Blood flow restriction exercise in high-performance sport settings: A practitioner survey

Clarkson, Matthew J, Scott, BR, Patterson, SD and Warmington, Stuart A (2025) Blood flow restriction exercise in high-performance sport settings: A practitioner survey. Journal of Sports Sciences, 43 (19). pp. 2133-2144. ISSN 0264-0414

Journal of Sports Sciences

ISSN: 0264-0414 (Print) 1466-447X (Online) Journal homepage: www.tandfonline.com/journals/rjsp20

Blood flow restriction exercise in high-performance sport settings: A practitioner survey

Matthew J. Clarkson, Brendan R. Scott, Stephen D. Patterson & Stuart A. Warmington

To cite this article: Matthew J. Clarkson, Brendan R. Scott, Stephen D. Patterson & Stuart A. Warmington (2025) Blood flow restriction exercise in high-performance sport settings: A practitioner survey, Journal of Sports Sciences, 43:19, 2133-2144, DOI: 10.1080/02640414.2025.2525710

To link to this article: https://doi.org/10.1080/02640414.2025.2525710

JOURNAL OF SPORTS SCIENCES
2025, VOL. 43, NO. 19, 2133–2144
https://doi.org/10.1080/02640414.2025.2525710

SPECIAL ISSUE PAPER

OPEN ACCESS Check for updates

Blood flow restriction exercise in high-performance sport settings: A practitioner survey

Matthew J. Clarkson [a], Brendan R. Scott [b,c], Stephen D. Patterson [d] and Stuart A. Warmington [e]

[a]Institute for Health and Sport, Victoria University, Melbourne, Victoria, Australia; [b]Centre for Healthy Ageing, Murdoch University, Perth, Australia; [c]Physical Activity, Sport and Exercise (PHASE) Research Group, School of Allied Health (Exercise Science), Murdoch University, Perth, Australia; [d]Faculty of Sport, Allied Health & Performance Sciences, St Mary's University, London, UK; [e]Institute for Physical Activity and Nutrition (IPAN), School of Exercise and Nutrition Sciences, Deakin University, Geelong, Victoria, Australia

ABSTRACT

The purpose of this study was to characterise how blood flow restriction (BFR) exercise is utilised by practitioners in high-performance sports settings. Participants ($n = 154$) engaged with the questionnaire, of which 123 provided data about their use of BFR with athletes in high-performance sports settings. The main findings indicated that BFR was primarily used for injury rehabilitation (81.3% of practitioners) or supplementary to traditional strength and conditioning programs for muscle hypertrophy (80.4%), limiting loss of muscle mass (71.9%), or muscle strengthening (51.6%). Participants used BFR with both team and individual sports, but with only a small subset of the athletes they worked with (65% of practitioners used BFR with less than 25% of their athletes). Cuff pressures were prescribed using both measured individualised occlusion pressures (56.1%) and arbitrary set pressures (52.8%). Despite practitioners' awareness of contraindications and the need for screening, formal screening tools were underutilised (55.7% of practitioners did not use a screening tool for clearance to use BFR). Ultimately, BFR exercise was largely prescribed in line with established guidelines, although the application of individualised cuff pressures and health screening processes may require further attention from practitioners in high-performance sports.

ARTICLE HISTORY
Received 26 September 2024
Accepted 17 June 2025

KEYWORDS
Physical conditioning; athletic performance; sports; athletes; rehabilitation

Introduction

Significant increases in muscle strength are widely considered to require high load resistance exercise training using at least 70% one-repetition maximum (1RM) (American College of Sports Medicine, 2020). However, growing evidence supports low-load resistance exercise with moderate blood flow restriction (BFR) to the exercising limbs as an alternative means of developing muscle strength (Grønfeldt et al., 2020). Despite this, the extent to which BFR training is used by practitioners within high-performance sport settings is not well documented.

By applying inflatable cuffs to the proximal aspect of active limbs during exercise, BFR partially inhibits arterial inflow and occludes venous outflow in between muscular contractions (Patterson et al., 2019). This altered haemodynamic response to exercise in turn leads to increased signalling of growth pathways and oxidative stress (Christiansen et al., 2018), resulting in significant adaptations despite the low mechanical load (Scott et al., 2016). Furthermore, while BFR applied during low-load resistance exercise appears to yield the largest muscle adaptations, other significant benefits have been observed with BFR applied during aerobic exercise (Conceição et al., 2019) or with passive BFR applications (Kubota et al., 2008; Takarada et al., 2000). These modalities also augment muscle oxidative capacity, muscle redox and cardiovascular adaptations, which would normally require vigorous intensities of training (Pignanelli et al., 2021). This positions BFR exercise training as a beneficial alternative to traditional training for those unable to tolerate the mechanical strain of high-intensity exercise. Commonly, this includes clinical populations and older adults, but it may also extend to athletes returning from injury or during de-loading periods of annual training plans. It may also be used supplementary to traditional high-intensity exercise to optimise training outcomes without a proportional increase in mechanical stress (Davids et al., 2023).

Training recommendations for BFR identify several exercise modalities, which may target a range of different training adaptations (Patterson et al., 2019). As such,

CONTACT Matthew J. Clarkson matthew.clarkson@vu.edu.au Institute for Health and Sport, Victoria University, PO Box 14428, Melbourne, VIC 8001, Australia

Supplemental data for this article can be accessed online at https://doi.org/10.1080/02640414.2025.2525710.

the prescription of BFR exercise remains highly variable (Patterson et al., 2019). The equipment used to apply BFR is also often poorly reported (Clarkson et al., 2020) and some equipment may not be able to regulate pressures accurately, resulting in further inconsistency of BFR application (Hughes et al., 2024). This presents a challenge for practitioners to curate a specific prescription from the existing recommendations depending on their targeted outcome. Existing recommendations are for 'healthy' and 'clinical' populations based on studies with recreationally active or untrained participants and are not targeted at addressing the demands of athletic populations. As such, the most effective method of implementation among athletic populations in high-performance settings remains uncertain (Pignanelli et al., 2021). For the purposes of the present research 'high performance settings' encapsulate environments supporting athletes or teams that compete at a national or international level, and environments that facilitate the development of athletes in pursuit of that level of competition (Sotiriadou & De Bosscher, 2018).

Attempts have been made previously to characterise BFR implementation by practitioners. This was initially done almost two decades ago, specifically capturing the use of KAATSU training (a device-specific BFR exercise application originating in Japan) across a range of service areas and with a diverse population of clients (Nakajima et al., 2006). However, this was limited in scope to only identify KAATSU use in Japan and only using KAATSU branded equipment. A more recent survey of practitioners (115 of whom had used BFR) around the world better identified the way in which BFR was prescribed across resistance exercise, aerobic exercise, and passive applications (Patterson & Brandner, 2018). While more comprehensive in identifying prescription variables, this survey covered BFR use with any population (healthy, clinical, or athletic), and over a third of respondents were based in universities rather than client-facing industry settings (Patterson & Brandner, 2018). More targeted surveys have been conducted since, capturing usage in clinical settings by allied health professionals ($N = 308$) (Scott et al., 2024) and usage with athletes in North American sports settings ($N = 72$) (Colapietro et al., 2022). However, at present, no worldwide survey looking exclusively at BFR usage by practitioners in high-performance sports settings exists. Regional surveys are likely to capture specific sports with targeted training objectives that may not be as generalisable elsewhere. Surveys of mixed populations may not identify specific usage among athletic populations, resulting in more diverse prescriptions that may hold less value to practitioners in high-performance sports. Therefore, the objective of the present study is to characterise the usage of BFR training with athletes by practitioners in high-performance sports settings around the world.

Materials and methods

An online questionnaire was developed to survey practitioners working with athletes in high-performance sports settings about their usage of BFR exercises with athletes for the purpose of athlete preparation and conditioning, recovery, or rehabilitation. Inclusion criteria required participants to be aged older than 18 years; actively practising within the high-performance sports industry; using or prescribing BFR exercises with athletes; and sufficient English language competency. Information provided by participants who did not meet these criteria were not considered in the results presented here. The survey was disseminated and open for submissions between November 2022 and May 2023. It was disseminated through social media, direct emails, and professional networks.

The survey was promoted to practitioners working in high-performance sports and working directly with athletes (this included high-performance managers, strength and conditioning coaches, rehabilitation specialists, physiotherapists, exercise physiologists, sports scientists, or similar). All participants were provided brief participant information summaries and requested to complete an embedded consent form, with affirmative consent required before being able to access the survey questions. This research project and its methods were approved by the Victoria University Human Research Ethics Committee (*ID: HRE22–158*).

Survey data were collected using online questionnaire software (Qualtrics XM, Provo, UT, USA; See Supplementary File 1). The survey contained five sections, consisting of a total of 36 open and closed questions to understand the high-performance settings in which BFR exercise is being used, and how it is being implemented by practitioners in these settings. These sections included (1) Participant Demographics, (2) Professional Engagement and Setting, (3) Objectives with BFR exercise, (4) Prescription of BFR exercise, and (5) Issues or considerations with implementation of BFR training.

The questionnaire was developed by the authors and informally pilot tested by four exercise and sports scientists with variable understanding of BFR exercise to ensure clarity of the questions. Feedback from the pilot testing informed amendments to questions for clarity improved functionality of individual questions, and improvements to survey structure and flow.

Descriptive statistics (counts and frequencies) were calculated from analysis of the survey report. Where possible, responses to open questions were coded into themes relevant to the related questions and included in the descriptive statistics. For responses regarding how participants gauged the efficacy of BFR, a basic thematic analysis was completed by an individual member of the research team (MJC). This aligned with phases defined by Braun and Clarke including familiarisation with the raw data, generating initial codes, searching for and reviewing themes, defining and naming themes, and reporting findings (Braun & Clarke, 2006). More detailed responses may have contributed to more than one theme. Where answers were unclear or not directly addressing the question, the answer was excluded from the analysis. Qualitative comments representative of identified themes were reported for context. Data was managed and analysed using Microsoft Excel for Microsoft 365 (v2406, Microsoft Corp., Washington, WA, USA).

Results

Informed consent was provided by 164 participants. Of these, 10 did not complete any further questions in the survey. A further 31 participants provided at least some of the basic demographic information requested, and information about the type and level of sports their athletes competed in. While they provided some information about their experiences with the implementation of BFR exercise with athletes, they provided no information about the variables used. The information from these 31 partially completed responses was still used in characterising the settings in which BFR exercise is utilised in high-performance sports. The remaining 123 participants provided responses to questions about the application of BFR in high-performance sports settings, with most providing information about the variables they use to prescribe BFR.

Table 1 includes participant demographics for survey respondents. Of note, several participants worked with multiple organisations, and held multiple professional titles; therefore, the number of some items in Table 1 exceed the number of participants.

High-performance settings and athlete demographics

Demographic information of the participants, including their professional title and the high-performance setting in which they work are presented in Table 1. Information about the athletes with whom the participants utilise BFR are shown in Table 2.

Table 1. Survey participant demographics.

	Responses		Responses
Sex (n = 154)		Country of employment (n = 151)	
Male	136	England	74
Female	18	USA	16
Age (*n* = 154)		Ireland	7
18–24 y	7	Canada	5
25–34 y	85	Scotland	5
35–44 y	55	Australia	4
45–54 y	5	Italy	4
>55 y	0	Malaysia	3
Not disclosed	2	Netherlands	3
Type of organisation* (*n* = 145)		Portugal	3
National level sports team/environment	89	Argentina	2
International level sports team/environment	35	India	2
High-performance centre/private facility	28	New Zealand	2
Youth sports/development academy	16	Northern Ireland	2
University/research facility	16	Spain	2
Amateur level sports team/environment	11	Turkey	2
National sports institute	9	Wales	2
Commercial gym	3	Andorra	1
State/regional sports institute	2	Croatia	1
Contractor	1	Czech Republic	1
Government health service	1	Denmark	1
Profession/role* (*n* = 145)		France	1
Physiotherapist/physical therapist	69	Indonesia	1
Strength and conditioning coach	58	Israel	1
Sports scientist	35	Mexico	1
Rehabilitation specialist	23	Poland	1
Athletic trainer	9	Singapore	1
Exercise physiologist	5	Slovenia	1
Consultant	1	South Africa	1
Athlete	1	Sweden	1

*= Some individual participants provided responses including multiple options, thus the aggregate of responses exceeds the sample size of respondents.

Implementation of blood flow restriction exercise

An overview of the implementation of BFR during exercise is presented in Table 3. The method to determine the pressure to be applied during BFR exercise varied. However, most used either a percentage of measured arterial/limb occlusion pressure (56.1%) or a set pressure based on the scientific literature (36.6%). While many participants used multiple exercise modalities, the main exercise modalities utilised with BFR was resistance training (97.6%), followed by passive applications (40.7%), and aerobic training (39.8%). More than half of participants (55.7%) have not used a screening tool for clearance to use BFR, with many determining athlete clearance via independent screening by medical/allied health staff (67.4%), and device-specific 'in-app' screening tools (27.9%).

Table 2. Demographic characteristics of athletes prescribed blood flow restriction by survey participants.

	Responses		Responses
Athlete age range* (*n* = 128)		**Percentage of athletes using BFR (*n* = 128)**	
<18 y	24	76–100%	8
18–30 y	122	51–75%	17
31–40 y	42	26–50%	20
41–50 y	3	11–25%	33
>50 y	1	0–10%	50
Level of athletes* (*n* = 145)		**Sport* (*n* = 145)**	
Individual (n = 88)*		Football (Soccer)	84
International	56	Rugby (Union)	36
National championship	60	Athletics (Track)	28
State/regional championship	30	Swimming	20
Amateur	5	Basketball	18
Recreational	2	Athletics (Field)	16
Team (n = 133)*		Tennis	11
International	46	Football (American)	10
Tier 1 national league	81	Combat sports/Martial Arts	9
Tier 2 national league	31	Gymnastics	9
Tier 3 and lower national	21	Powerlifting	9
State/regional league	18	Weightlifting (Olympic)	9
Amateur	6	Baseball	8
Aim of BFR training* (*n* = 128)		Rugby (League)	8
Injury rehabilitation	104	Cricket	7
Muscle hypertrophy	103	Football (Gaelic)	6
Limiting loss of muscle mass	92	Rowing/Canoeing/Kayaking	6
Muscle strengthening	66	Cycling	5
Pain management	57	Hockey	5
Enhance recovery	43	Triathlon	5
Improving cardiovascular fitness	20	Netball	4
Bone strengthening	16	Skiing/Snowboarding	4
Potentiation/activation	3	Football (Australian Rules)	3
Local muscular endurance	1	Ice skating	3
De-loading/reduced mechanical stress	1	Other racquet sports	3
Phase of annual plan BFR used* (*n* = 128)		Climbing sports	2
Musculoskeletal rehabilitation	94	Volleyball	2
All year	45	Diving	1
Recovery sessions/phases	38	Golf	1
Preparatory/pre-season phase	20	Handball	1
De-loading sessions/phases	19	Lacrosse	1
Competition phase	14	Skeleton/Luge	1
Pre-competition/taper phase	9		

*= Some individual participants provided responses including multiple options, thus the aggregate of responses exceeds the sample size of respondents; BFR = blood flow restriction.

The exercise prescription variables utilised by participants during the application of BFR are presented in Table 4. For resistance training, all BFR practitioners included lower body exercises, with 60.2% also including upper body exercises. Most participants utilised both single- and multi-joint exercise (68.9%), and 3 (40.8%) or 4 (79.6%) sets per exercise. Typical 30/15/15/15 fixed-repetition schemes for BFR were prescribed (58.3%), with other common ranges being 10–15 reps (31.1%) or > 20 reps (29.1%). Moreover, 36.9% of respondents always used exercise to failure. Prescribed external load was most commonly 30–39% of maximum strength (58.3%), using cuff pressures of 40–80% AOP/LOP (47.6%), and 1–3 BFR exercise sessions per week (87.4%).

For aerobic training, cycling (89.5%) and running (36.8%) were commonly prescribed as continuous (44.7%) rather than interval training (18.4%), while many prescribed both (36.8%). Exercise to failure was rare (5.3%), with most sessions being 10–20 min (71.1%). Like resistance training, participants predominately prescribed cuff pressures for aerobic training as 40–80% AOP/LOP (68.4%).

For passive application of BFR, participants were mostly prescribed 5 minute cycles (82.5%) using 3 (75%), 4 (35%), or 5 or more cycles (25%). Approximately half the participants (55%) prescribed higher pressures with passive applications than they would with active modalities, with many prescribing pressures > 80% AOP/LOP (35.0%).

Participants were asked to provide details for how they evaluate the effectiveness of BFR training relative to other forms of training. Of the 98 responses provided by participants, 12 were unable to be coded. From the remaining 86 responses, the majority (74%) indicated they only evaluated the efficacy of BFR through standard pre- to post-training measurements (theme 1: 'Pre-to-

Table 3. Overview of the implementation of blood flow restriction during exercise.

	Responses		Responses
Pressure determination* (*n* = 123)		**Exercise modalities used with BFR* (*n* = 123)**	
Measured % LOP/AOP	69	Resistance training	120
Arbitrary/fixed pressure from scientific literature	45	Passive applications	50
Perceived cuff tightness/pressure (rating)	26	Aerobic training	49
Arbitrary/fixed pressure value you select	20	Neuromuscular electrostimulation	6
Percentage of resting blood pressure	6	**BFR used by athletes unsupervised (*n* = 99)**	
Estimated LOP/AOP (equations)	5	Yes	36
Percentage of the individual's limb circumference	4	No	63
Pressure directed by BFR device	2	**Percentage of athletes completing BFR unsupervised (*n* = 36)**	
BFR device type used* (*n* = 123)		<20%	17
Automatic inflatable tourniquet	70	20–50%	9
Handheld pump inflatable cuffs	67	51–80%	7
Elastic knee wraps/floss bands	11	>80%	3
BFR garment (Embedded Elastic Wrap)	9	**Established screening tool used for BFR clearance (*n* = 106)**	
KAATSU training device	1	Yes	47
BFR device brands used* (*n* = 106)		No	59
Occlusion Cuffs	34	**Screening tools used* (*n* = 43)**	
VALD AirBands	29	Screening by medical/Allied Health staff	29
Delfi PTS	17	No screening at all	21
Fit Cuffs	9	AirBands screening tool (in-app)	10
Hytro BFR wearables	9	Screen known BFR contraindications and inform of risks	9
MAD-UP Pro	9	Self-developed screening tool	7
SUJI	9	Australian Institute of Sport BFR screening questionnaire	5
TheBFR.co Sports Rehab Tourniquet	5	English Institute of Sport BFR screening questionnaire	5
SAGA Fitness BFR Bands	5	Based on BFR literature	5
Smart Cuffs	4	PAR-Q	3
H+ Cuffs	3	SAGA screening tool (in-app)	2
Unbranded	3	Unsure	2
B Strong	1	**Continuous or intermittent inflation [Resistance training] (*n* = 103)**	
Hokanson Rapid Cuff Inflator	1		
		Continuous (including deflated between exercises)	72
		Intermittent	15
		Depends on situation	16

*= Some individual participants provided responses with multiple options, thus the aggregate of responses exceeds the sample size of respondents; LOP = limb occlusion pressure; AOP = arterial occlusion pressure; BFR = blood flow restriction; PAR-Q = Physical Activity Readiness Questionnaire.

Post Measures') using assessments relative to their outcomes of interest. However, a small subset (6%) indicated they objectively compared the outcomes of those using BFR to those who do not (theme 2: 'Non-BFR Comparison'), specific examples including:

> Comparison between previous cases that did not utilize BFR training with those that have [through] regular objective testing using handheld dynamometer and/or Biodex isokinetic testing.

> [compared with athletes not using BFR] we managed to use BFR to successfully maintain limb girths or at least reduce how much is lost during a non-loading period. We have also found accelerated muscle mass growth in limbs that have had to be totally immobile or unloaded for extended periods.

Some (13%) responses indicated that, based on their professional experience (theme 3: 'Subjective Expertise'), the inclusion of BFR had positive effects:

> Mainly in RTP [return to play] . . . we use same outcome measures for force production prior to return [and compare those training] with or without BFR. Anecdotally, I believe we achieve intended outcomes/adaptations earlier when using BFR.

> Experience of having not used it and now using it a lot is that we see a huge improvement and benefit from using BFR and use it to [help manage] injuries throughout a season.

There also seemed to be an interest in more formally measuring the efficacy of BFR compared to traditional training among athletes. A small proportion of participants (7%) identified the challenges of establishing efficacy without a more controlled evaluation (theme 4: 'Interest in More Rigorous Evaluation'):

> I'm designing my own research to investigate differences within our organization. Circumference measurement, NRS [numerical rating scale] for pain, isokinetic strength testing, etc.

> Specifically for hypertrophic adaptations, we [are looking to] utilise both DXA [dual energy x-ray absorptiometry] and ultrasound and observe muscle thickness and pennation angle changes with BFR.

Several (14%) indicated that there were too many challenges to effectively assessing the added benefit of BFR compared with traditional training (theme 5: 'Efficacy Confounded'). This was most notably because BFR was

Table 4. Prescription variables applied by participants during blood flow restriction exercise and passive blood flow restriction applications.

Resistance Training	Responses	Aerobic Training	Responses	Passive	Responses
Upper vs lower body (n = 103)		**Exercise modality (n = 38)**		**Duration applied in session* (n = 40)**	
Upper body only	0	Cycling	34	<10 min	6
Lower body only	41	Running	14	10–19 min	23
Both	62	Cross-trainer	2	≥20 min	13
Type of exercises (n = 103)		Rower	2	**Inflation cycles per session* (n = 40)**	
Single-joint only	17	Ski Ergo	2	3	30
Multi-joint only	15	Arm Bike	1	4	14
Both	71	**Intensity*# (n = 28)^**		5+	10
Sets per exercise* (n = 103)		Zone 1	9	**Inflation cycle length* (n = 40)**	
1	1	Zone 2	3	1–2 min	4
2	5	Zone 3	9	3–4 min	7
3	42	Zone 4	8	5 min	33
4	82	Zone 5	1	**Rest between inflation cycles (n = 40)**	
5+	10	**Intensity parameter (n = 38)**		<1 min	2
Number of repetitions* (n = 103)		Perceptual rating	14	1–2 min	25
<10	12	Heart rate (%max or %HRR)	14	3–5 min	16
10–15	32	Self-selected	8	**Frequency per week* (n = 40)**	
16–20	13	Oxygen consumption	3	1–3	23
>20	30	**Interval or continuous (n = 38)**		4–6	12
30/15/15/15	60	Interval	7	Daily	6
Rest periods* (n = 103)		Continuous	17	Depends	4
≤30s	50	Both	14	**Is the BFR pressure different to that used during BFR exercise? (n = 40)**	
31-45s	20	**To failure (n = 38)**			
46-60s	37	No	36	Yes	22
>60s	25	Yes	1	No	18
External load* (n = 103)		Sometimes	1	**Specific BFR cuff pressure used* (n = 40)**	
<20% maximum	13	**Total duration* (n = 38)**		<40% AOP/LOP	0
20–29% maximum	33	<10 min	9	40–80% AOP/LOP	21
30–39% maximum	60	10–20 min	27	>80% LOP	14
40–49% maximum	32	21–30 min	5	<160 mmHg	2
50–59% maximum	18	>30 min	3	≥160 mmHg	8
≥60% maximum	6	**Frequency per week* (n = 38)**		Unknown/as per app	4
To failure (n = 103)		1–3	37		
No	54	4–6	4		
Yes	38	Daily	0		
Sometimes	11	**Specific BFR cuff pressure used* (n = 38)**			
Frequency per week* (n = 103)		<40% AOP/LOP	1		
1–3	90	40–80% AOP/LOP	26		
4–6	24	>80% LOP	0		
Daily	4	<160 mmHg	3		
Specific BFR cuff pressure* (n = 103)		≥160 mmHg	2		
<40% AOP/LOP	2	Depends on athlete	1		
40–80% AOP/LOP	49	Unknown/as per app	7		
>80% LOP	2				
<160 mmHg	19				
≥160 mmHg	17				
Depends on athlete	5				
Unknown/as per app	15				

* = Some individual participants provided responses spanning multiple options, thus the aggregate of responses exceeds the sample size of respondents; # = Some responses to the related survey question identified the intensity parameter without further quantification; ^ = (American College of Sports Medicine, 2020; Panassollo et al., 2024); LOP = Limb occlusion pressure; AOP = arterial occlusion pressure; BFR = blood flow restriction; HRR = heart rate reserve.

used in conjunction with other forms of exercise training:

> BFR is one part of a broad number of interventions. It would be impossible and impractical for us to single out the effect from BFR alone. Using an objectively measured criteria based approach we believe BFR training is a useful adjunct within rehab and athletic development.

> Every case is a real n = 1 study and BFR is used in conjunction with traditional strength training methods it's difficult to say exactly. I tend to lean on the research evidence which shows positive adaptations with BFR.

> We use it in conjunction with other modalities, so it is difficult to determine its effectiveness as a standalone modality.

Safety considerations and side effects

Participants were asked to identify any adverse symptoms reported by the athletes (Table 5). Delayed onset

Table 5. Adverse symptoms reported by athletes.

	Responses
Adverse Symptoms Reported (*n* = 98)*	
DOMS	58
Numbness	17
Bruising	15
Fainting/dizziness	8
Cold feeling	7
Pins & needles	2
Venous thrombosis	1
Migraine	1
Low back pain	1
Rhabdomyolysis	0
Athletes have expressed unwillingness to use BFR (*n* = 98)	
No	77
Yes	21
Reasons given for unwillingness to use BFR (*n* = 21)	
Too much discomfort	11
Unpleasant	6
Too unfamiliar	3
Frustration with device	1

*= Some individual participants provided responses spanning multiple options, thus the aggregate of responses exceeds the sample size of respondents; DOMS = delayed onset muscle soreness; BFR = blood flow restriction.

muscle soreness was reported by most participants (59.2%), with numbness (17.3%) and bruising (15.3%) the next most common. However, most other symptoms were rarer, having been reported by less than 10% of participants. Some participants indicated that they had athletes express an unwillingness to use BFR (21 of 98 responses, 21.4%). The reasons provided included too much discomfort, finding it 'unpleasant', it was too unfamiliar, or experiencing frustration with the BFR device used. Participants were also asked to identify any conditions that would prevent them from using BFR, or prompt them to seek medical clearance (Figure 1).

Discussion

This study aimed to investigate how BFR exercise is being implemented by practitioners working with athletes in high-performance sports settings. The main findings were that within these settings: (a) BFR is primarily utilised for injury rehabilitation and to supplement strength and conditioning programs; (b) BFR is utilised by small subsets of athletes in team and individual sports; (c) cuff pressures are commonly based on individualised measures of AOP/LOP or arbitrary pressures, and used during low-to-moderate external loads or exercise intensities; and (d) practitioners are aware of contraindications, however screening tools are underutilised. These findings suggest that BFR is mostly being utilised in line with current recommendations (Patterson et al., 2019), although the application of individualised cuff pressures and health screening processes may require further attention from practitioners in high-performance sports.

The participants in this survey were predominantly physiotherapists or physical therapists and strength and conditioning coaches. This was similar to a recent survey of BFR use in North American sports settings (Colapietro et al., 2022), although the present survey captured a much higher proportion of strength and conditioning coaches, more reflective of an earlier survey of general BFR use (Patterson & Brandner, 2018). The professional roles identified help explain the most reported aims of BFR training in the present survey. Physiotherapists/physical therapists and rehabilitation specialists primarily engage in injury management, return to play, and early reconditioning aligning with primary aims identified in the survey. This rehabilitation focus may also help explain why participants only used BFR with a relatively small proportion of their athletes. Strength and conditioning coaches are more traditionally involved in performance enhancement, which also aligned with the common aims identified in the survey. This was expected, as the primary outcomes of BFR training have historically been muscle strength and hypertrophy, with a smaller proportion of research promoting improvements in cardiovascular fitness (Patterson et al., 2019). However, the emphasis on enhancing recovery, as a non-traditional objective of BFR, was perhaps surprisingly high in the present survey. One recent survey identified BFR use for enhancing recovery as an aim for less than 1% of respondents (Scott et al., 2024). Although that survey was in predominantly clinical settings, whereas recovery is a more implicit focus in high-performance sports.

Participants primarily utilised BFR with athletes in team sports, such as football (soccer) and rugby union. However, other prominent sports were individual sports such as track athletics and swimming. Collectively, participants identified 32 sports played by athletes using BFR, spanning multiple levels of competition ranging from amateur teams and individual sports to professional Tier 1 national league teams and international level individual athletes. Such diversity highlights the versatility of BFR as a tool for athletes. This is also evident in the present survey through qualitative comments on the individualised utility of BFR, despite challenges in separately assessing the effect of BFR among other aspects of athletes' training.

Prescribed cuff pressure has long been a source of heterogeneity within the BFR research, with prescribed pressures often lacking clear justification (Clarkson et al., 2020). With the release of the widely accepted guidelines for BFR implementation in 2019 (Patterson et al., 2019), there has been a significant shift towards

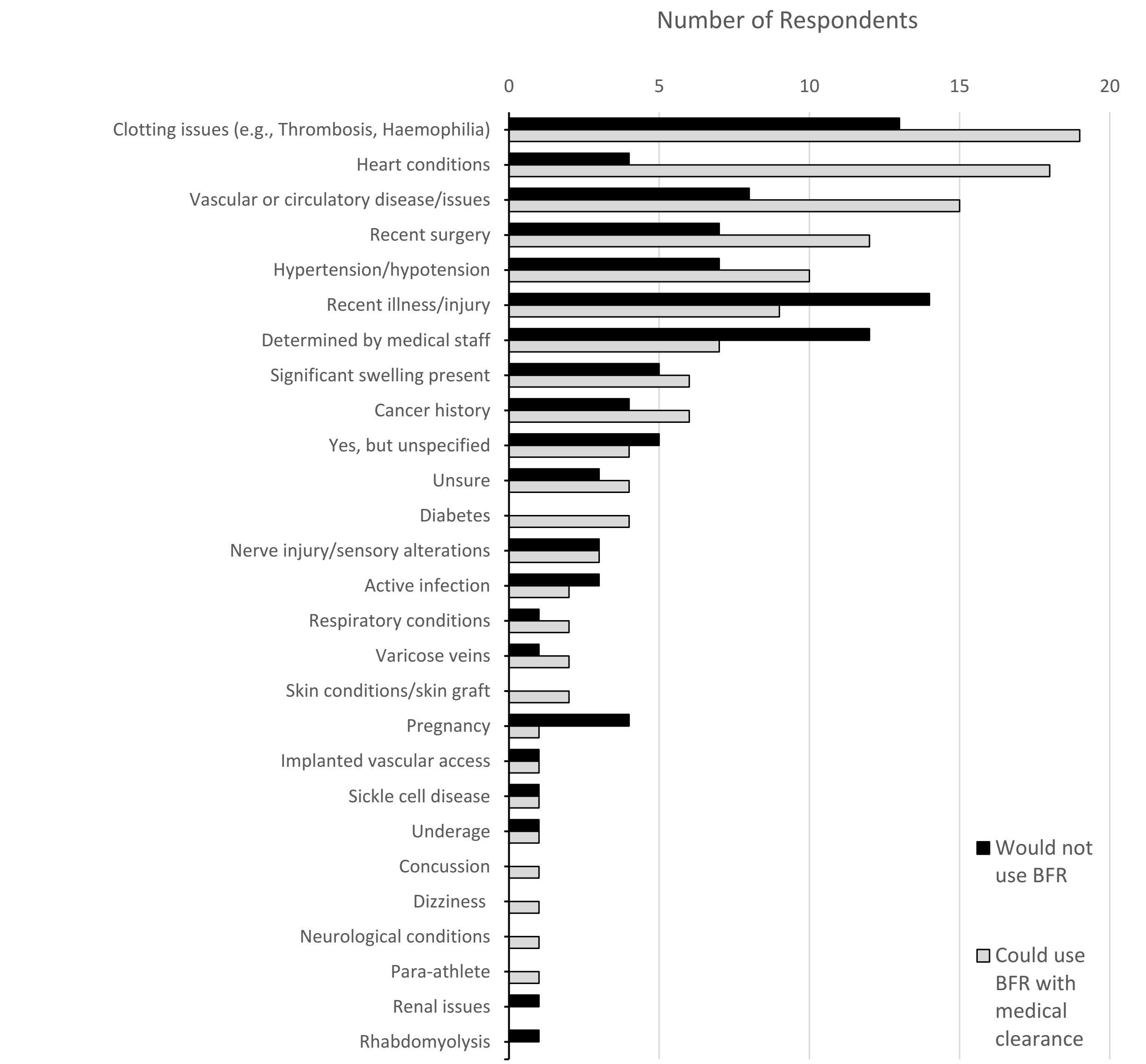

Figure 1. Responses to the question 'in addition to a specific screening tool, are there any a) specific conditions for which you would seek medical clearance to use blood flow restriction? and b) additional conditions for which you would not use blood flow restriction?' ($n = 97$).

prescribing BFR using individualised cuff pressures. One broader practitioner survey reported that only 11.5% of 250 respondents used individualised limb occlusion pressures when prescribing BFR cuff pressure, instead favouring a fixed pressure based on pressures used in the literature at the time (Patterson & Brandner, 2018). However, another more recent survey of healthcare practitioners, 81.1% of respondents were prescribing pressures using a percentage of measured limb or arterial occlusion pressure (Scott et al., 2024). This was similar in the only other survey of BFR use in sports, within North America with 80.9% (Colapietro et al., 2022). However, the present survey only showed that 56.1% of practitioners using BFR in high-performance sports settings were using a percentage of measured limb occlusion pressure or arterial occlusion pressure. Interestingly, 52.8% of practitioners are still using arbitrary or fixed pressures (noting some practitioners employ multiple approaches). This deviation from the BFR guidelines (Patterson et al., 2019) may be related to the types of equipment being used by practitioners captured in the present survey. A relatively even split between automatically regulating inflatable tourniquets ($n = 71$) and handheld manually inflated pressure cuffs ($n = 67$) were the devices most reported. The most prominent single brand of cuff used was a manually inflated unregulated cuff, used by almost one-third of responding practitioners. These manually inflated cuffs do not have an in-built mechanism to measure limb or arterial occlusion pressure in contrast to the automatically regulated alternatives. The inclusion of such features, the capacity to autoregulate pressures or not, and by extension the quality of the devices, are part of practitioners' considerations for the implementation of BFR (Clarkson et al., 2024). Among the brands identified by participants, the cost of the cuff systems ranges from approximately AUD$200 to AUD$8,000. Higher costs are broadly indicative of the advanced features such as in-built AOP/LOP assessment and autoregulation of cuffs. However, cost may be a prohibitive factor for practitioners, leading to most participants in the present survey adopting unregulated cuff systems. Recent research has identified that unregulated cuff systems may induce elevated acute haemodynamic responses to BFR compared with autoregulated cuff systems, leading to greater discomfort and higher exertion than intended (Hughes et al., 2018). Unregulated cuff systems may also result in greater DOMS and an increased likelihood of minor adverse events (e.g., light headedness), compared with autoregulated systems (Jacobs et al., 2023). Regardless, the most frequently reported pressures being applied for all BFR applications were still within the recommended range of 40–80% AOP/LOP (Patterson et al., 2019). This was true for each of resistance training, aerobic training, and passive applications of BFR.

More practitioners utilised BFR with resistance training compared with aerobic training. However, somewhat surprisingly, the passive application of BFR was utilised just as commonly as aerobic training with BFR. While there is evidence that passive BFR applications may enhance recovery from exercise induced muscle damage (Patterson et al., 2021), there is limited and mixed evidence supporting its use for enhancing performance compared with aerobic BFR training (Scott et al., 2023; Silva et al., 2019; Smith et al., 2022).

Resistance training prescriptions largely adhered to the recommended guidelines (Patterson et al., 2019). A notable deviation was the use of prescribed external loads somewhat normally distributed around 30–39% of 1RM, slightly higher than the external load distributions captured in previous surveys (Colapietro et al., 2022; Patterson & Brandner, 2018; Scott et al., 2024). These were also towards the high end of the load recommendations in the BFR guidelines (Patterson et al., 2019), potentially due to the high-performance setting and a greater tolerance to higher loads among athletes.

Aerobic training was also largely prescribed in line with recommended guidelines (Patterson et al., 2019) and data from previous surveys regardless of population (Colapietro et al., 2022; Patterson & Brandner, 2018; Scott et al., 2024). Interestingly though, there were a range of intensities prescribed across Zone 1, Zone 3, and Zone 4. Speculatively, this may be attributed to variable aims of aerobic BFR training in this survey, such as injury rehabilitation, enhancing recovery, and improving cardiovascular fitness. However, questions in this survey were not structured for the aims of BFR training to be linked to the modality or intensity of BFR training used, especially with individual practitioners prescribing a broad mix of different BFR applications depending on their athletes.

Practitioner applications of passive BFR have comparatively limited reporting compared with resistance and aerobic training, with only one survey capturing its use (Patterson & Brandner, 2018). Prescription variables in the present survey largely aligned with this prior survey (Patterson & Brandner, 2018). However, the present survey showed 82.5% of practitioners prescribed 5 minute inflation cycles, approximately double those captured in the prior survey where 4–5 minute inflation cycles (the longest among survey respondents) were used 40.6% of the time (Patterson & Brandner, 2018). This is perhaps due to the recommended prescription for passive BFR being updated since publication of the 2018 survey (Patterson et al., 2019), and this now being adopted into industry practice.

A prior survey of BFR use among healthcare practitioners highlighted the importance of screening to mitigate safety concerns of implementing BFR with 'at-risk' populations (Scott et al., 2024). While 'at-risk' individuals would be less prevalent in high-performance sports settings, potential contraindications such as clotting disorders, significant injury history, compartment syndrome, and neurological conditions may still be present. For this reason, athletes using BFR for the first time or after a significant break from using the technique, or following surgery, significant injury or illness have been recommended to be screened (Crow et al., 2021). Despite this, 55.7% of practitioners responding to the present survey do not use a screening tool for clearance to use BFR with their athletes. Among those that do, 67.4% rely on clearance by other medical or allied health staff rather than formal screening, and several did not use any established screening tool consistently or had developed their own screening tool. Furthermore, only a small portion of practitioners responding to our questions about medical clearance listed the prominent concerns of clotting issues such as deep vein thrombosis or history of thrombolytic events, heart conditions and vascular or circulatory conditions or illnesses as requiring clearance. While this may be due to the paucity of athletes presenting with these concerns, even fewer practitioners noted clearance being required for recent surgery or recent injuries and illnesses, which would be more common among athletes. Few practitioners identified presentations they would not use BFR with, including recent injuries or illnesses and clotting issues, with some relying solely on decisions from medical staff to specify that BFR could not be used. This approach is somewhat concerning despite the expected lower prevalence of 'at risk' individuals using BFR within this setting. Screening remains an important step in implementing BFR training, so we strongly encourage practitioners to implement formal screening for absolute contraindications to BFR use using established tools (Crow et al., 2021), or recommended checklists from the literature (Nascimento et al., 2022).

In line with previous surveys, delayed onset muscle soreness (DOMS) was the most reported adverse symptom. The prevalence of DOMS identified in the present survey was in between the reported prevalence in previous surveys of 39.1% (Patterson & Brandner, 2018), 61.5% (Colapietro et al., 2022), and 65.8% (Scott et al., 2024). Scott et al. (2024) attributed this to their more clinical and older adult cohorts. However, Colapietro et al. (2022) had the highest percentage of practitioners reporting athletes experiencing DOMS with BFR. It is logical for the clinical cohorts more unaccustomed to exercise to more readily experience DOMS, but perhaps for athletic populations being similarly unaccustomed to BFR specifically, despite a high volume and consistent dose of traditional training, may elicit DOMS regardless (Barnett, 2006). Other adverse symptoms reported in the present survey such as numbness, bruising, fainting or dizziness, and 'pins and needles' are not uncommon with BFR use (Brandner et al., 2018; Patterson et al., 2019), and were reported with similar prevalence in each of the preceding surveys (Colapietro et al., 2022; Patterson & Brandner, 2018; Scott et al., 2024).

Limitations existed in structural elements of the present survey, such as free-text responses yielding such diverse responses that categorization of the outputs was difficult. Conversely, in some cases free-text options did not appear to provide enough guidance to respondents and elicited answers misaligned with the intention of the question. Additionally, the option to provide multiple responses to questions at times limited the interpretation of findings. For example, participants who utilised multiple modalities of BFR (resistance training, aerobic training, or passive), may also have indicated multiple aims of using BFR (muscle hypertrophy, pain management, enhancing recovery), yet the survey was not able to elucidate specific aims aligned with each modality. Similarly, participants working with athletes in different sports may have used multiple BFR modalities, but the survey did not capture whether individual BFR modalities were more commonly used with athletes in particular sports. Unfortunately, this limited further statistical examination of any associations between categorical variables collected in this study. It is necessary to identify that dissemination of the survey by the research team through social media, direct emails, and professional networks may be a potential source of selection bias. While participants were located across 30 different countries, most responses came from a largely centralised region of Western Europe. This may have been influenced by the inclusion criteria requiring respondents to have sufficient English language competency to complete the questionnaire. While this would improve comprehension of the survey questions, it may have been exclusionary to international practitioners from non-English-speaking backgrounds. As such, our findings may not be as generalisable internationally as per the intention of the survey. Regardless, this is the first and largest worldwide survey exploring practitioner use of BFR in high-performance sports settings. It contributes to the broader characterisation of practitioner BFR use which has been a point of limited attention to-date.

In conclusion, BFR is primarily used for injury rehabilitation, muscle hypertrophy, limiting loss of muscle mass, muscle strengthening, and pain management in high-performance sports settings. Practitioners appear to largely follow existing prescription recommendations. However, the number of practitioners still using arbitrary-fixed pressures was comparable to those using individualised pressures based on measured limb occlusion pressures, contravening the recommended guidelines (Patterson et al., 2019). Screening for contraindications was not consistent and, in some cases, not done using robust screening tools. However, the reported adverse side effects were limited.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by internal resources (Victoria University).

ORCID

Matthew J. Clarkson http://orcid.org/0000-0003-0447-9269
Brendan R. Scott http://orcid.org/0000-0002-2484-4019
Stephen D. Patterson http://orcid.org/0000-0003-4667-9939
Stuart A. Warmington http://orcid.org/0000-0002-2414-7539

Author contributions

Conceptualisation: MJC, SAW Survey development: All Survey distribution: All Methodology: All Data extraction: MJC Project administration: MJC Resources: MJC Software: MJC Validation: MJC Visualisation: MJC Writing – original draft: MJC Writing – review & editing: All

Ethics approval

Ethics approval was provided by the Victoria University Human Research Ethics Committee (ID: HRE22–158) on 12 October 2022.

References

American College of Sports Medicine. (2020). *ACSM's guidelines for exercise testing and prescription*. Lippincott Williams & Wilkins.

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes: Does it help? *Sports Medicine*, *36*(9), 781–796. https://doi.org/10.2165/00007256-200636090-00005

Brandner, C. R., May, A. K., Clarkson, M. J., & Warmington, S. A. (2018). Reported side-effects and safety considerations for the use of blood flow restriction during exercise in practice and research. *Techniques in Orthopaedics*, *33*(2), 114–121. https://doi.org/10.1097/BTO.0000000000000259

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Christiansen, D., Murphy, R. M., Bangsbo, J., Stathis, C. G., & Bishop, D. J. (2018). Increased FXYD1 and PGC-1α mRNA after blood flow-restricted running is related to fibre type-specific AMPK signalling and oxidative stress in human muscle. *Acta Physiologica*, *223*(2), e13045. https://doi.org/10.1111/apha.13045

Clarkson, M. J., May, A. K., & Warmington, S. A. (2020). Is there rationale for the cuff pressures prescribed for blood flow restriction exercise? A systematic review. *Scandinavian Journal of Medicine & Science in Sports*, *30*(8), 1318–1336. https://doi.org/10.1111/sms.13676

Clarkson, M. J., McMahon, B., & Warmington, S. A. (2024). Comparing adaptations from blood flow restriction exercise training using regulated or unregulated pressure systems: A systematic review and meta-analysis. *Clinical Rehabilitation*, *10*, 1–20. https://doi.org/10.1177/02692155241271040

Colapietro, M. A., Lee, J. Z., & Vairo, G. L. (2022). *Survey of blood flow restriction training applications in sports Medicine and performance practice across North America*. *The Journal of Strength & Conditioning Research*, *10*, 1519.

Conceição, M. S., Junior, E. M. M., Telles, G. D., Libardi, C. A., Castro, A., Andrade, A. L. L., Brum, P. C., Urias, Ú., Kurauti, M. A., & Júnior, J. M. C. (2019). Augmented anabolic responses after 8-wk cycling with blood flow restriction. *Medicine & Science in Sports & Exercise*, *51*(1), 84–93. https://doi.org/10.1249/MSS.0000000000001755

Crow, J., Scott, B. R., Brennan, H., Binnie, M., Saunders, A., Gaviglio, C., & Culhane, P. (2021). *Blood flow restriction training guidelines* [Position Statement]. Australian Institute of Sport. https://www.ais.gov.au/position_statements/best_practice_content/blood-flow-restriction-training-guidelines

Davids, C. J., Roberts, L. A., Bjørnsen, T., Peake, J. M., Coombes, J. S., & Raastad, T. (2023). Where does blood flow restriction fit in the toolbox of athletic development? A narrative review of the proposed mechanisms and potential applications. *Sports Medicine*, *53*(11), 2077–2093. https://doi.org/10.1007/s40279-023-01900-6

Grønfeldt, B. M., Lindberg Nielsen, J., Mieritz, R. M., Lund, H., & Aagaard, P. (2020). Effect of blood-flow restricted vs heavy-load strength training on muscle strength: Systematic review and meta-analysis. *Scandinavian Journal of Medicine & Science in Sports*, *30*(5), 837–848. https://doi.org/10.1111/sms.13632

Hughes, L., Rosenblatt, B., Gissane, C., Paton, B., & Patterson, S. D. (2018). Interface pressure, perceptual, and mean arterial pressure responses to different blood flow restriction systems. *Scandinavian Journal of Medicine & Science in Sports*, *28*(7), 1757–1765. https://doi.org/10.1111/sms.13092

Hughes, L., Swain, P. M., Lai, T., & McEwen, J. A. (2024). It's time to regulate-the importance of accurate surgical-grade tourniquet autoregulation in blood flow restriction exercise applications. *Physical Therapy in Sport*, *67*, 41–46. https://doi.org/10.1016/j.ptsp.2024.02.001

Jacobs, E., Rolnick, N., Wezenbeek, E., Stroobant, L., Capelleman, R., Arnout, N., Witvrouw, E., & Schuermans, J. (2023). Investigating the autoregulation of applied blood flow restriction training pressures in healthy, physically active adults: An intervention study evaluating acute training responses and safety. *British Journal of Sports Medicine*, *57*(14), 914–920. https://doi.org/10.1136/bjsports-2022-106069

Kubota, A., Sakuraba, K., Sawaki, K., Sumide, T., & Tamura, Y. (2008). Prevention of disuse muscular weakness by restriction of blood flow. *Medicine & Science in Sports & Exercise*, *40*(3), 529–534. https://doi.org/10.1249/MSS.0b013e31815ddac6

Nakajima, T., Kurano, M., Iida, H., Takano, H., Oonuma, H., Morita, T., Meguro, K., Sato, Y., & Nagata, T. (2006). Use and safety of KAATSU training: Results of a national survey. *International Journal of KAATSU Training Research*, *2*(1), 5–13. https://doi.org/10.3806/ijktr.2.5

Nascimento, D. D. C., Rolnick, N., Neto, I. V. D. S., Severin, R., & Beal, F. L. R. (2022). A useful blood flow restriction training risk stratification for exercise and rehabilitation. *Frontiers in Physiology*, *13*, 808622. https://doi.org/10.3389/fphys.2022.808622

Panassollo, T. R. B., Mawston, G., Taylor, D., & Lord, S. (2024). Targeting exercise intensity and aerobic training to improve outcomes in Parkinson's disease. *Sport Sciences for Health*, *20*(2), 287–297. https://doi.org/10.1007/s11332-024-01165-0

Patterson, S. D., & Brandner, C. R. (2018). The role of blood flow restriction training for applied practitioners: A questionnaire-based survey. *Journal of Sports Sciences*, *36*(2), 123–130. https://doi.org/10.1080/02640414.2017.1284341

Patterson, S. D., Hughes, L., Warmington, S., Burr, J., Scott, B. R., Owens, J., Abe, T., Nielsen, J. L., Libardi, C. A., Laurentino, G., Neto, G. R., Brandner, C., Martin-Hernandez, J., & Loenneke, J. (2019). Blood flow restriction exercise: Considerations of methodology, application, and safety. *Frontiers in Physiology*, *10*. https://doi.org/10.3389/fphys.2019.00533

Patterson, S. D., Swan, R., Page, W., Marocolo, M., Jeffries, O., & Waldron, M. (2021). The effect of acute and repeated ischemic preconditioning on recovery following exercise-induced muscle damage. *Journal of Science and Medicine in Sport*, *24*(7), 709–714. https://doi.org/10.1016/j.jsams.2021.02.012

Pignanelli, C., Christiansen, D., & Burr, J. F. (2021). Blood flow restriction training and the high-performance athlete: Science to application. *Journal of Applied Physiology*, *130*(4), 1163–1170. https://doi.org/10.1152/japplphysiol.00982.2020

Scott, B. R., Girard, O., Rolnick, N., McKee, J. R., & Goods, P. S. R. (2023). An updated panorama of blood-flow-restriction methods. *International Journal of Sports Physiology and Performance*, *18*(12), 1461–1465. https://doi.org/10.1123/ijspp.2023-0135

Scott, B. R., Loenneke, J. P., Slattery, K. M., & Dascombe, B. J. (2016). Blood flow restricted exercise for athletes: A review of available evidence. *Journal of Science and Medicine in Sport*, *19*(5), 360–367. https://doi.org/10.1016/j.jsams.2015.04.014

Scott, B. R., Marston, K. J., Owens, J., Rolnick, N., & Patterson, S. D. (2024). Current implementation and barriers to using blood flow restriction training: Insights from a survey of allied Health practitioners. *The Journal of Strength & Conditioning Research*, *38*(3). https://doi.org/10.1519/JSC.0000000000004656

Silva, J. C. G., Pereira Neto, E. A., Pfeiffer, P. A. S., Neto, G. R., Rodrigues, A. S., Bemben, M. G., Patterson, S. D., Batista, G. R., & Cirilo-Sousa, M. S. (2019). Acute and chronic responses of aerobic exercise with blood flow restriction: A systematic review. *Frontiers in Physiology*, *10*. https://doi.org/10.3389/fphys.2019.01239

Smith, N. D., Scott, B. R., Girard, O., & Peiffer, J. J. (2022). Aerobic training with blood flow restriction for endurance athletes: Potential benefits and considerations of implementation. *The Journal of Strength & Conditioning Research*, *36*(12), 3541–3550. https://doi.org/10.1519/JSC.0000000000004079

Sotiriadou, P., & De Bosscher, V. (2018). Managing high-performance sport: Introduction to past, present and future considerations. *European Sport Management Quarterly*, *18*(1), 1–7. Taylor & Francis.

Takarada, Y., Takazawa, H., & Ishii, N. (2000). Applications of vascular occlusion diminish disuse atrophy of knee extensor muscles. *Medicine & Science in Sports & Exercise*, *32*(12), 2035–2039. https://doi.org/10.1097/00005768-200012000-00011