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Review

Blood flow restricted exercise for athletes: A review of available evidence

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ABSTRACT

Objectives: This study aimed to collate current evidence regarding the efficacy of various blood flow restriction (BFR) strategies for well-trained athletes, and to provide insight regarding how such strategies can be used by these populations.
Design: Review article.
Methods: Studies that had investigated the acute or adaptive responses to BFR interventions in athletic participants were identified from searches in MEDLINE (PubMed), SPORTDiscus (EBSCO) and Google Scholar databases up to April 2015. The reference lists of identified papers were also examined for relevant studies.
Results: Twelve papers were identified from 11 separate investigations that had assessed acute and adaptive responses to BFR in athletic cohorts. Of these, 7 papers observed enhanced hypertrophic and/or strength responses and 2 reported alterations in the acute responses to low-load resistance exercise when combined with BFR. One paper had examined the adaptive responses to moderate-load resistance training with BFR, 1 noted improved training responses to low-work rate BFR cardiovascular exercise, and 1 reported on a case of injury following BFR exercise in an athlete.
Conclusions: Current evidence suggests that low-load resistance training with BFR can enhance muscle hypertrophy and strength in well-trained athletes, who would not normally benefit from using light loads. For healthy athletes, low-load BFR resistance training performed in conjunction with normal high-load training may provide an additional stimulus for muscular development. As low-load BFR resistance exercise does not appear to cause measureable muscle damage, supplementing normal high-load training using this novel strategy may elicit beneficial muscular responses in healthy athletes.

1. Introduction

Athletes competing in a range of contact and non-contact sports employ resistance training to enhance sport-specific muscular development and subsequent performance.[1,2] Traditional guidelines state that for substantial increases in muscle size and strength, resistance training should be performed using at least 70% of the concentric 1-repetition maximum (1RM).[3] However, increasing evidence supports the use of low-load resistance exercise combined with moderate blood flow restriction (BFR) to facilitate hypertrophic and strength gains.[4,5] This novel strategy involves the use of cuffs placed proximally around a limb, with the aim of maintaining arterial inflow while occluding venous return during exercise.[6,7] While current research agrees that this strategy can promote improvements in muscular size and strength, the definitive mechanisms underpinning these responses have not been fully elucidated.[8–10] The primary mechanisms proposed include increased metabolic stress,[11] increased muscle fibre recruitment,[12,13] cellular swelling,[14] enhanced intramuscular signalling for protein synthesis[15–17] and proliferation of myogenic stem cells,[18] all of which are thought to promote muscular development.

An important benefit of BFR resistance exercise is that relatively light loads can be used to facilitate hypertrophic responses similar to traditional high-load unrestricted resistance training.[4,17,19] This has applications for individuals who may not be able to tolerate the mechanical stresses associated with higher-load resistance exercise.[20] As such, several investigations have focused on

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implementing BFR exercise within older and clinical populations.[21,22] While low-load BFR exercise has obvious implications for athletes during rehabilitation from an injury,[23] using this training strategy for healthy, well-trained athletes has not received as much research attention. With increasing interest in the applications of BFR exercise from strength and conditioning coaches, it is now important to collate current evidence and determine the efficacy of this training method for athletic cohorts. Therefore, the aim of this article was to review the research that has assessed the adaptive or acute responses to BFR exercise in well-trained athletes.

2. Methods (literature search)

During April 2015, an English language search of MEDLINE (PubMed), SPORTDiscus (EBSCO) and Google Scholar databases was performed to identify papers that had employed a BFR intervention for athletic participants. Combinations of the following keywords were used as search terms: 'blood flow restriction'; 'occlusion'; 'athlete'; 'well-trained'; 'hypertrophy'; 'strength'; 'resistance exercise'; 'kaatsu'; 'vascular occlusion'; and 'ischemia'. The reference lists of identified papers were also examined for relevant studies.

Studies were selected based on the following inclusion criteria: (1) the study specifically states that the population investigated was comprised of athletes; (2) BFR was implemented during resistance or aerobic exercise to examine acute or adaptive responses; (3) the full text of the study was available in English; (4) the study was published in a peer-reviewed scientific journal. Thirteen separate papers from 12 investigations were identified. One study was excluded from further review, as the gender of participants and differences in the volume of exercise between groups was not reported.[24]

Due to the low number of investigations published, and the broad range of strategies and methodological approaches used in BFR research, this paper was constructed as a descriptive review article. These studies are summarised in Table 1, and the findings from these investigations are synthesised with the wider body of BFR research using non-athlete populations to provide further information regarding the efficacy of BFR exercise. Practical applications for the use of BFR exercise in athletic participants are also detailed, including recommendations for the implementation of BFR training.

3. BFR training responses in athletes

Several investigations have demonstrated enhanced muscular development in athletes following low-load BFR resistance training. In early research, Takarada et al.[25] examined the effects of resistance exercise combined with BFR in elite rugby players. Participants performed 8 weeks of low-load resistance training (bilateral knee extension twice weekly), comprised of 4 sets to failure at 50% 1RM with 30 s inter-set recovery, either with or without BFR (196 ± 6 mmHg). Following the training period, the BFR group recorded greater increases in isokinetic knee extension torque and muscular endurance than the work-matched control group. Furthermore, cross-sectional area (CSA) of the knee extensors was significantly increased following the BFR training period, though this was not measured in the control training group. Similar findings have been reported for female netball athletes,[26,27] who trained 3 times per week for 5 weeks using bilateral knee extension and flexion (3 sets to fatigue with 30 s inter-set rest at 20% 1RM) with BFR (160–230 mmHg), or performed the equivalent training under systemic hypoxia (arterial oxygen saturation maintained at 80%) or with no additional stimulus (control). Increases in muscular strength, endurance and CSA were observed in the BFR and systemic hypoxia groups, compared to the control.

Collectively, these data demonstrate that significant improvements in muscular strength and size following low-load BFR training are possible in well-trained athletes. An interesting finding from Manimmanakorn et al.,[26] was that these enhanced muscular responses translated into improved performance in sport-specific fitness tests including 5 m sprint, 505 agility, and 20 m shuttle run tests. However, it is unclear whether similar improvements could have been observed if the athletes underwent a traditional resistance training program using heavier loads. Furthermore, it is likely that such changes in performance indicators following BFR training are dependent on the actual performance tests and the type of athlete.[28]

While the inflatable cuffs that are commonly used in research allow for strict control of the BFR stimulus, this equipment may not be practical for athletes training in large groups. Aside from the cost associated with purchasing many specialised BFR cuffs, it is important that the user is trained in how to apply and control the pressure of these cuffs. Therefore, to train large groups at one time using BFR, a more practical method may be necessary to make this training strategy viable. The use of elastic wraps for BFR, often referred to as practical BFR, was first proposed by Loenneke and Pujol[29] and has since been demonstrated to provide a safe, effective and ecologically valid occlusive stimulus for BFR training.[30] While this method of applying BFR does not allow for strict control of the pressure applied to the limb, which could have implications regarding subsequent training responses, its practicality makes this an attractive strategy for athletes. Recently, two separate investigations have demonstrated that low-load BFR training using elastic wraps can produce muscular changes in collegiate American football players.[31,32]

Yamanaka et al.[31] trained Division IA American football athletes with at least 5 years resistance training experience using a 30–20–20–20 repetition scheme for the bench press and squat (20% 1RM and 45 s inter-set rest). Participants performed this low-load training either with or without BFR 3 times per week in addition to their normal off-season strength training sessions for 4 weeks. Following the training period, 1RM for the bench press and squat increased significantly more in the BFR group (7.0% and 8.0%, respectively) than in the control group (3.2% and 4.9%, respectively). Furthermore, significantly greater increases in upper and lower chest girth were measured in the BFR group (3.7 and 2.6 cm, respectively) than the control (1.0 and 1.2 cm, respectively), though there were no differences in girth measurements for the thighs.

More recently, Luebbers et al.[32] employed a similar training protocol for collegiate American football players. Players trained 4 days each week for 7 weeks using an upper- and lower-body split program in one of four groups; (1) traditional high-load training, (2) traditional high-load training supplemented with low-load training, (3) traditional high-load training supplemented with low-load BFR training and (4) modified traditional training (excluding high-load bench press and squatting variations) with low-load BFR training. Supplemental bench press and squat exercises were performed following upper- and lower-body sessions, respectively. Results indicated that the group performing high-load training supplemented with low-load BFR training demonstrated the largest increases in squat 1RM (24.9 kg improvement, compared to 6.0–14.1 kg increase in other groups). This trend was also observed for the bench press, though the results did not reach significance (8.7 kg compared to 2.7–7.3 kg increase in other groups). However, there were no significant changes in post-training girth measurements recorded in any condition. Considering the extensive resistance training history of these participants (7.1 ± 2.2 years), it is possible that the duration of the training intervention was not long enough to significantly differentiate between the groups for the bench press strength. Furthermore, given the propensity of young males to include bench pressing into their