occlusion training, rehabilitation and physical therapy, strength, surgery

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INTRODUCTION

Knee surgeries are among the most common orthopedic interventions, frequently performed to address conditions such as anterior cruciate ligament (ACL) injuries, meniscal tears, severe cartilage damage and various ligament injuries, and instabilities [1]. These conditions, often arising from trauma, degenerative changes, or chronic overuse injuries, particularly in physically active populations and aging individuals, can result in significant pain, muscle inhibitions, and functional impairments if left untreated [2]. Despite advancements in surgical techniques and perioperative care, the postoperative period remains challenging due to complications such as persistent pain, muscle atrophy, joint stiffness, and functional limitations. These complications can delay recovery, hinder the return to daily activities and sports participation, and reduce quality of life [3,4]. Addressing these challenges requires a structured and individualized rehabilitation program to optimize recovery and minimize long-term disability.

Postoperative rehabilitation is critical for mitigating these challenges and optimizing outcomes. Rehabilitative strategies aim to prevent muscle atrophy, restore muscle strength, joint range of motion (ROM), and functional capacity while managing pain and minimizing the risk of complications. Traditional rehabilitation protocols often emphasize progressive resistance training to counteract muscle weakness and atrophy; however, high mechanical loads may not always be feasible due to joint stress and patient discomfort in the early postoperative phase [5]. In recent years, Blood Flow Restriction (BFR) training has emerged as a promising adjunct in rehabilitation. BFR involves applying a pneumatic cuff or elastic band to restrict venous return while partially reducing arterial inflow to the limb during low-intensity exercises, inducing physiological adaptations similar to those achieved with high-intensity training [6,7].

The efficacy of BFR training is based on its ability to stimulate muscle hypertrophy and strength gains at lower intensities by enhancing metabolic stress and inducing a hypoxic environment, which promotes the release of growth factors and hormones stimulating muscle protein synthesis, increasing proliferation of myogenic satellite cells and activating type II muscle fibers [8]. BFR has shown promise in various populations, including athletes recovering from injuries, elderly individuals with sarcopenia, and patients undergoing rehabilitation for musculoskeletal conditions [9]. Given its ability to promote muscle hypertrophy and functional recovery while minimizing joint strain, BFR training seems particularly suitable for early postoperative phases when mechanical loading is contraindicated [10]. Studies have shown significant improvements in various rehabilitation outcomes such as muscle strength, pain reduction, and functional capacity with BFR training compared to traditional rehabilitation protocols [11]. BFR may offer a valuable, low-load alternative for improving recovery outcomes after surgeries, particularly in populations where high-load exercises are contraindicated. Despite its benefits, concerns remain regarding safety, appropriate dosing, and its integration into standard rehabilitation protocols.

In recent years, the BFR method has gained widespread use in patients with postoperative restricted weight-bearing status, muscular inhibition, postoperative pain, and those seeking to achieve preoperative functional levels following knee surgeries [12]. In the context of postoperative knee rehabilitation, BFR training has emerged as an adjunctive therapy to accelerate recovery and improve outcomes [9]. This review aims to provide a comprehensive overview of the role of BFR in rehabilitation after various knee surgeries by examining its effects, safety profile, and clinical applications. By synthesizing the latest evidence, this paper seeks to guide clinicians and researchers in optimizing rehabilitation strategies for patients undergoing various knee surgeries.

MATERIALS AND METHODS

The review of the current literature was carried out on PubMed in November and December 2024. The search strategy is shown in Figure 1. The inclusion criteria for the studies were as follows: To have the full text in English or Turkish, have a population of patients (human) with any pathology of the knee and undergone surgery, have at least one control group, and use BFR method as a postoperative application in rehabilitation. The papers including books/book chapters, conference/symposium abstracts, editor comments, editorial letters, case studies, study protocols, reviews, expert opinions, and meta-analyses were excluded from the review. Additionally, studies that included BFR applications to the knee after surgery in different patient groups were also excluded from the study.

Database	Search Strategy	Results
PubMed	1. ((((((Blood flow restriction[Title/Abstract])) OR (blood flow restrictive[Title/Abstract])) OR (kaatsu training[Title/Abstract])) OR (occlusion training[Title/Abstract])) OR (ischemic training[Title/Abstract])) OR (Hypoxic Training[Title/Abstract]),,,"""blood flow restriction""[Title/Abstract] OR ""blood flow restrictive""[Title/Abstract] OR ""kaatsu training""[Title/Abstract] OR ""occlusion training""[Title/Abstract] OR ""ischemic training""[Title/Abstract] OR ""hypoxic training""[Title/Abstract]" 2. ((((((((knee[Title/Abstract]) OR (knee surgery[Title/Abstract])) OR (post-operative[Title/Abstract])) OR (operative[Title/Abstract])) OR (post-surgery[Title/Abstract])) OR (postoperative[Title/Abstract])) OR (recontruction[Title/Abstract])) OR (ACL[Title/Abstract])) OR (prosthesis[Title/Abstract]),,,"""knee""[Title/Abstract] OR ""knee surgery""[Title/Abstract] OR ""post-operative""[Title/Abstract] OR ""operative""[Title/Abstract] OR ""post-surgery""[Title/Abstract] OR ""postoperative""[Title/Abstract] OR ""recontruction""[Title/Abstract] OR ""ACL""[Title/Abstract] OR ""prosthesis""[Title/Abstract]" 3. (((((hemiplegia[Title/Abstract]) OR (multiple sclerosis[Title/Abstract])) OR (parkinson[Title/Abstract])) OR (biological[Title/Abstract])) OR (neurological[Title/Abstract])) OR (preoperative[Title/Abstract]),,,"""hemiplegia""[Title/Abstract] OR ""multiple sclerosis""[Title/Abstract] OR ""parkinson""[Title/Abstract] OR ""biological""[Title/Abstract] OR ""neurological""[Title/Abstract] OR ""preoperative""[Title/Abstract]" 4. (((((review[Title/Abstract]) OR (meta-analysis[Title/Abstract])) OR (systemic review[Title/Abstract])) OR (narrative review[Title/Abstract])) OR (study protocol[Title/Abstract])) OR (letter[Title/Abstract]),,,"""review""[Title/Abstract] OR ""meta-analysis""[Title/Abstract] OR ""systemic review""[Title/Abstract] OR ""narrative review""[Title/Abstract] OR ""study protocol""[Title/Abstract] OR ""letter""[Title/Abstract]" 5. (((#1) AND (#2)) NOT (#3)) NOT (#4)	269

Figure 1. Search strategy.

Quality Assessment

The methodological quality of the studies was evaluated using the Physiotherapy Evidence Database (PEDro) scale, an 11-item scale with a maximum score of 10 [13]. One author (BKK) independently assessed the included studies, and any discrepancies were resolved through consultation with another author (GP) to ensure consistency (Table 1).

RESULTS

Initially, 269 articles were identified through the database search based on the determined strategies. Following the view of the studies for eligibility and adherence to inclusion/exclusion criteria, nineteen studies were included in the review (Fig. 2).

Quality assessment studies were classified based on their total PEDro scores as follows: those scoring 0-3 were rated as "poor" scores between 4 and 5 were considered "fair" scores ranging from 6 to 8 were deemed "good" and scores from 9 to 10 were categorized as "excellent" [14]. In this review, using the PEDro scoring system, seven studies were classified as "fair" [15-21], twelve studies were rated as "good" [5,6,22-31]. The average PEDro score of the reviewed studies was 5.84, which can be classified as "fair to good".

The characteristics of the studies included in the review, along with details regarding the patient cohorts, surgical techniques employed, duration from injury or hospital admission to surgical intervention, initiation of BFR application post-surgery, and time to return to activity or sports, are summarized in Table 2.

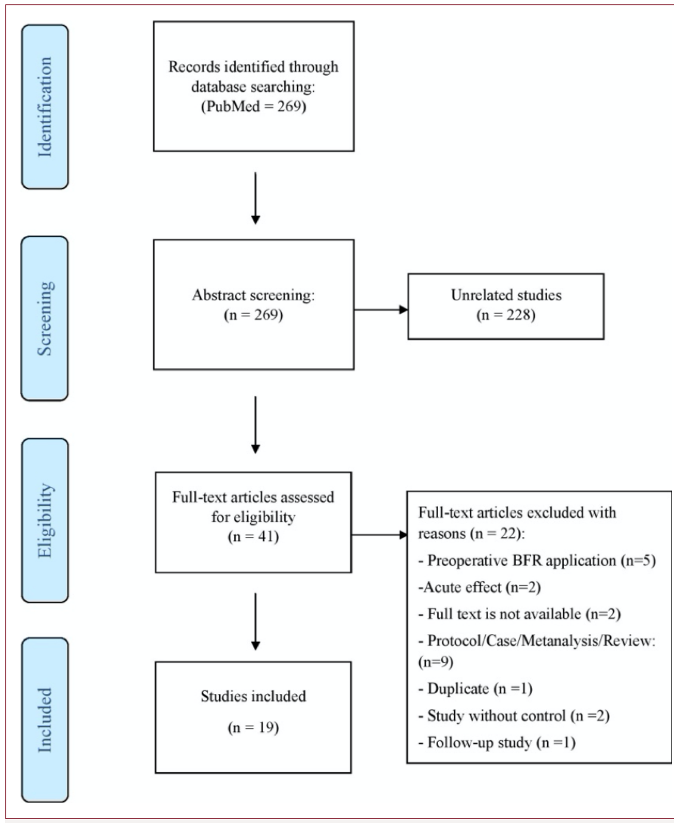

Figure 2. PRISMA flowchart.

Table 1. PEDro scoring of the reviewed studies

Authors	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	TOTAL
Curran et al. [27]	+	+	+	+	-	-	-	+	-	+	+	6
Devana et al. [15]	+	-	-	+	-	-	-	+	-	+	+	4
Erickson et al. [31]	+	+	+	+	+	-	+	+	-	+	+	8
Hughes et al. [6]	+	+	+	+	-	-	+	+	+	+	+	8
Iversen et al. [28]	+	+	-	+	-	-	+	+	-	+	+	6
Jack et al. [29]	+	+	-	+	-	-	+	+	-	+	+	6
Ke et al. [5]	+	+	+	+	-	-	+	+	-	+	+	7
Kilgas et al. [16]	+	-	-	+	-	-	-	+	-	+	+	4
Kong et al. [17]	+	-	-	+	-	-	-	+	+	+	+	5
Li et al. [22]	+	+	-	+	-	-	-	+	+	+	+	6
Majors et al. [18]	+	-	-	+	-	-	-	+	+	+	+	5
Mason et al. [23]	+	+	+	+	-	-	+	-	-	+	+	6
Ohta et al. [19]	+	-	-	+	-	-	-	+	-	+	+	4
Park et al. [25]	+	+	+	+	+	-	+	+	-	+	+	8
Roman et al. [20]	+	-	-	+	-	-	-	+	-	+	+	4
Takarada et al. [21]	+	-	-	+	-	-	-	+	-	+	+	4
Tennent et al. [24]	+	+	+	+	-	-	+	+	-	+	+	7
Tramer et al. [26]	+	+	-	+	-	-	+	+	+	+	+	7
Vieira De Melo et al. [30]	+	+	+	+	-	-	-	-	-	+	+	6

Table 2. The methodological characteristics of the included studies

Authors (Year)	Study Design	Diagnosis-Surgery	Concomitant Surgery Procedure(s)	Groups	Cohort of Patients (n, gender)	Mean Age (SD) years	Time to Surgery (d)	Time for surgery to BFR initiation	Time From Surgery to RTS/A (d)
Curran et al. [27]	RCT	ACL Reconstruction (BPTB, STG, QT)	MMR, LMR, MMX, LMX, CMB, Other	Concentric T	8 (3 M, 5 F)	16.1 (2.6)	7.00 (5.56)	10 weeks	295.25 (52.20)
				Eccentric T	8 (2 M, 6 F)	18.8 (3.9)	4.25 (2.32)		278.13 (65.74)
				BFR + Concentric	9 (5 M, 4 F)	15.3 (0.9)	7.11 (3.14)		281.00 (53.46)
				BFR + Eccentric	9 (5 M, 4 F)	16.0 (1.7)	5.44 (4.45)		279.67 (47.23)
Devana et al. [15]	Retrospective Cohort Study	ACL Reconstruction (BPTB, AT)	None	BFR	22 (12 M, 10 F)	18.59 (1.10)	N/A	After the Suture Removal (Mean Day N/A)	409 (134)
				Non-BFR	33 (13 M, 20 F)	19.45 (1.30)			332 (100)
Erickson et al. [31]	RCT	ACL Reconstruction (PT, HT)	MR, Partial MX	BFR	23 (13 M, 10 F)	21.1 (6.3)	19.5 (16.9)	Initiated at 2 Weeks Post-Surgery	N/A
				Sham BFR	25 (15 M, 10 F)	21.5 (5.3)	24.9 (16.8)		
Hughes et al. [6]	RCT	ACL Reconstruction (HT)	N/A	HL-RT	12 (10 M, 2 F)	29 (7)	N/A	24 (1) days	N/A
				BFR-RT	12 (7 M, 5 F)	29 (7)		23 (2) days	
Iversen et al. [28]	RCT	ACL Reconstruction (HT)	None	BFR	12 (7 M, 5 F)	24.9 (7.4)	75 (33)	Day 2 After Surgery	N/A
				Non-BFR	12 (7 M, 5 F)	(29.8) (9.3)	162 (114)		
Jack et al. [29]	RCT	ACL Reconstruction (BPTB)	N/A	BFR	17 (12 M, 5 F)	28.1 (7.4)	65 (30)	Within 7 Days Post-Surgery	192.6 (9.3)
				Non-BFR	15 (7 M, 8 F)	24.1 (7.2)	65 (36)		249 (16.2)
Ke et al. [5]	RCT	Arthroscopic Partial Meniscectomy	N/A	BFR	19 (12 M, 7 F)	37.58 (11.44)	214. 2 (214.5)	Day 2 After Surgery	N/A
				Non-BFR	19 (9 M, 10 F)	37.74 (11.27)	246.6 (258)		
Kilgas et al. [16]	Cross-sectional	ACL Reconstruction (PT, HT)	N/A	BFR	9 (3 M, 6 F)	26 (8)	1825 (730)	N/A	N/A
				Healthy Con	9 (3 M, 6 F)	26 (6)	-		
Kong et al. [17]	Retrospective Controlled Trial	ACL Reconstruction	None	BFR	15 (11 M, 4 F)	29.6 (7.6)	N/A	3 Days After Surgery	N/A
				Non-BFR	15 (11 M, 4 F)	27.53 (8.43)			
				NMES	15 (12 M, 3 F)	29.13 (9.07)			
Li et al. [22]	RCT	ACL Reconstruction	N/A	BFR- 40% AOP	9	29.67 (3.97)	159.46 (41.79)	8 Weeks After Surgery	N/A
				BFR- 80% AOP	8	30.50 (5.26)	155.75 (66.29)		
				Non-BFR	6 Gender N/A	28.33 (5.19)	141.19 (63.91)		
Majors et al. [18]	Retrospective Controlled Trial	Total Knee Arthroplasty	N/A	BFR	12 (4 M, 8 F)	66.92	N/A	> 365 days After Surgery	N/A
				Non-BFR	36 (16 M, 20 F)	69.89			

Table 2. The methodological characteristics of the included studies (Cont.)

Authors (Year)	Study Design	Diagnosis-Surgery	Concomitant Surgery Procedure(s)	Groups	Cohort of Patients (n, gender)	Mean Age (SD) years	Time to Surgery (d)	Time for surgery to BFR initiation	Time From Surgery to RTS/A (d)
Mason et al. [23]	RCT	Meniscal Repair/ Chondral Restoration Surgery	None	BFR	8 (8 M)	23 (3)	N/A	Within 1 Week of Surgery	N/A
				Non-BFR	9 (8 M, 1 F)	23 (4)			
Ohta et al. [19]	RCT	ACL Reconstruction (HT)	N/A	BFR	12 (12 M, 9 F)	28 (9.7)	N/A	2 Weeks After Surgery	N/A
				Non-BFR	22 (12 M, 20 F)	30 (9.7)			
Park et al. [25]	RCT	High Tibial Osteotomy	N/A	BFR- 40% AOP	14 F	59.8 (1.2)	N/A	N/A	N/A
				BFR- 80% AOP	13 F	58.7 (1.2)			
				Non-BFR	15 F	57.5 (1.3)			
Roman et al. [20]	Cohort Study	ACL Reconstruction (QT)	None	BFR	16 (6 M, 10 F)	14.84 (1.6)	N/A	Within 2 Weeks After Surgery (Mean: 8.4 days)	254.94 (33.2)
				Non-BFR	16 (6 M, 10 F)	15.35 (1.3)			250.81 (63.8)
Takarada et al. [21]	Experimental Study	ACL Reconstruction	N/A	BFR	8 (4 M, 4F)	22.4 (2.1)	N/A	3 Days After Surgery	N/A
				Sham BFR	8 (4 M, 4F)	23.0 (2.5)			
Tennent et al. [24]	RCT	Knee Arthroscopy	None	BFR	10 (7 M, 3 F)	37.0	N/A	21.5 days	N/A
				Non-BFR	7 (5 M, 2 F)	37.0		20.0 days	
Tramer et al. [26]	RCT	ACL Reconstruction (BPTB, HT, QT)	None	BFR	23 (11 M, 12 F)	26.5 (12.0)	N/A	2 Weeks After Surgery	N/A
				Non-BFR	22 (14 M, 8 F)	27.0 (11.0)			
Vieira De Melo et al. [30]	RCT	ACL Reconstruction (HT)	N/A	BFR	12 (8 M, 4 F)	41.1 (9.8)	N/A	After Discharge (Mean Day N/A)	N/A
				Non-BFR	12 (9 M, 3 F)	39.6 (10.8)			

n: Number; d: Days; SD: Standard deviation; F: Female; M: Male; ACL: Anterior cruciate ligament; BPTB: Bone–patellar tendon–bone autograft; QT: Quadriceps tendon autograft; HT: Hamstring tendon autograft; STG: Semitendinosus-gracilis tendon autograft; AT: Achilles tendon allograft; CMB; multiple meniscal intervention; LMR: Lateral meniscal repair; LMX: Lateral meniscectomy; MMR: Medial meniscal repair; MMX: Medial meniscectomy; Other: Meniscal abrasion or debridement; BFR: Blood flow restriction; AOP: Arterial occlusion pressure; Con: Controls; BFR-RT: Blood flow restriction resistance training; Non-BFR: Non-Blood flow restriction; Sham BFR: Sham-Blood flow restriction; HL-RT: High-load resistance training; NMES: Neuromuscular electrical stimulation; RTS/A: Return to sport/activity; N/A: Not available.

Among the studies included in the review, thirteen were randomized controlled trials (RCTs) [5,6,19,22-31], three were retrospective cohort studies [15,17,18], one was a cross-sectional study [16], one was a cohort study [20], and one was an experimental study [21]. The studies collectively included 635 patients (313 males, 299 females, and 23 patients of unknown gender), with mean ages ranging from 14.84 (1.6) years [20] to 69.89 years [18].

The primary surgical diagnoses were anterior cruciate ligament reconstruction (ACLR), investigated in 14 studies [19,20,27], followed by total knee arthroplasty (TKA) [18], meniscal repair and chondral restoration [23], arthroscopic partial meniscectomy [5], and high tibial osteotomy (HTO) [25].

The time to surgery ranged from as short as 4.25 (2.32) days [27] to 1825 (730) days [16], reflecting diverse chronicity of the conditions treated. 12 studies not reported.

Only four studies reported the duration from surgery to return to sport (RTS). For BFR interventions, RTS times ranged from 192.6 (9.3) days [29] to 409 (134) days [15], while for non-BFR protocols, it ranged from 249 (16.2) days [29] to 332 (100) days [15].

Detailed information regarding the BFR devices, cuff placement, cuff types and widths, arterial occlusion pressure (AOP) determination methods, cuff pressures, occlusion durations, and any reported adverse events in the included studies were given in Table 3. Most studies used the Personalized Tourniquet System (Delphi Medical Innovations, Canada) with cuffs placed proximally on the involved limb. AOP was commonly determined using automatic systems, Doppler ultrasound, or manual methods, with pressures typically ranging from 40% to 80% limb occlusion pressure. BFR was generally applied throughout each exercise session, with durations varying across studies. No adverse events were reported in most studies, minimal events such as discomfort [19,22] or dull pain were noted in some cases [19].

The exercise protocols, time for BFR initiation, outcome measures, and findings from studies are presented in Table 4. Most studies employed low-intensity BFR protocols (20-30% of 1 RM) with rest intervals of 30 seconds to 2 minutes, conducted 2-5 sessions per week over periods ranging from 2 to 16 weeks. Only the study by Curran et al. [27] applied BFR with high-intensity exercises (70% of 1 RM) for 16 sessions 10 weeks after the surgery in ACLR patients. Outcome measures primarily focused on quadriceps strength, muscle morphology, knee functions, and performance. The initiation of BFR training after surgery was generally early, starting as soon as 2 days post-surgery in several studies [5,28] or delayed up to 365 days or more [18].

Muscle Strength and Muscle Activation

A total of 17 studies evaluated quadriceps and/or hamstring strength using isokinetic dynamometry, handheld dynamometry, or 1/10 repetition maximum (RM) tests. Eight studies employing BFR showed significant superiority of BFR interventions compared to non-BFR protocols [5,17,19,20,22,24,25,30]. The remaining 7 studies found significant improvements with no difference between groups [6,18,23,26,27,29,31]. One study reported significant residual quadriceps strength similar to that of healthy controls [16]. Only one study assessed quadriceps activation and showed a significant increase in BFR groups compared to Non-BFR groups [27].

Muscle Morphology and Physiology

Ten studies evaluated changes in muscle morphology with MRI or ultrasound. Among these, three studies reported superior improvements with BFR [5,19,22], while another three studies found similar changes with no significant differences between BFR and non-BFR groups [6,27,31]. Iversen [28] observed a reduction in muscle size in both groups after a 14-day intervention, whereas Takarada et al. [21] reported a smaller reduction in the BFR group compared to the sham-BFR group. In Park et al.'s study [25], muscle size decreased in the non-BFR and BFR with 40% of AOP groups but remained unchanged in participants in the BFR with 80% of AOP groups. Additionally, Kilgas et al. [16] documented an increase in muscle size with BFR training, reaching levels comparable to healthy controls. One study assessed vastus lateralis muscle physiology through biopsy, reporting similar changes in the BFR and control groups [31].

Pain

Pain was assessed in two studies using the Visual Analog Scale (VAS), with BFR participants exhibiting significantly greater improvements [5,25].

Knee Functions and Performance

Twelve studies evaluated knee function and performance using scales such as the International Knee Documentation Committee (IKDC), the Knee Injury and Osteoarthritis Outcome Score (KOOS), the Lysholm Score, the Lower Extremity Functional Scale, and the Veterans RAND 12-Item Health Survey (VR12), as well as performance tests including gait analysis, squat tests, step tests, walking, sit-to-stand, and stair climbing. Among these, seven studies demonstrated that BFR was superior in improving functional outcomes [5,6, 20,22,24,25,30], whereas the remaining five studies reported comparable improvements between groups [17,23,26,29,31].

Table 3. The methodological characteristics of the included studies in terms of BFR implementation

Authors (Year)	BFR Device	Cuff Placement	Cuff Type/ Width	AOP Determination	Cuff Pressure	Occlusion Duration	Adverse Event(s)
Curran et al. [27]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Proximal thigh of the involved limb	Easi-Fit Tourniquet Cuff	Delfi System automatically calculated AOP in supine lying.	80% limb occlusion pressure	BFR was applied throughout each exercise set's duration.	N/A
Devana et al. [15]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	N/A On the involved limb	N/A	Delfi System automatically calculated AOP.	80% limb occlusion pressure	Approximately 5 mins for each exercise.	N/A
Erickson et al. [31]	BFR: Personalized Tourniquet System (Delphi Medical Innovations, Canada) Sham BFR: KAATSU Nano (KAATSU Global Inc., USA)	Proximal thigh N/A	BFR: Easi-Fit Tourniquet Cuff Sham BFR: KAATSU Air Bands	N/A	BFR: 60% limb occlusion pressure Sham BFR: 20 mmHg pressure	BFR was applied throughout each exercise's duration.	N/A
Hughes et al. [6]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Most proximal part of involved limb subsequently non-involved limb	Easy-Fit Contour Nylon Cuff 11.5 cm x 86 cm x 5 mm thick	Delfi System automatically calculated AOP in the body positions that the BFR training applied.	80% limb occlusion pressure	N/A	None
Iversen et al. [28]	Portable pressure pump (Trigger Aneroid DS66; Welch Allyn, Skaneateles Falls, USA)	Most proximal thigh of the involved limb	14-cm wide contoured Pneumatic Occlusion Cuff (Delphi)	None	130 mmHg to 180 mmHg	Occlusion stimulus for 5 mins, followed by 3 mins rest, repeated 5 times/session.	N/A
Jack et al. [29]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Proximal thigh of the involved limb	Easi-Fit Tourniquet Cuff	Delfi System automatically calculated AOP.	80% limb occlusion pressure	N/A	None

Table 3. The methodological characteristics of the included studies in terms of BFR implementation (Cont.)

Authors (Year)	BFR Device	Cuff Placement	Cuff Type/ Width	AOP Determination	Cuff Pressure	Occlusion Duration	Adverse Event(s)
Ke et al. [5]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Most proximal part of involved limb subsequently non-involved limb	Easy-Fit Contour Nylon Cuff 11.5 cm x 86 cm x 5 mm thick	Ultrasound was used to detect the pulse of the dorsal artery of the foot.	80% limb occlusion pressure	BFR was applied throughout each exercise's duration for a maximum of 5 mins.	None
Kilgas et al. [16]	Aneroid Sphygmomanometer (Briggs, Healthcare, Waukegan, USA)	Proximal thigh of the involved limb	18-cm Wide Cuff	Doppler ultrasound was used to detect the pulse of the femoral artery in seated position.	50% limb occlusion pressure	BFR was applied throughout each exercise's duration.	None
Kong et al. [17]	Smart Cuffs Device (Smart Tools Plus, OH, USA)	Proximal thigh of the involved limb	Hand-pumped blood pressure cuff	N/A	40% of the systolic blood pressure, increased by 10 mmHg per two weeks	N/A	None
Li et al. [22]	AirBands Wireless Compression Device (VALD, AU)	Proximal thigh N/A	AirBands Leg Cuff	The device automatically measured AOP.	40% and 80% limb occlusion pressure	BFR was applied throughout each exercise's duration.	Discomfort
Majors et al. [18]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Most proximal thigh of the involved limb	Easi-Fit Tourniquet Cuff 10 cm width	Delfi System automatically calculated AOP.	50-80% limb occlusion pressure	8 minutes	None
Mason et al. [23]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Proximal thigh of the involved limb	Easi-Fit Tourniquet Cuff. Sizes were chosen according to the patients: 27.9 to 40.6 cm, 38.1 to 55.9 cm, or 53.3 to 76.2	Delfi System automatically calculated AOP.	80% limb occlusion pressure	BFR was applied throughout each exercise's duration.	N/A
Ohta et al. [19]	Portable Hand-Pumped Air Tourniquet	Proximal thigh of the involved limb	N/A	N/A	180 mmHg	Maximum 15 minutes	Discomfort or a dull pain in 2 patients

Table 3. The methodological characteristics of the included studies in terms of BFR implementation (Cont.)

Authors (Year)	BFR Device	Cuff Placement	Cuff Type/ Width	AOP Determination	Cuff Pressure	Occlusion Duration	Adverse Event(s)
Park et al. [25]	Pneumatic Tourniquet (B Strong Training System, Parksity, Utah)	Proximal thigh of the involved limb	N/A	Doppler Ultrasound (ACUSON SC2000, Siemens) was used to detect posterior tibial artery pulse, in prone lying position.	40% and 80% limb occlusion pressure	BFR was applied throughout each exercise's duration (5 mins).	N/A
Roman et al. [20]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Proximal thigh of the involved limb	Easi-Fit Tourniquet Cuff 4.5 inch–wide	Delfi System automatically calculated AOP in supine position.	60-80% limb occlusion pressure	BFR was applied throughout each exercise's duration (8 mins).	None
Takarada et al. [21]	Pneumatic Occlusion Cuff Device	Proximal thigh of the involved limb (100 mm below the hip joint)	Pneumatic Cuff width; 90 mm, Length; 700 mm	N/A	BFR: Initial: 180 mmHg. Final: 200-260 mmHg. Sham BFR: 0 mmHg	BFR was applied throughout the exercise session. Sham BFR was applied during 37 mins session.	N/A
Tennent et al. [24]	Personalized Tourniquet System (Delphi Medical Innovations, Canada)	Proximal thigh of the involved limb	Easi-Fit Tourniquet Cuff	Doppler ultrasound	80% limb occlusion pressure	BFR was applied throughout each exercise's duration including rest (5 mins).	None
Tramer et al. [26]	Pneumatic Torniquet (Smart Tool Plus, Strongsville, OH)	Proximal thigh of the involved limb	N/A	Doppler ultrasound was used to detect dorsalis pedis pulse in long sitting position.	80% limb occlusion pressure	BFR was applied throughout each exercise's duration.	None
Vieira De Melo et al. [30]	Pneumatic bag (Cuff Scientific Leg®, Brazil)	In the region close to the inguinal ligament of both limbs	7 cm × 52 cm pneumatic bag	Vascular Doppler (DV-610B®; MEDMEGA, Brazil) was used to detect the posterior tibial artery pulse, in supine lying position.	80% limb occlusion pressure	BFR was applied throughout each exercise's duration.	None

BFR: Blood flow restriction; SHAM-BFR: Sham-Blood flow restriction; cm: centimeter; mins: minutes; mm: millimeter; AOP: Arterial occlusion pressure; N/A: Not available.

Table 4. The exercise protocols, outcomes, and findings of the included studies

Authors (Year)	Groups	Exercise Protocol	Time for surgery to BFR	Frequency/ Duration	Outcome Measures	Results
Curran et al. [27]	Concentric T Eccentric T BFR + Concentric T BFR + Eccentric T	Concentric Groups: Conc Period: 70% of 1 RM. Ecc Period: 20% of 1 RM. Eccentric Groups: Ecc Period: 70% of 1 RM. Conc Period: 20% of 1 RM. 4*10 reps Single Leg Press. Rest: 2 mins	10 weeks	2 sessions/week For a total of 8 weeks	- QF Strength Isokinetic Dynamometer - QF Activation Superimposed burst technique - QF Volume Ultrasound - Time to RTS	Similar increases in both groups, and no significant differences between groups at any time point.
Devana et al. [15]	BFR Non-BFR	BFR: 20-50% of 1 RM 1*30 reps, 3-5*15 reps 2-3 different exercises Rest: 30-45 sec and 1 min. All groups followed the standard ACLR rehabilitation protocol.	After the Suture Removal (Mean Day N/A)	3-4 sessions/week Continued until 90% of uninvolved limb's strength achieved.	- QF Strength: Handheld Dynamometer Limb Symmetry Index - Time to RTS	Significant faster RTS time in non-BFR, more rapid quadriceps strength gains and LSI in BFR.
Erickson et al. [31]	BFR Sham BFR	BFR: 20-30% of 1 RM. Sham BFR: 60-70% of 1 RM. 1*30, 1*20, 1*10 reps. ACLR rehabilitation exercises. Rest: 30 sec and 1-2 min	Initiated at 2 Weeks Post-Surgery	1-month pre-surgery and 4-5 months post-surgery	- QF Strength: Isokinetic Dynamometer - QF Morphology: MRI - Physiology: VL muscle biopsy - Knee Function: 3D gait analysis	Similar increases in both groups, and no significant differences between-groups were found for any outcomes.
Hughes et al. [6]	BFR-RT HL-RT	BFR-RT: 30% of 1 RM 1*30 reps, 3*15 reps HL-RT: 70% of 1 RM 3*10 reps Single Leg Press Rest: 30 sec	24 (1) days 23 (2) days	2 sessions/week For a total of 8 weeks	- 10 RM strength: Leg press machine - Morphology: Ultrasound -ROM: Goniometer Knee Functions: IKDC,	Similar significant increases in strength and muscle morphology in both groups. Similar significant

Table 4. The exercise protocols, outcomes, and findings of the included studies (Cont.)

Authors (Year)	Groups	Exercise Protocol	Time for surgery to BFR	Frequency/ Duration	Outcome Measures	Results
					KOOS, Lysholm Scale, - Balance: Modified SEBT - Effusion: Circumference taping - Knee joint laxity: KT-1000 arthrometer	decrease in laxity in both groups. Greater improvements in ROM, functions, balance, and effusion in BFR.
Iversen et al. [28]	BFR Non-BFR	BFR: 20 reps in 5 mins*5 sets Non-BFR: Same protocol without occlusion. 3 QF exercises. Rest: 3 mins	Day 2 After Surgery	2 sessions/day For a total of 14 days	- QF CSA: MRI	Similar significant reduction of quadriceps CSA in both groups. BFR: 13.8% (1.1%) Non-BFR: 13.1% (1.0%)
Jack et al. [29]	BFR Non-BFR	BFR: 20-30% of 1 RM 1*30 reps, 3*15 reps Rest: 30 sec 8 different exercises. Both groups followed standard rehabilitation protocol.	Within 7 Days Post-Surgery	2 sessions/week For a total of 12 weeks	- BMD, BM, LE-LM: DEXA - Functional outcomes: Single-leg squat, Single-leg eccentric step-down - 1 RM (leg press, hamstring curl) - Balance: Y-balance test - Time to RTS	Only in Non-BFR significant decreases in BMD, BM, and LE-LM. Similar functional results between groups. Y-balance anterior reach was greater in BFR. Faster RTS time in BFR. BFR: 6.4±0.3 months. Non-BFR: 8.3±0.5 months
Ke et al. [5]	BFR Non-BFR	BFR: 30% of 1RM 1*30 reps, 3*15 reps. Rest: 30 sec. Closed chain pedaling. Conc: Ecc (1:1). Both groups followed routine rehabilitation training.	Day 2 After Surgery	2 sessions/week For a total of 8 weeks	- QF Strength: Isokinetic Dynamometer - QF Thickness: Ultrasound - Thigh circumference: Tape measurement - Pain	Significant enhancements in QF strength and thickness only in BFR. Greater improvements of ROM, knee functions, balance,

Table 4. The exercise protocols, outcomes, and findings of the included studies (Cont.)

Authors (Year)	Groups	Exercise Protocol	Time for surgery to BFR	Frequency/ Duration	Outcome Measures	Results
					Visual Analogue Scale - Knee function: Lysholm Scale - ROM - Balance: One-leg standing test	pain, and thigh circumference in BFR.
Kilgas et al. [16]	BFR Healthy Con	Home-based BFR Resistance band, bodyweight 3*30 reps Knee extension, half-squats. 3*2-min walking. Rest: 1 min and 2 min. Healthy Con: No training	N/A	5 sessions/week For a total of 4 weeks	- QF Strength: Leg extension machine - QF Thickness: Ultrasound - Symmetry index	Significant enhancements were achieved in QF strength, thickness, and symmetry index with BFR, and were like healthy controls.
Kong et al. [17]	BFR Non-BFR NMES	BFR: 10-20-30% of 1 RM. 1*30 reps, 3*15 reps. Rest: 30 sec and 2 min. Non-BFR: ROM, NWB, CKC and OKC exercises. 3*15 reps. NMES: 0-10-20% of BW. 3*15 reps. 50 Hz, 20 mins. 5 sec contraction 10 sec rest. Groups performed the same rehabilitation exercises.	3 Days After Surgery	3 sessions/week For a total of 12 weeks	- QF and Hamstring Strength and Endurance: Isokinetic Dynamometer - Thigh circumference: Tape measurement - Knee Functions: Lysholm Scale, IKDC - Balance: Y-balance test	BFR and NMES improved QF and hamstring function, with BFR superior for hamstring endurance and balance (anterior reach), and NMES superior for thigh circumference at 15 cm. Lysholm and IKDC scores improved in all groups.

Table 4. The exercise protocols, outcomes, and findings of the included studies (Cont.)

Authors (Year)	Groups	Exercise Protocol	Time for surgery to BFR	Frequency/ Duration	Outcome Measures	Results
Li et al. [22]	BFR- 40% AOP BFR- 80% AOP Non-BFR	BFR: Elastic bands and Barbell 2 different QF exercises 1*30 reps, 3*15 reps Rest: 30 sec All patients completed the same rehabilitation protocol.	8 Weeks After Surgery	2 sessions/week For a total of 8 weeks	- QF Strength: Isokinetic Dynamometer - QF Thickness: Ultrasound - Knee Functions: IKDC - Balance: Y-balance test	80% of AOP group showed superior improvements in quadriceps strength, thickness, and peak torque compared to the 40% AOP and control groups. Superior improvements in IKDC and balance in both BFR groups over the control.
Majors et al. [18]	BFR Non-BFR	BFR: 20-30% of 1 RM 1*30 reps, 3*15 reps Rest: 30 sec and 1 min 7 different exercises Non-BFR: Standard rehabilitation protocol	> 365 days After Surgery	2 sessions/week For a total of 6 weeks	- QF and Hamstring Strength: Isokinetic Dynamometer - Rate of TKA revision	No significant difference in strength outcomes and rate of TKA revision between groups.
Mason et al. [23]	BFR Non-BFR	1*30 reps, 3*15 reps Rest: 30 sec and 2 min Four phased rehabilitation program was followed by all groups.	Within 1 Week of Surgery	2-3 sessions/week For a total of 12 weeks	- QF and Hamstring Strength: Isokinetic Dynamometer - Thigh circumference: Tape measurement - Functions: Lower Extremity Functional Scale - Symmetry index	Similar changes in both groups.
Ohta et al. [19]	BFR Non-BFR	1-3 sets, 20-60 reps A progressive	2 Weeks After Surgery	6 sessions/week For a total of 16	- QF and Hamstring Strength: Isokinetic	Significantly greater improvements in

Table 4. The exercise protocols, outcomes, and findings of the included studies (Cont.)

Authors (Year)	Groups	Exercise Protocol	Time for surgery to BFR	Frequency/ Duration	Outcome Measures	Results
		rehabilitation protocol consisting of low-intensity, mostly CKC exercises were applied.		weeks	Dynamometer - QF, Hamstring, Adductors' CSA: MRI	QF and hamstring strength, CSA enlargement, in BFR compared to Non-BFR.
Park et al. [25]	BFR with 40% AOP BFR with 80% AOP Non-BFR	BFR: 1-3 on OMNI-RES (30% of 1 RM) 1*30 reps, 3*15 reps 3 different exercises Rest: 3 mins All groups followed the same low-intensity program.	N/A	2 sessions/week For a total of 12 weeks	- QF and Hamstrings' CSA: MRI - QF Strength: Isokinetic Dynamometer - Pain Visual Analogue Scale - Knee Functions: IKDC	Significant CSA decrease in BFR (40% AOP) and Non-BFR groups, no change in BFR (80% AOP). Knee extension strength, pain, and function improved in all groups, with the highest increase in the BFR with AOP 80%.
Roman et al. [20]	BFR Non-BFR	BFR: 20-30% of 1 RM (OMNI-RES) 1*30 reps, 3*15 reps Rest: 30 sec	Within 2 Weeks After Surgery (Mean: 8.4 days)	2 sessions/week For a total of 12 weeks	- QF and Hamstring Strength: Isokinetic Dynamometer -Knee Strength Symmetry Index - Knee Functions: IKDC - Time to RTS	Superior strength improvement in BFR group compared to Non-BFR. Lower but insignificant limb strength symmetry in BFR. Better reported knee function scores in BFR. Similar RTS time for groups.
Takarada et al. [21]	BFR Sham BFR	BFR: 5 mins occlusion x 5 sets. Rest: 3 mins. Sham BFR: Cuff without inflation placed on thigh for 37 min.	3 Days After Surgery	2 sessions/day Daily Application For a total of 2 weeks	- QF and Hamstrings' CSA MRI	QF and Hamstring CSAs significantly decreased more in the Sham BFR than BFR.

Table 4. The exercise protocols, outcomes, and findings of the included studies (Cont.)

Authors (Year)	Groups	Exercise Protocol	Time for surgery to BFR	Frequency/ Duration	Outcome Measures	Results
Tennent et al. [24]	BFR Non-BFR	All participants followed the standard protocol. BFR: 30% of 1 RM 1*30 reps, 3*15 reps Rest: 30 sec Standard program + leg press, leg extension, reverse press Non-BFR: Standard program	21.5 days 20.0 days	2 sessions/week For a total of 6 weeks	- QF and Hamstring Strength: Isokinetic Dynamometer - Thigh circumference: Tape measurement - Knee Functions: KOOS, VR12 - Physical Performance: Self-selected walking velocity, sit-to-stand 5 times, 4 square step test, timed stairs ascent	The BFR group showed significant increases in thigh girth and greater improvements in physical outcomes, including timed stair ascent and VR-12 mental score. Strength gains were nearly double those of Non-BFR.
Tramer et al. [26]	BFR Non-BFR	BFR: BW and weights 1*30 reps, 3*15 reps 4 different home-based exercises Rest: 30 sec and 2 mins. Non-BFR: Same exercises without occlusion	2 Weeks After Surgery	5 sessions/week For a total of 2 weeks	- QF Strength Handheld Dynamometer - Patient-Reported Outcome Measurements - ROM - Thigh circumference: Tape measurement	All patients showed less strength loss in the operative leg. No significant differences were found between the groups for all outcome measures.
Vieira De Melo et al. [30]	BFR Non-BFR	BFR: 30% of 1 RM 1*30 reps, 3*15 reps Non-BFR: 70% of 1 RM 3*10 reps Leg press and Flexor Chair Conc: Ecc (2:2) Rest: 30 sec and 5 mins	After Discharge (Mean Day N/A)	2 sessions/week For a total of 12 weeks	- QF and Hamstring Strength: Handheld dynamometer - Knee Functions: Lysholm Scale, IKDC, KOOS	Greater improvements in BFR.

Balance

Dynamic balance was evaluated in five studies using the Y Balance Test, the Modified Star Excursion Balance Test, and the One-Leg Standing Test. All studies notified BFR provided significantly greater enhancements in balance compared to controls [5,6,29], anterior reach in the Y-balance test were superior in BFR participants [17,22].

Range of Motion (ROM) and Laxity

Three studies assessed ROM with goniometer and one knee joint laxity with KT-1000. BFR interventions led to significantly greater ROM improvements in two studies [5,6], while comparable significant differences between the groups were achieved in one study [26]. A similar significant decrease in both BFR and HL-RT groups was observed for knee laxity assessment [6].

Thigh Circumference

Changes in thigh circumference were evaluated in six studies using a tape measure. Two studies reported greater improvements in the BFR groups [5,6,24], one study found significant improvements with BFR compared to non-BFR but not superior to NMES [17], and two studies reported no significant differences between the groups [23,26].

Return to Sport/Activity (RTS/A)

RTS time was evaluated in four studies. One study reported faster RTS in the BFR group [29], another found faster RTS in the non-BFR group [15], while two studies reported similar RTS times between the groups [20,27].

DISCUSSION

The reviewed literature provides a comprehensive evaluation of the effects of BFR training on postoperative rehabilitation outcomes following various knee surgeries, including ACLR, TKA, meniscectomy, and HTO. The included studies, encompassing diverse clinical populations, demonstrated heterogeneity in patient demographics, surgical techniques, timelines, and intervention and rehabilitation methods. The variability in cuff pressures, occlusion durations, and exercise protocols used across studies highlights the need for standardization. Most studies applied 60-80% AOP with consistent improvements across outcomes. However, differences in cuff placement, type, and determination of occlusion pressure introduce heterogeneity that could affect reproducibility. Such variability highlights the need for personalized rehabilitation protocols when incorporating BFR training, given its broad applicability across age groups and surgical diagnoses. These findings highlight the efficacy of early and consistent BFR training in post-surgical rehabilitation.

Muscle Strength and Muscle Activation

Following surgical procedures, muscle strength and joint functions may be decreased due to various reasons, making rehabilitation essential for both preventing further deterioration, safely restoring the functions, and promoting full recovery [32]. Seventeen studies assessed muscle strength and demonstrated significant increases, with 47% of studies showing superior strength gains with BFR interventions compared to non-BFR protocols. This supports the findings of the meta-analysis by Zhou et al. [33], which demonstrated that low-intensity BFR training is effective in preserving and enhancing muscle strength post-surgery. The single study reporting increased quadriceps activation across BFR and non-BFR groups underscores the potential for enhanced neuromuscular recruitment.

Muscle Morphology and Physiology

Ten studies evaluated muscle morphology, with findings indicating that BFR helps mitigate muscle atrophy. Similar to our results, Wengle et al. [34] reported in their review of studies applying BFR after knee surgery that BFR was superior to control in improving muscle mass. Particularly BFR with higher AOP leads better results [22,25]. This is consistent with the findings of a preview study [35], which highlighted AOP as a critical factor in muscle hypertrophy. Additionally, evidence of similar physiological changes in biopsy studies suggests that BFR and traditional training elicit comparable adaptations, affirming its use as a low-intensity alternative.

Pain

BFR exercise has been suggested to enhance exercise-induced hypoalgesia, which may explain the pain reductions reported in the two studies included in our review (meniscectomy and HTO) [5,25]. Additionally, Hughes and Patterson [36] found that high-pressure BFR resistance exercise increased pressure pain thresholds in the exercising limb more than low-load or high-load resistance exercises, with the hypoalgesic effect persisting for up to 24 hours post-exercise. However, given that pain outcomes were assessed in only two studies, the evidence remains limited, and no definitive conclusions can be drawn. Furthermore, a meta-analysis examining ACLR rehabilitation reported that BFR did not provide superior pain relief compared to traditional rehabilitation methods [33]. This discrepancy may be due to variations in patient populations, individual pain perception, rehabilitation intensity, BFR protocols, and adherence across studies. Therefore, further high-quality research is necessary to better understand the potential hypoalgesic effects of BFR and its role in post-surgical pain management.

Knee Functions and Performance

Functional recovery after knee surgeries is crucial, as it significantly impacts patients' quality of life, return to activity/activity participation, and long-term outcomes. Superior improvements in knee function and performance were evident in 58% of reviewed studies, reinforcing previous literature that supports BFR's role in functional recovery [33]. Similar findings were observed in a couple of meta-analyses, which highlighted BFR's efficacy in improving functional scores, particularly in ACLR patients [33,37].

Balance

All five studies assessing balance noted greater significant enhancements with BFR, consistent with earlier findings by Zhou et al. [33]. Since there is a link [38], enhanced balance outcomes by BFR protocols could be attributed to the combination of neuromuscular adaptations and strength improvements.

Range of Motion (ROM) and Laxity

Maintaining or improving joint mobility following surgeries is essential for restoring function and preventing long-term complications. In surgeries such as the ACLR, joint laxity is a critical factor to address as it can impact stability and increase the risk of re-injury; therefore, rehabilitation programs targeting optimal recovery should improve stability. By implementing BFR, 66.7% of the studies evaluating ROM reported superior results after 8 weeks of application [5,6], while 33.3% showed similar results to traditional methods after just 2 weeks of application [26]. Additionally, BFR yielded similar results in joint laxity with HL-RT [6]. BFR appears to be a potentially valuable tool for enhancing joint mobility and stability, particularly following ACLR with an 8-week rehabilitation program.

Thigh Circumference

Thigh circumference measurement is a simple and effective method commonly used in clinical settings to monitor muscle atrophy or hypertrophy. BFR's ability to increase thigh circumference aligns with Charles et al. [39], who demonstrated its efficacy in reducing muscle atrophy.

Return to Sport/Activity (RTS/A)

Return to sport/activity time is crucial as it directly impacts a patient's recovery process, showing the regain of full functional capacity and the risk of reinjury before resuming various-intensity levels of activities. In the current review, the variability in RTS times between BFR and non-BFR groups was observed. The diversity of factors influencing RTS time includes the type and severity of the injury, rehabilitation process, psychological readiness, and individual variations in recovery, making it a highly individualized and complex process [40,41]. Although BFR is promising to enhance the capacity for patients to return to activities [42], there is a need for more well-structured studies examining the effects of BFR on RTS time, including the potential influencing factors.

Limitation

This review has several limitations. First, the included studies exhibited considerable heterogeneity in various aspects, including study design, participant characteristics, surgical procedures, BFR protocols, and outcome measures. This variability poses challenges for direct comparisons and limits the generalizability of the findings. Differences in surgical techniques and BFR application methods may have influenced the reported outcomes, making it difficult to draw uniform conclusions. Second, while the majority of studies were of good quality, some had limited sample sizes and lacked detailed reporting on intervention fidelity, limiting the strength of conclusions. Third, follow-up durations varied, with some studies not extending long enough to assess sustained benefits or long-term outcomes. Additionally, the variability in methods for determining AOP, cuff/device, or protocol properties introduces potential inconsistencies in BFR application. Another limitation of this review is that we only used PubMed for data retrieval, which may have led to missing relevant studies from other databases like Scopus, Embase, or Web of Science. Future reviews should consider a broader search strategy for a more comprehensive analysis.

CONCLUSION

BFR training has demonstrated significant similar or superior benefits in rehabilitation and various outcomes while maintaining a favorable safety profile, even when implemented early in the postoperative period. This method appears to be a promising approach to traditional rehabilitation following knee surgeries. Future research should prioritize protocol standardization and the assessment of long-term outcomes. Additionally, given the promising effects reported in most studies, further investigation is warranted to explore its impact across a broader range of knee surgeries in the postoperative period.

DECLARATIONS

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Peer-review: Externally peer-reviewed.

ABBREVIATIONS

ACL: Anterior cruciate ligament

ACLR: Anterior cruciate ligament reconstruction

AOP: Arterial occlusion pressure

BFR: Blood flow restriction

HL-RT: High-load resistance training

HTO: High tibial osteotomy

IKDC: International Knee Documentation Committee

KOOS: Knee Injury and Osteoarthritis Outcome Score

Non-BFR: Non-Blood flow restriction

NMES: Neuromuscular Electrical Stimulation

PEDro: Physiotherapy Evidence Database Scale

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RCTs: Randomized controlled trials

RM: Repetition maximum

ROM: Range of motion

RTS/A: Return to sport/activity

Sham-BFR: Sham-Blood flow restriction

TKA: Total knee arthroplasty

VAS: Visual Analog Scale

VR12: Veterans RAND 12-Item Health Survey

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