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Chronic adaptations to blood flow restriction aerobic or bodyweight resistance training: A systematic review

Tulasiram Bommasamudram[a,b], Zoe G. Morrell[b], Matthew J. Clarkson[c], Kirtana Raghurama Nayak[d,e], Rajagopal Kadavigere[f], Aaron P. Russell[b] and Stuart A. Warmington[a,b]

[a]Department of Exercise and Sports Sciences, Manipal College of Health Professions, Manipal Academy of Higher Education, Manipal, India; [b]Institute for Physical Activity and Nutrition (IPAN), School of Exercise and Nutrition Sciences, Deakin University, Geelong, Australia; [c]Institute for Health and Sport, Victoria University, Melbourne, Victoria, Australia; [d]Department of Physiology, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India; [e]Department of Medical Education, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India; [f]Department of Radiodiagnosis and Imaging, Kasturba Medical College (KMC), Manipal Academy of Higher Education, Manipal, India

ABSTRACT
This systematic review aimed to examine the chronic adaptations of blood flow restriction (BFR) in conjunction with aerobic and bodyweight resistance training. A search of the electronic databases PubMed (MEDLINE), CINAHL, SPORTDiscus® (via EBSCOhost), Embase, and Cochrane (Central) was conducted to identify relevant published studies. The inclusion criteria encompassed a healthy adult sample population (>18 years), original studies, chronic exercise training interventions (minimum 2 weeks duration) employing aerobic BFR exercise or bodyweight resistance BFR exercise, and comparisons with equivalent intensity non-BFR aerobic or bodyweight resistance training. Thirty-three ($n = 33$) studies met the inclusion criteria and were included in the review. Among the included studies, chronic adaptations to BFR aerobic training were characterized by significant improvements in aerobic capacity (4–9%), muscle strength (6–31%), and muscle hypertrophy (2–11%) compared to non-BFR aerobic training. Furthermore, bodyweight resistance BFR training increased muscle hypertrophy (3–5%) and strength (4–11%). The findings suggest that both aerobic and bodyweight BFR training provide interchangeable options for practitioners prescribing BFR without access to a traditional equipment filled training environment, supporting flexibility in exercise programme design tailored to individual preferences, facility constraints, and specific fitness goals.

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KEYWORDS
Blood flow restriction; aerobic exercise; bodyweight resistance exercise; randomised control trial

Introduction

Engaging in regular aerobic exercise or bodyweight resistance exercise positively impacts health and fitness parameters (Oja et al., 2011; B. J. Schoenfeld et al., 2015). However, aerobic and bodyweight training typically aim to achieve different outcomes. For example, aerobic exercises such as walking, running, or cycling are most commonly utilised to improve cardiovascular fitness (Scribbans et al., 2016), reduce the risk of chronic disease (Cahalin et al., 2022), and assist in weight management (Posadzki et al., 2020). Bodyweight exercises, such as squats, lunges, and planks are most commonly utilised for the development of skeletal muscle strength (B. J. Schoenfeld et al., 2015), endurance (Oja et al., 2011), and hypertrophy (B. Schoenfeld & Grgic, 2018), while aiding injury prevention (Watson et al., 2017).

The emergence of blood flow restriction (BFR) training where limb blood flow during exercise is limited by applying a pneumatic cuff or elastic wrap (Patterson et al., 2019), provides a novel alternative to achieve positive training outcomes. This low-intensity method typically utilises 20% one-repetition maximum (1RM) for resistance exercises (Yasuda et al., 2005) or a similar percentage of maximum effort for aerobic (Clarkson et al., 2017), or bodyweight exercises (Head et al., 2015), to elicit benefits that exceed those achieved with equivalent intensity exercise without BFR. The degree of blood flow restriction is commonly set at 40–80% of the total limb/arterial occlusion pressure (LOP/AOP) measured at rest, with the magnitude of training adaptations generally falling between those observed for light- and high-intensity training (Clarkson et al., 2017; Head et al., 2015; Yasuda et al., 2005). These include gains in muscle strength and muscle size, which interestingly occur for a range of exercise modalities including walking, cycling, running and resistance training. Therefore, the application of BFR to low-load or light-intensity exercise to enhance health outcomes is particularly significant for populations with compromised health and reduced capability to undertake heavy-load or high-intensity training.

Therefore, while aerobic and bodyweight BFR training offer exercise options that benefit a wide range of individuals, including those with limited equipment or physical capabilities (Patterson et al., 2019), beyond these general fitness

CONTACT Stuart A. Warmington stuart.warmington@deakin.edu.au Institute for Physical Activity and Nutrition (IPAN), School of Exercise and Nutrition Sciences, Deakin University, Geelong, Australia; Kirtana Raghurama Nayak kirtana.pai@manipal.edu Department of Physiology, Kasturba Medical College, Manipal Academy of Higher Education, Manipal 576104, India

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applications, BFR training holds promise in athletic and sport-specific contexts (Yang et al., 2024). BFR training facilitates muscular adaptations while minimising stress on joints and connective tissues, making it especially useful for athletes managing injury risk or in recovery (Wortman et al., 2021). The low-intensity nature of aerobic and bodyweight BFR exercises combined with the hypoxic conditions induced by BFR lead to enhanced endurance and muscle growth (Christiansen et al., 2018). This approach allows athletes to pursue performance gains without the high mechanical stress of intense training.

Aerobic and bodyweight BFR exercises require minimal equipment compared to resistance exercises and are generally perceived as less intense than traditional high-intensity training, making them approachable for beginners and those with exercise limitations (Patterson et al., 2019). Unlike high-load resistance training, aerobic and bodyweight exercises typically involve low-to-no external load, which may be perceived as less demanding. This raises the question of whether similar adaptive benefits might be achieved with either form of BFR training, given their relative ease of implementation. If so, aerobic and bodyweight BFR training could serve as equally effective, interchangeable options when access to specialized equipment is limited, making them highly relevant for both home-based and equipment-constrained settings.

In light of these considerations, this systematic review aims to assess the effects of aerobic or bodyweight BFR exercise on muscular strength, hypertrophy, physical function, and indicators of aerobic performance. By comparing these effects to non-BFR aerobic or bodyweight training this review seeks to provide insights into the potential benefits and accessibility of these modes of BFR exercise.

Methodology

Literature search strategy and information sources

A search of English-language literature was conducted using electronic databases, in PubMed (MEDLINE), CINAHL, SPORTDiscus® (via EBSCOhost), Embase, and Cochrane (Central). The search was conducted for results up to June 2024. The search employed Boolean operators in titles, abstracts, and keywords of indexed documents (Supplementary file 1), focusing on content related to BFR and variations of aerobic and/or bodyweight training. Additionally, a secondary search was performed by manually screening the reference lists of all included papers. Any known papers suggested by the research team that were not covered in the initial search were also added for manual screening. Figure 1 illustrates the flow of papers through the study selection process using the PRISMA 2020 flow diagram.

Eligibility criteria

The criteria for inclusion and exclusion were established and agreed upon by all seven authors. During the initial study selection process, three authors independently conducted a blinded standardized eligibility assessment by screening the titles and abstracts (TB, ZM, SW). To be considered eligible, the manuscript had to meet the following criteria: inclusion of aerobic or bodyweight training with BFR, English language, an otherwise healthy sample population aged 18 years or older, original studies, and chronic exercise sessions (minimum 2 weeks of training).

Study selection

If the screening of the title and abstract did not provide relevant information, the complete article was obtained and reviewed by any two of the three reviewers (TB, ZM, SW), using Covidence. Any discrepancies that arose during screening were resolved through discussion among all three authors. Letters to the editor, conference abstracts, and literature reviews were excluded as they did not meet the criteria for methodological and/or critical assessment.

Data extraction

The following data from the included studies were extracted by two reviewers (TB, SW): 1) Author and year, 2) Participant characteristics, 3) Intervention details, 4) BFR characteristics, 5) BFR equipment used, and 6) Main findings.

Quality assessment

The risk of bias in the included studies was assessed by two reviewers (TB, SW) using the Cochrane Scientific Committee's Risk of Bias (ROB) 2.0 tool. The tool assigns scores indicating 'high', 'moderate', or 'low' risk of bias. The results of each individual evaluation were visually presented using 'traffic light' plots, following the guidelines of each evaluation tool, to display the domain-level judgments.

Results

Search results

The database search yielded 987 articles. After removing duplicates, 695 article titles obtained from the databases were imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Upon careful examination of titles, abstracts, and keywords, 47 studies were identified for retrieval and subjected to full-text analysis. After assessing the inclusion criteria, 28 studies met the eligibility criteria. Additionally, through reference screening, 5 more studies were identified that met the inclusion criteria, resulting in 33 studies included in the systematic review (Figure 1).

Study characteristics

Table 1 presents detailed information about the participants involved in each included study. The analysis encompassed 768 participants from 33 different studies, providing an average of 23 participants in each study. However, the individual study sample sizes ranged from 10 to 51 participants. Of the total participants, 491 were males, while 277 were females. Specifically, 16 studies included only male participants (Abe et al., 2006; Abe, Fujita, et al., 2010a; Amani et al., 2018; Amani-

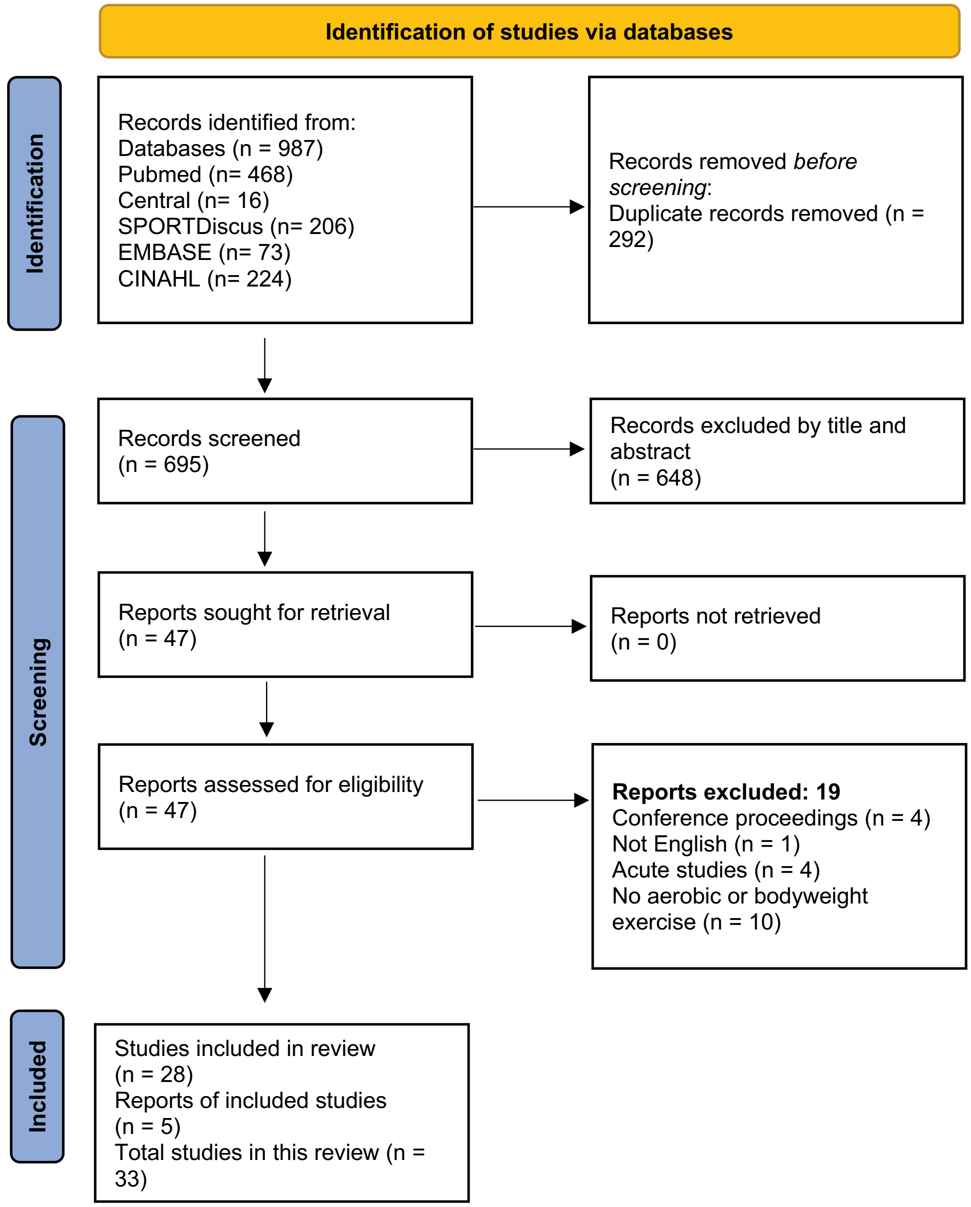

Figure 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases.

Shalamzari et al., 2020; Amani-Shalamzari, Farhani, et al., 2019a; Behringer et al., 2017; Chen, Hsieh, Ho, Ho, et al., 2022b; Chen, Hsieh, Ho, Lin, et al., 2022a; Christiansen et al., 2019; Conceição et al., 2019; Held, Rappelt, Deutsch, et al., 2023a; Junior et al., 2019; Karabulut et al., 2021; Park et al., 2010; Razi et al., 2022; Tangchaisuriya et al., 2022), 5 studies included only female participants (Amani-Shalamzari, Rajabi, et al., 2019b; Iida et al., 2011; Ishii et al., 2005; Kargaran et al., 2021; Ozaki, Sakamaki, et al., 2011b), and 12 studies recruited both males and females (Abe, Sakamaki, et al., 2010b; Cai et al., 2021; Clarkson et al., 2017; Head et al., 2015; Held et al., 2020; Held, Rappelt, Rein, et al., 2023b; Kang et al., 2015; Lan et al., 2022; Ozaki, Miyachi, et al., 2011a; Paton et al., 2017; Thompson et al., 2024; Yokokawa et al., 2008).

BFR pressure application was conducted using either pneumatic cuffs ($n = 28$) or elastic wraps ($n = 5$). Among the studies that employed pneumatic cuffs, 18 utilized an absolute BFR pressure applied across all study participants (Abe et al., 2006; Abe, Fujita, et al., 2010a; Abe, Sakamaki, et al., 2010b; Amani et al., 2018; Cai et al., 2021; Chen, Hsieh, Ho, Ho, et al., 2022b; Chen, Hsieh, Ho, Lin, et al., 2022a; Christiansen et al., 2019; Iida et al., 2011; Ishii et al., 2005; Junior et al., 2019; Kargaran et al., 2021; Lan et al., 2022; Ozaki, Miyachi, et al., 2011a; Ozaki, Sakamaki, et al., 2011b; Park et al., 2010; Razi et al., 2022; Yokokawa et al., 2008). However, nine studies adopted an individualized approach to determine BFR pressure, incorporating methods based on total arterial/limb occlusion pressure (AOP/LOP) ($n = 6$) (Clarkson et al., 2017; Conceição et al., 2019; Held, Rappelt, Deutsch, et al., 2023a; Held, Rappelt, Rein, et al., 2023b; Tangchaisuriya et al., 2022; Thompson et al., 2024), systolic blood pressure ($n = 2$) (Amani-Shalamzari et al., 2020; Amani-Shalamzari, Farhani, et al., 2019a), and limb circumference ($n = 1$) (Amani-Shalamzari, Rajabi, et al., 2019b). Consequently, BFR pressure ranged from 80 to 220 mmHg in studies employing individualized approaches, approximating 30–100% of AOP/LOP. In studies utilizing pneumatic cuffs, the

Table 1. Summary of the articles reviewed for blood flow restriction training adaptations (*n* = 33) with an overview of the participants, intervention, BFR cuff pressure and cuff width, BFR equipment, and main findings.

Author, Year	Participants Characteristics	Intervention	BFR Cuff Pressure and cuff width	BFR Equipment used	MAIN FINGINGS
Aerobic training with BFR					
Abe et al. (2006)	**BFR** (*n* = 9; ♂); 21 ± 3 y; 174 ± 6 cm; 64 ± 5 kg **non-BFR** (*n* = 9; ♂); 21 ± 3 y; 174 ± 3 cm; 66 ± 6 kg	Walking: 5 × 2 min, 1 min rest, 50 m.min $^{-1}$; 2.d $^{-1}$; 6 ses.w^{-1}; 3 w	160 mmHg (↑ 10 mmHg.d^{-1}; max 230 mmHg) LOP – NM	Kaatsu-Master, Sato Sports Plaza, Tokyo, Japan	CSA (Hamstring and Quads): **BFR: 8**% ↑ * and 6% ↑ *; **non-BFR**: NC Muscle volume (Hamstring and Quads) **BFR**: 6% ↑ * and 4% ↑ *; **non-BFR**: NC Strength (Leg press and Leg curl): **BFR**: 7% ↑ * and 8% ↑ *; **non-BFR**: NC
Abe et al. (2010a)	**BFR** (*n* = 9; ♂);172 ± 7 cm; 61 ± 8 kg; **non-BFR** (*n* = 10; ♂); 171 ± 4 cm; 62 ± 6 kg	Cycling: 40% VO_{2max} 3 ses.w^{-1}; 8 w **BFR**: 15 min **non-BFR**: 45 min;	160 mmHg (↑ 10 mmHg.w^{-1}; max 210 mmHg) LOP – NM	Kaatsu-Master, Sato Sports Plaza, Tokyo, Japan	CSA (Thigh and Quads): **BFR**: 3% ↑ * and 5% ↑ *; **non-BFR**: NC Muscle volume (Thighs and Quads) **BFR**: 4% ↑ * and 5% ↑ *; **non-BFR**: NC Strength (KE and KF): **BFR**: 8% ↑ * and NC; **non-BFR**: NC VO_2max: **BFR**: 6% ↑ *; **non-BFR**: NC
Abe et al. (2010b)	**BFR** (*n* = 11; 2♂, 9♀); 60–78 y; 152 ± 1 cm; 54 ± 9 kg **non-BFR** (*n* = 8; 2♂, 6♀); 60–78 y; 155 ± 1 cm; 54 ± 7 kg	Walking: 20 min; 5 ses.w^{-1}; 6 w	160 mmHg (↑ 10 mmHg.w^{-1}; max 200 mmHg) LOP – NM	Kaatsu-Master, Sato Sports Plaza, Tokyo, Japan	CSA (Mid-thigh and lower leg): **BFR**: 6% ↑ * and 5% ↑ *; **non-BFR**: NC Isometric strength (KE): **BFR**: 12% ↑ *; **non-BFR**: NC Isokinetic strength (KE and KF) **BFR**: 11% ↑ * and 16% ↑ *; **non-BFR**: NC Thigh muscle mass: **BFR**: 6% ↑ *; **non-BFR**: NC Functional ability tests: **BFR**: ↑ *; **non-BFR**: NC VO_{2peak}: **BFR**: NC; **non-BFR**: NC
Amani et al. (2018)	♂ soccer players (24 ± 2 y; 73 ± 4 kg; 176 ± 4 cm); **BFR** (*n* = 10) **non-BFR** (*n* = 10) **Control** (*n* = 9)	Running – W1–3 × 400 m; 60–65% MHRR; W2–4 × 400 m; 65–70% MHRR	180 mmHg (1st ses only 140 mmHg) LOP – NM	Adjustable cuffs	VO_2max: **BFR**: 4% ↑ *; **non-BFR**: 1% ↑ *; **Control**: 4% ↓ * RPE: **BFR**: 4% ↓ *; **non-BFR**: 2% ↓ *; **Control**: 4% ↑ *
Amani-Shalamzar et al. (2019a)	♂ futsal players; 23 ± 2 y; 174 ± 5 cm; 68 ± 7 kg **BFR** (*n* = 6); **non-BFR** (*n* = 6)	3-a-side game futsal 3 min futsal +2 min rest 10 ses.w^{-1}; 3 w	110% leg sBP (↑ 10% x 2 ses); LOP ⇒ sBP; 13 cm wide	Pneumatic cuffs (Ghamat, Pooyan, Tehran, Iran)	Peak torque (KE and KF): **BFR**: 31 ± 8% ↑ *; 24 ± 8% ↑ *; **non-BFR**: 15 ± 8% ↑ *; 8 ± 6% ↑ * EMG (VL, VM, RF): **BFR & non-BFR**: ↑ * Futsal Performance: **BFR**: 11 ↓ *; **non-BFR**: 6 ↓ *
Amani-Shalamzar et al. (2019b)	Collegiate ♀; **BFR-IP-CI** (*n* = 8); **BFR-II-CPP** (*n* = 8); **BFR-II-CCP** (*n* = 8); **BFR-IP-II** (*n* = 8);	Running: 2 min *10sets, 1 min rest; 3 ses.w^{-1}; 4 w	50% AOP, and 100% AOP; AOP ⇒ thigh circumference; 5 cm wide	Pneumatic cuffs (Ghamat, Pooyan, Tehran, Iran)	VO_2max: **BFR-IP-CI**: 10% ↑ *; **BFR-II-CPP**: 11% ↑ * **BFR-II-CCP**: 15% ↑ *; **BFR-IP-II**: 8% ↑ * Strength (Isometric): **BFR-IP-CI**: 19% ↑ *; **BFR-II-CPP**: 20% ↑ * **BFR-II-CCP**: 31% ↑ *; **BFR-IP-II**: 21% ↑ * Peak power: **BFR-IP-CI**: 21% ↑ *; **BFR-II-CPP**: 18% ↑ * **BFR-II-CCP**: 28% ↑ *; **BFR-IP-II**: 14% ↑ *

(*Continued*)

Table 1. (Continued).

Author, Year	Participants Characteristics	Intervention	BFR Cuff Pressure and cuff width	BFR Equipment used	MAIN FINGINGS
Amani-Shalamzar et al. (2020)	♂ futsal players; 23 ± 2 y; 174 ± 5 cm; 68 ± 7 kg **BFR** ($n = 6$); **non-BFR** ($n = 6$)	3-a-side game futsal 3 min futsal +2 min rest; 10 ses.w^{-1}; 3 w	110% leg sBP (↑ 10% x 2 sess) LOP ⇒ sBP; 13 cm wide	Pneumatic cuffs (Ghamat, Pooyan, Tehran, Iran)	Peak torque (KE and KF): **BFR**: 31 ± 8% ↑ * and 24 ± 8% ↑ * **non-BFR**: 15 ± 8% ↑ * and 8 ± 6% ↑ * EMG (VL, VM, RF): **BFR & non-BFR**: ↑ * Futsal Performance: **BFR**: 11% ↓ *; **non-BFR**: 6% ↓ * HR and RPE: **BFR**: ↑ *; **non-BFR**: ↑ *
Behringer et al. (2017)	Healthy ♂ sports students; **BFR** ($n = 12$); 26 ± 26 y; 181 ± 7 cm; 79 ± 9 kg. **non-BFR** ($n = 12$); 22 ± 2 y; 181 ± 6 cm; 77 ± 7 kg	6 × 100 m sprints (60–70% Vmax); 1 min rest per rep; 2 ses.w^{-1}; 6 w	LOP – NA; 13 cm wide	Elastic knee wraps (Best Body Nutrition, Auerbach, Germany)	Sprint time: **BFR**: ↓ * **non-BFR**: ↓ * Strength (RFD): **BFR**: 25% ↑ *; **non-BFR**: NC Muscle thickness (RF, BF & BB): **BFR**: ↑ *; **non-BFR**: NC
Chen et al. (2022a)	Endurance trained ♂ athletes; **BFR** ($n = 10$); 21 ± 1 y; 175 ± 2 cm; 66 ± 2 kg; **non-BFR** ($n = 10$); 22 ± 01 y; 180 ± 2 cm; 72 ± 3 kg	Running – 5 sets of 3 min (50% HRR with 1 min break); 3 ses.w^{-1}; 8 w	154 ± 6 mmHg; LOP ⇒ 1.3*sBP; 14 cm wide	Inflatable cuffs, Spirit, Taipei, Taiwan	VO_2max: **BFR**: 5 ↑ *; **non-BFR**: NC Muscle mass: **BFR**: ↑ *; **non-BFR**: NC Strength (Isokinetic KE, KF): **BFR**: 17% ↑ *, 19% ↑ *; **non-BFR**: NC
Chen et al. (2022b)	Endurance trained ♂ athletes; **BFR** ($n = 10$); 21 ± 2 y; 175 ± 7 cm; 66 ± 4 kg; **non-BFR** ($n = 10$); 22 ± 01 y; 180 ± 2 cm; 72 ± 3 kg	Running – 5 sets of 3 min (50% HRR with 1 min break); 3 ses.w^{-1}; 8 w	154 ± 6 mmHg; LOP ⇒ 1.3*sBP; 14 cm wide	Inflatable cuffs, Spirit, Taipei, Taiwan	Maximal running performance: **BFR**: ↑ *; **non-BFR**: NC Muscular endurance: **BFR**: ↑ *; **non-BFR**: NC Muscular strength: **BFR**: 15% ↑ *; **non-BFR**: NC HR: **BFR**: 13% ↑ *; **non-BFR**: NC RPE: **BFR**: 66% ↑ *; **non-BFR**: NC
Christiansen et al. (2023a)	10 Recreationally active ♂; 25 ± 4 years; 183 ± 6 cm; 83.6 ± 14 kg; **BFR** – one leg **non-BFR**- other leg	Cycling – 3 × 2 min bouts (60%, 70% and 80% Wmax); 1 min break and 2 min of active recovery; 3 ses.w^{-1}; 6 w	180 mmHg; LOP – NM; 13 cm wide	Nylon cuff (Riester, Jungingen, Germany)	KE performance: **BFR**: 23% ↑ *; **non-BFR**: 11% ↑ * Femoral arterial blood flow: **BFR**: ↑ *; **non-BFR**: NC Thigh K+: **BFR**: ↓ *; **non-BFR**: NC
Clarkson et al. (2017)	Physically inactive; 11 ♂, 8 ♀ **BFR** ($n = 10$); 69 ± 6 y; 167 ± 8 cm; 77 ± 11 kg; **non-BFR** ($n = 9$); 70 ± 7 y; 166 ± 8 cm; 77 ± 9 kg	Walking: 10 min; 4 km.h^{-1}; 4 ses.w^{-1}; 6 w	134 ± 4 mmHg; 60% LOP; 10.5 cm wide	BFR cuffs (Dual Port, single bladder cuff, Zimmer, ATS 3000)	6MWT: **BFR**: ↑ *; **non-BFR**: NC QCST: **BFR**: 3 fold ↑ *; **non-BFR**: NC 30SSTS: **BFR**: 3-fold ↑ *; **non-BFR**: NC Timed up and go test: **BFR**: 2-fold ↓ *; **non-BFR**: NC
Conceição et al. (2023b)	♂ sedentary; **BFR** ($n = 10$); 21 ± 3 y; 78 ± 8 kg; 177 ± 7 cm; **non-BFR** ($n = 10$); 24 ± 2 y; 81 ± 11 kg; 176 ± 7 cm; **non-BFR RT** ($n = 10$); 23 ± 3 y; 78 ± 12 kg; 175 ± 9 cm	Cycling – **BFR** – 30 mins, 40% VO_2R; 4 ses.w^{-1}; 8 w; **non-BFR** – 30 mins, 70% VO_2R; 4 ses.w^{-1}; 8 w; **non-BFR RT** – 4 sets, 70% 1 RM leg press; 4 ses.w^{-1}; 8 w	80% of AOP; 18 cm wide	Inflatable cuffs	CSA (VL): **BFR**: 11% ↑ *; **non-BFR**: NC **non-BFR RT**: 12% ↑ * Strength (Leg press):**BFR**: 9% ↑ *; **non-BFR**: NC **non-BFR RT**: 35% ↑ * VO_2max: **BFR**:11% ↑ *; **non-BFR**: 21% ↑ * **non-BFR RT**: NC

(*Continued*)

Table 1. (Continued).

Author, Year	Participants Characteristics	Intervention	BFR Cuff Pressure and cuff width	BFR Equipment used	MAIN FINGINGS
Held et al. (2020)	Elite rowers; **BFR** ($n = 16$); 12 ♂, 4 ♀; 22 ± 3 y; 180 ± 9 cm; 74 ± 11 kg; **non-BFR** ($n = 15$); 11 ♂, 4 ♀; 22 ± 4 y; 181 ± 8 cm; 72 ± 12 kg	Rowing, cycling, running and strength – 2 × 10 min ses, 10 min rest; 3 ses.w^{-1}; 5 w	LOP – NA; 13 cm wide	Elastic knee wraps (Best Body Nutrition, Auerbach, Germany)	VO_2max: **BFR**: 9% ↑ *; **non-BFR**: NC Strength (Squat): **BFR**: NC; **non-BFR**: NC
Held et al. (2023a)	♂ Swimmers; **BFR** ($n = 10$); 23 ± 4 y; 178 ± 7 cm; 69 ± 10 kg; **non-BFR** ($n = 8$); 23 ± 2 y; 184 ± 7 cm; 71 ± 7 kg	Swimming – 2 × 10 min ses, 10 min rest; 3 ses. w^{-1}; 5 w	LOP – 75%; 8 cm wide	Occlusion Cuff Elite, The Occlusion Cuff, Belfast, United Kingdom	VO_2peak: **BFR**: ↑; **non-BFR**: ↓
Held et al. (2023b)	Climber; **BFR** ($n = 9$); 6 ♂, 3 ♀; 22 ± 6 y; 175 ± 8 cm; 65 ± 12 kg; **non-BFR** ($n = 9$); 4 ♂, 5 ♀; 19 ± 3 y; 170 ± 9 cm; 61 ± 7 kg	Climbing – 2 × 10 min ses, 10 min rest; 3 ses.w^{-1}; 5 w	LOP – 75%	Occlusion Cuff Elite, The Occlusion Cuff, Belfast, United Kingdom	Arm strength: **BFR**: ↓; **non-BFR**: ↓ Arm endurance: **BFR**: ↓; **non-BFR**: ↓ Grip strength: **BFR**: ↑; **non-BFR**: ↓ Grip endurance: **BFR**: ↑ **non-BFR**: ↓
Iida et al. (2011)	**BFR** ($n = 9$); 67 ± 2 y; 150 ± 1 cm; 52 ± 2 kg; **non-BFR** ($n = 7$); 69 ± 3 y; 150 ± 2 cm; 53 ± 3 kg	Walking: 67 m min^{-1} for 20 min; 5 ses.w^{-1}; 6 w	140–200 mmHg; LOP – NM	Kaatsu-Master, Sato Sports Plaza, Tokyo	Venous compliance: **BFR**: 19% ↑ *; **non-BFR**: NC Venous flow: **BFR**: 21% ↑ *; **non-BFR**: NC
Junior et. al. (2019)	**BFR** ($n = 11$); 51 ± 3 y, 170 ± 8 cms, 82 ± 8 kg; **non-BFR** ($n = 10$); 53 ± 3 y, 168 ± 7 cms, 82 ± 13 kg	Walking – 6 kmh^{-1}, 5% grade, 5 reps of 3-min walk, 1-min rest btw reps; 3 ses.w^{-1}; 6 w	80 mmHg (↑ 10 mmHg. w^{-2}); 18 cm wide	Sphygmomanometer	HR: **BFR**: ↓ *; **non-BFR**: NC HRV: **BFR**: ↑ *; **non-BFR**: NC
Karabulut et al. (2021)	Recreationally active ♂ students; **BFR – LI** ($n = 10$; 82 ± 4 kg); **non-BFR – LI** ($n = 8$; 86 ± 11 kg); **non-BFR – HI** ($n = 11$; 93 ± 8 kg) **Control** ($n = 10$; 88 ± 5 kg)	Treadmill based exercise – 30 mins, 3 ses.w^{-1}; 6 w; LI – 30-40% VO_2R; HI – 60-70% VO_2R	LOP – 60%; LOP ⇒ thigh circumference; 5 cm wide	KAATSU-Master System, Sato Sports Plaza, Tokyo, Japan	VO_2max: **BFR – LI**: 8% ↑ *; **non-BFR – LI**: NC **non-BFR – HI**: NC; **Control**: NC BP, HR, pulse wave velocity: NC in all groups

(*Continued*)

Table 1. (Continued).

Author, Year	Participants Characteristics	Intervention	BFR Cuff Pressure and cuff width	BFR Equipment used	MAIN FINGINGS
Kargaran et al., (2021)	63 ± 3 y; 157 ± 5 cm; 68 ± 11 kg **BFR** (n = 8 ♀) **non-BFR** (n = 8 ♀) **Control** (n = 8 ♀)	**BFR** - Walking + cognitive tasks –20-min; 45% HRR **non-BFR** - Walking 20 min; 45%HRR **Control** - No walking	150–155 mmHg (↑ 15–20 mmHg.w^{-2}; max 200 mmHg); AOP – 50%; AOP ⇒ thigh circumference, sBP and dBP; 5 cm wide	Pneumatic cuffs (Gha-mat Pooyan, Tehran, Iran)	6MWT: **BFR**: ↑ *; **non-BFR**: NC **Control**: NC 30SSTS: **BFR**: ↑ *; **non-BFR**: NC **Control**: NC TUG test: **BFR**: ↑ *; **non-BFR**: NC **Control**: NC Sleep quality: **BFR**: ↑ *; **non-BFR**: ↑ * **Control**: NC Biceps curl, Upper muscle quality, Sharpened-Romberg test, Mini-mental state examination, Emotionality, activity, sociability survey: **BFR**: NC; **non-BFR**: NC **Control**: NC Psychological status: **BFR**: NC; **non-BFR**: NC **Control**: NC
Lan et al., (2022)	College students **BFR** (n = 13), 4♂, 9♀; 20 ± 1 y; 163 ± 9 cms; 57 ± 10 kgs; **non-BFR** (n = 13), 3♂, 10♀; 21 ± 2 y; 167 ± 8 cms; 64 ± 14 kgs; **non-BFR HIIT** (n = 12), 4♂, 8♀; 22 ± 3y; 170 ± 11 cms; 65 ± 17 kgs; **Control** (n-12), 2♂, 10♀; 20 ± 2 y; 168 ± 8 cms; 60 ± 10 kgs	Running - **BFR** – 15 min ses at 57–63%HRmax; **non-BFR** – 45 min ses 64–70% HRmax 1st w, 64–76% HRmax; 7 w; **non-BFR HIIT** – 4 × 4 min, 85–90% HRmax, 3-min rest 64–76% HRmax 1st w; 4-min 90–95%HRmax, 3-min rest at 64–76% HRmax for 7 w; 3 ses.w^{-1}; 8 w	200 mmHg (↑ 20 mmHg.w^{-1}); LOP – NM; 5–8 cm wide	B STRONG (USA)	VO_2max: **BFR**: 12% ↑ *; **non-BFR**: 13% ↑ * **non-BFR HIIT**: 10 ↑ *; **Control**: NC RPE: **BFR**: ↓ *; **non-BFR**: NC **non-BFR HIIT**: NC; **Control**: NC Muscle mass: **BFR**: 2% ↑ *; **non-BFR**: 2% ↑ * **non-BFR HIIT**: 1% ↑ *; **Control**: NC Fat mass: **BFR**: NC; **non-BFR**: ↓ * **non-BFR HIIT**: NC **Control**: NC
Ozaki et al., (2011a)	Older sedentary adults **BFR** (n = 13), 3♂, 10♀; 66 ± 1 y; 156 ± 1 cms; 56 ± 1.5 kgs; **non-BFR** (n = 10), 2♂, 8♀; 68 ± 2 y; 154 ± 2 cms; 56 ± 2.8 kgs	Walking - 20 min ses at 40% HRR; 4 ses.w^{-1}; 10 w	140 mmHg (↑ 10 mmHg.w^{-2}; max 200 mmHg); LOP – NM; 5 cm wide	KAATSU-Master System, Sato Sports Plaza, Tokyo, Japan	Thigh CSA: **BFR**: 3% ↑ *; **non-BFR**: NC Knee extension: **BFR**: NC; **non-BFR**: NC Knee flexion: **BFR**: 15% ↑ *; **non-BFR**: NC Arterial compliance: **BFR**: 40% ↑ *; **non-BFR**: 44% ↑ *
Ozaki et al., (2011b)	Older sedentary ♀ **BFR** (n = 10); 64 ± 1 y; 154 ± 2 cms; 54 ± 1 kgs; **non-BFR** (n = 8); 68 ± 1 y; 152 ± 2 cms; 53 ± 3 kgs	Walking- 20 min ses at 45% HRR; 4 ses.w^{-1}; 10 w	140 mmHg (↑ 10 mmHg.w^{-1}; max 200 mmHg); LOP – NM; 5 cm wide	KAATSU-Master System, Sato Sports Plaza, Tokyo, Japan	Thigh CSA: **BFR**: 3% ↑ *; **non-BFR**: NC Muscle volume: **BFR**: 4% ↑ *; **non-BFR**: NC VO_2peak: **BFR**: 9% ↑ *; **non-BFR**: 10% ↑ * Knee extension: **BFR**: 22% ↑ *; **non-BFR**: NC Knee flexion: **BFR**: 22% ↑ *; **non-BFR**: 4% ↓ *
Park et al., (2010)	College athletes ♂ **BFR** (n = 7); 20 ± 1 y; 187 ± 3 cms; 84 ± 5 kgs; **non-BFR** (n = 5); 21 ± 1 y; 193 ± 9 cms; 92 ± 9 kgs	Walking – 3 min reps; 5 sets; 4–6 km^{-1} at 5% grade; 1 min rest 2 ses.d^{-1}; 6 d.w^{-1}; 2 w	160 mmHg (↑ 10 mmHg.d^{-1}; max 220 mmHg); LOP – NM; 11 cm wide	Automatic Air Tourniquet systems, DTS-2000, Daesung CO., Korea	Anaerobic capacity: **BFR**: 3% ↑ *; **non-BFR**: NC Maximal Minute ventilation: **BFR**: 11% ↑ *; **non-BFR**: NC VO_2max: **BFR**: 12% ↑ *; **non-BFR**: NC Knee extension: **BFR**: NC; **non-BFR**: NC Knee flexion: **BFR**: NC; **non-BFR**: NC

(Continued)

Table 1. (Continued).

Author, Year	Participants Characteristics	Intervention	BFR Cuff Pressure and cuff width	BFR Equipment used	MAIN FINGINGS
Paton et al., (2017)	Healthy and recreationally active; (10 ♂ and 6 ♀; 25 ± 7 years, 173 ± 8 cm and 75 ± 14 kg); **BFR** ($n = 8$) **non-BFR** ($n = 8$)	Running – 80% of peak running velocity; 2 sets of 5 reps (30 secs each); 2 $ses.w^{-1}$; 4 w	LOP – NA; 7.5 cm wide	Elastic wraps (Get Strength Heavy Duty, Waiuku, New Zealand)	VO_2max: **BFR**: NC; **non-BFR**: NC Minute ventilation: **BFR**: NC; **non-BFR**: NC Running economy: **BFR**: NC; **non-BFR**: NC TTE: **BFR**: NC; **non-BFR**: NC Peak running velocity: **BFR**: NC; **non-BFR**: NC Increment time: **BFR**: NC; **non-BFR**: NC
Razi et al., (2022)	Healthy ♂; **BFR** ($n = 9$); 45 ± 5 y; 172 ± 5 cm; 82 ± 7 kg; **Non-BFR** ($n = 9$); 43 ± 6 y; 175 ± 4 cm; 87 ± 4 kg	Walking: 5 × 2 min reps; 1 min rest per rep; 3 $ses.w^{-1}$; 8 w	140 mmHg (↑ 10 $mmHg.w^{-1}$); max 200 mmHg; LOP – NM	Sphygmomanometer (Rudolf Riester GmbH, Jungingen, Germany	TG and Fibrinogen: **BFR**: ↓ *; **non-BFR**: ↓ * CRP, LDL, HDL **BFR & non-BFR**: NC
Tangchaisuriya et al., (2022)	♂ masters road cyclists; **BFR** ($n = 17$); 40 ± 4 y; 174 ± 5 cms; 71 ± 7 kgs; **non-BFR** ($n = 16$);41 ± 4 y; 172 ± 5cms; 67 ± 6 kg; **non-BFR HIIT** ($n = 17$); 42 ± 4 y; 172 ± 5 cms; 68 ± 7 kgs	Cycling – Common for all groups- 120 min, ~55%–60% PPO; 2 $ses.w^{-1}$; 75 min of cycling at ~ 65%–70% PPO 2 $ses.w^{-1}$; **non-BFR –** 2 $ses.w^{-1}$; 75 mins ~ 65%–70% PPO; 85–90 rpm; **non-BFR HIIT -** 2 $ses.w^{-1}$; 4 × 4 min interval 80% PPO;2 min at 30% PPO at 85–90 rpm; **BFR HIIT -** 4 × 4 min interval; 1st and 3rd bout, 80% PPO; 2nd, 4th 60% of PPO; 2 min at 30% PPO at 85–90 rpm; 6 $ses.w^{-1}$; 12 w	30% of AOP; 11 cm wide	SC10 (pneumatic cuff, segmental pressure cuff; Hokanson, Bellevue, WA)	VO_2max: **BFR HIIT**: 8% ↑ *; **non-BFR**: 4% ↑ * **non-BFR HIIT**: 7% ↑ * Brachial, popliteal artery FMD **BFR HIIT**: NC**; non-BFR**: NC **non-BFR HIIT**: NC CSA and thickness: **BFR HIIT**: ↑ *; **non-BFR**: NC **non-BFR HIIT**: NC Strength (Isokinetic KE and KF): **BFR HIIT**: 6% ↑ * and 15% ↑ * **non-BFR**: NC and 6% ↑ * **non-BFR HIIT**: NC and 5% ↑ * Cycling performance: **BFR HIIT**: ↑ *; **non-BFR**: NC **non-BFR HIIT**: ↑ * RBC, HB, HDL, LDL, TG, BG: **BFR HIIT**: ↓ * LDL; NC **non-BFR**: NC; **non-BFR HIIT**: NC
Thompson et al., (2023)	Recreationally active; 26 ± 11 y; 176 ± 8 cms; 78 ± 11 kgs; **BFR HV** ($n = 8$); 5 ♂, 3 ♀ **BFR LV** ($n = 10$); 8 ♂, 2 ♀ **non-BFR HV** ($n = 10$); 8 ♂, 2 ♀	Walking: $5kmph^{-1}$, 5% grade; 5 × 3 min reps; 1 min rest per rep; **BFR HV** – $2.d^{-1}$; 5 $ses.w^{-1}$; 4 w **BFR LV** – 2 $ses.w^{-1}$; 6 w **non-BFR HV** – $2.d^{-1}$; 5 $ses.w^{-1}$; 4 w	LOP – 100%	Automated BFR tourniquet system (PTSi, Delfi Medical Innovations Inc. Vancouver, Canada)	VO_2max: **BFR HV**: 8% ↑ *; **BFR LV**: 9% ↑ * **non-BFR HV**: NC Blood volume, Haemoglobin, Hormonal regulation: **BFR HV**: NC; **BFR LV**: NC **non-BFR HV**: NC
Bodyweight BFR training					
Cai et al., (2021)	Untrained **BFR** ($n = 10$; 8 ♂ and 2 ♀); 20 ± 0.2 y; 169 ± 3 cm; 69 ± 3 kg; **non-BFR** ($n = 10$; 8 ♂ and 2 ♀); 21 ± 0.5 y; 168 ± 2 cm; 64 ± 4 kg	WBV – 10 sets; 1 min of static squat +26 hz vibration with 1 min rest; 20 min, 3 $ses.w^{-1}$; 8 w	140–200 mmHg; LOP ⇒ thigh circumference; 9 cm wide	Handheld sphygmomanometer.	Muscle strength: **BFR**: 11% ↑ *; n**on-BFR**: 4% ↑ * Muscular endurance: **BFR**: 49% ↑ *; n**on-BFR**: 15% ↑ * Thigh size: **BFR**: 3% ↑ *; n**on-BFR**: NC

(*Continued*)

Table 1. (Continued).

Author, Year	Participants Characteristics	Intervention	BFR Cuff Pressure and cuff width	BFR Equipment used	MAIN FINGINGS
Head et al., (2015)	**BFR** ($n = 7$) 2♂, 5♀; 26 ± 4 y; 168 ± 9 cm; 64 ± 10 kg; **non-BFR** ($n = 5$) 2♂, 3♀; 25 ± 1 y; 171 ± 4 cm; 67 ± 6 kg	BW – single leg squat W1–3 sets, W2-6 - 4 sets.w^{-1}; reps until fatigue; 1 min rest btw set; 2 ses.w^{-1}; 6 w	LOP – NA; 7.62 cm wide	Elastic wraps (Max Strength, Cheshire, UK	Strength (Isokinetic): **BFR**: NC; n**on-BFR**: NC Single leg vertical jump **BFR**: NC; n**on-BFR**: NC Thigh girth: **BFR**: NC; n**on-BFR**: NC
Ishii et al., (2005)	**BFR** ($n = 11$ ♀); 67 ± 2 y; 150 ± 1 cm; 52 ± 2 kg; **non-BFR** ($n = 11$ ♀); 69 ± 3 y; 150 ± 2 cm; 53 ± 3 kg	Circuit training (knee up, bent knee push up, leg raise, seated knee flexion, squat, forward lunge); 3 ses.w^{-1}; 8 w	UL 50–80 mmHg; LL 80–120 mmHg; LOP ⇒ limb circumference	KAATS Sportswear (PHENIX Co. Ltd., Tokyo. Japan)	CSA: **BFR: 3**% ↑ *; n**on-BFR**: NC
Kang et al., (2015)	College students: **BFR** ($n = 10$); 3♂, 7 ♀; 24 ± 3 y; 166 ± 7 cm; **non-BFR** ($n = 7$); 2♂, 5♀; 27 ± 5 y; 166 ± 8 cm	BW (front lunges and squats) – 30 mins; 3 ses.w^{-1}; 6 w	11–13 RPE scale; LOP – NA; 5 cm wide	Elastic wrap	Thigh circumference (R and L): **BFR**: 5% ↑ * and 5% ↑ *; **non-BFR**: NC Peak torque (KE and KF): **BFR**: NC and 14% ↑ *; **non-BFR**: NC and 13% ↑ *
Yokokawa et al., (2008)	**BFR** ($n = 24$); 8♂, 16♀; 72 ± 4 y **non-BFR Balance exercise** ($n = 27$); 9♂, 18♀; 71 ± 4 y	BW (half squats, forward lunges, calf raises, knee lifts, crunches, KE and KF) Balance exercise (forward and lateral reach; forward and backward steps; standing and walking) 2 ses.w^{-1}; 8 w	70–80 mmHg (↑ 10 mmHg.w^{-1}; max 140–150 mmHg; LOP – NM; 3.3 cm wide	M.P.S.-700 (Sato and manufactured by VINE Medical Instruments, Tokyo, Japan)	10 m walking time: **BFR**: 9% ↓ *; **non-BFR**: 9% ↓ * Functional Reach Test: **BFR**: 9% ↑ *; **non-BFR**: 4% ↑ * Left KE: **BFR**: 20% ↑ *; **non-BFR**: NC Right KE: **BFR**: NC; **non-BFR**: NC Left Grip power: **BFR**: NC; **non-BFR**: NC Right Grip power: **BFR**: NC; **non-BFR**: NC Timed up and go test: **BFR**: 15% ↓ *; **non-BFR**: NC

Participants characteristics data presented as mean ± SD as indicated.

30SSTS, 30-second sit-to-stand; 6MWT, Six-minute walk test; AOP, arterial occlusion pressure; BB, biceps brachii; BF, biceps femoris; BFR, blood flow restriction pressure; BG, blood glucose; BW, bodyweight resistance exercise; cm, centimetre; CRP, c-reactive protein; CSA, cross sectional area; d, day; dBP, diastolic blood pressure; FMD, flow-mediated dilation; HB, haemoglobin; HDL, high density lipoprotein; HIIT, High intensity interval training; HR, Heart rate; HRmax, heart rate maximum; HRV, Heart rate variability; HV, high volume; II-CPP, increased intensity-constant partial pressure; II-CCP, increased intensity-constant complete pressure; IP-CI, increased pressure-constant intensity; IP-II, increased pressure-increased intensity; kgs, kilograms; KE, knee extension; KF, knee flexion; LDL, low density lipoprotein; LL, Lower Limb; LOP, limb occlusion pressure; LV, low volume; NA, not applicable; NC, no change; NM, no mention; PPO, peak power output; QCST, Queen's college step test; RBC, red blood cell; RF, rectus femoris; RFD, rate of force development; RPE, Rating of perceived exertion; sBP, systolic blood pressure; ses, session; TG, triglyceride; TTE, time to exhaustion; TUG, Timed up and go; UL, Upper Limb; VL, vastus lateralis; VM, vastus medialis; VO2max, maximal oxygen uptake; VO2peak, peak oxygen uptake; VO2R, oxygen uptake reserve; W, week; WBV, Whole body vibration; y, years; *, statistically significant of group and time interaction.

widths of the cuffs ranged from 5 to 18 cm. Notably, 13 studies implemented a progressive strategy, increasing BFR pressure by 10–20 mmHg or 10% every 1–2 weeks (Abe et al., 2006; Abe, Fujita, et al., 2010a; Abe, Sakamaki, et al., 2010b; Amani-Shalamzari et al., 2020; Amani-Shalamzari, Farhani, et al., 2019a; Junior et al., 2019; Kargaran et al., 2021; Lan et al., 2022; Ozaki, Miyachi, et al., 2011a; Ozaki, Sakamaki, et al., 2011b; Park et al., 2010; Razi et al., 2022; Yokokawa et al., 2008). In studies using elastic wraps, widths of wraps ranged from 5 to 13 cm (Behringer et al., 2017; Head et al., 2015; Held et al., 2020; Kang et al., 2015; Paton et al., 2017).

There were 28 studies which investigated the effects of aerobic BFR training, while 5 studies examined bodyweight BFR training. In studies investigating aerobic training, modes included walking (*n* = 11) (Abe et al., 2006; Abe, Sakamaki, et al., 2010b; Clarkson et al., 2017; Iida et al., 2011; Junior et al., 2019; Karabulut et al., 2021; Ozaki, Miyachi, et al., 2011a; Ozaki, Sakamaki, et al., 2011b; Park et al., 2010; Razi et al., 2022; Thompson et al., 2024), cycling (*n* = 4) (Abe, Fujita, et al., 2010a; Christiansen et al., 2019; Conceição et al., 2019; Tangchaisuriya et al., 2022), running (*n* = 8) (Amani et al., 2018; Amani-Shalamzari, Rajabi, et al., 2019b; Behringer et al., 2017; Chen, Hsieh, Ho, Ho, et al., 2022b; Chen, Hsieh, Ho, Lin, et al., 2022a; Lan et al., 2022; Paton et al., 2017), a combination of running, rowing, and cycling (Held et al., 2020), swimming (Held, Rappelt, Deutsch, et al., 2023a), and 3-a-side futsal (*n* = 2) (Amani-Shalamzari et al., 2020; Amani-Shalamzari, Farhani, et al., 2019a). In studies investigating bodyweight training (Cai et al., 2021; Head et al., 2015; Ishii et al., 2005; Kang et al., 2015; Yokokawa et al., 2008), all studies used different exercises or combinations of exercises, such as squats, forward lunges, calf raises, knee extension and flexion exercises (Table 1).

Aerobic training

The effect of aerobic training on aerobic capacity was evaluated in 15 of 28 studies. Aerobic BFR training improved aerobic capacity by 4–12% in 13 studies (Abe, Fujita, et al., 2010a; Amani et al., 2018; Amani-Shalamzari, Rajabi, et al., 2019b; Chen, Hsieh, Ho, Lin, et al., 2022a; Conceição et al., 2019; Held et al., 2020; Held, Rappelt, Deutsch, et al., 2023a; Karabulut et al., 2021; Lan et al., 2022; Ozaki, Sakamaki, et al., 2011b; Park et al., 2010; Tangchaisuriya et al., 2022; Thompson et al., 2024), while remaining unchanged in 2 studies (Abe, Sakamaki, et al., 2010b; Paton et al., 2017). Equivalent intensity non-BFR aerobic training improved aerobic capacity by 1–10% in only 3 studies (Amani et al., 2018; Ozaki, Sakamaki, et al., 2011b; Tangchaisuriya et al., 2022). Moderate intensity non-BFR running improved aerobic capacity by 1% in soccer players (Amani et al., 2018), while walking improved aerobic capacity by 10% in older adults (Ozaki, Sakamaki, et al., 2011b). Most equivalent intensity non-BFR aerobic training studies (*n* = 6) showed that aerobic capacity remained unchanged (Abe, Sakamaki, et al., 2010b; Chen, Hsieh, Ho, Lin, et al., 2022a; Held et al., 2020; Karabulut et al., 2021; Park et al., 2010; Paton et al., 2017).

Strength was evaluated in 17 of 28 aerobic training studies. Aerobic BFR training increased knee extension strength by 6–31% (*n* = 7) (Abe, Fujita, et al., 2010a; Abe, Sakamaki, et al., 2010b; Amani-Shalamzari et al., 2020; Amani-Shalamzari, Farhani, et al., 2019a; Chen, Hsieh, Ho, Lin, et al., 2022a; Christiansen et al., 2019; Tangchaisuriya et al., 2022), and knee flexion strength by 15–24% (*n* = 4) (Abe, Sakamaki, et al., 2010b; Amani-Shalamzari et al., 2020; Amani-Shalamzari, Farhani, et al., 2019a; Tangchaisuriya et al., 2022). Strength remained unchanged in 3 studies (Held et al., 2020; Ozaki, Miyachi, et al., 2011a; Park et al., 2010). Aerobic BFR training increased the rate of force development by 25% in 1 study while remaining unchanged following non-BFR aerobic training (Behringer et al., 2017). For studies that included an equivalent intensity non-BFR aerobic exercise training group (*n* = 7), strength remained unchanged with non-BFR aerobic training (Abe, Fujita, et al., 2010a; Abe, Sakamaki, et al., 2010b; Behringer et al., 2017; Conceição et al., 2019; Held et al., 2020; Ozaki, Miyachi, et al., 2011a; Park et al., 2010). However, where non-BFR aerobic exercise training at moderate- to high-intensity was the comparator, strength increased in young individuals in 4 studies (Amani-Shalamzari et al., 2020; Amani-Shalamzari, Farhani, et al., 2019a; Christiansen et al., 2019; Tangchaisuriya et al., 2022), and in older adults with walking in 1 study (Abe, Sakamaki, et al., 2010b), with knee extension and flexion strength specifically improving by 11–15% and 4–11%, respectively.

Outcome measures indicative of hypertrophy were assessed in 10 of 28 studies. These included thigh girth/circumference or muscle cross-sectional area. Aerobic BFR training improved all measures indicative of hypertrophy. Thigh muscle mass increased by 2–6% (Abe et al., 2006; Lan et al., 2022), while muscle cross-sectional area increased by 3–11% (Abe, Fujita, et al., 2010a; Abe, Sakamaki, et al., 2010b). In contrast, only 1 equivalent intensity non-BFR aerobic training study showed a 2% increase in muscle mass (Lan et al., 2022). However, the duration of training sessions was three times that of the BFR training group (15 minutes vs 45 minutes). All other non-BFR aerobic training interventions failed to show any significant changes in measures indicative of muscle hypertrophy (Abe, Fujita, et al., 2010a; Abe, Sakamaki, et al., 2010b; Behringer et al., 2017; Chen, Hsieh, Ho, Ho, et al., 2022b; Conceição et al., 2019; Ozaki, Miyachi, et al., 2011a; Ozaki, Sakamaki, et al., 2011b; Tangchaisuriya et al., 2022).

Physical function in older adults was evaluated in 3 out of 28 studies, using measures such as the six-minute walk test, the thirty-second sit-to-stand test, and the timed up-and-go test. Aerobic BFR training led to improvements in 2 of these studies (Abe, Sakamaki, et al., 2010b; Clarkson et al., 2017), with Clarkson et al., (2017) reporting a 2–3-fold improvement in physical function. In contrast, 1 study found no change (Kargaran et al., 2021).

Additional adaptations to Aerobic BFR training

Although beyond the scope of this review, aerobic BFR training has been shown to enhance several athletic performance variables. These include improvements in sport-specific metrics such as futsal performance (11%), faster sprint times, and enhanced cycling performance, including measures like time-to-exhaustion and power output (refer to Table 1). Such adaptations are particularly valuable for athletes seeking to improve performance while minimizing high-intensity loading, making aerobic BFR training a practical tool for periods of recovery, rehabilitation, or low-impact conditioning. In addition, physiological measures including haemodynamics (heart rate, vascular compliance) and circulating hormones/metabolites (high-density lipoprotein, C-reactive protein). Psychological assessments, including emotionality, mini-mental state examination, sociability survey, and overall psychological status, all remained unchanged.

Bodyweight exercise

None of the bodyweight BFR training studies examined aerobic capacity. However, 1 study measured muscle endurance using leg press repetitions to failure at 70% 1-repetition maximum (Cai et al., 2021). Bodyweight BFR training induced a 49% increase in leg press endurance compared with a 15% increase following non-BFR bodyweight training (Cai et al., 2021).

Strength was measured in 4 of 5 training studies. Bodyweight BFR training increased strength by 11–20% in 3 studies (Cai et al., 2021; Head et al., 2015; Yokokawa et al., 2008). However, in 1 study, while knee flexion strength increased by 14%, knee extension strength remained unchanged (Kang et al., 2015). Non-BFR bodyweight training increased strength by 4–13% in 2 studies (Cai et al., 2021; Kang et al., 2015), but remained unchanged in 2 studies (Head et al., 2015; Yokokawa et al., 2008). Strength remained unchanged following both bodyweight BFR and non-BFR bodyweight training in 1 study (Head et al., 2015).

Outcome measures indicative of hypertrophy were assessed in 4 of 5 bodyweight training studies. Bodyweight BFR training increased thigh muscle girth/circumference by 3–5% in 2 studies (Cai et al., 2021; Kang et al., 2015), and muscle cross-sectional area by 3% in 1 study (Ishii et al., 2005), while no hypertrophy was evident in 1 study with bodyweight BFR training (Head et al., 2015). Conversely, all studies that examined non-BFR bodyweight training reported no hypertrophy (Cai et al., 2021; Head et al., 2015; Ishii et al., 2005; Kang et al., 2015).

Physical function was assessed in only 1 bodyweight training study, and in older adults (Yokokawa et al., 2008). Bodyweight BFR training reduced 10-metre walking time by 9%, improved functional reach test performance by 9% and timed-up-and-go by 15%. In comparison, non-BFR bodyweight training did not affect 10-meter walking time or timed-up-and-go but did improve functional reach test performance by 4% (Yokokawa et al., 2008).

Methodological quality control and publication bias

The ROB 2.0 tool was used to assess the 33 included studies (Figure 2). Regarding the risk of bias from the randomization process, most studies (26) raised '*some concerns*', while seven studies had a low risk of bias. One requirement for this review was that studies had to be randomized controlled trials. Most of the studies followed randomization, participant allocation, or concealment. However, 6 of the included studies did not provide enough information about specific aspects of how randomization was achieved. Access to trial protocols was not possible, and no trial provided registration information. So, we assessed deviations from the intended interventions with *some concern* in Domain 2. No trials reported missing data, and the number of randomized participants matched the statistical analyses. Thus, all trials were identified with low risk in Domain 3. For objective outcomes where measurement could be influenced by lack of blinding, 21 studies didn't provide information on blinding, causing some concerns in Domain 4. There was no clear indication of reporting bias among the studies included in Domain 5, which could limit the interpretation or applicability of the findings.

Discussion

The primary aim of this review was to systematically compare existing research on the chronic training adaptations following aerobic and bodyweight training combined with BFR. The adaptations of interest were muscle strength, hypertrophy, aerobic capacity, and physical function. The review included 33 studies focused on the effects of aerobic or bodyweight training with BFR. The main findings reveal that both aerobic BFR training and bodyweight BFR training produce broadly similar magnitudes of improvement in muscle strength and hypertrophy, whereas equivalent-intensity non-BFR training commonly had no significant effect. Specifically, muscle strength increased by 6–31% with aerobic BFR training and by 11–20% with bodyweight BFR training, while hypertrophy increased by 2–11% with aerobic BFR training and 3–5% with bodyweight BFR training. In addition, while only aerobic BFR training studies examined aerobic capacity, this increased by 4–12%. Very few studies examined physical function, and all of these were in older adult populations, with most demonstrating improvements in functional tests following BFR training (Table 2).

Traditional resistance training usually requires moderate to high loads for significant improvements in muscle strength and hypertrophy (Lopez et al., 2021). In contrast, low-load BFR training can be equally effective for strength and hypertrophy

Table 2. Summarizing the findings of aerobic BFR and bodyweight BFR training with outcome variables.

Outcomes (pre-post)	Aerobic BFR	Bodyweight BFR
Muscle Strength	6–31% ($n = 13$)	11–20% ($n = 4$)
Muscle Hypertrophy	2–11% ($n = 8$)	3–5% ($n = 4$)
Muscle Endurance	-	49% ($n = 1$)
Aerobic Capacity	4–12% ($n = 13$)	-
Physical Function	6–28% ($n = 3$)	9–15% ($n = 1$)

Study	Risk of bias domains: D1	D2	D3	D4	D5	Overall
Abe et al. 2006	+	-	+	-	+	-
Abe et al. 2010a	+	-	+	-	+	-
Abe et al. 2010b	+	-	+	-	+	-
Amani et al. 2018	-	-	+	-	+	-
Amani-Shalamzar et al. 2019a	-	-	+	-	+	-
Amani-Shalamzar et al. 2019b	+	-	+	-	+	-
Amani-Shalamzar et al. 2020	-	-	+	-	+	-
Behringer et al. 2017	+	+	+	+	+	+
Cai et al. 2021	+	-	+	-	-	-
Chen et al. 2022a	+	-	+	-	+	-
Chen et al. 2022b	+	-	+	-	+	-
Christiansen et al. 2019	+	+	+	+	+	+
Clarkson et al. 2017	+	-	+	-	+	-
Conceição et al. 2019	+	-	+	-	+	-
Head et al. 2015	+	+	+	+	+	+
Held et al. 2020	+	-	+	-	+	-
Held et al. 2023a	+	-	+	-	+	-
Held et al. 2023b	+	+	+	+	+	+
Iida et al. 2011	+	-	+	-	+	-
Ishii et al. 2005	+	+	+	-	+	-
Junior et. al. 2019	+	-	+	-	+	-
Kang et al. 2015	+	-	+	-	+	-
Karabulut et al. 2021	-	-	+	-	+	-
Kargaran et al. 2021	-	+	+	+	+	-
Lan et al. 2022	+	+	+	+	+	+
Ozaki et al. 2011a	-	+	+	+	+	-
Ozaki et al. 2011b	+	+	+	+	+	+
Park et al. 2010	+	-	+	-	+	-
Paton et al. 2017	+	-	+	-	+	-
Razi et al. 2022	+	+	+	+	+	+
Tangchaisuriya et al. 2022	+	-	+	+	+	-
Thompson et al. 2023	+	-	+	+	+	-
Yokokawa et al. 2008	+	-	+	+	+	-

Figure 2. Risk of bias of the included studies, according to the RoB 2.0 tool using the 'traffic light' plots of the domain-level judgements for each individual result (McGuinness & Higgins, 2021). Yellow spots indicate some concerns; green spots indicate low. D1: Bias arising from the randomization process. D2: Bias due to deviations from intended intervention. D3: Bias due to missing outcome data. D4: Bias in measurement of the outcome. D5: Bias in selection of the reported result.

and more effective than non-BFR low-load resistance training (Grønfeldt et al., 2020). However, adaptations from aerobic BFR training are generally less pronounced than those from BFR resistance training (de Lemos Muller et al., 2024; Geng et al., 2024). Interestingly, the present review demonstrates that both aerobic BFR training and bodyweight resistance BFR training produce broadly similar magnitudes of change for muscle strength and hypertrophy. While it may be unexpected for light-intensity non-BFR aerobic training to impact strength and hypertrophy, it is just as unexpected for bodyweight (unweighted) resistance non-BFR training when prescribed using standard training volumes (i.e. 3–4 sets of 8–12 reps and NOT to failure). With the application of BFR to these forms of exercise combined with the similarity in outcomes demonstrated in the present review, this provides practitioners with two potential modes of exercise when combined with BFR training to target strength and hypertrophy and which facilitates flexibility for client preference, access and capability (Bellissimo et al., 2022; Cai et al., 2021; Ishii et al., 2005; Poon et al., 2023). For athletic populations, this flexibility in exercise choice can allow for effective strength and hypertrophy maintenance even in low-resourced or low-intensity recovery settings, such as during rehabilitation phases or off-seasons. However, it is important to interpret these findings with caution given there are very few studies ($n = 5$) and mixed results observed from studies using bodyweight BFR training. As such, more research is required in this area.

Given that bodyweight BFR training and aerobic BFR training yield similar strength and hypertrophy outcomes, it is reasonable to expect that similar improvements in aerobic capacity may be possible from both training methods. However, none of the studies reviewed examined aerobic capacity following bodyweight BFR training. This presents an opportunity for future research to explore the effects of bodyweight BFR training on aerobic capacity and compare it to aerobic BFR training. In contrast, there was a clear and robust improvement in aerobic capacity with aerobic BFR training (12 of 15 studies) (Tables 1 and 2). In fact, despite the light-intensity nature of aerobic BFR training, on occasions, these improvements in aerobic capacity were of similar magnitude to those observed for a more traditional intense aerobic training group (Abe, Fujita, et al., 2010a; Conceição et al., 2019; Karabulut et al., 2021; Lan et al., 2022). Such results are promising for the general and athletic population seeking to enhance aerobic capacity without high-intensity loading, which may be beneficial for endurance training phases or injury-recovery periods (Wortman et al., 2021; Yang et al., 2024). Additionally, BFR training appears to enhance sports performance, such as futsal and cycling (Amani-Shalamzari, Farhani, et al., 2019a; Tangchaisuriya et al., 2022).

For Physical Function, despite there being few studies and all studies being in older adults, aerobic BFR training and bodyweight resistance BFR training both demonstrated significant improvements across all employed tests of physical function. While only one study examined physical function following bodyweight BFR training, they found significant improvement in timed-up-go test (15%) and 10-meter walking test (9%) (Yokokawa et al., 2008). Similarly, following aerobic BFR training, significant improvements were observed for timed-up-and-go (12–16%) 30-second sit-to-stand (14–28%) and 6-minute walk test (6–9%) (Clarkson et al., 2017). This reinforces the choice of BFR training modes for practitioners aiming to target improvements in physical function where availability of exercise equipment is limited (e.g. for home-based training). However, given these are few studies and all in older adults, further evidence is warranted to explore this notion of alignment between outcomes for physical function (and aerobic capacity) following both aerobic BFR and bodyweight resistance BFR training.

This is the first systematic review to examine and compare outcomes from aerobic BFR training and bodyweight BFR training. One limitation is the heterogeneity of the included studies for the methods employed (modes of exercise, duration, intensity, BFR cuff width and pressure) and participant characteristics (age, gender, and fitness levels), which makes the outcomes of the review difficult to generalise to the field. In addition, while being beyond the scope of the primary question of this review this variability limits the capability of this review to make broader recommendations on likely 'best practice' prescription variables that may be considered for use with aerobic or bodyweight resistance BFR exercise. Lastly, while most of the included studies examined muscle strength and hypertrophy, few examined physical function, and no study examined aerobic capacity following bodyweight resistance BFR training.

Practical application and conclusion

This systematic review emphasizes the beneficial effects of aerobic BFR training, including improvements in muscle strength, hypertrophy, aerobic capacity, and physical function. While there is less research on BFR training using bodyweight exercises, current findings are encouraging, showing gains in strength, muscle development, and functional capabilities. For athletes, this implicates aerobic BFR training as being of benefit to enhance cardiovascular fitness with minimal joint stress, making it suitable for recovery, while bodyweight BFR training may better support rehabilitation or periods where equipment access is limited to improve endurance, strength and hypertrophy. The results indicate that both aerobic and bodyweight BFR training offer viable alternatives for those who prescribe BFR programs without access to conventional gym equipment, offering the ability to customize exercise plans to individual preferences, space limitations, and specific health objectives.

Continued investigations should aim to conduct comparative analyses between aerobic and bodyweight BFR training, with or without additional modalities as comparators, to further understand these positive outcomes, particularly focusing on the relatively unexplored areas of physical function and aerobic capacity.

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ORCID

Tulasiram Bommasamudram http://orcid.org/0000-0002-8077-7359
Matthew J. Clarkson http://orcid.org/0000-0003-0447-9269
Kirtana Raghurama Nayak http://orcid.org/0000-0001-6124-2239
Rajagopal Kadavigere http://orcid.org/0000-0003-3486-8740
Aaron P. Russell http://orcid.org/0000-0002-7323-9501
Stuart A. Warmington http://orcid.org/0000-0002-2414-7539

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