Is Blood Flow Restriction Training Beneficial for Athletes?

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ABSTRACT

BLOOD FLOW RESTRICTION (BFR) TRAINING INVOLVES USING SPECIALIZED STRAPS TO INTENTIONALLY REDUCE CIRCULATION (OCCLUDE) TO EXERCISING MUSCLES. THE ADDITION OF BFR TO STANDARD TRAINING APPROACHES RESULTS IN GREATER MUSCLE HYPERTROPHY AND PERFORMANCE IMPROVEMENTS IN UNTRAINED AND CLINICAL POPULATIONS. HOWEVER, ITS IMPLICATIONS IN HEALTHY ATHLETES HAVE NOT BEEN REVIEWED. THE AIM OF THIS ARTICLE IS TO PROVIDE A CONCISE OVERVIEW OF THE PRACTICALITY OF BFR TRAINING FOR ATHLETIC PERFORMANCE. ALTHOUGH INITIAL FINDINGS SHOW PROMISE, BFR TRAINING IS RELATIVELY NEW AND MORE RESEARCH IS NEEDED TO ESTABLISH SPECIFIC RECOMMENDATIONS FOR VOLUME, INTENSITY, FREQUENCY, EXERCISE SELECTION, DURATION, AND STRAP PRESSURE.

INTRODUCTION

Over the past decade, blood flow restriction (BFR) training (or KAATSU) has received attention from researchers, coaches, and strength and conditioning specialists as a potential performance enhancement modality. BFR training uses specially designed straps (or pressurized cuffs) applied to the proximal end of a limb to partially occlude arterial and venous circulation during exercise. When combined with low-intensity exercise programs, this technique promotes muscle hypertrophy and performance increases in various populations (3,6,7,14–16,19). The recent prevalence of BFR as a training modality has prompted development of special certifications for its use.

Several physiological mechanisms likely work in concert to induce BFR training's distinct adaptations. For example, low-intensity BFR exercise requires similar motor unit recruitment (muscle activation) patterns as traditional high-intensity (nonoccluded) exercise (23). This seems to contradict the classic "size principle," that motor unit recruitment occurs from small to large depending on the required force and speed. However, research has found that oxygen availability also dictates recruitment of higher order motor units (17) suggesting a possible rationale for increased muscle activation during BFR exercise. At the skeletal muscle level, BFR training reduces myostatin gene (9) and protein (8) expression, which subsequently induces hypertrophy (as myostatin is a negative regulator of muscle mass). This may be due to the hypoxic environment and metabolic byproduct accumulation during occlusion (11). Furthermore, plasma growth hormone concentrations increase approximately 290× above baseline after BFR exercise (20). Although the direct relationship between hormone stimulation and muscle adaptation is unclear (25), these data indicate that BFR undoubtedly provides a unique systemic stress. More information on physiological mechanisms have been reviewed previously (11), but clearly, several processes are responsible for BFR training's distinct benefits.

The American College of Sports Medicine recommends lifting at least approximately 70% of 1 repetition maximum (RM) for a given exercise to elicit maximum hypertrophy and strength improvements (4). However, BFR exercise in untrained populations stimulates significant increases in muscle size and strength using much lower intensities (~20% of 1RM) (1,3,6,7,14,19,23,29). BFR training has also been shown to be a useful rehabilitation modality (i.e., for those recovering from anterior cruciate ligament surgery) (22). These impressive findings have prompted recent research on BFR's effectiveness on athletic populations. It has been theorized that implementing BFR might benefit athletes by making the unloading phase of training more effective (10) or by preventing detraining during times when

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heavy resistance exercise is not possible. A review of recent BFR data is warranted due to its novelty and potential practical implications for practitioners. Therefore, the purpose of this article is to provide a concise overview of research findings on the benefits of BFR training for athletic performance.

BFR TRAINING STUDIES WITH ATHLETES

Although BFR research has increased substantially in the past decade, few well-controlled BFR training studies exist on athletic populations. This section presents a case-by-case review of all peer-reviewed investigations (to date) that (a) used athletes as participants, (b) used appropriate control group(s), and (c) used a longitudinal training study design. The table provides a summary outline of all 9 studies (2,5,13,15,16,18,21,24,27).

INITIAL BFR TRAINING STUDIES: KNEE EXTENSION/FLEXION

Takarada et al. (21,24) conducted the first BFR training studies on male athletes. They aimed to investigate the effects of BFR and low-intensity bilateral knee extension exercise training (8 weeks) on muscle growth and function using well-trained male athletes. When compared with a nonoccluded exercise group, knee extensor muscle cross-sectional area (CSA) significantly increased in the BFR groups (using magnetic resonance imaging). The muscle hypertrophy was coupled with significant knee extension strength improvements (measured through isokinetic dynamometry; speeds ranging from 0° to 180°/s) in the BFR group only. These studies were the first to show that low-intensity BFR training affects both muscle size and performance in athletic men.

Manimmanakorn et al. (15,16) were the first to investigate the effects of BFR training (5 weeks) on female athletes (netball players), comparing BFR, hypoxic (breathing low oxygen), and control training groups. Maximal oxygen uptake ($\dot{V}O_2$max), 5-m sprint, agility, strength, and endurance significantly improved after BFR and hypoxic training compared with the control group (15). Vertical jump and 10-m sprint performance did not differ among groups. In the follow-up study, female athletes increased muscle activation (electromyography [EMG]) after a 5-week BFR training period compared with controls (16). Interestingly, these investigations found similar results between the BFR and hypoxic training groups in most measures, suggesting whole-body hypoxia may impart similar adaptations to local occlusion with low-intensity exercise. Although the data are limited, BFR training may benefit athletic women by inducing performance gains in sport-specific tasks, such as short sprints and agility drills.

BFR TRAINING STUDIES: DYNAMIC MULTIJOINT EXERCISES

Three recent investigations used protocols and settings more in-line with actual strength and conditioning programs for athletes (5,13,27) as opposed to knee extension/flexion only programs used in the previously mentioned studies. The first was conducted on elite rugby players, standing out among these 3 as (a) it used an inflatable cuff (compared with elastic straps), (b) athletes in the BFR group only occluded during the exercise and released pressure during rest periods, and (c) used BFR in conjunction with 70% intensity for bench press, squat, and weighted pull-ups (5). Compared with controls, BFR training induced significant improvements in strength (bench press and squat), leg power (countermovement jump), and sprint performance (40 m) (5).

The second investigation (27) studied the effects of 4 weeks of BFR training at 20% of 1RM (bench press and squats) on American football players. BFR training produced significant strength increases in the bench press and squat (8 and 7% improvements, respectively) compared with control subjects. This study showed that BFR training can benefit even well-trained athletes, increasing strength in a relatively short duration (4 weeks). Furthermore, it illustrated the effectiveness of simple occlusion tools (such as elastic knee straps), making BFR a viable option for real-world applications.

The third investigation (13) also studied American football players. However, they used a more complex design using several different groups, some of which supplemented with BFR training (7 weeks) using elastic knee straps. They found that (a) combining high-intensity resistance training with BFR caused the largest increase in squat performance and (b) low-intensity BFR training elicited similar improvements to high-intensity lifts without BFR. To our knowledge, this is the only study comparing high-intensity resistance to BFR training in athletes. Supplemental BFR training in well-trained athletes may increase the magnitude (or rate) of lower-body strength gains, at least during a 7-week training program.

BFR TRAINING FREQUENCY WITH ATHLETES

The final 2 studies that fit our review criteria show the feasibility of more frequent training (2× per day) with BFR due to lower loads and levels of mechanical stress placed on the body. Abe et al. (2) recruited male track and field athletes (jumpers, sprinters) to complete an 8-day (2× per day) protocol with 3 sets and 15 repetitions for squats and leg curls (20% of 1RM). Compared with controls, BFR training imparted significant improvements in muscle size (midthigh CSA), strength (leg press performance), and 30-m sprint time. The significant improvements in sprint performance are especially impressive considering the study length (8 days) and athlete's high training status.

The last study (18) used a walking protocol with elite basketball players for 2 weeks. Participants walked occluded twice daily for 5 sets of 3 minutes (4–6 km/h at 5% incline) with 1-minute rest between sets (6 days per week). This elicited improvements in $\dot{V}O_2$max and peak knee flexion strength compared with controls. Thus, BFR training

Table
Blood flow restriction (BFR) training studies with athletes

Reference	Athletic population			BFR training program			BFR group adaptations (vs controls)	
	Sport	Sex	Age (y)	Occlusion (mm Hg)	Mode and duration	Volume and intensity	Performance	Muscle mass
Takarada et al. (21)	Rugby (*n* = 17)	M	LIO: 25.3 ± 0.8; LI: 26.5 ± 0.7; CON: 25.4 ± 0.6	196.0 ± 5.7	Knee extension (0–90°); 2×/wk for 8 wk	4 sets (50% 1RM) to failure (16.3 ± 0.7 repetitions)	↑ Knee extensor torque; ↑ dynamic endurance	↑ CSA (knee extensors through MRI)
Takarada et al. (24)	Not Specified (*n* = 18)	M	LIO: 21.3 ± 0.6; LI: 21.8 ± 0.8; VO: 22.2 ± 0.8	218 ± 8.1	Knee extension (0–90°); 2×/wk for 8 wk	5 sets (~20% 1RM) to failure (16.8 ± 2.1 repetitions)	↑ Isometric strength; ↑ isokinetic strength	↑ CSA (knee extensors through MRI)
Abe et al. (2)	Track and field (*n* = 15)	M	College age (not specified)	~240	Squats and leg curls; 2×/d for 8 d	3 sets (20% 1RM) of 15 repetitions	↑ Leg press strength; ↑ 30-m sprint performance (during initial 0–10m)	↑ CSA (muscle/bone)
Park et al. (18)	Basketball (*n* = 14)	M	BFR: 20.1 ± 1.2; CON: 20.8 ± 1.3	160–220	Walk training; 2×/d, 6 d/wk for 2 wk	5 sets of 3 min (4–6 km/h, 5% grade)	↑ $\dot{V}O_2$max; ↑ $V_E$max	NA
Yamanaka et al. (27)	Football (*n* = 32)	M	19.2 ± 1.8	Not specified (elastic bands)	Bench press and squats; 3×/wk for 4 wk	30 repetitions (20%) and 3 se 1RMts of 20 repetitions (20% 1RM)	↑ Strength (bench press and squat)	↑ Chest girth
Manimmanakorn et al. (15)	Netball (*n* = 30)	F	20.2 ± 3.3	160–230	Knee extension and flexion (0–90°); 3×/wk for 5 wk	6 sets (20% 1RM) to failure (mean repetitions: 24–36)	↑ Strength (MVC); ↑ Endurance (max reps); ↑ 5-m sprint performance; ↑ Agility performance; ↑ $\dot{V}O_2$max	↑ CSA (midthigh through MRI)

Table (continued)

Manimmanakorn et al. (16)	Netball (*n* = 30)	F	20.2 ± 3.3	160–230	Knee extension and flexion (0–90°); 3×/wk for 5 wk	6 sets (20% 1RM) to failure (mean repetitions: 24–36)	↑ Strength (MVC); ↑ Endurance (max reps)	↑ CSA (midthigh through MRI)
Cook et al. (5)	Rugby (*n* = 20)	M	21.5 ± 1.4	180	Bench press, squats, and pull-ups; 3×/wk for 3 wk	5 sets of 5 repetitions (70% 1RM)	↑ Strength (bench press, squat); ↑ Leg power (jump); ↑ 40-m sprint performance	NA
Luebbers et al. (13)	Football (*n* = 62)	M	20.3 ± 1.1	Not specified (elastic bands)	Lower- and upper-body resistance training; 4×/wk for 7 wk	Modified HI training protocol with 4 sets of 30 repetitions (20% 1RM)	↑ Strength (squat)	↔ Arm, chest, or thigh girth

BFR = blood flow restriction; CON = control; CSA = cross-sectional area; F = female; LI = low intensity (without occlusion); LIO = low-intensity occlusion; M = male; MRI = magnetic resonance imaging; MVC = maximum voluntary contraction; NA = not applicable; RM = repetition maximum; $V_E$max = maximal minute ventilation; VO = vascular occlusion (without exercise); $\dot{V}O_2$max = maximal oxygen uptake.

not only affected muscular strength but may also provide positive cardiovascular fitness adaptations in trained athletes.

PRACTICAL CONSIDERATIONS: OCCLUSION PRESSURE

Based on the gathered evidence, BFR training may be a valuable performance enhancing modality for athletes. Along with choosing the proper training protocols (e.g., mode, volume, intensity, duration), occlusion pressures applied to elicit adaptions must also be considered. Increasing pressure decreases oxygen supply to the musculature resulting in increased neural stimulation (17). However, increased cuff pressure can also lead to premature fatiguing (28), which may inhibit performance. More research is needed to investigate optimal pressures for each athlete, muscle group, and training goal.

Pressures of 50 mm Hg have elicited elevated EMG responses (19). On the contrary, strength and hypertrophy improvements have been noted with BFR training pressures up to approximately 240 mm Hg (2). This large variability among studies likely stems from equipment limitations and availability. According to Loenneke et al. (12), cuff width has a significant impact on pressure. A thicker cuff requires less pressure than a thinner cuff, which is probably why the authors theorize that a cuff with a width of 5 cm occludes optimally at 235 mm Hg (for most people) and a cuff with a width of 13.5 cm only requires 144 mm Hg. In real-world settings, quantifying cuff pressure might not be feasible (such as with using elastic raps). In this case, sufficient pressure can be achieved by tightening straps to a moderate perceptive pressure (e.g., 7 on a scale of 0–10) (26).

CONCLUSIONS

This concise review of BFR training studies on athletes suggests that it may impart improvements in muscular strength, hypertrophy, and performance. However, only 9 studies exist on this topic, making concrete conclusions tentative. That said, the available data suggest:

- BFR training elicits benefits in nonathletic and athletic populations.
- BFR training is effective in both male and female athletes.
- BFR training produces positive adaptions using both single and multijoint exercises in athletes.
- Both low-intensity (10–30% 1RM) and high-intensity (70% 1RM) programs seem to be beneficial BFR training intensities for athletes.
- Elastic knee straps and inflatable cuffs both elicit positive adaptations during BFR training (although inflatable cuffs have the ability to quantify occlusion pressure).
- BFR training may be useful as a stand-alone or supplemental program in athletes.
- Sport performance indicators, such as sprint, agility, and $\dot{V}O_2$max can be improved with BFR training in athletes.

Many aspects of BFR training remain unexplored. Future research should investigate the optimal split between BFR and traditional training methodologies, long-term implications of BFR training (past 8 weeks), and where to best integrate BFR in training macrocycles.

PRACTICAL APPLICATIONS

BFR training can effectively increase performance variables in athletes. Coaches and strength and conditioning specialists might benefit by using elastic knee straps as opposed to traditional occlusion cuffs in real-world sports settings (they are easy to use and cost-effective). However, it should be noted that BFR training is relatively new and more research is needed to establish specific recommendations for volume, intensity, frequency, exercise selection, and duration in various athletic populations. Personal exploration and caution should be used before implementing BFR into an athlete's training protocol.

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