DOI: 10.5114/areh.2024.139019

Original article

Advances in Rehabilitation, 2024, 38(1), 52–62

A – Research concept and design
B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

Received: 2024-01-02
Accepted: 2024-04-19
Published: 2024-04-19

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

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

[1]Department of Physiotherapy, University Institute of Applied Health Sciences, Chandigarh University, India

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

Abstract:

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

The scoping review was based on the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement. The review was based on material from the Cochrane Central Register of Controlled Trials, the Physiotherapy Evidence Database and PubMed.

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 included studies used interventions ranging from four to five sets of 10 to 15 repetitions at 20% to 30% of 1 repetition maximum load; progressive blood restriction ranged from 30%–80% of arterial occlusion pressure when the cuff was placed at the most proximal part of the thigh.

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

Keywords: blood flow occlusion training, knee, osteoarthritis

Introduction

Osteoarthritis (OA), the most common long-term joint ailment, is still one of the few age-related chronic conditions which has no known cure or treatment. Although the condition can impact large, medium and tiny joints, the most commonly afflicted is the knee in terms of pain; up to one in eight men and women over 60 years of age have knee symptoms [1]. It has been estimated that 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, it is now thought to include the entire joint, including the cartilage, ligament, subchondral bone, muscle, synovial membrane and meniscus-like periarticular soft tissues [3]. The condition is associated with musculoskeletal pain, stiffness, restricted range of motion, reduction in function, decreased independence, and decreased quality of life (QOL) [3,4]. Research indicates that women are two to three times more likely to experience knee OA than men; this 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 place considerable pressure on healthcare services by creating a need for both traditional therapies and joint replacements [4,6]. Indeed, 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. International standards recommend non-pharmacological approaches as the first line of treatment for knee OA; such initial treatments include physical therapy, patient education, and weight loss where necessary. The long-term impact of knee OA and associated expenditures to both patients and the healthcare system may be reduced with a combination of exercise and education [7].

A traditional method for increasing muscle strength and muscle mass is resistance training. However, individuals differ in their ability to withstand the severe mechanical forces placed on their joints during rigorous resistance exercise [5]. As such, there is a need for alternative strategies for gaining strength over the traditional approaches based on resistance training [8]. One emerging, promising, non-pharmacological strategy for the treatment of knee OA is based on a combination of resistance exercise with Blood Flow Restriction Training (BFRT) [9]. In such approaches, 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]. The procedure typically combines partial restriction of blood flow to the working muscles by the proximal application of a pneumatic cuff with low intensity (~20%–40% 1-repetition maximum (RM)) resistance training of the exercising limb [3]. BFR exercise will induce stronger physiological metabolic stress, including high levels of growth hormones and greater recruitment of type II muscle fibers, by inducing ischemia in the limbs [4,10].

Despite its known clinical benefits for other musculoskeletal conditions, and the strong evidence base for resistance training in treating knee OA, this training method has received little attention in knee OA rehabilitation. The results of this scoping review will increase the chance of implementation in clinical practice, and thus enable clinical practitioners to employ the appropriate parameters (e.g. cuff parameters, number of sets, repetitions and duration) for BFRT interventions in peer-reviewed publications. In addition, based on our evaluation of prior research, the study will recommend future directions for BFRT therapies for OA of the knee, and suitable requirements for exercise reporting.

Hence, the aim of this scoping review is to assess existing research on the use of BFRT for knee OA. This scoping study will be directed by the following questions about specific elements of the treatment: 1.) Which outcomes and outcome measures have been used in previous research? 2.) Which BFRT intervention and cuff parameters have been 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 later systematic reviews on the topic. As the study questions were exploratory in nature, the present study was performed as a scoping review based on the framework presented by Arksey and O'Malley [11]. The present study is also based on Preferred Reporting Items for Systematic Reviews and Meta-analysis Extension for Scoping Reviews (PRISMA-ScR) guidelines; these were created by the EQUATOR (Enhancing the Quality and Transparency Of health Research) Network for the development of reporting guidelines, and later approved by the St. Michael's Hospital Research Ethics Board [12].

Eligibility Criteria

The inclusion criteria were based on a modified version of PICO / PCoCo (Population, Intervention, Comparator, and Outcome) that is PCC (Population, Concept, and Context). All reviewed papers involved persons diagnosed with OA in the knee for any length of time. Mild to moderate, cases of unilateral or bilateral knee OA and those scheduled for Total Knee Replacement were all considered forms of knee OA. All OA-related symptoms were taken into consideration for inclusion. The study included articles written in English; however, articles published in other languages were included if their English translations were made available by the journal.

Any papers including subjects with concomitant injuries or non-knee OA medical problems were excluded. All papers included some form of BFRT application, such as BFRT carried out with bodyweight or external resistance. The review considered both experimental and quasi-experimental study types, and hence included randomized controlled trials and non-randomized controlled studies; it also included case series, case reports, and prospective and retrospective cohort studies. All included studies were published with open access.

Search Strategy/Information Sources

The search included key phrases from two fundamental concepts, *viz.* blood flow restriction (also known as "Kaatsu" or "Occlusion training") and osteoarthritis; the search terms were used consistently across all databases. All essential terms, and the concepts themselves, were linked using the Boolean operators "Or" and "And", respectively. Various databases were searched, including the Cochrane Central Register of Controlled Trials (CENTRAL), the Physiotherapy Evidence Database, and PubMed. In addition, the Cochrane Library (controlled trials, systematic reviews), MEDLINE, CINAHL, AMED, EMBase and SPORTDiscus were searched using a full search approach, tailored to each database. A search was also conducted of the ISRCTN and ClinicalTrials.gov trial registries. All databases were searched for articles published between 2014 and 2023.

Study selection

All found citations were gathered and submitted to Mendeley, and the duplicates were eliminated. Two independent reviewers then went over the titles and abstracts to ensure they met the inclusion requirements. Complete retrieval of potentially relevant studies was achieved. The whole text of the chosen citations was also carefully evaluated by two impartial reviewers based on 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 were followed in reporting the search results. As far as our understanding and adherence to the criteria allow, our study did not conduct a critical assessment, which is not necessary for the scoping review process.[12].

Data extraction/Data charting

Two independent reviewers extracted the data from the sources included in the scoping review. The data extraction included particulars about the population, concept, context,

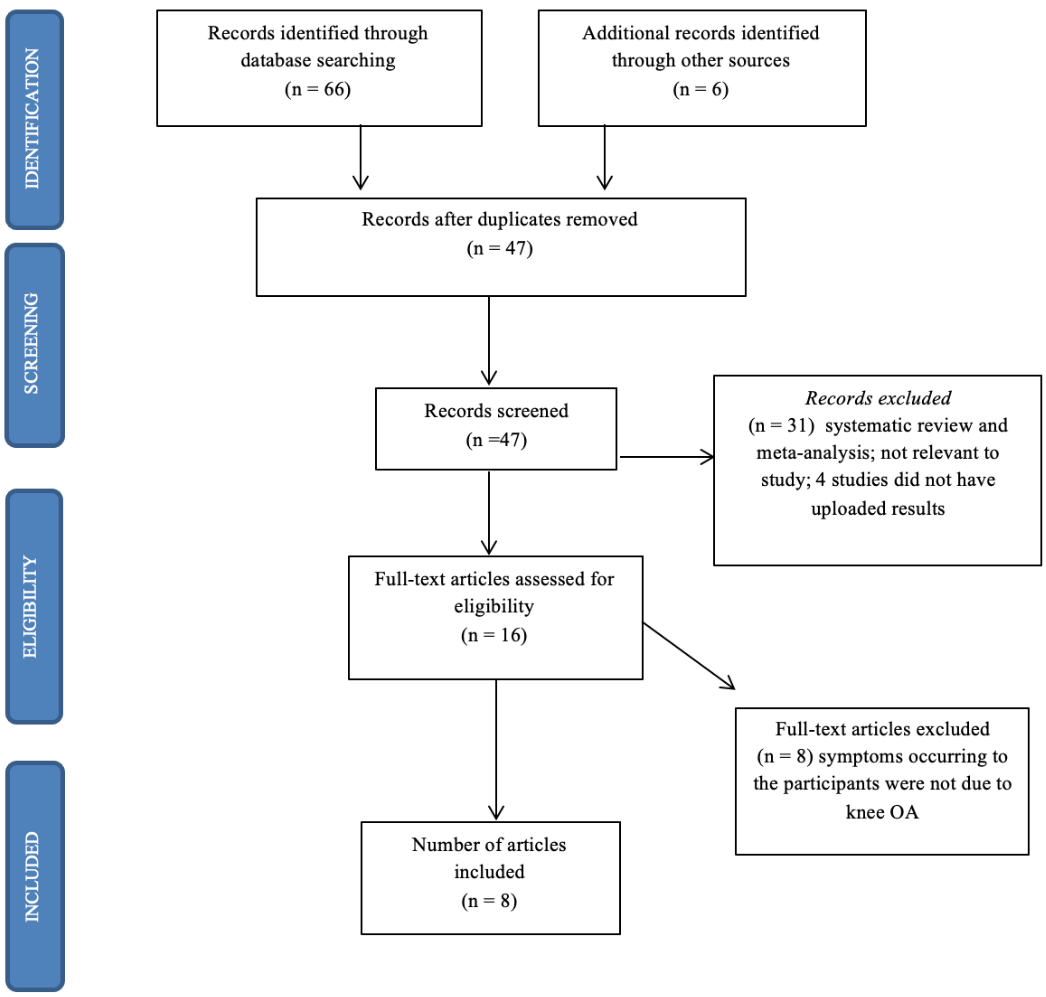

Fig. 1. Flow diagram of the study selection process

study methodologies, and important findings pertinent to the review questions. In addition, the study design, target population, sample size, procedures, BFRT intervention specifics, exercise regimens, and outcome metrics were also recorded. The BFRT treatments contained information on the type of BFRT, dosage, cuff settings, and techniques for advancing and modifying the training stimulus.

Results

Out of the 72 publications that were found through the literature search, eight satisfied the inclusion criteria and were included in the review, which is represented by the PRISMA flow chart (Figure 1). The eight included studies included seven randomized controlled trials (RCT) [2,3,5,8,13–15]and high-intensity resistance training (HI-RT, 80% 1RM, and one feasibility study [16].

Included Study Characteristics

Table 1 displays the extracted data along with a narrative synthesis. In all of the studies, the participants 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. For example, two RCTs compared the effects of low-intensity exercise with and without BFRT [2,8]: a further study compared the effectiveness of low-intensity exercises with and without BFRT and high-intensity resistance exercises [3]; another study compared 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. Depending on the study, the BFRT interventions were conducted twice, three times, or four times a week, with the programme ranging from four weeks to twelve weeks.

Outcome Measures

The included studies used a range of outcome measures. These included knee pain, function, strength, quadriceps cross-sectional area, quality of life, growth hormone (GH) level, and range of motion using the Knee Osteoarthritis Outcome Score (KOOS) and Western Ontario and McMaster Universities OA Index (WOMAC) questionnaire; they also evaluated 30s Chair Sit-to-stand Test (CST), Timed Up and Go test (TUG), dynamometer, instrumented leg press, 1RM, and 10 RM; in addition, they also employed MRI and CT scan, KOOS, blood test, and goniometer (Table 1).

Tab. 1. Details of included studies

Author, Year, Study design, Population	Intervention groups,exercises, duration	Training parameter	Cuff / BFRT parameters	Outcome measures	Conclusion/ outcome
Branco Ferraz (2018); RCT; n=48 women with knee OA, randomized into 3 groups [3].	i) HI-RT; (ii) LI-RT, and (iii) LI-RT with BFRT; The RT program = bilateral leg press and knee extension exercises; 2 times per week for 12 weeks	1st week: HI-RT performed 4 sets of 10 repetitions at 50% 1- 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 performed 5 sets of each exercise BFRT group = LI-RT with external pressure.	Cuff placement: inguinal fold, Width: 175 mm, Length 920 mm, Pressure: 1st week= 50% of the LOP and for further weeks = 70% of the LOP. Mean cuff pressure used: 97.4 ± 7.6 mmHg. The pressure was sustained throughout the session.	Lower-limb strength (5 attempts of 1-RM), quadriceps CSA (CT Scan), functionality (TST) and (TUG), and disease-specific inventory (pain, stiffness, functioning) by WOMAC, before and after the protocol.	BFRT established itself as a realistic and effective therapeutic adjunct in OA therapy.

Author, Year, Study design, Population	Intervention groups,exercises, duration	Training parameter	Cuff / BFRT parameters	Outcome measures	Conclusion/ outcome
Segal (2014); RCT; n=45 women, withsymptomatic knee OA, were randomized into 2 groups [8].	1) LLRT alone. 2) LLRT with concurrent BFR. Exercise = leg-press resistance training; Given 3 times per week for 4 weeks.	Four sets of bilateral leg presses [30 reps for 2 mins and a further 3 sets of 15 reps for 1 min each with a 30-sec break between each set] at 30% of their 1RM, using the instrumented leg press. BFRT group = same protocol with tourniquet pressure.	Cuff Placement: proximal thigh as near to the hip joint; width: 65 mm, length: 650 mm; pressure: during week 1= 100 mmHg [30% of LOP]; week 2, 3, 4=120 mmHg [40% of LOP]; Belt pressurized for 1 minute, then depressurized for 10 seconds, starting at 100, 120, or 140 mmHg in 20 mmHg increments, sustained during each set.	PRE and POST measurement of isotonic bilateral leg press strength, isokinetic knee extensor strength by instrumented pneumatic leg press, and quadriceps volume by MRI. Secondary measures: lower limb muscle power (leg press and stair climb). Knee pain by KOOS.	Strength increased when BFR was added to a 30% 1RM RT program.
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). Exercise = six sets of knee extension and flexion exercises.	3 sets x 15 reps with 1 min rest between sets. BFR group = cuff with 70% AOP applied to unaffected limbs.	Cuff width*length: 12 × 124 cm; cuff placement: proximal end of the legs; cuff pressure: 70% of AOP. The pressure was sustained throughout the session.	Blood lactate (BLA) and muscle growth hormones were measured at four-time points: pre-exercise, post-exercise, 15 minutes post-activity, and 30 minutes post-exercise.	Low-load resistance exercise with BFR increased post-exercise blood testosterone more effectively than high-load resistance exercise.
Petersson (2022); Feasibility study; n=14 elderly individuals with knee OA [16].	The BFR-walking exercise was carried out for 8-10 weeks, 4 times per week.	Participants walked for 20 minutes at a moderate pace (around 4 km/h) while simultaneously applying BFR to the affected 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-sec CST, TUG, 40mFPWT, and stair-climbing, Self-reported knee function (pain, ADL, QOL) by KOOS	Improvements in functional performance were seen in those who followed the intervention procedure.

Author, Year, Study design, Population	Intervention groups,exercises, duration	Training parameter	Cuff / BFRT parameters	Outcome measures	Conclusion/ outcome
Harper (2019); A Pilot RCT; n= 35 individuals with knee OA, >60 Years [13].	1) LLRT with BFR 2) MIRT; Exercise=leg press, leg extension, calf flexion, and leg curl was done for 12 weeks, 3 times per week.	1) 20% of 1RM with the addition of external compression. 2) 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 SPPB, and pain as measured by the WOMAC.	BFR was a realistic and safe treatment for older persons with knee OA.
Segal (2015); RCT; N= 42 men with knee OA, aged 45 and above [2].	1) LLRT 2) LLRT with concurrent BFR. Exercise = bilateral leg press for 4 weeks, 3 times per week.	1) 30% 1RM; 2) 30% 1RM with BFR.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, 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.
Hu (2023); multicenter RCT; n= 120 knee OA patients with MASLD, Age: ≥ 50 years [14].	1. WB training 2. BFR resistance training group. Three components to every session: ROM, strength, and stretching exercises. A 12-week course.	Stretch: Hold for 30s between each of the 3 reps. ROM: Continuous knee movement for the 30s with 3s hold at the end, repeat twice. Strength: 10 reps per group, held for 6s each, 3 total sets.	Nylon Cuff = 11.5 cm × 86 cm; 5 mm thick; Cuff placement: at limb's proximal end; Cuff pressure: set at 80% of LOP; Pressure gradually increased by the device within allowable limits.	At weeks 1, 4, and 12: pain by KOOS; ROM by goniometer; scaled maximum isotonic strength (10RM) using MED leg press; self-reported function (KOOS), and the outcomes of 30-sec CST, were measured.	BFR training improved muscle strength, reduced discomfort, and enhanced daily activities and sports for knee OA patients with MASLD compared to WB exercise alone.

Author, Year, Study design, Population	Intervention groups,exercises, duration	Training parameter	Cuff / BFRT parameters	Outcome measures	Conclusion/ outcome
Ogrezean (2023); Experimental cross-over design; n= 17 patients with end-stage knee OA; older than 55 [15]	3 experimental sessions spaced 3 days apart: control (no BFR), BFR at 40% LOP, and BFR at 80% LOP. Each session included four sets of low-load knee extensions (2 on Borg's CR10 Scale or 30% of 1RM).	Two or three sets of knee extensions to reach a 2 on Borg scale, resting 1 minute between sets. After a 5-minute break, 4 sets (30,15,15,15) of knee extensions with BFR applied throughout.	Pneumatic cuff: 11- cm wide; Cuff placement: most proximal portion of the thigh; cuff pressure: 40% and 80% of LOP.	Electromyography was used to determine nRMS, and nRMS spatial distribution (centroid displacement, modified entropy, and coefficient of variation), and nFmed from VM and VL. Participants completed pre-session surveys (WOMAC, PCS, CPSS) and reported post-session effects within 72 hours.	BFR at 80% AOP increases muscle activity significantly.

30 sec CST-30 second Chair Sit-to-stand Test, ADLs-Activities of Daily Living, BFR-Blood Flow Restriction, BFRT-Blood Flow Restriction Training, BLA-Blood Lactate, CPSS-Chronic Pain Self-Efficacy Scale, CSA-Cross Sectional Area, CT Scan-Computed Tomography, HIRT-High Intensity Resistance Training, KOOS-Knee Osteoarthritis Outcome Score, LIRT-Low Intensity Resistance Training, LL-RT-Low Load Resistance Training, LOP-Limb Occlusion Pressure, MASLD-Metabolic dysfunction Associated Steatotic Liver Disease, MIRT-Moderate Intensity Resistance Training, MRI-Magnetic Resonance Imaging, nFmed-Normalised median Frequency, nRMS-Normalised Root Mean Square, PCS-Pain Catastrophizing Scale, QOL-Quality of life, RCT-Randomized Controlled Trials, RM-Repetition Maximum, ROM-Range of Motion, RT-Resistance Training, SBP-Systolic Blood Pressure, SPPB-Short Physical Performance Battery, TST-Timed Stands Test, TUG-Timed Up and Go test, VL-Vastus Lateralis, VM-Vastus Medialis, WB-Weight bearing, WOMAC-Western Ontario and McMaster Universities OA Index

BFRT parameters /cuff parameters

In all included investigations, the BFRT cuff was applied to the most proximal part of the thigh; cuff widths varied from 6.5 to 17.5 cm. The size and type of cuff used varied considerably. The range for calculating occlusion pressure ranged from 30 to 80% of arterial occlusion or 80 to 180 mmHg in absolute pressure; however, in five studies, the percentage of occlusion pressure progressed with time, staying within the safety limits [2,3,8,14,16]. 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 [2,8,15] but significant differences were observed regarding the numbers of sets and repetitions: these ranged from three to five sets and ten to fifteen repetitions. One study used BFR during a twenty-minute walk [16].

In the studied investigations, training intensity was administered between 20% - 30% of 1RM, 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 immediately after the session, with a two-minute break between each type of exercise. The rest intervals between sets ranged from thirty to sixty seconds.

Outcomes

Blood flow-restricted low-intensity exercises appear to be a practical and effective therapeutic adjunct in OA therapy. They have been shown to alleviate knee discomfort and build muscle mass and strength in studies comparing them to other forms of resistance training. Research indicated that BFRT encouraged aging populationwhile delaying the decline of functionality and QOL and proved to be a safer technique for older people (Table 2).

Discussion

In the field of rehabilitation, interest has grown in the use of BFR, also known as Kaatsu, in conjunction with particular exercise regimens. In particular, despite being initially intended to help athletes in good health achieve even greater muscle strength, the past 20 years have seen BFRT gain popularity as a therapeutic approach for treating excruciating musculoskeletal disorders and severe functional gaps in a variety of patient populations. As BFRT is safe and effective at improving pain outcomes, it can be used in the rehabilitation of patients with knee OA [17].

Tab. 2. Variation in the outcome measures of the included articles

Author, Year, Study design, Population	Outcome measures
Branco Ferraz (2018) [3]	• Significant improvements with BFRT and HI-RT compared to LI-RT: • Leg press strength: BFRT (26%, $p < 0.0001$), HI-RT (33%, $p < 0.0001$) vs. LI-RT; • Knee extension 1-RM: BFRT (23%, $p < 0.0001$), HI-RT (22%, $p < 0.0001$) vs. LI-RT. • CSA increase: BFRT (7%, $p < 0.0001$), HI-RT (8%, $p < 0.0001$) vs. LI-RT. • TST improvement: BFRT (7%, $p < 0.05$), HI-RT (14%, $p < 0.05$) vs. LI-RT. • WOMAC physical function improvement: BFRT (−49%, $p < 0.05$), HI-RT (−42%, $p < 0.05$) vs. LI-RT. • WOMAC pain improvement: BFRT (−45%, $p < 0.05$), LI-RT (−39%, $p < 0.05$).
Segal (2014) [8]	• Baseline BMI: the BFR group had a lower BMI ($p = 0.02$). • Isotonic 1RM improvement: BFR group (28.3 ± 4.8 kg) vs. control (15.6 ± 4.5 kg), $p = 0.04$. • Isokinetic knee extensor strength: BFR group (0.07 ± 0.03 nm/kg) vs. control (-0.05 ± 0.03 nm/kg), $p = 0.005$. • No significant differences in quadriceps volume, leg press power, or knee-related pain between groups.
Chen (2022) [5]	• Perceived exertion ratings: BFR and RES groups (70% 1-RM) > CON group (30% 1-RM) ($p < 0.05$). • Post-exercise BLA levels: CON group < BFR and RES groups ($p < 0.05$). • GH levels at 15 minutes post-exercise: BFR group > CON group ($p < 0.05$). • IGF-1 levels post-exercise and at 15 minutes: CON group < BFR and RES groups ($p < 0.05$). • Testosterone levels post-exercise and at 15 minutes: CON group < RES group < BFR group ($p < 0.05$ for all comparisons).
Petersson (2022) [16]	• Non-completing participants: Higher baseline BMI ($p = 0.05$) and knee discomfort ($p = 0.06$), lower gait performance ($p = 0.04$). • Training adherence rate: 93%. • Average knee pain level: 0.7/10. • Self-reported function unchanged; functional performance improved.
Harper (2019) [13]	• BFR vs. MIRT mean difference: -1.87 Nm (-10.96, 7.23). • Pre to post-training change in maximal isokinetic peak torque: 9.96 Nm (5.76, 14.16).
Segal (2015) [2]	• Baseline group comparability: No significant differences in strength, age, BMI, or knee pathology. • Leg press 1RM improvement: Similar in control and BFR groups; no significant difference in muscle strength measures.
Hu (2023) [14]	• Significant increases in ROM and 10RM at 4 and 12 weeks. • At 12 weeks, KOOS pain, daily life function, and quality of life subscales significantly improved and differed between groups. • Similar improvements in 30-sec CST outcomes within and between study groups.
Ogrezeanu (2023) [15]	• VL: Higher nRMS with 80% AOP vs. 40% AOP ($p < 0.008$) and control ($p < 0.001$). • nRMS associated with health status, chronic pain self-efficacy, and pain catastrophizing (VM: 20.49, 20.42, 20.50; VL: 20.39, 0.27, 20.33). • nFmed slightly increased in VL with 40% AOP between sets 3 and 4.

30-sec CST-30 second Chair Sit-to-stand Test, AOP-Arterial Occlusion Pressure, BFRT-Blood Flow Restriction Training, BLA-Blood Lactate, BMI-Body Mass Index, CSA-Cross sectional Area, GH-Growth Hormone, HIRT-High Intensity Resistance Training, IGF-1-Insulin-like Growth Factor-1, KOOS-Knee Osteoarthritis Outcome Score, LIRT-Low Intensity Resistance Training, MASLD-Metabolic dysfunction Associated Steatotic Liver Disease, MIRT-Moderate Intensity Resistance Training, nFmed- Normalised Median Frequency, nRMS-Normalised Root-Mean-Square, QOL-Quality Of Life, RCT-Randomized Controlled Trials, RM-Repetition Maximum, TST-Timed Stands Test, TUG-Timed Up and Go test, VL-Vastus Lateralis, VM-Vastus Medialis, WOMAC-Western Ontario and McMaster Universities Osteoarthritis

During exercise, BFR acts by totally blocking the venous return flow and only partially allowing the arterial inflow [18]. As such, the pressure applied to the muscle should be just high enough to prevent venous return, but not so high as to prevent arterial input into the muscle [19]. 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 the pressure set during BFR exercise should depend 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 [20]. In addition, the adaptations induced by BFRT may be influenced by occlusion type, occlusion pressure, and occlusion time [20]. For these reasons, the purpose of this scoping review was to determine suitable BFR parameters (cuff parameters, number of sets, repetitions and duration) and their relationship in 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, as well as induce musculoskeletal adaptations [21]. One of the included studies looked at the feasibility of using BFR walking exercise for treating patients with long-term knee OA; the results 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 perceived knee pain were associated with lower training adherence [16]. Future research is warranted to understand the impact of BFR training paired with aerobic exercises in individuals with knee OA.

A recent comprehensive study found BFR training to have potential value in strengthening the quadriceps in patients who have atrophy and weakness associated with knee pathology, as well as in knee OA patients following knee surgery; in such cases, the use of brief, low-load resistance BFR training seems safe and innocuous [18]. Of the reviewed papers, seven studies assessed pain [2,3,8,13–16], four assessed functionality [3,14–16] and four evaluated quadriceps strength [2,3,8,14]. Two studies evaluated the cross-sectional area of the quadriceps [3,8].

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 [20]; one of the included studies yielded positive results for muscle GH after BFRT [5]. The use of the blood pressure cuff appears to result in several neutrally- or mechanically-mediated modifications to gait, and using these modifications in clinical populations could have consequences [22]. Likewise one of the included studies assessed pre and post-BFRT gait speed in knee OA patients, and found that functional performance improved after the intervention [13].

An essential bonus feature of BFRT is its ability to extend the range of motion. By increasing blood flow to the injured area, BFRT can assist in improving flexibility and lessen joint stiffness, which will make exercising easier [19,23,24]. One of the included articles examined the impact of BFR on knee OA rehabilitation using ROM as an outcome measure; indeed, the findings showed an improvement in ROM [14].

One of the included studies [15] investigated the neuromuscular reactions during acute resistance training with varying degrees of BFR in end-stage knee OA patients, and examined their relationship with 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].

These findings [15] are supported by those of another study [25], which sought to assess the effect of resistance training programs employing varying levels of BFR on exercise-induced hypoalgesia (EIH), i.e. acute post-exercise reduction in pain sensitivity, in patients with end-stage knee osteoarthritis. EIH can affect both exercising and non-exercising portions of the body, and is one potential benefit of treatment for knee OA patients [25]. However, despite experiencing a typical initial EIH following BFR training at 80% AOP, no differences in EIH were found between placebo (sham BFR), 40%, and 80% AOP. Nevertheless, the 80% AOP regimen quickly improved pressure pain thresholds (PPT) and decreased visual analogue scale (VAS) scores [25].

The aetiology and outcome of metabolic dysfunction, including dyslipidaemia, hyperglycaemia, hypertension, and inflammation, can be linked to knee OA [26]. One of the included studies compared the effects of traditional WB (Weight bearing) exercise and BFR training for treating knee OA patients with MASLD [14]; the findings indicate that BFR might be a promising technique for rehabilitation of such patients, as it reduces discomfort and eases everyday activities.

During low-intensity resistance training combined with blood flow restriction (LIRTBFR), a cuff is placed in the proximal region of the lower or upper limb to restrict blood flow; in such cases, the exercise is typically performed at intensities between 15% and 30% 1RM [27]. In seven investigations [2,3,5,8,13,14,16], 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. Thus, 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 [10,28]. This protocol was followed in three investigations [2,8,15], but significant differences were observed in the numbers of sets and repetitions of the prescribed exercises, ranging from 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 [10,28], in such cases, resting with an inflated or deflated cuff is a feasible alternative [28]. In the included studies, the cuff restraint was maintained for the duration of the training session, including the rest periods. It was removed immediately 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 recommends the use of occlusion pressure ranging from 40 to 80%. However, the included studies exhibited significant variation in BFRT arterial occlusion pressure, varying from 30 to 80%. This suggests that pressure should be customized based on assessments of arterial pressure and comfort levels [28].

This review has several limitations, particularly the small number of studies included; as such, further high-quality reviews with larger numbers of studies are needed. The included studies also demonstrated considerable heterogeneity in the BFRT parameters. Therefore, it is recommended that future BFRT studies on the rehabilitation of knee OA employ standardized methods and reporting of interventions 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 pain, strength, muscle mass, hormone levels, functionality, and general quality of life in patients with knee OA. One possible example programme for treating knee OA using BFRT could be as follows: two to four times per week, progressing blood restriction ranging from 30%–80% of arterial occlusion pressure; four or five sets of 10-15 repetitions at 20%–30% of 1RM; 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 according to these guidelines, BFR training might be a safe and efficient procedure. Most importantly, healthcare professionals must ensure that the patient is not contraindicated to execute the procedure.

Conclusion

In summary, this scoping review indicates that BFRT combined with low-intensity exercise is a safe and effective approach for improving various aspects of knee OA. Key parameters for BFRT in knee OA include 2-4 sessions per week, 4-5 sets of 10-15 repetitions at 20%–30% of 1RM, and gradual BFR ranging from 30%–80% of AOP. The cuff should be placed at the most proximal part of the thigh and deflated immediately after each session. Outcome measures should focus on pain, strength, muscle mass, hormone levels, functionality, ROM, and overall QOL. This evidence supports the use of BFRT as an alternative treatment for knee OA, with potential implications for future research and clinical practice.

Funding

This research received no external funding.

Conflicts of interest

The authors declare no conflict of interest.

References

1. O'Neill TW, Felson DT. Mechanisms of Osteoarthritis (OA) Pain. Curr Osteoporos Rep. 2018; 16: 611–6.
2. Segal N, Davis MD, Mikesky AE. Efficacy of Blood Flow-Restricted Low-Load Resistance Training For Quadriceps Strengthening in Men at Risk of Symptomatic Knee Osteoarthritis. Geriatr Orthop Surg Rehabil. 2015; 6: 160–7.
3. Ferraz RB, Gualano B, Rodrigues R, Kurimori CO, Fuller R, Lima FR, et al. Benefits of Resistance Training with Blood Flow Restriction in Knee Osteoarthritis. Med Sci Sports Exerc. 2018; 50: 897–905.
4. Wang H-N, Chen Y, Cheng L, Wang S-T, Hu D-X, Wang L-N, et al. Effect of low-load resistance training with different degrees of blood flow restriction in patients with knee osteoarthritis: study protocol for a randomized trial. Trials. 2022; 23: 6.
5. Chen Y, Wang J, Li S, Li Y. Acute effects of low load resistance training with blood flow restriction on serum growth hormone, insulin-like growth factor-1, and testosterone in patients with mild to moderate unilateral knee osteoarthritis. Heliyon. 2022; 8: e11051.
6. Elkady SM, Abd Elrazik RK, AbdelMonem AF, Elhamrawy MY, Mashaal A, Atef D, et al. Effects of kinesiotape versus soft brace on selected parameters in patients with knee osteoarthritis. Adv Rehabil. 2023; 37: 1–8.
7. Dantas LO, Salvini T de F, McAlindon TE. Knee osteoarthritis: key treatments and implications for physical therapy. Brazilian J Phys Ther. 2021; 25: 135–46.
8. Segal NA, Williams GN, Davis M, Wallace RB, Mikesky A. Efficacy of Blood Flow Restricted Low-Load Resistance

Training in Women with Risk Factors for Symptomatic Knee Osteoarthritis. Phys Med Rehabil. 2015; 7: 376–84.

9. Cerqueira MS, de Brito Vieira WH. Effects of blood flow restriction exercise with very low load and low volume in patients with knee osteoarthritis: protocol for a randomized trial. Trials. 2019; 20: 135.
10. Patterson SD, Hughes L, Warmington S, Burr J, Scott BR, Owens J, et al. Blood Flow Restriction Exercise : Considerations of Methodology, Application, and Safety. 2019; 10: 1–15.
11. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. Int J Soc Res Methodol Theory Pract. 2005; 8: 19–32.
12. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. Ann Intern Med. 2018; 169: 467–73.
13. 13. Harper SA, Roberts LM, Layne AS, Jaeger BC, Gardner AK, Sibille KT, et al. Blood-Flow Restriction Resistance Exercise for Older Adults with Knee Osteoarthritis: A Pilot Randomized Clinical Trial. J Clin Med. 2019; 8.
14. Hu C, Zhu B, Wang Y, Yang F, Zhang J, Zhong W, et al. Effectiveness of blood flow restriction versus traditional weight-bearing training in rehabilitation of knee osteoarthritis patients with MASLD: a multicenter randomized controlled trial. Front Endocrinol (Lausanne). 2023; 14: 1–9.
15. Ogrezeanu DC, López-Bueno L, Sanchís-Sánchez E, Carrasco JJ, Cuenca-Martínez F, Suso-Martí L, et al. Neuromuscular Responses and Perceptions of Health Status and Pain-Related Constructs in End-Stage Knee Osteoarthritis During Resistance Training With Blood Flow Restriction. J Strength Cond Res. 2024; 38(4): 762-72.
16. Petersson N, Jørgensen SL, Kjeldsen T, Mechlenburg I, Aagaard P. Blood Flow Restricted Walking in Elderly Individuals With Knee Osteoarthritis: a Feasibility Study. J Rehabil Med. 2022; 54.
17. Rangaraj A. Blood Flow Restriction Training in Osteoarthritis. Biomed J Sci Tech Res. 2022; 42: 33870–6.
18. Álvarez CB, Santamaría PIK, Fernández-Matías R, Pecos-Martín D, Achalandabaso-Ochoa A, Fernández-Carnero S, et al. Comparison of blood flow restriction training versus non-occlusive training in patients with anterior cruciate ligament reconstruction or knee osteoarthritis: A systematic review. J Clin Med. 2021; 10: 1–23.
19. Cognetti DJ, Sheean AJ, Owens JG. Blood Flow Restriction Therapy and Its Use for Rehabilitation and Return to Sport: Physiology, Application, and Guidelines for Implementation. Arthrosc Sport Med Rehabil. 2022; 4: e71–6.
20. Fekri-Kurabbaslou V, Shams S, Amani-Shalamzari S. Effect of different recovery modes during resistance training with blood flow restriction on hormonal levels and performance in young men: a randomized controlled trial. BMC Sports Sci Med Rehabil. 2022; 14: 1–10.
21. Hori A, Saito R, Suijo K, Kushnick MR, Hasegawa D, Ishida K, et al. Blood flow restriction accelerates aerobic training-induced adaptation of V ˙ O 2 kinetics at the onset of moderate-intensity exercise. Sci Rep. 2022; 12: 1–10.
22. Faras TJ, Laporte MD, Sandoval R, Najjar F, Ade V, Stubbs P. The effect of unilateral blood flow restriction on temporal and spatial gait parameters. Heliyon. 2019; 5: 1–16.
23. Saraf A, Goyal M, Goyal K. Blood Flow Restriction Training-An Overview and Implication in New Generation Physical Therapy: A Narrative Review. J Lifestyle Med. 2022; 12: 63–8.
24. Da Silva-Grigoletto ME, Neto EP, Behm DG, Loenneke JP, La Scala Teixeira CV. Functional Training and Blood Flow Restriction: A Perspective View on the Integration of Techniques. Front Physiol. 2020; 11.
25. Ogrezeanu DC, López-Bueno L, Sanchís-Sánchez E, Suso-Martí L, López-Bueno R, Núñez-Cortés R, et al. Exercise-induced hypoalgesia with end-stage knee osteoarthritis during different blood flow restriction levels: Sham-controlled crossover study. PM R. 2023; 15: 1565–73.
26. Han AL. Association between metabolic associated fatty liver disease and osteoarthritis using data from the Korean national health and nutrition examination survey (KNHANES). Inflammopharmacology. 2021; 29: 1111–8.
27. Dos Santos LP, Santo RC do E, Ramis TR, Portes JKS, Chakr RM da S, Xavier RM. The effects of resistance training with blood flow restriction on muscle strength, muscle hypertrophy and functionality in patients with osteoarthritis and rheumatoid arthritis: A systematic review with meta-analysis. PLoS One. 2021; 16: e0259574.
28. Burton I, McCormack A. Blood Flow Restriction Resistance Training in Tendon Rehabilitation: A Scoping Review on Intervention Parameters, Physiological Effects, and Outcomes. Front Sport Act Living. 2022; 4: 1–12.