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# Blood Flow Restriction Training (BFR)

In blood flow restriction training, a limb is partially occluded with a cuff and trained with low loads. The controlled studies in humans focus on the musculoskeletal system. The most cited work in the field is methodological: it addresses cuff width and arterial occlusion, not therapeutic success.

**674**

STUDIES IN  
TOTAL

**387**

IN HUMANS

**200**

OF WHICH  
CONTROLLED

**5**

IN ANIMALS

**1**

IN THE LAB

Figures from the IHR study database · Last updated 2026-10-04

## How to Read This Dossier

### ESTABLISHED

measured in humans, with a comparison group

### PLAUSIBLE

supported by mechanism, animal studies or observation

### HYPOTHESIS

a likely connection that still needs to be tested

## Blood Flow Restriction Training (BFR) at a Glance

### ORIGIN:

Blood flow restriction training is a procedure in which a pressure cuff is applied proximally to an extremity and inflated to a defined pressure while training with low load.

### EVIDENCE BASE:

674 evaluated studies · 200 controlled human studies · 187 observational studies · 83 review articles · 5 animal studies · 1 cell culture study

### STRONGEST EVIDENCE:

- **Proven:** Musculoskeletal system — meta-analysis [42]: 47 included studies; from 19 studies with 400 participants, mean strength advantage 0.4 Nm under BFR endurance exercise, 0.3 kg under BFR strength exercise.
- **Proven:** Musculoskeletal system — meta-analysis in older adults [48]: 11 studies with N=238; BFR added to low-load training produced a pooled effect of 2.16 (95 % CI 1.61 to 2.70), during walking 3.09 (2.04 to 4.14).
- A review of 19 upper-body studies [50] showed that low-load BFR increased muscle size and strength proximal and distal to the stimulus, whereas volume-matched training without BFR produced no such adaptations.
- An RCT [27] showed in the musculoskeletal system: in 26 participants, strength increased proximal and distal to the cuff more than in the non-occluded limb and in the control group ( $P < 0.05$ ), approximately twice as large.
- A critical review [49] concludes that the available evidence does not support the assumption that BFR combined with low-intensity exercise increases the incidence of muscle damage.

### LIMITATIONS:

- The protocols are heterogeneous: cuff width, pressure, application site, exercise selection and training duration vary, and cuff width alone influences the pressure required for arterial occlusion.
- Many controlled studies measure surrogate endpoints such as strength, muscle cross-sectional area or laboratory parameters rather than disease course; some combine BFR with high-intensity training, so the contribution of restriction cannot be isolated.
- A meta-analysis on knee pain [40] found that strength training with BFR did not relieve pain more than strength training alone (SMD -0.37, 95 % CI -0.93 to 0.19); evidence quality was low.

### CLASSIFICATION:

Blood flow restriction training is a procedure with extensive controlled research in the musculoskeletal system, whose synthesis depends primarily on the heterogeneity of the protocols.

## 1. What Blood Flow Restriction Training Is

In blood flow restriction training, a pressure cuff is applied proximally to an extremity and inflated to a defined pressure while training with low load. Venous return is throttled while arterial inflow is partially preserved. Training is typically performed with strength exercises or cycle ergometry, and the cuff remains in place during the effort. The literature in the field addresses methodology in detail: cuff width, application site, pressure level and whether pressure is set absolutely or relative to the individual occlusion pressure. One study examines autoregulation of the applied pressure in healthy, physically active adults.

For the evaluation of all studies it is crucial that blood flow restriction does not denote a uniform intervention. Cuff width, pressure, application site, exercise selection and training duration vary between studies, and cuff width alone influences the pressure required for arterial occlusion. Some studies use device-supported pressure control, others use practical BFR without pressure measurement. Target variables range from muscle cross-sectional area and strength through haemostasis parameters and the exercise pressor reflex to molecular markers such as mTORC1 signalling and muscle protein synthesis. This diversity explains why findings can be summarised only to a limited extent.

## 2. What the Studies Show in Detail

The key human studies and the most important reviews — by application area, with population, duration, preparation, outcome measure and result as reported by the original studies. Numbers appear only where the study states them.

Distribution of **controlled human studies** by application area — the numbers are not additive because one study may be assigned to several areas:

| APPLICATION AREA        | CONTROLLED STUDIES |
|-------------------------|--------------------|
| Musculoskeletal system  | 161                |
| Safety and tolerability | 70                 |

| APPLICATION AREA       | CONTROLLED STUDIES |
|------------------------|--------------------|
| Heart and circulation  | 33                 |
| Fatigue and stress     | 32                 |
| Bones and joints       | 28                 |
| Metabolism             | 25                 |
| Inflammatory processes | 5                  |
| Cognition and psyche   | 4                  |

## Musculoskeletal System

The BFR group showed a 93 % greater pain reduction during activities of daily living ( $p=0.02$ ). In participants with painful resisted knee extension ( $n=39$ ), isometric knee-extension moment increased more under BFR than under standard ( $p<0.01$ ). No difference between groups was found for the Kujala Patellofemoral Score ( $p=0.31$ ) or worst pain ( $p=0.24$ ). In 34 patients after anterior cruciate ligament reconstruction (19 female, 15 male; mean age  $16.5 \pm 2.7$  years), a randomised study examined BFR with high-intensity exercise: leg press at 70 % 1RM, concentric or eccentric, four sets of ten repetitions, twice weekly for eight weeks starting from the tenth postoperative week [29]. The study reports that BFR with high-intensity exercise did not improve quadriceps function after reconstruction.

A randomised controlled study had healthy participants train standardised with BFR on one extremity for six weeks; excluded were cardiac, pulmonary and haematological diseases, pregnancy and previous surgery of the extremity [27]. 26 persons completed the protocol (16 BFR, 10 control; mean age 27 years; 62 % female). Strength increased proximal and distal to the BFR cuff more than in the non-occluded limb and in the control group ( $P<0.05$ ); the improvement was approximately twice as large. In 20 college-aged men with at least one year of strength-training experience, a randomised crossover study examined practical BFR on the elbow flexors over eight weeks [28].

**PROVEN** A systematic review with meta-analysis screened 916 hits and included 47 studies [42]. From 19 studies with 400 participants, there was a mean advantage of 0.4 Nm for strength under BFR endurance loading compared to control, and 0.3 kg under BFR strength loading. From 19 studies with 377 participants, the mean difference in muscle size (cross-sectional area) was 0.4 cm<sup>2</sup>. A meta-analysis on older people screened 2658 articles and included 11 studies with  $N=238$  [48]; under low-load training, the addition of BFR yielded a pooled effect of 2.16 (95% CI 1.61 to 2.70), and for walking 3.09 (95% CI 2.04 to 4.14). A review of 19 studies on the upper body found that low-load BFR training increased muscle size and strength proximal (chest, shoulders) and distal (biceps, triceps) to the stimulus, whereas volume-matched training without BFR did not elicit such adaptations [50]; the quantitative evaluation was limited by heterogeneous protocols.

Acutely, torque declined similarly between pressures [ $-15.5$  (5.9) Nm,  $P=0.344$ ]. After eight weeks of training, muscle size (10%), peak isotonic strength (18%), peak isokinetic torque ( $180^\circ/s = 23\%$ ,  $60^\circ/s = 11\%$ ) and muscular endurance (62%) increased similarly between high and low pressure. Another study in 40 participants found that pressure and load had little influence on torque, yet muscle activation increased in all conditions ( $P<0.05$ ) and was higher at 30% 1RM than at 20% 1RM; the rise from 40% to 50% arterial occlusion was evident (66% vs. 87% maximal voluntary contraction at 30% 1RM), and higher pressures did not increase it further [45]. A critical review concludes that the available evidence does not support the assumption that BFR with low-intensity exercise increases the incidence of muscle damage [49].

## Bones and Joints

In a randomised, double-blind controlled study, women over 45 years with risk factors for symptomatic knee osteoarthritis were randomised to either low-load strength training (30% 1RM) alone or with concurrent BFR [26]. For four weeks, leg-press training was performed three times weekly; the BFR group wore a cuff that progressively restricted femoral blood flow over the training weeks. Isometric leg-press strength, isokinetic knee-extension strength and quadriceps volume by magnetic resonance imaging were measured; secondary outcomes were leg strength (leg press and stair climbing); knee pain served to assess tolerability. Of 45 enrolled women, 40 completed the programme. In a randomised study of 30 patients with end-stage gonarthrosis, three groups received either usual clinical care without prehabilitation, prehabilitation with sham BFR or prehabilitation with BFR [36]. The protocol consisted of cycle-ergometer training twice weekly for six weeks; BFR was applied periodically three times per leg at 40% of individual limb-occlusion pressure.

A systematic review on anterior-cruciate-ligament reconstruction and knee osteoarthritis identified 159 publications and included ten studies [34]. Four studies found a significant strength improvement, two a significant increase in cross-sectional area, four a significant pain improvement and one a significant improvement in functionality and quality of life. Another systematic review evaluated nine studies (eight at evidence level 1, one at level 2) and comprised 165 patients and 170 controls [10]; BFR was used after anterior-cruciate-ligament reconstruction, after routine knee arthroscopy and in knee osteoarthritis and patellofemoral pain, with occlusion and exercise protocols varying. A systematic review with meta-analysis on rheumatoid arthritis and osteoarthritis examined low-intensity training with BFR for strength, muscle mass and functionality [39].

A systematic review of randomised and non-randomised studies examined the effect of BFR exercise on haemostasis in healthy individuals and in patients with hypertension, diabetes, obesity and ischaemic heart disease [32]; it remained unclear whether vascular compression damages endothelial cells or promotes thrombus formation. A systematic review in adults over 50 years asked whether BFR elicits skeletal-muscle hypertrophy and improves strength and physical function [35]; it notes that many studies were conducted in healthy young men with small samples and limited follow-up.

## Metabolism

Ten participants performed rhythmic isometric knee extension under five experimental conditions: BFR at 40%, 60% and 80% of limb-occlusion pressure (LOP) at a load of 20% of maximal voluntary strength and without BFR at 20% (LL) and 80% (HL) [31]. Torque, muscle activity by electromyography, tissue oxygenation by near-infrared spectroscopy, whole-body oxygen consumption, blood lactate and heart rate were measured. In the LL and B-40 conditions, most measures remained constant; at B-60 and B-80, marked fatigue with a decline in maximal torque was observed ( $p < 0.05$ ). Blood lactate rose from baseline at HL, B-60 and B-80 ( $p < 0.05$ ), and submaximal EMG activity was higher at B-60 and B-80 than at LL. In a randomised crossover, ten healthy men ( $28.1 \pm 6.5$  years) performed unilateral biceps curls with and without BFR [37]; arterial and venous catheters were placed in the exercising arm. Intravascular pressures were more elevated under BFR than without ( $p < 0.001$ ), and blood-gas analyses showed a BFR-induced metabolic acidosis ( $p < 0.05$ ) with increased lactate production ( $p < 0.05$ ).

A paper on risk stratification points out that BFR can elicit elevated blood pressure, abnormal cardiovascular responses and effects on vascular health, and that caution is warranted in persons with existing cardiovascular disease such as hypertension, diabetes mellitus and chronic kidney disease [30]; because of possible thrombosis risks, risk stratification via history, signs and symptoms is recommended. A review on the role of metabolic stress describes the accumulation of metabolites (lactate, inorganic phosphate and hydrogen ions) in muscle cells and names low-intensity strength training with BFR as well as high-intensity interval training as ways to maximise metabolic stress [51].

## Heart and Circulation

AUTO was superior in the exhaustion protocol ( $p < 0.001$ ) and showed less muscle soreness 24 hours after exercise ( $p < 0.001$ ). Perceived exertion and discomfort were higher with NAUTO, both in the fixed protocol (RPE:  $p = 0.014$ , RPD:  $p < 0.001$ ) and in the exhaustion protocol (RPE:  $p = 0.028$ , RPD:  $p < 0.001$ ). Sixteen adverse events (7.14%) were recorded, with sevenfold frequency in the fixed protocol for NAUTO versus AUTO (NAUTO  $n = 7$  vs. AUTO  $n = 1$ ) and five (NAUTO) versus three (AUTO) in the exhaustion protocol. In a randomised crossover, a study compared the haemodynamics of strength and endurance BFR with high- and low-intensity loading without BFR [38]. During leg press, haemodynamics under low load with BFR (80% of resting systolic pressure) resembled high-intensity loading and exceeded low load (systolic pressure  $152 \pm 3$  mmHg vs.  $153 \pm 3$  vs.  $143 \pm 3$ ,  $P < 0.05$ ); on the treadmill it resembled low load and was below high-intensity loading ( $124 \pm 2$  mmHg vs.  $123 \pm 2$  vs.  $140 \pm 3$ ,  $P < 0.05$ ).

A paper on the exercise pressor reflex argues that the reflex cardiovascular response to BFR has so far received little attention in the literature, although it has been known since the work of Alam and Smirk in the 1930s that reduced perfusion of exercising muscle elicits this reflex [43]. A review on well-trained athletes identified twelve papers from eleven investigations [47]: seven papers observed enhanced hypertrophic and/or strength responses, two reported changes in acute responses to low-load strength training with BFR, one examined adaptations to moderate-load strength training with BFR, one improved training responses to cardiovascular BFR training with low loading rate, and one reported an injury case after BFR exercise in an athlete.

## Further Investigations

A systematic review with meta-analysis on knee pain included eight randomised clinical trials, five of them in the quantitative synthesis [40]. The pooled standardised mean difference showed that strength training with BFR did not relieve pain more than strength training alone (SMD:  $-0.37$  cm, 95% CI  $-0.93$  to  $0.19$ ) and did not improve knee function more (SMD:  $-0.23$  points, 95% CI  $-0.71$  to  $0.26$ ); evidence quality was low. In 42 healthy participants (age  $28.1 \pm 7.7$  years), arterial occlusion pressure of the upper arm was measured in supine, sitting and standing positions by three blinded examiners using a cuff with hand pump and a hand-held Doppler ultrasound device [41]. Occlusion pressure was significantly higher in the sitting position than supine ( $P < 0.031$ ) and higher supine than standing ( $P < 0.031$ ).

A review on perceived barriers to BFR application lists determination of training pressures, access to suitable technology for the respective target group, comprehensive and systematic medical screening, and strategies to reduce the high perceived demands of training and promote long-term adherence as barriers [53].

## Inflammatory Processes

In a study, healthy adults performed leg extensions three times weekly for four weeks with low load and BFR (30% of strength) or with high load (80%), the cuff being inflated to 30% above systolic blood pressure [46]. Strength, pulse-wave velocity, ankle-brachial index, prothrombin time and nerve-conduction velocity were measured before and after training, as well as coagulation markers (fibrinogen and D-dimer), fibrinolysis (tissue plasminogen activator, tPA) and inflammation (high-sensitivity C-reactive protein, hsCRP) after the first and last exercise session. Strength rose by 8% under BFR and by 13% under high load ( $P < 0.01$ ). Pulse-wave velocity, ankle-brachial index, prothrombin time and nerve-conduction velocity did not change in either group ( $P > 0.05$ ). tPA antigen rose immediately after acute sessions of both protocols by 30–40% ( $P = 0.01$ ); fibrinogen, D-dimer and hsCRP remained unchanged ( $P > 0.05$ ).

**HYPOTHESIS** A review on the role of inflammation and immune cells in BFR adaptation describes that BFR with low-intensity strength training increases muscle mass and strength in various populations and generates pronounced metabolic stress that is proposed to promote muscle growth via enhanced recruitment of fast-twitch fibres, a greater endocrine response and/or enhanced cell swelling [52]. After exercise, neutrophils are the first immune cells to initiate remodelling, among other mechanisms via increased cytokine production and recruitment of monocytes and macrophages that support phagocytosis, myoblast differentiation and formation of new myotubes.

## Gut and Microbiome

For the area of gut and microbiome, no study on blood-flow-restriction training exists that examined this endpoint. Whether the procedure influences the gut flora or inflammatory processes in the gut is an open question that would require dedicated studies with appropriate endpoints.

## Overall Picture

Across domains, systematic reviews and meta-analyses carry the most weight: for strength and muscle size they show consistent advantages under low load with BFR versus control or low load without BFR [42][48][50], and for pain and function in knee pain a meta-analysis finds no additional benefit over strength training alone [40]. Individual studies paint a mixed picture: in patellofemoral pain BFR was superior for everyday pain [25], after anterior-cruciate-ligament reconstruction with high-intensity exercise it was not [29]. Pressure height appears to play a subordinate role [44][45].

Safety and tolerability data derive predominantly from small, short-term studies in healthy individuals [46][49], whereas risk groups with cardiovascular or coagulation-related diseases have so far been addressed mainly conceptually [30][32]. Autoregulated pressures performed more favourably than fixed pressures in one study [33]. Across all domains, larger, independently replicated studies with uniform protocols and longer follow-up periods are still outstanding; these should also include older people and patient groups.

### Methodology of the Evidence Base

The supporting works are controlled human studies and crossover designs in small samples, mostly between ten and 80 participants, with training durations of four to eight weeks [25][27][28][29][31][33][37][38][46]. Endpoints are strength (isometric, isokinetic, isotonic), muscle size (ultrasound, magnetic resonance imaging, cross-sectional area), pain and function via scores and scales, and acute physiological measures such as lactate, tissue oxygenation, haemodynamics and intravascular pressures. In addition, several systematic reviews and meta-analyses are available [10][34][35][39][40][42][48][50]. Larger samples, uniform occlusion and exercise protocols, longer follow-up and studies in patient groups with relevant comorbidities remain open.

### The most cited works address the method, not the benefit

The most frequently cited work in the field is a basic-science overview of methodology, application and safety; in second place is a paper on cuff width and its influence on arterial occlusion. The remaining top positions also deal with the acute response: mTORC1 signalling and muscle protein synthesis in older men, the influence of relative restriction pressure on muscle activation and adaptation, and the exercise pressor reflex. Visibility of the field therefore rests on the question of how the method is applied and what it acutely triggers.

Controlled human studies focus on the musculoskeletal system, and their results are not uniform. One of the most cited randomised trials found that BFR combined with high-intensity training did not improve quadriceps function after ACL reconstruction. Other frequently cited works report strength and hypertrophy effects at low load, for example in women with risk factors for symptomatic knee osteoarthritis or with practical BFR in periodised training. The assumption that restriction enhances every training stimulus is therefore not consistently supported; load, pressure and application context are decisive.

## 3. How Robust the Research Is

Research is distributed across several levels. In addition to controlled human studies there are numerous observational works as well as reviews and mechanistic studies, with only a few basic-science studies. Within the controlled human studies the musculoskeletal system clearly dominates; safety, cardiovascular, fatigue, bone and metabolism follow. Only isolated controlled studies exist on inflammation, cognition, gut and immune system. The most cited controlled studies address patellofemoral pain, knee osteoarthritis, proximal, distal and contralateral effects on the leg, muscle hypertrophy in periodised training, rehabilitation after ACL reconstruction, risk stratification, restriction pressures and haemostasis.

Methodologically the field is divided in two. There are double-blind randomised trials, systematic reviews and meta-analyses, for example on strength and hypertrophy in older adults. This is offset by pronounced heterogeneity of protocols that complicates pooling. Many controlled studies measure surrogate endpoints such as strength, muscle cross-section or laboratory parameters rather than disease course. Some works combine BFR with high-intensity training, so the contribution of restriction itself is not isolated. Safety questions rest predominantly on observational and mechanistic studies, including a review on haemostasis and a paper that names the exercise pressor reflex as a safety aspect.

## 4. What Is Frequently Claimed — and What the Data Support

| CLAIM                                                       | EVIDENCE BASE                                                                                                                                |
|-------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Muscle building and strength in healthy trained individuals | Controlled studies and a meta-analysis on older people are available; strength and muscle cross-section are measured, mostly under low load. |
| Rehabilitation after ACL reconstruction                     | A much-cited randomised study shows no additional benefit when BFR is combined with high-intensity training; reviews summarise the findings. |
| Knee osteoarthritis and patellofemoral pain                 | Double-blind randomised studies and systematic reviews are available here; this is the best-studied clinical area.                           |
| Safety and haemostasis                                      | A systematic review on haemostasis and a study on risk stratification exist; the basis is predominantly observational and mechanistic.       |

## 5. The Most Robust Works

Ordered by strength of evidence, not by prominence: reviews and studies with large participant numbers first. The complete evaluation covers substantially more works; the most robust are listed here.

### Controlled Human Studies

- <sup>1</sup> Effects of blood flow restriction exercise interventions on patellofemoral pain syndrome: a systematic review and meta-analysis (2026) — Systematic review, 508 participants
- <sup>2</sup> Effects of blood flow restriction therapy for lower limb dysfunction in stroke patients: a systematic review and meta-analysis (2026) — Systematic review, 522 participants
- <sup>3</sup> Blood flow restriction improves lower limb muscle function in adults with musculoskeletal disorders: A systematic review and meta-analysis (2026) — Systematic review, 638 participants
- <sup>4</sup> The Effectiveness of Blood Flow Restriction Training on Rehabilitation After Anterior Cruciate Ligament Reconstruction: A Systematic Review and ... (2026) — Systematic review, 643 participants
- <sup>5</sup> Blood Flow Restriction Training After Orthopedic Procedures: A Scoping Review of Current Trends and Functional Outcome Assessments (2026) — Systematic review, 831 participants
- <sup>6</sup> Comparative Efficacy and Safety of Blood Flow Restriction Training for Knee Osteoarthritis: A Network Meta-Analysis (2025) — Systematic review, 866 participants
- <sup>7</sup> Comparative effectiveness of neuromuscular, virtual reality, proprioceptive, blood flow restriction and conventional training after ACL ... (2026) — Systematic review, 972 participants
- <sup>8</sup> Do blood flow restriction exercises offer additional benefits when compared to conventional exercises in musculoskeletal rehabilitation? A systematic ... (2026) — Systematic review, 1,652 participants
- <sup>9</sup> Effects of Blood Flow Restriction Therapy in Individuals With Knee Osteoarthritis: Overview of Systematic Reviews (2026) — Systematic review, 5,656 participants
- <sup>10</sup> Blood Flow-Restricted Training for Lower Extremity Muscle Weakness due to Knee Pathology: A Systematic Review (2019) — Systematic review, 165 participants
- <sup>11</sup> Blood Flow Restriction Enhances Recovery After Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis of Randomized ... (2025) — Review article, 245 participants
- <sup>12</sup> Effect of Blood Flow Restriction Technique on Delayed Onset Muscle Soreness: A Systematic Review (2022) — Review article, 118 participants
- <sup>13</sup> Acute and Chronic Effects of Blood Flow Restriction Training in Physically Active Patients With Anterior Cruciate Ligament Reconstruction: A ... (2024) — Review article, 152 participants
- <sup>14</sup> Acute effect of low-load resistance exercise with blood flow restriction on oxidative stress biomarkers: A systematic review and meta-analysis (2023) — Review article, 158 participants

- <sup>15</sup> The effects of blood flow restriction training on early muscle strength and mid-term knee function following anterior cruciate ligament ... (2025) — Review article, 276 participants
- <sup>16</sup> Comparison of blood flow restriction training rehabilitation and general rehabilitation exercise after anterior cruciate ligament reconstruction: A ... (2025) — Review article, 376 participants
- The Effect of Low Intensity Resistance Training with Blood Flow Restriction on Fall Resistance in Middle-Aged and Older Adults: A Meta-Analysis (2023) — Review article, 419 participants
- The effects of blood flow restriction training on post activation potentiation and upper limb muscle activation: a meta-analysis (2024) — Review article, 484 participants
- Effect of resistance training with blood flow restriction on muscle damage markers in adults: A systematic review (2021) — Review article, 301 participants
- The impact of blood flow restriction training on tendon adaptation and tendon rehabilitation - a scoping review (2025) — Review article, 122 participants
- <sup>17</sup> Credibility of Blood Flow Restriction Training in Patients With Knee Osteoarthritis: A Systematic Review and Meta-analysis (2025) — Review article, 228 participants
- <sup>18</sup> Blood flow restriction training compared to conventional training in people with knee pain: a systematic review with meta-analysis (2025) — Review article, 418 participants
- <sup>19</sup> The effects of low-load resistance training combined with blood flow restriction on knee rehabilitation in middle-aged and elderly patients: A ... (2025) — Review article, 241 participants
- The effects of blood flow restriction training on post activation potentiation and fatigue level: systematic review with meta-analysis (2025) — Review article, 347 participants

## 6. Summary

**PROVEN** The most robust statements derive from reviews and meta-analyses on the musculoskeletal system. A meta-analysis [42] with 47 included studies shows average strength advantages of 0.4 Nm under BFR endurance loading and 0.3 kg under BFR strength loading as well as a difference in muscle size of 0.4 cm<sup>2</sup>. A meta-analysis on older adults [48] with 11 studies and N=238 reports a pooled effect of 2.16 (95 % CI 1.61 to 2.70) for low-load training and 3.09 (2.04 to 4.14) for walking. A review of 19 upper-body studies [50] found gains in muscle size and strength proximal and distal to the stimulus. A critical review [49] does not support the assumption that BFR combined with low-intensity exercise increases muscle damage more frequently.

**PLAUSIBLE** The variety of protocols explains why findings can be summarised only to a limited extent. **Hypothesis:** A uniform specification of pressure relative to individual occlusion pressure could make studies more comparable. **Hypothesis:** The exercise pressor reflex, whose cardiovascular response has been known since Alam and Smirk in the 1930s [43], could be given greater consideration in safety assessment. A review on haemostasis [32] leaves open whether vascular compression damages endothelial cells or promotes thrombus formation.

A study would need to clarify whether BFR with a uniform protocol and pressure relative to individual occlusion pressure improves clinical endpoints rather than surrogate measures. It remains open whether the addition of BFR to strength training improves pain and function in knee pain more than strength training alone; the meta-analysis [40] found no advantage here at low evidence quality. Likewise, the question remains whether vascular compression damages endothelial cells or promotes thrombus formation [32]. An independent replication with uniform pressure specification and clinical endpoints would increase the comparability of the findings.

## 7. What Remains Open

- **Pressure control:** According to which measure should the restriction pressure be set — absolute, relative to occlusion pressure or self-regulating during loading?
- **Clinical endpoints:** Which patient-relevant outcomes such as function, pain and course do controlled studies measure beyond strength and muscle cross-section?
- **Safety in at-risk patients:** Which pre-existing conditions preclude an application, and how robust is the proposed risk stratification?

## Frequently Asked Questions

### How is the restriction pressure determined?

The studies employ different approaches: absolute pressures, pressures relative to the individual arterial occlusion pressure, or autoregulation during exertion. One study in healthy, physically active adults examined autoregulation of the applied pressure and the acute training response. A uniform standard cannot be derived from the available studies; pressure selection remains part of the respective protocol.

### Is BFR suitable for older people?

A frequently cited systematic review with meta-analysis on older people examines strength and muscle hypertrophy. Another review addresses patients over 50 years and the outcomes muscle hypertrophy, strength and physical function. The findings are based predominantly on low-load training; transferability to individual clinical situations must be examined separately in each case.

### What distinguishes practical BFR from device-supported training?

In the device-supported approach, pressure is controlled and frequently aligned with the individual occlusion pressure. Practical BFR operates without pressure measurement, for example with an elastic bandage and a subjectively chosen application pressure. A frequently cited controlled study examined practical BFR in periodised strength training and reports muscle hypertrophy. Whether the two approaches produce comparable effects is an open question.

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Chen J, Wu L, Li C, Yan H · 2025

### International Health Research

Research, put in context. Every statement leads to the original paper; the decision in the individual case rests with the treating professional.  
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