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Blood Flow Restriction Training in Musculoskeletal Rehabilitation: Clinical Applications, Safety, Risk Stratification, and Practical Implementation – A Narrative Review

Wojciech Ziębka [WZ], ORCID https://orcid.org/0009-0000-6835-6773
E-mail: ziebka.wojciech@gmail.com
A. Falkiewicz Specialist Hospital in Wroclaw, Poland
Oliwia Dziewięcka [OD], ORCID https://orcid.org/0009-0008-7784-1680
E-mail: odziewiecka24@wp.pl
A. Falkiewicz Specialist Hospital in Wroclaw, Poland
Michał Błażuk [MB], ORCID https://orcid.org/0009-0001-6959-0526
E-mail: mblazuk11@gmail.com
Karol Jonscher Municipal Medical Center in Lodz, Poland
Dominik Zając [DZ], ORCID https://orcid.org/0009-0004-0415-5322
E-mail: dominik.zajac.science@gmail.com
Central Clinical Hospital of UCC WUM, Warszawa, Poland
Damian Broda [DB], ORCID https://orcid.org/0009-0003-2825-2082
E-mail: damianbrodapl@gmail.com
10th Military Clinical Hospital with Polyclinic in Bydgoszcz, Poland
Wiktoria Mikulska [WM], ORCID https://orcid.org/0009-0000-3246-2945
E-mail: wikus0909@gmail.com
Medical University of Silesia, Katowice, Poland
Natalia Sak [NS], ORCID https://orcid.org/0009-0009-3601-3771
E-mail: natalia.sak@onet.pl
Provincial Specialist Hospital named after Blessed Father Jerzy Popieluszko in Wloclawek, Poland
Kamila Tasior [KT], ORCID https://orcid.org/0009-0001-2731-8831
E-mail: kamila.tasior@gmail.com
Medical University of Silesia, Katowice, Poland

Katarzyna Sikora [KS], ORCID https://orcid.org/0000-0002-6955-3549
E-mail: kasia.sikora27@gmail.com
University Clinical Hospital No. 4 in Lublin, Poland
Julia Wilanowska [JW], ORCID https://orcid.org/0009-0009-4928-9435
E-mail: Jula9893@gmail.com
Medical University of Silesia, Katowice, Poland
Aleksandra Broda [AB], ORCID https://orcid.org/0009-0000-4701-7983
E-mail: aleksandra.phamthu@gmail.com
Medical University of Warsaw, Warsaw, Poland
Corresponding Author
Wojciech Ziębka, E-mail: ziebka.wojciech@gmail.com

Abstract

Background. Blood flow restriction training (BFRT) combines exercise with external cuff pressure applied proximally to a limb. It is used in musculoskeletal rehabilitation when higher-load resistance exercise is temporarily inappropriate, poorly tolerated, or not feasible.

Aim. This narrative review synthesizes the physiological rationale, clinical applications, safety evidence, risk stratification, cardiovascular and hemodynamic considerations, arterial occlusion pressure (AOP) and limb occlusion pressure (LOP) methodology, cuff- and device-related factors, and practical implementation of BFRT in musculoskeletal rehabilitation.

Material and methods. A narrative literature search was conducted in PubMed, Scopus, and Web of Science, with Google Scholar used as a supplementary source, for publications available up to 1 June 2026. Clinically relevant evidence from musculoskeletal, orthopedic, sports medicine, and rehabilitation settings was prioritized, including systematic reviews, meta-analyses, randomized controlled trials, position statements, and clinically oriented reviews. No protocol was registered, and no formal risk-of-bias assessment or quantitative synthesis was performed.

Results. Low-load BFRT may produce greater strength- and muscle mass-related adaptations than comparable low-load exercise without BFR, but it has not demonstrated consistent superiority over conventional high-load resistance training. It has been studied after anterior cruciate ligament reconstruction, in knee osteoarthritis and knee pain, knee arthroplasty, tendon rehabilitation, and selected other applications. Findings are condition-specific and limited by heterogeneous protocols, comparators, outcomes, and incomplete adverse-event reporting. Evidence in medically complex patients remains limited. Safe implementation requires appropriate screening, risk stratification, individualized pressure prescription, and monitoring. AOP and LOP are related but not fully interchangeable reference measures; measured values depend on the individual, limb, cuff, device, posture, detection method, and assessment conditions.

Conclusions. BFRT may be considered as an optional adjunctive or bridging low-load strategy for selected patients when higher-load strengthening is temporarily limited. It should be integrated into progressive rehabilitation rather than used as a universal substitute for conventional resistance training. Clinical decisions should reflect patient risk, tolerance, rehabilitation goals, and the certainty of available evidence.

Key words: blood flow restriction; blood flow restriction training; musculoskeletal rehabilitation; limb occlusion pressure; arterial occlusion pressure; risk stratification; exercise therapy

1. Introduction

Blood flow restriction (BFR) involves applying an external cuff or tourniquet to the proximal region of a limb to partially restrict arterial inflow and more substantially restrict venous outflow [1]. Blood flow restriction training (BFRT) refers to exercise performed under this restriction. In rehabilitation and return-to-sport settings, BFRT has been proposed as a means of providing a muscular training stimulus while reducing the external loads placed on injured, painful, postoperative, or healing tissues [2]. This review primarily addresses resistance exercise combined with BFR; aerobic exercise and passive BFR are considered only where they inform safety, physiology, or clinical interpretation.

Muscle weakness and atrophy are common after musculoskeletal injury or surgery and in chronic musculoskeletal disorders, contributing to impaired function and delayed recovery [4,5]. Progressive resistance training remains a cornerstone of rehabilitation, but higher-load exercise may be poorly tolerated during early recovery because of pain, edema, joint irritation, graft- or tissue-healing considerations, or reduced load tolerance [5]. Quadriceps strength and muscle mass deficits may persist after anterior cruciate ligament reconstruction [6], while pain and joint loading can limit conventional strengthening in some patients with knee osteoarthritis [7]. These constraints have contributed to interest in low-load BFRT.

Systematic review evidence suggests that low-load BFRT may improve strength more than comparable low-load exercise alone [4]. However, it may be less effective than high-load resistance training for maximal strength development, even when hypertrophy-related adaptations are similar [24]. In clinical musculoskeletal populations, available comparisons are heterogeneous and the certainty of evidence is low to very low for several outcomes [8]. BFRT is therefore most appropriately considered as an adjunctive or bridging intervention rather than a universal replacement for progressive high-load resistance training.

BFRT has been investigated after anterior cruciate ligament reconstruction, in knee osteoarthritis and knee pain, knee arthroplasty, tendon rehabilitation, and selected upper-limb or postoperative applications [7,9–11]. Findings vary by diagnosis and outcome. Reviews after anterior cruciate ligament reconstruction suggest possible benefits for muscle mass and patient-reported function, but confidence is limited by heterogeneity and risk of bias [9]. A recent meta-analysis reported limited effectiveness for early postoperative muscle strength recovery while suggesting possible mid-term improvement in International Knee Documentation Committee scores [12]. In a double-blind randomized placebo-controlled trial, adding BFRT to standard rehabilitation before and after reconstruction did not improve quadriceps muscle function beyond standard rehabilitation alone [13]. In knee osteoarthritis, some reviews report improvements in pain and quadriceps strength, whereas others find no clear advantage over conventional resistance training for symptom-related outcomes [7,14]. Evidence in knee arthroplasty remains preliminary and protocol-dependent [11].

Implementation requires attention to more than efficacy. Safety evidence, patient screening, cardiovascular and thrombotic risk, cuff selection, individualized pressure prescription, and device-related variability are central to responsible clinical use [1,15]. Available studies suggest a relatively favorable short-term safety profile in selected musculoskeletal populations, particularly in knee-related conditions, but adverse-event reporting is inconsistent and medically complex patients remain underrepresented [16]. BFRT can also alter blood pressure, heart rate, and other hemodynamic variables, which may be relevant in patients with cardiovascular or vascular risk [15,17,18].

Pressure prescription is a further methodological concern. Arterial occlusion pressure (AOP) and limb occlusion pressure (LOP) are related individualized occlusion-reference measures, although their terminology, detection methods, and device-specific procedures are not fully standardized. In this review, the original term used by each study is retained, while "individualized occlusion pressure" is used when the discussion applies broadly to either measure. Measured values are influenced by cuff width, limb size, blood pressure, cuff placement, device type, posture, and assessment conditions [1,19,20]. Consequently, fixed pressures and values transferred across devices, cuffs, limbs, or measurement contexts may not produce equivalent restriction.

This narrative review integrates clinical applications, safety and adverse events, risk stratification and clinical precautions, cardiovascular and hemodynamic considerations, individualized occlusion-pressure methodology, cuff- and device-related factors, and practical implementation. Its purpose is to support cautious, evidence-informed use of BFRT within progressive musculoskeletal rehabilitation.

2. Materials and methods

This article was designed as a narrative review of BFRT in musculoskeletal rehabilitation. It was intended to provide a clinically oriented synthesis rather than a systematic review or meta-analysis. No formal review protocol was registered.

A literature search was conducted in PubMed, Scopus, and Web of Science for publications available up to 1 June 2026. Google Scholar was used as a supplementary source to identify additional clinically relevant articles and publications not readily retrieved through the primary databases. Search terms related to the intervention included "blood flow restriction," "blood flow restriction training," "BFR," "BFRT," "KAATSU," "occlusion training," and "vascular occlusion training." These were combined with rehabilitation-, condition-, safety-, and methodology-related terms, including "musculoskeletal rehabilitation," "orthopedic rehabilitation," "sports rehabilitation," "ACL reconstruction," "knee osteoarthritis," "knee arthroplasty," "tendon rehabilitation," "safety," "adverse events," "contraindications," "risk stratification," "cardiovascular response," "hemodynamics," "arterial occlusion pressure," "limb occlusion pressure," "cuff width," and "cuff pressure."

The search focused primarily on publications from 2015 to 2026 to capture contemporary evidence relevant to BFRT practice. Selected earlier publications were retained when they provided foundational evidence on physiological mechanisms or cuff-pressure methodology [3,21]. Sources were selected and prioritized according to clinical relevance, methodological strength, and alignment with the aims of the review. Priority was given to position statements, systematic reviews, meta-analyses, randomized controlled trials, scoping reviews, and clinically oriented narrative reviews. Human studies relevant to musculoskeletal or orthopedic rehabilitation, sports rehabilitation, resistance exercise, safety, cardiovascular responses, risk stratification, individualized occlusion pressure, cuff characteristics, device factors, or implementation were emphasized. Non-English publications, animal or in vitro studies, and reports without clear relevance to clinical musculoskeletal rehabilitation were generally not prioritized.

The literature was synthesized narratively and organized into thematic sections. Clinical evidence was grouped into general musculoskeletal rehabilitation, anterior cruciate ligament reconstruction, knee osteoarthritis or knee pain, knee arthroplasty, tendon-related rehabilitation, and selected other applications [4,7,9–11]. Safety evidence was grouped into reported adverse events, pre-participation screening, risk stratification, and cardiovascular or hemodynamic considerations [15–18]. Methodological and implementation evidence was grouped into individualized occlusion-pressure assessment, cuff width, device variability, pressure prescription, and reporting quality [19–22].

No formal risk-of-bias assessment was performed, and no pooled statistical analysis or quantitative synthesis was undertaken. Because article selection and interpretation were narrative, the review may be subject to selection and emphasis bias. Its conclusions should therefore be interpreted as a clinically oriented synthesis rather than an exhaustive or formally graded summary of all available evidence.

3. Physiological rationale and mechanisms

BFRT uses external cuff pressure to partially restrict arterial inflow and more substantially restrict venous outflow during exercise [1]. This produces a localized hypoxic and metabolite-rich environment, with blood pooling distal to the cuff [1,3]. The resulting physiological stress may allow low-load exercise to provide a greater strength- or hypertrophy-related stimulus than low-load exercise without BFR [4].

Local hypoxia and metabolite accumulation are proposed to increase metabolic stress during low-intensity resistance exercise [3]. Restricted venous outflow may promote lactate and other metabolite accumulation, fatigue, cell swelling, and activation of anabolic signaling pathways [3,23]. The relative contribution of these mechanisms remains uncertain, but they may partly explain the increases in muscle mass and strength observed in some BFRT studies [24].

BFRT appears to rely more heavily on metabolic stress than conventional high-load resistance exercise, which produces greater mechanical tension [3]. This distinction is clinically relevant when high joint, muscle, or tendon loads are temporarily unsuitable [2,10]. Low-load BFRT can outperform comparable low-load resistance exercise without BFR for some strength and hypertrophy outcomes, whereas high-load resistance training may produce greater maximal strength gains [1,24]. Mechanistic plausibility therefore supports BFRT as a load-management option, not as evidence that it should replace higher-load training once such training is appropriate.

Reduced oxygen availability and metabolite accumulation may accelerate fatigue, increase afferent feedback, and promote earlier recruitment of higher-threshold motor units during low-load exercise [3,5,23]. A systematic review and meta-analysis found greater muscle excitation with low-load BFRT than with low-load training without BFR, although evidence for central activation and corticospinal excitation was less consistent [25]. These effects may be relevant after injury or surgery, where atrophy can coexist with altered neuromuscular control [5,6,25].

BFRT can also produce cardiovascular, pulmonary, endocrine, and other systemic responses, but their clinical significance remains incompletely established [26]. Age, postoperative status, immobilization, comorbidities, blood pressure control, vascular health, and thrombotic risk may affect tolerance [15,16,26]. Mechanistic evidence should therefore be interpreted alongside clinical evidence, patient risk, and the practical conditions under which pressure is applied. The magnitude of the physiological stimulus is also likely to depend on the exercise modality, restriction pressure, duration of cuff inflation, rest intervals, and whether pressure is maintained or released between sets. These variables differ substantially across studies and may partly explain inconsistent clinical outcomes. Mechanistic findings derived from healthy or physically active participants should not be transferred directly to postoperative or medically complex rehabilitation populations without considering differences in baseline function, vascular health, medication use, and exercise tolerance.

4. Clinical applications in musculoskeletal rehabilitation

4.1. General clinical considerations

Low-load BFRT may be useful when injury, surgery, pain, or tissue-loading concerns temporarily limit higher-load resistance exercise [2,4,5]. Across musculoskeletal rehabilitation, it may improve strength more than comparable low-load exercise alone [4]. It should not, however, be described as generally superior to high-load resistance training. Heavy-load training may produce greater maximal strength gains, while hypertrophy outcomes may be more comparable [24]. In clinical populations, differences in diagnosis, intervention duration, exercise selection, cuff width, pressure prescription, comparator interventions, and outcome measures limit generalization [8]. The clinical role of BFRT should therefore be determined by the reason for load restriction and the intended rehabilitation outcome. Strength, hypertrophy, pain, physical function, and patient-reported outcomes should not be treated as interchangeable endpoints. A protocol that is useful for preserving muscle size during a period of restricted loading may not produce an additional benefit for maximal strength or sport-specific function. BFRT should therefore be evaluated against a clinically relevant comparator and incorporated only when it addresses a defined limitation in the rehabilitation program.

4.2. Anterior cruciate ligament reconstruction

Anterior cruciate ligament reconstruction is a prominent application because quadriceps weakness, muscle atrophy, and functional deficits may persist despite rehabilitation [6,27,28]. BFRT has been investigated during phases in which higher-load strengthening is limited by pain, edema, postoperative joint stress, graft-related considerations, or reduced load tolerance [6,12,29].

Systematic reviews and meta-analyses suggest possible benefits for selected outcomes, including muscle mass and patient-reported function, but evidence for quadriceps strength is inconsistent [9,12,27]. Interpretation is constrained by differences in intervention timing, cuff pressures, exercise protocols, comparator groups, and outcome measures [6,9,30]. A double-blind randomized placebo-controlled trial in athletes found no additional improvement in quadriceps muscle function when BFRT was added to standard rehabilitation before and after reconstruction [13]. Overall, BFRT may support selected postoperative outcomes, but a consistent additional effect on quadriceps strength has not been established. Timing may be important: early postoperative protocols are constrained by pain, swelling, graft protection, and limited exercise selection, whereas later protocols compete with increasingly tolerable conventional strengthening. Differences between prehabilitation, early postoperative use, and later-stage strengthening should therefore be considered when interpreting apparently conflicting results. The clinical decision to use BFRT should be based on the patient's current loading capacity rather than on the diagnosis alone.

4.3. Knee osteoarthritis and knee pain

Knee osteoarthritis and nontraumatic knee pain are relevant applications because pain and joint loading may reduce tolerance to higher-load exercise [31–33]. Some randomized trials and systematic reviews report improvements in pain, quadriceps strength, and selected functional outcomes [7,31,34]. Other reviews find no clear advantage over conventional resistance training for symptom-related outcomes [7,14,33].

Differences in patient selection, diagnosis, comparators, exercise protocols, cuff parameters, and outcomes probably contribute to these inconsistencies [32,34,35]. BFRT may be considered primarily as a lower-load alternative when conventional higher-load resistance exercise is poorly tolerated, rather than because superior effects on pain, physical function, or quadriceps strength have been established. A lower-load protocol may still be clinically useful through improved tolerability even when between-group differences in outcomes are small.

Conversely, BFR should not compensate for inadequate exercise progression or replace conventional loading when symptoms and joint tolerance permit it.

4.4. Knee arthroplasty

Current evidence in knee arthroplasty is based predominantly on preoperative BFRT or prehabilitation studies intended to influence postoperative strength and function [11]. Direct evidence for BFRT initiated after knee arthroplasty remains limited. The small available evidence base shows mixed findings and substantial variation in intervention duration, protocol, and outcome measurement [11].

The evidence is therefore insufficient to support routine BFRT for all knee arthroplasty patients. When considered for selected patients, decisions should account for surgical status, thrombotic risk, wound and limb condition, medical comorbidity, and the rehabilitation team's ability to supervise and monitor treatment [5,11,36].

4.5. Tendon-related rehabilitation and selected other applications

Tendon rehabilitation is an emerging application when pain or limited tolerance to higher muscle-tendon loads restricts conventional strengthening progression [10]. A scoping review identified potential uses, but the available studies are heterogeneous in population, intervention parameters, and outcomes [10]. Evidence remains preliminary and does not support firm, diagnosis-wide recommendations.

BFRT has also been explored in upper-extremity elbow flexor and extensor training, with reported improvements in muscle strength and size [37]. These findings are not sufficient to establish effectiveness across upper-limb musculoskeletal disorders. Such applications should be treated as exploratory and interpreted in relation to the specific diagnosis, tissue-loading goals, and available clinical evidence [5,8].

5. Safety and adverse events

Available evidence suggests a relatively favorable short-term safety profile in selected musculoskeletal populations, particularly in knee-related conditions, but safety reporting is incomplete and definitions of adverse events vary [16]. Many trials exclude medically complex patients, limiting generalization. BFRT should therefore not be described as risk-free, even when serious events appear uncommon in published reports [16,38].

Commonly reported symptoms include discomfort or dull pain, acute muscle fatigue, delayed-onset muscle soreness, tingling or paresthesia, numbness, dizziness or fainting, bruising, and subcutaneous hemorrhage [16,38,39]. These symptoms are often transient or low grade, but they warrant reassessment rather than being accepted automatically as an unavoidable feature of treatment. Relevant modifications may include reducing cuff pressure, checking cuff position, changing exercise volume or frequency, lengthening rest intervals, or discontinuing the session [1,16,38].

Potentially serious complications described in the literature include venous thrombosis, pulmonary embolism, syncope, persistent neurological symptoms, excessive muscle damage, and rhabdomyolysis [16,38,39]. A systematic review in musculoskeletal disorders identified rare reports of upper-extremity deep vein thrombosis and rhabdomyolysis, while also noting that many studies reported safety inadequately or not at all [16]. The available evidence does not permit precise estimation of event rates, particularly in postoperative, older, or medically complex patients. Interpretation is further complicated by differences in cuff systems, pressure determination, exercise dose, duration of inflation, supervision, and follow-up. Studies that report no adverse events may still provide limited reassurance when event definitions, surveillance procedures, and withdrawal reasons are not described. Future clinical

studies should report both expected transient symptoms and medically important adverse events using explicit definitions and standardized monitoring periods.
BFRT should be stopped or deferred when a patient develops unusual or escalating pain, persistent or worsening numbness or paresthesia, dizziness or presyncope, cardiopulmonary symptoms, new neurological symptoms, excessive swelling, signs of vascular compromise, or other symptoms inconsistent with the expected exercise response [15,38]. Persistent or concerning findings may require medical evaluation. These stopping criteria complement, but do not replace, pre-participation risk assessment.

6. Risk stratification, clinical precautions, and contraindication considerations

Pre-participation screening should review medical history, current symptoms, comorbidities, recent surgery or immobilization, cardiovascular and vascular status, thrombotic history, and medications or substances that may alter cardiovascular or coagulation risk [15]. Screening should guide whether BFRT can proceed, should be modified, requires enhanced monitoring or medical consultation, or should be deferred in favor of another intervention. Because clinical studies often use restrictive eligibility criteria, evidence is limited for many patients commonly encountered in rehabilitation [15,16].
Several conditions have been proposed as risk factors or reasons for additional caution, including cardiovascular disease, poorly controlled hypertension, peripheral vascular disease, impaired circulation, diabetes mellitus, chronic kidney disease, clinically relevant inflammatory disease, coagulation disorders, previous venous thromboembolism, pregnancy or the postpartum period, recent surgery, prolonged immobilization, lymphedema or marked swelling, and medication- or substance-related factors that may increase thrombotic or cardiovascular risk [15,40]. Practice-oriented guidance and expert opinion also identify active infection, open wounds, and malignancy as circumstances that may warrant careful assessment or temporary deferral [40]. These considerations are not supported by validated BFRT-specific contraindication criteria and should not be interpreted as having the same evidential basis as vascular, thrombotic, or unstable cardiovascular concerns.
These factors should not be interpreted as a universal list of absolute contraindications. On pragmatic clinical grounds, an acute unexplained limb symptom, unstable medical status, active local infection, or an unhealed wound under or near the cuff may justify temporary deferral. Other circumstances, including malignancy or complex systemic disease, may require medical consultation, closer monitoring, or selection of an alternative intervention. Decisions should consider the severity and stability of the condition, the planned exercise dose, the limb being treated, the availability of supervision, and the clinician's competence. A practical decision pathway may distinguish patients who can proceed with routine monitoring, those who require a modified protocol or enhanced observation, those who should obtain medical clearance, and those in whom treatment should be deferred. This approach is more defensible than labeling every comorbidity as either an absolute contraindication or a negligible concern. The patient should also be informed about expected sensations, uncertain risks, and symptoms that require immediate reporting.
Thrombotic risk warrants particular attention after surgery or prolonged immobilization [1,15]. Venous thrombosis and pulmonary embolism do not appear to be frequent BFRT-related events in published studies, but rare events have been reported and adverse-event surveillance remains incomplete [16,38]. Baseline venous thromboembolism risk may already be elevated because of surgery, immobility, comorbidity, or other prothrombotic factors. A history of venous thromboembolism, impaired coagulation, marked unilateral swelling, symptoms suggestive of vascular compromise, or uncertain thrombotic risk may justify physician consultation before BFRT is considered [15,38].

The risk stratification model proposed by Nascimento et al. offers a practical framework for considering baseline health status and condition-specific risk, but it has not been externally validated as a definitive clinical decision rule [15]. It should therefore support rather than replace clinical judgment, shared decision-making, referral when appropriate, and reassessment when the patient's medical status changes.

7. Cardiovascular and hemodynamic considerations

Although BFRT uses low external loads, it can alter heart rate, blood pressure, cardiac output, stroke volume, oxygenation indices, vascular function markers, and blood lactate [15,17,18]. The magnitude and direction of these responses vary with exercise type and load, the limb exercised, occlusion pressure, continuous or intermittent restriction, device type, duration of restriction, and participant characteristics [17,18]. Findings from one protocol should not be assumed to apply to another.

A systematic review reported increased heart rate and blood lactate, variable effects on blood oxygen saturation, increased cardiac output, and either no significant change or a decrease in stroke volume across included studies [17]. Activation of the exercise pressor reflex, including metaboreflex and mechanoreflex components, has been proposed as one explanation for the cardiovascular response to blood-flow-restricted resistance exercise [18]. The ischemic and metabolite-rich environment may amplify pressor responses in susceptible individuals.

Cardiovascular disease should not be treated as a single, uniform absolute contraindication. Evidence from selected cardiovascular populations suggests that low-load BFRT may improve muscle strength, function, and some cardiovascular parameters, but this evidence is based on few studies, small samples, varied diagnoses, and heterogeneous protocols [41]. It does not establish routine safety or effectiveness across all cardiovascular conditions [15,41].

Patients with poorly controlled hypertension, heart failure, vascular disease, impaired vascular health, thrombotic risk, or uncertain cardiovascular status may require medical consultation, closer supervision, or an alternative intervention [15,18]. When BFRT is used, baseline symptoms, blood pressure control, exercise tolerance, and vascular history should inform prescription. Blood pressure and cardiovascular symptoms may require monitoring in higher-risk patients, particularly during initial sessions or after changes in pressure or exercise dose [15,17,18]. Concerning symptoms or excessive responses should prompt cessation and reassessment. Continuous cuff inflation may produce different hemodynamic and perceptual responses from intermittent release, and upper- and lower-limb exercise may not be equivalent. Clinicians should therefore avoid applying a single cardiovascular interpretation to all BFRT protocols. Where monitoring is indicated, measurements should be obtained under consistent conditions and interpreted in relation to the patient's baseline values, symptoms, medication use, and the expected response to the selected exercise.

8. Arterial occlusion pressure, limb occlusion pressure, cuff width, and device-related factors

The method used to apply external pressure influences the degree of restriction, perceptual response, cardiovascular stress, and comparability between protocols [1,17,22]. Fixed or arbitrary cuff pressures are problematic because the pressure required to occlude arterial flow depends on cuff width, limb size, blood pressure, cuff placement, and device characteristics [1,21]. Prescribing exercise pressure relative to an individualized AOP or LOP is therefore commonly recommended [1,19,20,22].

AOP and LOP are related individualized occlusion-reference measures, although their terminology, detection methods, and device-specific procedures are not fully standardized [1,19]. Exercise pressure is commonly prescribed as a percentage of the measured individualized occlusion pressure. This approach reduces the limitations of applying the same absolute pressure to patients with different limb dimensions, blood pressure profiles, or cuff systems [1,19,20]. The measured value is not a fixed biological constant; it is specific to the individual, limb, cuff, device, posture, detection method, and assessment conditions [19,20,42].

Cuff width is a major determinant of occlusion pressure [1,21,42]. Wider and narrower cuffs may require different absolute pressures to produce similar arterial restriction. Limb circumference and other anthropometric characteristics also influence the pressure required for occlusion [1,42]. Some evidence suggests that sex may contribute to differences in AOP, but such effects should be interpreted together with cuff width and limb anthropometry rather than in isolation [42]. No cuff width should be considered universally preferable without reference to the patient, limb, device, and clinical purpose [1,22,42].

Different BFR systems may yield different AOP or LOP values and should not be assumed to be interchangeable [19,20,22]. Device type, cuff design, detection method, and measurement posture can affect the measured individualized occlusion pressure. Supine and standing assessments may differ, and device-related differences have been observed across postures [20]. Values obtained with one cuff, system, limb, or assessment procedure should not automatically be transferred to another. When the device, cuff, limb position, or relevant patient characteristic changes, reassessment may be necessary.

Clinical records and research reports should document the device, cuff width and material where available, limb assessed, measurement position, method used to detect arterial occlusion, measured individualized occlusion pressure, and exercise pressure [19,20,22]. Reporting cuff pressure alone limits reproducibility and may obscure clinically meaningful differences between protocols. Individualized occlusion pressure may be determined using Doppler ultrasound, pulse detection, or automated device algorithms, but these approaches should not be assumed to provide identical values. The assessment should follow the manufacturer's validated device-specific procedure where available, and distal circulation should be reassessed when clinically indicated. Reassessment of occlusion pressure is particularly relevant after substantial changes in limb swelling, body position, blood pressure, or rehabilitation status.

9. Practical implementation

9.1. General implementation principles

BFRT should be integrated into a progressive rehabilitation program and linked to a specific clinical reason for using lower external loads [2,5]. It should not be applied as a routine stand-alone intervention or continued after its load-management purpose has resolved. Implementation requires an appropriate device and cuff, individualized pressure assessment, exercise prescription, screening, monitoring, and a plan for progression.

9.2. Patient selection and screening

Before treatment, clinicians should review the diagnosis, rehabilitation phase, tissue-loading restrictions, symptoms, medical history, cardiovascular and thrombotic risk, vascular status, recent surgery or immobilization, and medication-related factors [15]. Screening should determine whether BFRT is appropriate, whether it requires modification or enhanced monitoring, and whether medical consultation is indicated. Postoperative and medically complex patients may require qualified supervision and closer reassessment [15,16,38]. Before the first session, patients should receive a clear explanation of the purpose of BFRT, the sensations commonly experienced under the cuff, the planned duration of restriction, and the symptoms that should be reported immediately. As a pragmatic clinical measure, documenting baseline pain, swelling, neurological symptoms, and relevant vascular findings may help clinicians interpret changes during or after treatment.

9.3. Cuff selection and individualized pressure assessment

The cuff is generally applied proximally on the target limb [1]. Cuff width, material, limb characteristics, and device type influence both the measured individualized occlusion pressure and the exercise stimulus [22,42]. Cuff selection and application should be kept consistent across sessions when possible and documented in clinical records.

Pressure should preferably be prescribed relative to an individualized occlusion pressure rather than as an arbitrary absolute value [1,19]. The assessment conditions should match the intended application as closely as practical. Pressure should be reconsidered when the cuff, device, limb position, or clinically relevant patient factors change [19,20].

9.4. Exercise prescription

Exercise selection should reflect the rehabilitation phase, tissue-loading tolerance, symptoms, goals, and risk profile [2,5]. Resistance exercise with BFRT is commonly performed at lower external loads than conventional high-load training, often with multiple sets, higher repetitions, and short rest periods [1,5]. Frequently reported examples include approximately 20–40% of one-repetition maximum and a 30-15-15-15 repetition scheme. These are commonly used templates rather than universal prescriptions and should be modified according to the exercise, patient, and clinical context [1,5]. Other variables—including exercise selection, contraction type, range of motion, rest duration, frequency, and whether pressure is maintained between sets—also affect the total dose. As a conservative pragmatic approach rather than a validated universal rule, an initial session may use lower volume or pressure to assess tolerance, particularly in deconditioned, postoperative, or anxious patients. Changing one or a limited number of variables at a time may also make responses easier to interpret, but this strategy should not be presented as a mandatory evidence-based progression method.

9.5. Monitoring and stopping criteria

During treatment, clinicians should monitor local discomfort, pain, numbness, tingling, unusual fatigue, dizziness, presyncope, cardiopulmonary symptoms, neurological symptoms, swelling, and signs of vascular compromise [15,38]. Higher-risk patients may also require monitoring of blood pressure, exercise tolerance, and cardiovascular symptoms [15,18].

Unusual, worsening, or persistent symptoms should prompt immediate reassessment. Depending on the finding, the clinician may reduce pressure, correct cuff position, decrease load or volume, lengthen rest, alter exercise selection, discontinue the session, defer further BFRT, or seek medical evaluation [15,38].

9.6. Progression within rehabilitation

Progression should be based on symptoms, tissue-healing considerations, functional goals, and increasing tolerance to conventional loading [2,5]. As higher-load resistance exercise becomes appropriate, BFRT may be reduced, reserved for selected exercises, or discontinued. The transition should be driven by rehabilitation needs rather than by a fixed BFRT duration. Protocol heterogeneity and limited evidence in medically complex patients reinforce the need for individualized clinical reasoning [8,15,22].

10. Conclusions

BFRT may provide a useful low-load training stimulus for selected patients whose pain, postoperative status, or tissue-loading tolerance temporarily limits conventional higher-load resistance exercise [4,5]. It may outperform comparable low-load exercise without BFR for some strength- and muscle mass-related outcomes, but it has not shown consistent superiority over high-load resistance training [4,24].

Its clinical value depends on appropriate patient selection, risk assessment, individualized occlusion-pressure prescription, cuff and device characteristics, monitoring, and planned progression [1,15,22]. Evidence remains heterogeneous and condition-specific, while safety data are limited by incomplete reporting and underrepresentation of medically complex patients [8,16]. BFRT should therefore be used as an optional component of progressive rehabilitation rather than as a universal or permanent substitute for conventional resistance training.

Author's Contributions:

Conceptualization: Wojciech Ziębka, Oliwia Dziewięcka, Michał Błażuk
Methodology: Damian Broda, Wiktoria Mikulska, Natalia Sak
Check: Wojciech Ziębka, Oliwia Dziewięcka, Dominik Zając
Investigation: Natalia Sak, Katarzyna Sikora
Resources: Kamila Tasior, Julia Wilanowska, Aleksandra Broda
Data curation: Wiktoria Mikulska, Julia Wilanowska
Writing - rough preparation: Wojciech Ziębka, Oliwia Dziewięcka, Dominik Zając
Writing - review and editing: Wojciech Ziębka, Michał Błażuk, Oliwia Dziewięcka
Supervision: Damian Broda, Kamila Tasior, Wiktoria Mikulska
Project administration: Katarzyna Sikora, Aleksandra Broda
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