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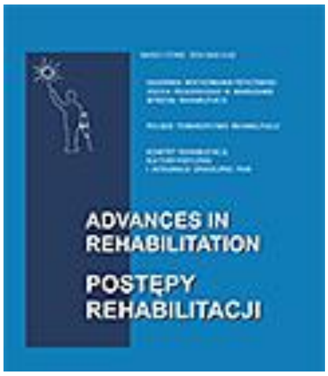

Original article

Title: A scoping review on outcomes, interventions and cuff parameters for blood flow restriction training in the treatment of knee osteoarthritis

Authors: Gurjant Singh, Monika Hariramani, Saumya Kothiyal

Gurjant Singh - 0000-0002-7421-8868
Monika Hariramani - 0009-0002-7281-791X
Saumya Kothiyal - 0000-0001-8630-6382

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A scoping review on outcomes, interventions and cuff parameters for blood flow restriction training in the treatment of knee osteoarthritis

Gurjant Singh*[E-F], Monika Hariramani[A-D], Saumya Kothiyal[B-C]

Department of Physiotherapy, University Institute of Allied Health Sciences, Chandigarh University, India

Abstract

The most common type of arthritis that alters a joint's mechanical and structural properties is osteoarthritis (OA). Resistance training combined with blood flow restriction training (BFRT) is one of the new and promising non-pharmacological strategies for treating OA that has received attention recently. This paper aims to identify the outcomes and outcome measures used for BFRT in knee OA, evaluating BFRT intervention and cuff parameters.

The Preferred Reporting Items for Systematic Reviews and Meta-analysis Extension for Scoping Reviews is followed while reporting on scoping reviews. The Cochrane Central Register of Controlled Trials, the Physiotherapy Evidence Database, and PubMed were among the databases that were searched for research.

Eight studies were included. The range of outcomes used in the study were knee pain, function, strength, quadriceps cross-sectional area, quality of life, disease severity, growth hormone level, and Range of motion. The parameters that were used in the included studies ranged from 4-5 sets of 10-15 repetitions at 20%–30% of 1RM load; progressive blood restriction ranging from 30%–80% of arterial occlusion pressure occurred with placement of the cuff at the most proximal part of the thigh.

Low-intensity exercise training combined with blood flow restriction (BFR) used with appropriate parameters is a viable alternative to traditional strategies for improving knee OA patients' pain, strength, muscle mass, hormones, functionality, range of motion, and overall quality of life.

Keywords: blood flow occlusion training, knee, osteoarthritis

***Correspondence:** Gurjant Singh Assistant Professor, Department of Physiotherapy, University Institute of Allied Health Sciences, Chandigarh University; email: singh.guri547@gmail.com

Introduction

The most common long-term joint ailment, osteoarthritis (OA), is still one of the few age-related chronic conditions for which no known cure or treatment can halt the disease's advancement. Large, medium, and tiny joints can all be impacted, but the knee is the most commonly afflicted in terms of painful condition; up to one in eight men and women over 60 years of age have knee symptoms [1]**.** As estimated, nearly 45% of all individuals are at risk of developing knee OA [2].

OA is a diverse chronic illness that has traditionally been defined by cartilage involvement; however, according to recent considerations, it is thought to include the entire joint, including cartilage, ligament, subchondral bone, muscle, synovial membrane, menisci-like periarticular soft tissues [3]. The clinical symptoms that are associated with OA are musculoskeletal pain, stiffness, restricted range of motion, reduction in function, decreased independence, and decreased quality of life (QOL) [3],[4]. According to studies, females have a 2-3 times higher incidence rate of knee OA than males, which may be related to a variation in the biomechanical environment during walking induced by variable strength and muscle activation modalities [5]. This indicates the high prevalence of knee OA, which could be a leading cause of enormous financial pressures on healthcare services, such as traditional therapies and joint replacements [4],[6]. Healthcare systems incur billions of dollars annually in costs related to pharmaceutical intake and hospital stays for the treatment of OA [7]. Symptoms are often associated with physical inactivity, which is a major global contribution to the incidence of chronic diseases and has been connected to morbidity and death in the modern age. To treat knee OA, non-pharmacological approaches are strongly advised as the first line of treatment by international standards that follow rigorous methodology. The suggested initial treatments for these individuals' symptoms include physical therapy, patient education, and weight loss where necessary. The long-term impact of knee OA and associated expenditures to patients and the healthcare system may be reduced with exercise and education combined [7].

A traditionally used conventional method for increasing muscle strength and muscle mass is resistance training. Individuals differ in their ability to withstand the severe mechanical forces placed on their joints during rigorous resistance exercise [5]. Due to the risk imposed by exercise loads, there is a need for alternative strategies for gaining strength over the traditionally used resistance training [8]. One of the emerging, promising, non-pharmacological strategies for the treatment of knee OA in recent considerations is resistance exercise with Blood Flow Restriction Training (BFRT) [9]. Blood flow restriction (BFR) is achieved by applying external pressure with a pneumatic cuff. The imposed pressure prevents venous outflow while allowing arterial inflow [2]. It usually combines pneumatic cuff-affiliated partial restriction produced in the blood flow to the working muscles when applied proximally with the low intensity (~20%–40% 1-RM) resistance training of the exercising limb [3]. BFR exercise will induce a stronger physiological metabolic stress, including growth hormones and higher recruitment of type II muscle fibers, by inducing ischemia in the limbs [4],[10].

Despite the clinical benefits found for other musculoskeletal conditions and the knowledge of resistance training being the most evidence-based treatment available for knee OA, the method of training has received little attention in knee OA rehabilitation. A higher chance of implementation in clinical practice will be made possible by the outcomes, which will enable clinical practitioners to get the parameters of study BFRT interventions through peer-reviewed journal publishing. In addition, the evaluation will recommend future directions for BFRT therapies for OA in the knee and the requirements for exercise reporting. As a result, the goal of this scoping review is to assess existing research on the use of BFRT for knee OA. The scoping study will be directed by the following review questions about specific elements of BFRT therapies in knee OA rehabilitation: 1.) What were the outcomes and outcome measures in published research? 2.) In published research, which BFRT intervention and cuff parameters were used?

Method

Scoping reviews are advised for mapping important concepts, evidence gaps, and forms of evidence within a particular subject. They can also help guide future research and the possibility of doing systematic reviews on the topic. Because the study questions were exploratory, a scoping review was carried out. The framework step of Arksey and O'Malley (Arksey & O'Malley, 2005) was carried out. The PRISMA-ScR, or Preferred Reporting Items for Systematic Reviews and Meta-analysis Extension for Scoping Reviews, is followed while reporting on scoping reviews, which after receiving approval from the St. Michael's Hospital Research Ethics Board, was created by published standards by the EQUATOR (Enhancing the Quality and Transparency Of health Research) Network for the development of reporting guidelines [11]. Examining current BFRT therapies in cases with knee OA for the first time in the literature was the goal of this scoping study.

Eligibility Criteria

A modified (Population, Intervention, Comparator, and Outcome) PICO (PCoCo) PCC (Population, Concept, and Context), which is advised for scoping reviews, served as the basis for the inclusion criteria of the scoping review. Research involving persons diagnosed with OA in the knee for any length of time was taken into consideration. Mild to moderate, unilateral or bilateral knee OA and those scheduled for Total Knee Replacement were both considered forms of knee OA. All OA-related symptoms were taken into consideration for inclusion. Articles that were written in English were included in the study. Also, the articles published in other languages were included only if their English translations were made available by the journal.

Excluded from consideration were studies including subjects with concomitant injuries or non-knee OA medical problems. BFRT, comprising any kind or format, such as BFRT carried out with bodyweight or external resistance, was the notion of interest for patients with knee OA. Including randomized controlled trials and non-randomized controlled studies, this scoping review took into account experimental and quasi-experimental study types. Furthermore taken into consideration for inclusion were case series, case reports, and prospective and retrospective cohort studies. Every study that was taken into account was published with open access.

Search Strategy / Information Sources:

Key phrases from two fundamental concepts—blood flow restriction (also known as "Kaatsu" or "Occlusion training") and osteoarthritis—were included in the search technique, which was used consistently across all databases. Each concept's essential terms and the concepts themselves were linked using the Boolean operators "Or" and "And," respectively. The Cochrane Central Register of Controlled Trials (CENTRAL), the Physiotherapy Evidence Database, and PubMed were among the databases that were searched for research. A full search approach was implemented, tailored to each database, including the Cochrane Library (controlled trials, systematic reviews), MEDLINE, CINAHL, AMED, EMBase, SPORTDiscus, and others. A search was also conducted through the trial registries below: The ISRCTN and ClinicalTrials.gov. We looked through databases to find articles published between 2014 and 2023.

Study selection:

All found citations were gathered after the search, and submitted to Mendeley, and duplicates were eliminated. The two independent reviewers then went over the titles and abstracts to make sure they met the review's inclusion requirements. Complete retrieval of potentially relevant studies was achieved. The whole text of the chosen citations was carefully evaluated by two impartial reviewers by the inclusion criteria. At every stage of the research selection process, conflicts between the reviewers were settled by discussion or by the advice of a third reviewer. PRISMA-ScR guidelines are followed in reporting the search results. A critical assessment was not carried out in compliance with the guidelines for conducting scoping reviews [11].

Data extraction / Data charting:

Two independent reviewers extracted data from sources that were part of the scoping review. Particulars about the population, concept, context, study methodologies, and important findings pertinent to the review questions were all included in the data extraction. Aspects including the study's design, target population, sample size, procedures, BFRT intervention specifics, exercise regimens, and outcome metrics were among the dimensions retrieved from the data. The BFRT treatments contained information on the kind, dosage, cuff settings, and techniques for advancing and modifying the training stimulus. Table 1 displays the extracted data along with a narrative synthesis that accompanies the tabulated results.

Tab. 1. Details of included studies

.No.	Author, Year, Study design, Population	Intervention Groups, Exercises, Duration	Training Parameter	Cuff / BFRT Parameters	Outcome measures	Conclusion/ Outcome

1.	Rodrigo Branco Ferraz; 2018; RCT (Randomized Controlled Trials); N=48 women with knee OA, randomized into 3 groups [3].	i) High-intensity resistance training (HI-RT); (ii) low-intensity resistance training (LI-RT), and (iii) LI-RT with blood flow restriction (BFRT); The RT program was comprised of bilateral leg press and knee extension exercises using conventional strength training machines;	1st week: HI-RT performed 4 sets of 10 repetitions at 50% 1-Repetition Maximum (RM), whereas LI-RT performed 4 sets of 15 repetitions at 20% 1-RM. 2nd week: 80% and 30% 1-RM for HI-RT and LI-RT, respectively. 5th week to 12th week: all groups increased the number of sets performed for each exercise from four	Cuff placement: inguinal fold Width: 175 mm Length 920 mm Pressure: 1st week= 50% of the limb occlusion pressure (LOP) and for further weeks= 70% of the LOP was applied, The average cuff pressure: was 139.2 ± 10.8 mmHg, and the Average cuff pressure used: was 97.4 ± 7.6 mmHg.	Lower-limb strength [5 attempts of 1 (RM)], quadriceps cross-sectional area [Computed tomography (CT Scan)], functionality [timed-stands test (TST) and timed-up-and-go test (TUG)], and disease-specific inventory (pain, stiffness, functioning), [Western Ontario and McMaster Universities OA Index (WOMAC)], before (PRE) and after (POST) the protocol.	BFRT and HI-RT both increased muscle strength, quadriceps muscle mass, and function. Importantly, BFRT was able to relieve pain while employing lower loads and causing less joint stress, establishing itself as a realistic and effective therapeutic adjunct in OA therapy.

		2 times per week for 12 weeks	to five. BFRT group protocol was the same as LI-RT but with external pressure.	The pressure was sustained throughout the session.		

2.	Neil A Segal; 2014; RCT; n=45 women, who had at least one risk factor of symptomatic knee OA, were randomized into 2 groups [8].	1) Low-load resistance training alone. 2) Low load resistance training with concurrent BFR. The exercise included leg-press resistance training. Given 3 times per week for 4 weeks.	4 sets of bilateral leg presses[30 reps for 2 mins and further 3 sets of 15 reps for 1 min each with 30 sec break between each set] at 30% of their 1RM, using the instrumented leg press. The same was true for the BFRT group along with tourniquet pressure.	Participants sat in a chair, Cuff Placement: to the proximal thigh as near to the hip joint; width: 65 mm, length: 650 mm; pressure: during week 1, beginning pressure= 100 mmHg [30% of LOP]; week 2, 3, 4=120 mmHg [40% of LOP]; The belt was repeatedly pressurized for 1 minute and then depressuriz	PRE and POST measurement of isotonic bilateral leg press strength, isokinetic knee extensor strength by instrumented pneumatic leg press, and quadriceps volume by magnetic resonance imaging (MRI). Secondary measures: lower limb muscle power (leg press and stair climb). Knee pain by the Knee Osteoarthritis Outcome Score (KOOS)	Leg press and knee extensor strength in women at risk for knee OA increased when BFR was added to a 30% 1RM resistance training program as compared to the same program without BFR.

				ed for 10 seconds in increments of 20 mmHg from 100, 120, or 140 mmHg. The pressure was sustained throughout the set.		

.	Yangguang Chen; 2022; RCT; n=18 postmenopausal female patients with mild to moderate unilateral knee OA [5].	1. A 30% 1-RM resistance exercise with BFR (BFR group); 2. A 70% 1-RM resistance exercise without BFR (RES group); 3. A 30% 1-RM resistance exercise without BFR (CON group). The exercise involved six sets of knee extension and flexion exercises.	Each Exercise of 3 sets, 15 repetitions of each set, with 1 min interval between each set was performed. For the BFR group, a cuff with 70% AOP on their unaffected limbs was applied.	Cuff width*length: 12 × 124 cm; cuff placement: upper third of the thigh (proximal end of the legs); cuff pressure: 70% of AOP. The pressure was sustained throughout the session.	At four different time points—before exercise, immediately after exercise, 15 minutes after activity, and 30 minutes after exercise—levels of blood lactate (BLA) and hormones associated with muscle growth were measured through blood testing.	Compared to high-load resistance exercise, low-load resistance exercise with BFR was better in increasing post-exercise blood testosterone levels.

.	Naija Petersson; 2022; Feasibility study; n=14 elderly individuals diagnosed with knee OA [12].	4 times each week, 1 supervised session and 3 unsupervised sessions, the BFR-walking exercise was carried out for 8-10 weeks.	Participants walked for 20 minutes outside at a moderate pace (around 4 km/h) while simultaneously applying BFR to the affected leg (BFR-leg).	Cuff placement: most proximal portion of the participant's thigh; cuff width: 11cm; cuff pressure: 60% of AOP, after 10 mins of walking pressure progressed.	Pre and post-testing [8-10 weeks] for Functional performance by 30-s chair sit-to-stand test (30-sec CST), Timed Up and Go (TUG), 40-m fast-paced walking (40mFPWT), and stair-climbing (11-step SCT) Self-reported knee function(pain, ADL's, Quality of life (QOL)) by KOOS	In patients with knee OA, blood flow-restricted walking exercise seemed possible. Improvements in functional performance were seen in those who followed the intervention procedure, while self-reported function remained the same.

5.	Sara A Harper; 2019; A Pilot RCT; n= 35 individuals with knee OA, >60 Years [13].	1)low-load resistance training with BFR 2) moderate-intensity resistance training (MIRT). Using standard isotonic resistance training equipment, leg press, leg extension, calf flexion, and leg curl was done for 12 weeks, 3 times per week.	1) Perform-ed exercises at 20% of 1RM with the addition of external compression. 2) Performed exercises at 60% of 1RM	Cuff placement: proximal thigh of both legs. Cuff pressure: mmHg = 0.5 (SBP) + 2(thigh circumference) + 5]. The cuff remained inflated throughout each exercise.	Quadriceps strength by dynamometer, Gait speed, performance on the Short Physical Performance Battery (SPPB), and pain as measured by the WOMAC were among the study's outcomes.	According to this pilot RCT, BFR was a realistic and safe treatment for older persons with knee OA.

6.	Neil Segal; 2015; RCT; N= 42 men with knee OA, aged 45 and above [2].	1) Low-load resistance training 2) low-load resistance training with concurrent BFR. Exercise included bilateral leg press for 4 weeks, 3 times per week.	1)30% 1RM was given. 2) 30% 1RM with external pressure through the cuff. 4 sets were done as follows: 30 reps + 30 secs rest + 15 reps + 30 sec rest+ 15 reps + 30 sec rest + 15 reps.	Cuff placement: proximal aspect of each thigh Cuff width: 65 mm Cuff length: 650 mm Cuff pressure: 30 mmHg for the first training and 40 mmHg for all subsequent training. The pressure was sustained throughout the set.	Pre-post assessment of isotonic double-leg press strength by instrumented pneumatic leg press with digital output, isokinetic knee extensor strength by isokinetic dynamometer & knee pain by KOOS.	The BFR was not linked to a worsening of knee pain, although the control group's knee pain significantly decreased.

7.	Chengfang Hu; 2023; A multicenter RCT; n= 120 knee OA patients with metabolic dysfunction-associated steatotic liver disease (MASLD) Age: ≥ 50 years [14].	1. Weight bearing (WB) training 2. BFR resistance training group. There were three components to every session: ROM, strength, and stretching exercises. A 12-week course.	Stretch exercise: Hold for 30 seconds between each of the three repetitions. ROM exercise: Knee movement should be continuous for 30 seconds, with a 3-second hold at the end. Repeat twice. Strength exercise: 10 repetitions per group, held for 6 seconds each, and 3 repeats total.	Nylon Cuff = 11.5 cm × 86 cm; 5 mm thick; Cuff placement: at limb's proximal end; Cuff pressure: set at 80% of LOP; The cuff pressure was gradually increased by the device which adapts the pressure automatically to within allowable bounds.	At weeks 1, 4, and 12, the following measures were measured: pain by KOOS; range of motion (ROM) by goniometer; scaled maximum isotonic strength (10RM) using MED leg press; self-reported function (KOOS), and the outcomes of the 30-second chair sit-to-stand test (30-sec CST).	When compared to WB exercise alone, BFR training improved muscle strength, decreased discomfort, and improved everyday life and sports activities for patients with knee OA. BFR needs to be suggested for knee OA patients with MASLD who require rehabilitation.

8.	Daniel C. Ogrezeanu; 2023; Experimental cross-over design; n= 17 patients with end-stage knee OA; age older than 55 [15].	Three days separated the three experimental sessions. The subjects completed three levels of concurrent BFR in random order: control (no BFR), BFR at 40% LOP, and BFR at 80% LOP. They also completed four sets of low-load knee extensions (2 on Borg's CR10 Scale or	To reach a 2 on Borg's CR10 Scale, subjects completed 2-3 sets of 2 repetitions of full-range seated knee extension at a regulated pace of 1.5 s/phase (corresponding with the training activity). They rested for 1 minute in between sets. After that, there was a 5-minute break before starting the BFR	Pneumatic cuff: 11-cm wide; Cuff placement: most proximal portion of the thigh; cuff pressure: 40% and 80% of LOP.	High-density surface electromyography was used to determine the normalised root-mean-square (nRMS), nRMS spatial distribution (centroid displacement, modified entropy, and coefficient of variation), and normalised median frequency (nFmed) from the vastus medialis (VM) and lateralis (VL). Before the session, the participants responded to the following surveys: The WOMAC score was used to clinically evaluate the	BFR during knee extensions at 80% AOP increases VM activity and VL amplitude distribution by more than 40% AOP and control. The results obtained thus far support the idea that BFR training can be a practical and useful therapeutic adjunct in the treatment of severe knee OA.

		30% of 1RM).	training. The workout included four sets of seated knee extensions (30, 15, 15, and 15 reps), with one-minute rest intervals in between. BFR was used during both sets and pauses.		stiffness, pain, and physical function of the osteoarthritic knee under study (the first knee to be replaced in bilateral cases). The Pain Catastrophizing Scale (PCS) was used to evaluate the degree of catastrophizing, and the Chronic Pain Self-Efficacy Scale (CPSS) was used to measure perceived self-efficacy and the capacity to deal with the consequences of chronic pain. All participants were questioned about any potential negative effects within 72 hours following each session.	

Table 2: Statistical presentation of variation in outcome measures of the included articles

S.No.	Author, Year, Study design, Population	Statistical presentation of outcome measures
1.	Rodrigo Branco Ferraz; 2018; RCT (Randomized Controlled Trials); N=48 women with knee OA randomized into 3 groups [3].	The study found significant improvements in various measures with blood flow restriction training (BFRT) and high-intensity resistance training (HI-RT) compared to low-intensity resistance training (LI-RT): • Leg press strength (26% and 33% increase for BFRT and HI-RT, respectively) and knee extension 1-Repetition Maximum (23% and 22% increase for BFRT and HI-RT, respectively) showed substantial within-group gains compared to LI-RT (all $P < 0.0001$). • Cross-sectional area (CSA) increased by 7% and 8% with BFRT and HI-RT, respectively, significantly larger than LI-RT (all $P < 0.0001$). • BFRT and HI-RT demonstrated comparable improvements in the timed-stands test (TST) (7% and 14% increase, respectively) with HI-RT showing larger gains compared to LI-RT. • Scores on the timed-up-and-go test (TUG) did not show substantial differences between or within groups. • Both BFRT and HI-RT significantly improved Western Ontario and McMaster Universities Osteoarthritis (WOMAC) physical function (−49% and −42%, respectively; all $P < 0.05$). BFRT and LI-RT also improved WOMAC pain (−45% and −39%, respectively; all $P < 0.05$

2.	Neil A Segal; 2014; RCT; n= 45 women, who had at least one risk factor of symptomatic knee OA, were randomized into 2 groups [8].	• Baseline parameters showed no significant intergroup differences, except for a lower body mass index (BMI) in the BFR group (P = 0.0223). • The BFR group exhibited a substantial improvement in isotonic 1RM compared to the control group (28.3 ± 4.8 kg vs. 15.6 ± 4.5 kg, P = 0.0385). Additionally, isokinetic knee extensor strength relative to body mass significantly increased in the BFR group (0.07 ± 0.03 nm/kg) compared to a decrease in the control group (-0.05 ± 0.03 nm/kg) (P = 0.0048). • Changes in quadriceps volume, leg press power, and knee-related pain did not significantly differ between the groups.
3.	Yangguang Chen; 2022; RCT; n=18 postmenopausal female patients with mild to moderate unilateral knee OA [5].	• Perceived exertion ratings increased significantly in both the BFR and RES groups (70% 1-RM resistance exercise) compared to the CON group (30% 1-RM) (P < 0.05), with similar magnitudes. • Post-exercise blood lactate (BLA) levels were lower in the CON group compared to the BFR and RES groups (P < 0.05). • Growth hormone (GH) levels in the BFR group were significantly higher than those in the CON group at 15 minutes post-exercise, unlike the RES group. • Insulin-like growth factor-1 (IGF-1) levels were significantly lower in the CON group compared to the BFR and RES groups post-exercise and at 15 minutes later (P < 0.05).

		• Testosterone levels were lowest in the CON group post-exercise and 15 minutes later, followed by the RES group and then the BFR group (P < 0.05 for all comparisons).
4.	Naija Petersson; 2022; Feasibility study; n=14 elderly individuals diagnosed with knee OA [12].	• Baseline body mass index (BMI) and knee discomfort were higher (p = 0.05 and p = 0.06, respectively) in non-completing participants, with lower gait performance (p = 0.04). • Among fully processed case data, the training adherence rate was 93%, and the average knee pain level in the affected leg was 0.7 on a 10-point scale. • Self-reported function remained unchanged, while functional performance improved.
5.	Sara A Harper; 2019; A Pilot RCT; N=35 individuals with knee OA, >60 Years [13].	• The mean difference between groups (BFR vs. moderate-intensity resistance training [MIRT]) was -1.87 (-10.96, 7.23) Nm (Newton metre). • The pre- to post-training change in maximal isokinetic peak torque across three movement speeds was 9.96 (5.76, 14.16) Nm.
6.	Neil Segal; 2015; RCT; N= 42 men with knee OA, aged 45 and above [2].	• At baseline, there were no significant differences between groups in muscular strength, age, BMI, or knee pathology. • Despite improvement in leg press 1RM in both groups, primary or secondary measures of muscle strength did not differ significantly between the control and BFR groups.

7.	Chengfang Hu; 2023; A multicenter RCT; n= 120 knee OA patients with metabolic dysfunction-associated steatotic liver disease (MASLD) Age: ≥ 50 years [14].	• Significant increases in range of motion (ROM) and scaled 10-repetition maximum (10RM) were observed at 4 and 12 weeks across the groups. • At the 12-week assessment, Knee Osteoarthritis Outcome Score (KOOS) pain, daily life function, and quality of life subscales significantly improved and differed between groups after adjusting for baseline values. • Notable and similar improvements in the 30-second chair sit-to-stand test (30-sec CST) outcomes were observed both within and between study groups.
8.	Daniel C. Ogrezeanu; 2023; Experimental cross-over design; n= 17 patients with end-stage knee OA; age older than 55 [15].	• No variations were observed between conditions in the vastus lateralis (VL), but in the vastus medialis (VM), normalised root-mean-square (nRMS) was higher with 80% of arterial occlusion pressure (AOP) compared to 40% AOP ($p < 0.008$) and control ($p < 0.001$). • Results of nRMS showed associations with health status, chronic pain self-efficacy, and pain catastrophizing (VM: 20.49, 20.42, 20.50; VL: 20.39, 0.27, 20.33), mainly observed in the VL but varying across conditions.

		• Overall, the normalised median frequency (nFmed) did not change between sets 3 and 4; however, it slightly increased in the VL with 40% AOP.

$P \leq 0.05$ defines significant results

Results

Included Study Characteristics:

A summary of the features and results of the included studies is given in Table 1, and statistical results are mentioned in Table 2. Out of the 72 publications that were found through the literature search, 8 satisfied the inclusion criteria and were included in the review, which is represented by the PRISMA flow chart (Figure 1). Seven randomized controlled trials (RCT) [3],[8],[5],[13],[2],[14],[15], and one feasibility study [12] make up the total of the 8 included studies. Participants in all of the studies had either unilateral or bilateral knee OA symptoms. Some studies compared the effectiveness of BFRT with other types of training for OA in the knee, such as two RCT comparing the effects of low-intensity exercises with and without BFRT in knee OA [8],[2]; one study comparing the effectiveness of low-intensity exercises with and without BFRT and high-intensity resistance exercises [3], one study comparing the effectiveness of low-load exercises with BFR and high-intensity resistance exercise [5] and another study comparing the effects of low-intensity exercises with and without BFRT and moderate-intensity resistance training [13]. Another study compared the effects of WB exercise and BFR training on knee OA [14]. In most of the studies, resistance training exercises involved leg presses knee flexion, and extension exercises. The BFRT interventions were conducted twice, three times, or four times a week for a length ranging from four weeks to twelve weeks.

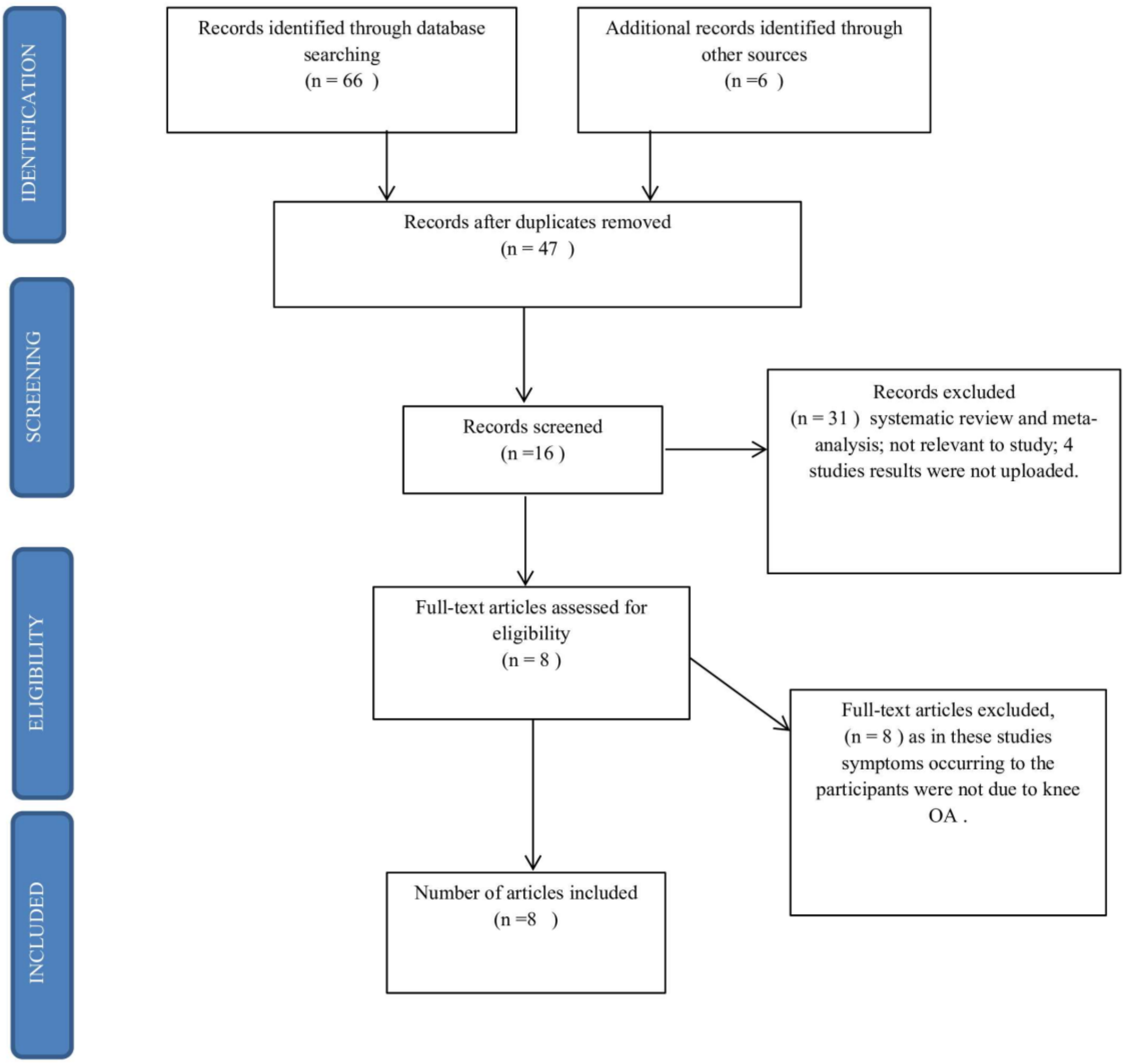

Fig. 1. Flow diagram of the studies selection process

Outcome Measures:

The included studies assessed knee pain; function; strength; quadriceps cross-sectional area; quality of life; growth hormone (GH) level; and range of motion using the KOOS and WOMAC questionnaire; 30-sec CST, TUG, 40mFPWT; dynamometer, instrumented leg press, 1RM, and 10 RM; MRI and CT scan; KOOS; blood test; and goniometer, respectively (refer to Table 1).

BFRT parameters /cuff parameters:

A BFRT cuff was applied to the most proximal part of the thigh in all included investigations; cuff widths varied from 6.5 to 17.5 cm. There were notable variances in the size and type of cuffs used. The range for calculating occlusion pressure was either 30 to 80% in the percentage of arterial occlusion or 80 to 180 mmHg in absolute pressure, although in 5 studies the percentage of occlusion pressure progressed with time, staying within the safety limits [3],[8],[12],[2],[14]. The suggested BFRT protocol, consisting of four sets, with 30 repetitions in the first set and 15 repetitions in each successive set [10] was followed in three investigations [8],[2],[15], but there were significant differences in the sets and repetitions of the prescribed exercises. Across investigations, there were three to five sets and ten to fifteen repetitions. One study used BFR during a twenty-minute walk [12]. In investigations, training intensity was administered between 20% - 30% of 1-RM, while training frequency varied from two to four times per week, with the duration ranging from 4 to 12 weeks. The cuff restraint was maintained for the duration of the training session, including the rest periods. It was removed right away after the session, with a two-minute break in between each type of exercise. The rest intervals between sets ranged from thirty to sixty seconds.

Outcomes:

A practical and effective therapeutic adjunct in OA therapy, blood flow-restricted low-intensity exercises have been shown to alleviate knee discomfort and build muscle mass and strength, in studies comparing them to other forms of resistance training. Studies concluded that BFRT encouraged non-agenerians while delaying the decline of functionality and QOL. Concerning older people, BFRT proved to be a safer technique (refer to Table 2).

Discussion:

In the field of rehabilitation, using BFR in conjunction with particular exercise regimens has grown in popularity recently and attracted a lot of study interest. Particularly, over the past 20 years, BFRT which was initially intended to help athletes in good health achieve even greater muscle strength, has gained popularity as a therapeutic approach for a variety of patient populations suffering from excruciating musculoskeletal disorders and severe functional gaps. As BFRT is safe and effective at improving pain outcomes, it can be used in the rehabilitation of patients with knee OA [16].

During exercise, BFR, also known as Kaatsu, is the result of totally blocking the venous return flow and only partially allowing the arterial inflow [17]. Applying pressure to the muscle should be just high enough to prevent venous return, but not so high as to prevent arterial input into the muscle [18]**.** Higher BFR pressure seems to enhance the cardiovascular response and frequently causes the soreness that comes with this kind of exercise. As a result, it is advised that pressure be set during BFR exercise depending on arterial occlusion pressure (AOP) measurement [10]**.**

Resistance training induces physiological adaptations that depend on various factors, such as the type of muscle contraction (concentric and eccentric), the number of sets, repetitions, the intensity of the exercise, the muscle groups involved, and the recovery period between sets [19]. The occlusion type, occlusion pressure, and occlusion time are the three variables that potentially influence the adaptations during BFRT [19]. For these reasons, the purpose of this scoping review was to determine the BFR parameters and their relationship to individuals with knee OA.

When the BFR approach is combined with low-intensity aerobic exercise, it has been demonstrated to increase maximal oxygen uptake and increase the muscle oxidative capacity brought on by aerobic training, in addition to musculoskeletal adaptations [20]**.** One of the included studies looked at the feasibility of BFR walking exercise for people with OA in their knees that has been present for a long time, the results of the study revealed that the exercise regimen was feasible, increased functional performance, and did not worsen knee pain or cause discomfort with the cuff. The viability and consistency of BFR walking seem to be influenced by individual characteristics; low baseline levels of fast-paced walking, a high body mass index, and a high degree of felt knee pain were associated with lower training adherence [12]. Future research is warranted to understand the impact of BFR training paired with aerobic exercises in individuals with knee OA.

BFR training may be useful in strengthening quadriceps in patients who have atrophy and weakness associated with knee pathology, according to a recent comprehensive study, also following knee surgery or in knee OA patients, the use of brief, low-load resistance BFR training seems safe and innocuous [17]**.** 7 studies assessed pain [3],[8],[12],[13],[2],[14],[15], 4 assessed functionality [3],[12],[14],[15] and 4 studies evaluated strength of quadriceps [3],[8],[2],[14]. 3 studies evaluated the cross-sectional area of the quadriceps and all the studies gave positive results for BFRT. It was shown that active recovery during resistance training with BFR may result in more notable gains in serum GH, and muscle strength by raising muscle activation and metabolic load [19], one of the included studies measured muscle GH after BFRT, which yielded positive results [5]. There are several neutrally or mechanically mediated modifications to gait brought about by the blood pressure cuff. Utilizing these modifications in clinical populations could have consequences [21]. Likewise one of the included studies assessed pre and post-BFRT gait speed, according to which functional performance improved after the intervention in knee OA patients [13].

The ability of BFRT to extend the range of motion is an essential bonus feature. By increasing blood flow to the injured area, BFRT can assist in improving flexibility and lessen joint stiffness, which will make exercising easier [22],[23],[18]. One of the included articles examined the impact of BFR on knee OA patients' rehabilitation using ROM as an outcome measure; the findings showed ROM improvement [14].

One of the included studies [15], investigated the neuromuscular reactions during acute resistance training with varying degrees of BFR in patients with end-stage knee OA and their relationship to health status, kinesiophobia, pain catastrophizing, and chronic pain self-efficacy. The study concluded that BFR during knee extensions at 80% AOP increases VM activity and VL amplitude distribution by more than 40% AOP [15]. The study's findings [15] are supported by those of another study [24], which sought to assess the effect of resistance training programs with varying levels of BFR on exercise-induced hypoalgesia (EIH) in patients with end-stage knee osteoarthritis. EIH, being an acute post-exercise reduction in pain sensitivity that can affect both exercising and non-exercising portions of the body, is one potential benefit of treatment for knee OA patients [24]. Despite a typical initial EIH following BFR training at 80% AOP, there are no differences in EIH comparing BFR training with placebo (sham BFR), 40%, and 80% AOP. On the other hand, the 80% AOP regimen quickly improved pressure pain thresholds (PPT) and decreased visual analogue scale (VAS) scores [24].

The etiology and outcome of metabolic dysfunction, including dyslipidemia, hyperglycemia, hypertension, and inflammation, can be linked to knee OA. The existence or lack of the metabolic syndrome as well as each of its symptoms are linked to knee OA [25], one of the included studies has compared the effects of traditionally used WB exercise and BFR training for treating knee OA patients with MASLD [14], according to which BFR need to be suggested for rehabilitation of such patients, as it reduces discomfort and eases everyday activities.

A cuff placed in the proximal region of the lower or upper limb restricts blood flow during low-intensity resistance training combined with blood flow restriction (LIRTBFR), which is performed at intensities between 15% and 30% 1RM [26]. In seven investigations [3],[8],[5],[12],[13],[2],[14], training intensity was administered between 20%-30% of 1-RM, while training frequency varied from two to four times per week.

It is commonly known that to achieve physiological adaptations from LIRTBFR, a higher number of repetitions is needed. It is recommended to perform 75 repetitions of the exercises divided into four sets, with 30 repetitions in the first set and 15 repetitions in each successive set [10],[27]. It was followed in three investigations [8],[2],[15], but there were significant differences in the sets and repetitions of the prescribed exercises. Across investigations, there were three to five sets and ten to fifteen repetitions.

Each study had a different set of guidelines regarding rest intervals and whether or not cuff pressure was maintained during sets and exercises. However, lengthier rest intervals may restrict potential adaptations by reducing metabolic stress in comparison to shorter rest intervals, as prior research has demonstrated [10],[27], resting with an inflated or deflated cuff is a feasible alternative [27]. In the included studies the cuff restraint was maintained for the duration of the training session, including the rest periods. It was removed right away after the session, with a two-minute break in between each type of exercise. The rest intervals between sets ranged from thirty to sixty seconds.

The literature does include recommendations for occlusion pressure that range from 40 to 80%, despite significant variations in the BFRT arterial occlusion pressure of the included studies, which varied from 30 to 80%. This suggests that pressure should be customized based on assessments of arterial pressure and comfort levels [27].

This review has several limitations, particularly the small number of studies included, highlighting the need for future high-quality studies with a larger number of studies. There was considerable heterogeneity of the BFRT parameters implemented in studies, with standardized methods and reporting of interventions required in future BFRT studies in the rehabilitation of knee OA to enhance clinical translation of the research interventions.

It has been demonstrated that combining low-intensity exercise training with BFR is a safer and more successful way to improve knee OA patients' pain, strength, muscle mass, hormones, functionality, and general quality of life. To treat knee OA using BFRT, one could utilize the following parameters: 2-4 times per week; progressing blood restriction ranging from 30%–80% of arterial occlusion pressure; 4-5 sets of 10-15 repetitions at 20%–30% of 1RM; and positioning the cuff at the most proximal portion of the leg. When the session is over, the cuff needs to be deflated right away. When applied following the suggested practice methodology, BFR training is a safe and efficient procedure. Furthermore, healthcare professionals must ensure that the patient is not contraindicated to execute the procedure.

Conclusion

Low-intensity exercise training combined with BFR is a safe and viable alternative to traditional strategies for improving knee OA patients' pain, strength, muscle mass, hormones, functionality, ROM, and overall QOL. To treat knee OA with BFRT, the following parameters could be used: 2-4 times per week; 4-5 sets of 10-15 repetitions at 20%–30% of 1RM; progressive blood restriction ranging from 30%–80% of arterial occlusion pressure; and placement of the cuff at the most proximal part of the thigh. The cuff should be deflated immediately after the session.

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