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Utilizing Low-Intensity Blood Flow Restriction Training to Improve Aerobic Capacity in Physically Active and Injured Individuals: A Critically Appraised Topic

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Purpose: To determine if, in physically active individuals, low-intensity Blood Flow Restriction (BFR) training is more effective than training without BFR at improving measures of aerobic capacity. **Methods:** A database search was conducted for articles that matched inclusion criteria (minimum level 2 evidence, physically active participants, comparison of low-intensity BFR to no BFR training, comparison of pre-post testing with aerobic fitness or performance, training protocols >2 weeks, studies published after 2010) by two authors and assessed by one using PEDro scale (a minimum of 5/10 was required) to ensure level 2 quality studies that were then analyzed. **Results:** Four studies met all inclusion criteria. Three of the studies found significant improvements in aerobic capacity (VO_2max) using BFR compared to no BFR. While the fourth study reported significant improvements in time to exertion (TTE) training with BFR, this same study did not find significant improvements in measures of aerobic capacity with BFR training. All compared BFR to non-BFR training. It was noted that high-intensity training without BFR was superior to both low-intensity training with and without BFR with respect to improvements in aerobic capacity. **Conclusions:** Moderate evidence exists to support the use of low-intensity BFR training to improve measures of aerobic capacity in physically active individuals over not using BFR. Clinicians seeking to maintain aerobic capacity in their patients who are unable, for various reasons, to perform high levels of aerobic activity may find low-intensity BFR training useful as a substitution while still receiving improvements in measures of aerobic capacity. ***Key Words:*** *Blood Flow Restriction training (BFR); aerobic capacity, physically active, critically appraised topic.*

CLINICAL SCENARIO

Blood flow restriction (BFR) training has recently become an extremely popular training method.[1,2] BFR training requires the reduction of arterial blood flow to the working muscles while occluding venous return during exercise performance. The theory behind BFR training is that the working muscles undergo an ischemic state (a decrease in both intramuscular oxygen delivery and metabolite clearance) that creates a more stressful muscular environment and ultimately stimulates physical adaptations.[1,3] Prior studies have shown that BFR applied during low-intensity resistance training can produce significant muscle hypertrophy and strength gains similar to that of traditional high-intensity resistance training but using loads as low as 30% of the 1 repetition maximum.[4,5] Resistance training supplemented with BFR has also been shown to elicit joint improvements in both strength and endurance capacity.[6-8] Recent studies have focused more on the combination of BFR and aerobic exercise as an adapted training method for either maintaining or improving aerobic performance in physically active individuals at a lower training intensity.[9-11] Low-intensity aerobic exercise in combination with BFR has been proposed as an efficient single training method to address both strength and endurance in the same exercise session.[10] Improvements in measures of aerobic capacity (such as VO_{2max} or maximal oxygen uptake) are crucial for individuals whom seek to be physically active for longer periods of time, or for individuals seeking maintenance of aerobic capacity when high-intensity training cannot be performed. The ability to maintain or increase aerobic capacity with low intensity effort is critical to those who have experienced periods of inactivity possibly due to injury or in healthy individuals in which detraining has occurred and continued training at a high mechanical load is contraindicated. Due to a lack of studies that have investigated the effects of BFR during low-intensity endurance training, the question remains as to whether BFR applied during low-intensity endurance training has a better effect on measures of aerobic capacity than endurance training without the application of BFR.[11]

FOCUSED CLINICAL QUESTION

In physically active individuals, is low-intensity BFR training more effective than training without BFR at improving measures of aerobic capacity?

SEARCH STRATEGY

Terms used to guide Search Strategy

- **P**atient/Client Group: physically active individuals
- **I**ntervention: low-intensity blood flow restriction training OR low-intensity BFR training
- **C**omparison: no blood flow restriction training OR no BFR training
- **O**utcome(s): aerobic capacity OR VO_{2max} OR VO_{2peak} OR time to exhaustion (TTE)

Sources of Evidence Searched

- PubMed
- MEDLINE
- SPORTDiscus
- EBSCOHost
- Additional resources obtained via review of reference lists and hand search

Inclusion criteria

- Studies with minimum level 2 evidence
- Participants must be physically active
- Comparison of low-intensity BFR training and no BFR training
- Study must compare either pre-post testing assessments of aerobic fitness or aerobic performance (VO_{2max} OR VO_{2peak} OR TTE)
- Studies with a training protocol that lasted a minimum of 2 weeks
- Studies limited to past 10 years (2010 – 2020)

Exclusion criteria

- Studies performed over 10 years ago
- Not available in English language
- Examined only acute effects of BFR training during a single exercise session
- No mention of physically active individuals, aerobic capacity, comparison of low-intensity BFR training and no BFR training, or pre-post testing assessments of aerobic fitness or performance
- Level of evidence below 2

EVIDENCE OF QUALITY ASSESSMENT

Multiple databases were used to conduct a literature search in November 2019 to find high-quality studies that investigated the present question. Two authors (MM, KS) independently conducted the outlined search strategy using the specified search terms in the Boolean phase format and appraised the articles that satisfied the inclusion and exclusion criteria. Studies were assessed by one author (MM) using the Physiotherapy Evidence Database (PEDro) scale for randomized controlled trials, and categorized as a level 2 quality study, per the center for evidence-based medicine (CEBM) levels of evidence.

RESULTS OF SEARCH

A total of 4 relevant studies were identified and categorized as shown in Table 1 (based on Levels of Evidence, Centre for Evidence Based Medicine, 2011).[9-12]

Level of Evidence	Study Design/Methodology of Articles Retrieved	Number Located	Author (Year)
2	Randomized Control Trial	4	Abe et al[9] De Oliveria et al[10] Held et al[11] Kim et al[12]

Table 1. Summary of Study Designs of Articles Retrieved

Summary of Search, "Best Evidence" Appraised, and Key Findings

- The literature was searched for studies of level 2 evidence or higher [based on the Oxford Centre for Evidence-based Medicine 2011 Levels of Evidence (OCEBM)] that investigated the effect of low-intensity BFR training versus no BFR training on measures of aerobic capacity in physically active individuals.
- The literature search returned 7 possible studies related to the focused clinical question; 4 studies met the inclusion criteria and were thus included (Figure 1).[9-12] A summary of the included studies is presented in Table 2.
- The four studies were parallel group design randomized control trials (RCTs).[9-12]
- Three studies reported that there were significant improvements in measures of aerobic capacity (VO_{2max}) when using low-intensity BFR training versus not using BFR training.[9-11]
- One study reported significant improvements in exercise TTE training with BFR compared to no BFR use.[9]
- One study reported that there were significant improvements in aerobic capacity when using low-intensity BFR training versus low-intensity training without BFR.[10] However, high-intensity training without BFR showed greater improvements in aerobic capacity when compared to low- and high-intensity training with BFR.[10]
- One study reported that there were no significant improvements in measures of aerobic capacity when using low-intensity BFR training versus not using BFR training.[12]

RESUTLS OF EVIDENCE QUALITY ASSESSMENT

The studies included were identified as the 'best' evidence and selected for inclusion in the CAT analysis in accordance with the established inclusion and exclusion criteria, and due to the outcomes of aerobic capacity assessed. Selection of these studies best compared the use of BFR to no BFR use for the improvement of aerobic capacity during training at low intensities. Validity of the included studies was determined by the author's score using the Physiotherapy Evidence Database (PEDro) checklist for randomized controlled trials. The scores of 5/10 on the PEDro scale indicate the studies were of "fair" quality.[13] Rankings of the studies consistently missed scores for concealment of allocation and blinding of subjects and assessors.

	Abe et al.[9]	de Oliveira et al.[10]	Held et al.[11]	Kim et al. [12]
Study Design	Randomized Control Trial	Randomized Control Trial	Randomized Control Trial	Randomized Control Trial
Participants	19 physically active men (mean age: 23.0±1.7yr, **BFR-training:** n = 9; **CON-training:** n = 10) Subjects were eligible if they were physically active men, not participating in regular strength/resistance and/or aerobic training for a minimum of one year prior to the study and did not suffer from a chronic disease. Subjects were randomized to one of two groups: BFR-training or non-BFR control training group.	37 recreationally active subjects [mean age: 23.8±4yr, **HIT:** n = 10 (men: 7, women: 3); **HIT+BFR:** n = 10 (men: 3, women: 7); **BFR:** n = 10 (men: 8, women: 2); **LOW:** n = 7 (men: 4, women: 3)] Subjects were eligible if they were recreationally active and healthy with no known musculoskeletal or cardiorespiratory disease, not taking any medications known to affect the cardiorespiratory system, and not involved in resistance or endurance training programs at the time of the study. Subjects were randomized to one of four training groups: high-intensity interval training, combined high-intensity interval training with BFR, low-intensity interval training with BFR, or low-intensity interval training without BFR group.	31 elite rowers [**INT:** n = 16 (men: 12, women: 4; mean age: 21.9±3.2yr); **CON:** n = 15 (men: 11, women: 4; mean age: 21.7±3.7yr)] Subjects were eligible if they were elite rowers that had not reported any health impairments at the time of the study. Subjects were randomized to one of two groups: intervention (practical blood flow restriction (pBFR) group) or control group.	31 physically active college-aged men (mean age: 22.4±3.0yr, **VI:** n = 10; **LI-BFR:** n = 11; **CON:** n = 10) Subjects were eligible if they were physically active college-aged men and had not participated in a regular endurance or resistance exercise program for at least 4 months prior to the study. Subjects were randomized to one of three groups: vigorous-intensity cycling, low-intensity cycling with BFR, or no exercise control group.
Intervention Investigated	Cycle training protocol was performed on an electronically braked bicycle ergometer 1x/ day, 3days/week, for a total of 8weeks of training. Throughout the training period, both exercise intensity and duration remained constant in each group. **BFR-Training Group:**	Cycle training protocol was performed on a stationary cycle ergometer 3x/week over a total of 4weeks of training. Subjects warmed up for 5mins at 30% of Pmax prior to each training session. Each training session included 2 sets of 5 repetitions for the first 3 sessions that lasted 2min and was interspersed by 1min	Endurance rowing training protocol was performed in the boat and on the rowing ergometer 3x/week over a total of 5weeks of training. Throughout the 5week training period, both groups had the same training intensities, frequencies, and volumes. Both groups completed rowing training (low intensity	Cycle training protocol was performed 3x/week over a total of 6weeks of training. Subjects warmed up for 5mins on a stationary cycle ergometer prior to each training session. All subjects completed a 3week detraining period after completion of the 6week training period.

	Subjects performed cycle exercise training with pressure belts on both legs at a 40% of VO_2max for 15min. A belt pressure of 160-210 mmHg was selected and blood flow to the legs was restricted for a total of ~18min (~3min preparation time added to 15min cycling duration) during each training session. The belt pressure was released immediately at completion of training session. **CON-training Group:** Subjects performed cycle exercise training without the use of pressure belts on both legs at a 40% of VO_2max for 45min.	of passive rest. Thereafter, 1 repetition was added each week. Between sets the rest interval was 5min (3min active recovery at 30% Pmax followed by 2min of passive rest) **BFR Group:** Subjects performed cycle exercise training at low intensity with pressure cuff belts on the proximal portion of the both thighs at a ~30% Pmax. Pressure cuff belts were inflated to 140mm Hg in the first week of training during the 2min reps and deflated during the 1min periods of rest. Pressure was increased by 20mm Hg increments after 3 completed sessions. During week 4, the training pressure was 200mm Hg. **LOW Group:** Subjects performed cycle exercise training at low intensity without BFR at a ~30% Pmax. **HIT Group:** Subjects performed cycle exercise training at a variable power output without BFR. Each rep began at 110% Pmax with incremental decreases in intensity by 5% every 30sec (110%. 105%, 100%, 95% Pmax) **HIT+BFR Group:** Subjects performed cycle exercise training with combined HIT and BFR; thus, every session performed 50% as HIT (one set)	= 65% of HRmax and the first lactate threshold; moderate intensity = intensity between the first and second lactate threshold; high intensity = intensity above the second lactate threshold), cross training (running and cycling), and strength training to the same extent. **Intervention Group (INT):** Subjects performed boat-training and indoor-rowing training with pBFR elastic knee wraps on the proximal portion of the upper thighs. pBFR was only applied for two 10 min sessions interspersed with a 10min break. **Control Group (CON):** Subjects performed boat-training and indoor-rowing training without the use of pBFR elastic knee wraps on the proximal portion of the upper thighs.	**LI-BFR Group:** Subjects performed cycle exercise training with the use of elastic cuffs at the proximal portions of the thighs at a 30% of heart rate reserve (HRR) for 20min. Training pressure started at 160 mmHg. Pressure was increased by 20mmHg increments after the first 3weeks. During weeks 4-6, the final arbitrary training pressure was 180 mmHg. **VI Group:** Subjects performed 20min of cycle exercise training at 60% HRR for the first 3 weeks and at 70% HRR for the final 3weeks of training. **CON Group:** Subjects were asked not to participate in any structured exercise over the 6week training period.

		and 50% as BFR (the other set). At every session, the order of sets was alternated.		
Outcome Measures (Primary and Secondary)	**Primary Outcome:** Thigh and quadriceps muscle cross-sectional area and volume, VO_2max **Secondary Outcome(s):** Isometric knee extension and flexion strength, specific tension of quadriceps (qCSA)	**Primary Outcome:** onset blood lactate accumulation (OBLA), VO_2max, maximal power output (Pmax), isometric knee extension strength **Secondary Outcome(s):** magnitude of the training-induced changes between BFR and HIT	**Primary Outcome:** VO_2max **Secondary Outcome(s):** squat one-repetition max (SQ1RM)	**Primary Outcome:** Thigh muscle cross-sectional area (mCSA), body composition, concentric isotonic one-repetition maximum muscle strength for knee extension and flexion, and aerobic capacity (VO_2peak) **Secondary Outcome(s):** respiratory exchange ratio (RERpeak), HRmax
Main Findings	Absolute (and relative) VO_2max increased from pre- to post-training periods for the BFR-training group (6.5%, $p < 0.05$) but was unchanged for the CON-training group. Time until exhaustion increased from pre- to post-training periods for the BFR-training group (15.4%, $p < 0.01$), but was unchanged in the CON-training group. Muscle CSA increased from pre- to post-training periods for the thigh (3.4%, $p < 0.01$) and the quadriceps (4.6%, $p < 0.01$) in the BFR-training group but was unchanged in the CON-group. Maximal isometric knee extension strength tended to increase in the BFR-training group (7.7%, $p < 0.10$) but not in the	VO_2max increased from pre- to post-training periods for the BFR group (5.6 ± 4.2%, P = 0.006, ES = 0.33), HIT group (9.2 ± 6.5%, P = 0.002, ES = 0.9), and HIT + BFR (6.5 ± 5.5%, P = 0.03, ES = 0.33). VO_2max and Pmax was unchanged in the LOW group (0.4 ± 4.7%, P = 0.75 and 1.6 ± 3.9%, P = 0.34, respectively) OBLA increased from pre- to post-training periods for all groups: BFR group: 16 ± 13%, ES = 0.43; LOW group: 6 ± 4%; HIT group: 25 ± 13%, ES = 1.8; HIT + BFR group: 22 ± 12%, ES = 0.7. Pmax increased from pre- to post-training periods for the BFR group (11.7 ± 4.7%, P < 0.001, ES = 0.44), HIT group (15.0 ± 4.5%, P < 0.001, ES = 1.5), and HIT + BFR	VO_2max significantly increased from pre- to post-training periods for the INT group (+9.1± 6.2%, P < 0.001, ES = 1.335). There were no significant increases in VO_2max for the CON group (+2.5± 6.1%, ES= 0.3). VO_2max showed no significant time effect ($p = 0.320$, $n_p^2 = 0.035$) but did show a significant group×time interaction effect ($p = 0.004$, $n_p^2 = 0.256$) in favour of the INT group. SQ1RM increased for both the INT group (+5.4 ± 5.7%, P > 0.05, ES = 0.794) and CON group but were not significant (+4.6± 5.3%, P > 0.05, ES = 1.001).	On average, VO_2peak increased in the VI group between pre- to post-training periods (5.25%, $p < 0.05$) and between pre- and 3week-post training periods (6.68%, $p < 0.05$), in the LI-BFR group between pre- to post-training periods (1.96%, $p < 0.05$) and between pre- and 3week-post training periods (-1.23%, $p < 0.05$), and in the CON group between pre- to post-training periods (-1.17%, $p < 0.05$) and between pre- and 3week-post training periods (-2.57%, $p < 0.05$). VO_2peak did not show a significant group×time interaction ($p = 0.081$), group ($p = 0.500$), or time ($p = 0.356$) main effect. For both VI and LI-BFR groups, knee flexion strength was increased significantly

	CON-training group (1.4%, $p < 0.10$).	group (10.9 ± 4.5%, $P < 0.001$, ES = 0.39). T-test for isometric strength showed a significant increase only for the BFR group (11.4 ± 7.3%, $P < 0.001$, ES = 0.66). There was no difference demonstrated for the other groups.		between pre- and post- training periods ($p = 0.024$, $p = 0.01$) and between pre- and 3week-post training periods ($p = 0.039$, $p = 0.003$), respectively. For the LI-BFR group, leg lean mass was increased significantly between pre- and 3week -post training periods ($p = 0.024$) and between post- and 3week-post training periods ($p = 0.013$).
Level of Evidence	2	2	2	2
Validity Score	PEDro 5/10	PEDro 5/10	PEDro 5/10	PEDro 5/10
Conclusion	There was a significant increase in aerobic capacity and thigh muscle volume in young men for low-intensity (40% VO_2max) cycling BFR training of short duration (15min) compared to the control group.	Low-intensity interval BFR training over a 4week period showed significant improvements in VO_2max, Pmax, OBLA, and muscle strength. Over the same 4week training period, both the HIT and HIT + BFR groups only induced improvements for aerobic variables, with the HIT group having a higher effect size compared to that of the low-intensity interval BFR training and HIT + BFR groups. There were no significant changes in VO_2max and Pmax for the LOW group, who performed identical training to the low-intensity interval BFR training group, but without the use of BFR.	The pBFR training group showed considerable increases in VO_2max for elite rowers compared to that of the control group. There were no significantly beneficial effects on strength (SQ1RM) for the pBFR training group.	Low-intensity cycling with BFR did not show better responses in VO_2peak, bone-free lean body mass, fat mass, and knee extension muscle strength compared to the vigorous intensity cycling and no exercise control groups. Also, the responses in the low-intensity cycling with BFR group had a tendency to mimic the responses seen in the vigorous intensity group after 6weeks of training and the gains seemed to remain during the 3weeks of detraining.

Table 2. Characteristics of Included Studies

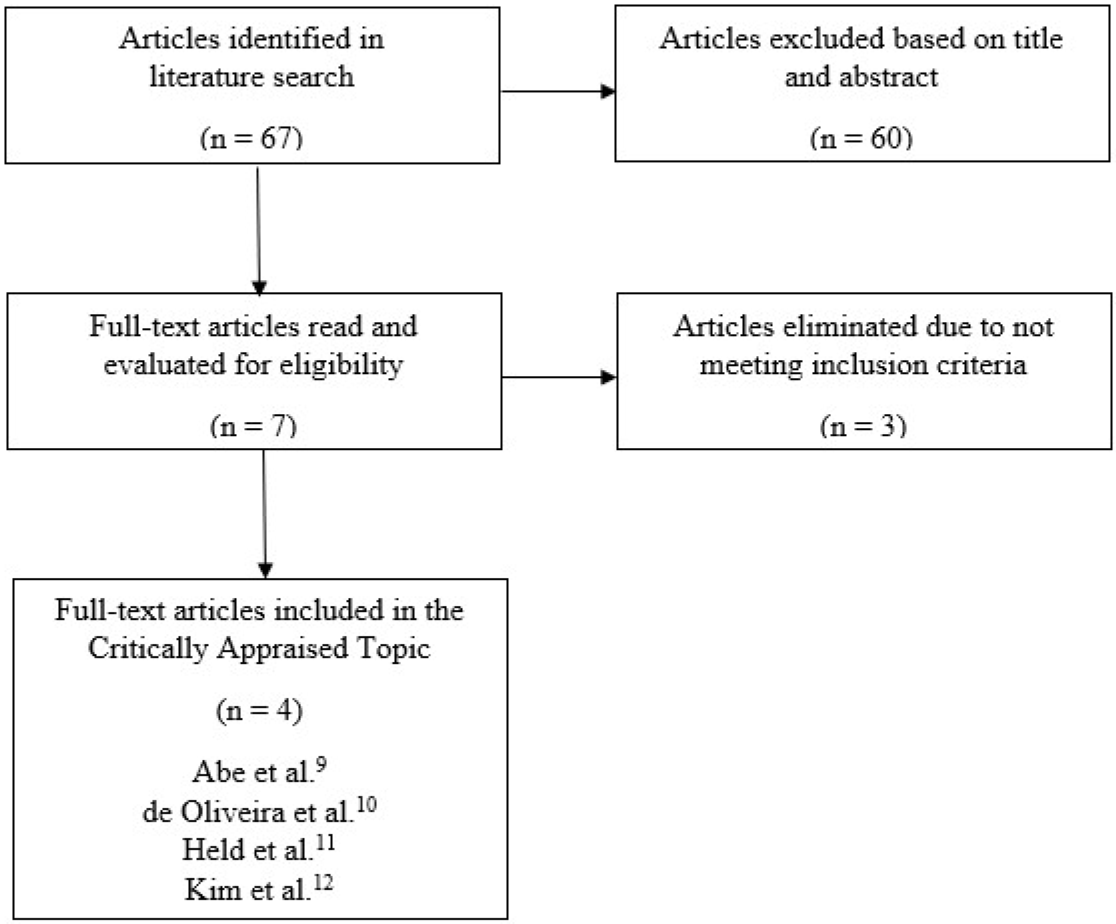

Figure 1. Summary of Search History and Included Studies

CLINICAL BOTTOME LINE

There is moderate evidence to support the use of low-intensity BFR training to improve measures of aerobic capacity over not using BFR training in healthy physically active individuals. Three of the studies found significant improvements in aerobic capacity using BFR compared to no BFR by measures of VO_{2max}, TTE, while only one study did not observe significant differences among BFR conditions. [9-12] However, this comes from a limited number of studies in which only one included participants that were healthy, elite rowers, and the participants in the other studies were all healthy and recreationally active, but untrained and not currently involved in regular strength or endurance training for several months prior to study participation.[9-12] Results in studies may vary based on data of highly conditioned elite athletes versus those who are active but untrained. Additionally, as none of these studies compared aerobic capacity benefits with the use of BFR in injured subjects, it is cautioned to generalize these findings to an injured population.

This has implications for clinicians seeking to maintain aerobic capacity in their healthy patients where high mechanical or high intensity loading is contraindicated or impractical. Many circumstances present that prohibit the use of high intensity endurance training such as returning from an illness or a healed injury. Additionally, periodization schedules during training of healthy individuals, or travel schedules in athletes may also prohibit bouts of high-intensity aerobic training. In such circumstances the use of low-intensity BFR can be implemented as a substitute where high-intensity training may not be possible yet receive improvements in measures of aerobic capacity.

STRENGTH OF RECOMMENDATION

Collectively, the studies included in this review received a consistent level 2 OCEBM evidence in support of low-intensity BFR training at improving measures of aerobic capacity in physically active individuals. Our recommendation is based on inconsistent evidence, the limited quality of patient-oriented evidence, and well-designed randomized controlled clinical trials at this time.

IMPLICATIONS FOR PRACTICE, EDUCATION, AND FUTURE RESEARCH

The results of this critically appraised topic support the evidence that low-intensity BFR training is more effective than no BFR training at improving measures of aerobic capacity in the physically active population. Specifically, low-intensity aerobic exercise in combination with BFR was more effective at improving aerobic capacity than that of low-intensity aerobic exercise alone.[9-11] de Oliveira et al found that low-intensity interval training with BFR had significant improvements in measures of aerobic capacity (5.6 ± 4.2%, $P = 0.006$, ES = 0.33) compared to that of just low-intensity interval training (0.4 ± 4.7%, $P = 0.75$).[10] However, high-intensity interval training alone without BFR (9.2 ± 6.5%, $p = 0.002$, ES = 0.9) and high-intensity training with BFR (6.5 ± 5.5%, $P = 0.03$, ES = 0.33) showed greater improvements in aerobic capacity than that of low-intensity BFR training. Interestingly, training with BFR at both high and low intensities resulted in similar improvements in VO_{2max}. Based on this study, a practical implication would be that low-intensity BFR training is not a suitable replacement for high-intensity training alone in healthy or non-injured individuals; however, training at low-intensity with BFR may be a suitable replacement during training periods where high-intensity work is contraindicated.[9-11]

It is important to keep in mind that the subjects used in these selected studies were all healthy and physically active; thus, the results may be different for individuals that are unhealthy or sedentary in nature. Also, although the aim of this critically appraised topic was to observe aerobic fitness changes in physically active individuals using BFR as an adjunctive modality, it is important to note that one of the studies observed physically active individuals who compete at an elite level.[11] Held et al. investigated elite rowers who trained at a low intensity endurance rowing (in the boat and on a rowing ergometer) with and without BFR.[11] Subjects in the intervention group used BFR at low intensity rowing for two 10-minute sessions three times per week for a total of 5 weeks of training. All subjects completed identical low, moderate, and high intensity training sessions over the course of the study period. Those in the BFR intervention group significantly improved VO_{2max} from 63.0 ± 7.0 ml/min/kg to 69.7 ± 9.4 ml/min/kg (an increase of +9.1 ±6.2%) ($p < 0.001$; ES = 1.335) whereas the non-BFR training group only experienced +2.5 ± 6.1% change between pre and post testing. The significant changes with strong effect sizes support positive outcomes in improving aerobic capacity in athletes that already have a high level of endurance capacity. The results of this study suggest that elite-level endurance athletes may find additional aerobic benefits when using BFR as an adjunctive training tool to their current training regime.

Of the three studies that observed physically active individuals who were non-competitive, the subjects were included based on the fact that they did not engage in a regular resistance or endurance programs prior to the start of their studies (physically active but not current consistently trained).[12] Recreationally active individuals, as previously mentioned in the de Oliveira et al study, and physically active individuals (those not participating in regular strength and/or aerobic training, ie; less than once a week) found positive increases in aerobic capacity using BFR training at low intensities.[10] Abe et al. demonstrated significant improvements in VO_{2max} (6.4%) and exercise TTE (15.4%) in the BFR-training group ($p < 0.05$) but no changes noted in the non-BFR training control group (−0.1 and 3.9%, respectively).[9] Due to the fact that the subjects in these studies were physically active and 'non-trained', and improved their VO_{2max} significantly while using BFR, gives promise to untrained or injured individuals who wish to maintain or increase levels of aerobic capacity without placing themselves at risk of an overuse injury or when high level intensity training is not possible.[9,10] Likewise, individuals who experience significant inactivity due to surgery or illness, and experience a significant level of detraining can improve aerobic capacity with low-intensity aerobic exercise with BFR significantly more than low-intensity training alone.

One study included in this analysis did not find positive improvements in aerobic capacity using BFR.[12] Kim et al did not find significant improvements in aerobic capacity for any of the study groups investigated.[12] Subjects either performed vigorous-intensity cycling on an ergometer, low-intensity cycling with BFR, or a non-exercising control. There was no significant group X time interaction ($p = 0.081$), group ($p = 0.500$), or time ($p = 0.356$) main effect for peak VO_{2max}. Peak VO_{2max} increased 5.25% pre-post in the vigorous-intensity cycling group, 1.96% in the low-intensity cycling and BFR group, -1.17% in the control. Potential reasons for non-significant findings were related to poor estimations of exercise intensity based on the utilization of a heart rate reserve (HRR) percentage. The authors speculate that the intensities selected may have been too low to improve aerobic capacity. Additional discrepancies may be due to differences in the duration of exercise sessions, and length of the training period.[12]

While three of the four randomized controlled trial studies included in this appraisal showed support for the use of BFR with low-intensity training to improve aerobic capacity, a recent systematic review suggested that the combination of BFR with aerobic exercise training can elicit improvements in aerobic performance regardless of training intensities.[14] Additionally, another recent systematic review found that aerobic exercise training performed with BFR significantly improves aerobic capacity more than exercising without BFR.[15] While these two studied are considered level 1 evidence, and both provide strong support for the use of BFR to improve aerobic capacity, they were not included in our appraisal as they contained randomized control trial studies in their analysis that did not fit our specific criteria for physically active populations and exercise protocols at low intensities.

Although the results of our appraisal are more in support of low-intensity BFR training as an effective training modality for improving aerobic capacity, there are some limitations of the selected studies, as they all vary in the treatment dosages applied. Occlusion pressures ranged from 160-200 mm Hg, 140-200 mm Hg, to 160-180 mm Hg with one study utilizing a practical BFR technique in which an elastic wrap was applied to the upper thigh at a 75% maximum stretch.[9-12] Training frequency was consistent among all the studies at 3 times per week, but the duration of training varied from 4, 5, 6, and 8 weeks.[9-12] Additionally, training intensities varied from cycling for 15 minutes at 40% VO_{2max}, 20 minutes at 30% HHR, to 2 sets of 5 repetition repeats (alternating 120 seconds of cycling exercise at 30% maximum power output with 60 seconds of rest between repetitions) for the Low-intensity BFR condition, and a High-intensity BFR training beginning with 110% maximum power output with 5% progressive decline in intensity every 30 seconds.[9-10,12] Held et al employed rowing training at 65% maximum HR for two 10 minutes training sessions with BFR with a 10 minute rest between sessions.[11]

The one study that did not find any differences between the BFR and control conditions cited potential discrepancies in results due to the use of HRR to set the intensity of exercise for the experimental groups indicating that the exercise intensity may have been too low in low-intensity BFR group to improve aerobic capacity.[12] Kim et al also used a resting brachial blood pressure to determine the restrictive pressures that were to be used on the thigh during BFR training.[12] A resting brachial blood pressure is not a good predictor of arterial occlusion to the thigh.[12] Additionally, based on this predictor, a uniform restrictive pressure (160-180mm Hg) for BFR training was used; however, for individuals that have different thigh sizes, a uniform restrictive pressure may not be appropriate and some subjects may have received more or less of a stimulus during training based on the size of their thighs.

Future research studies would benefit from including different study designs (cohort and prospective) and larger sample sizes in an effort to increase generalizability to the physically active population. Additionally, of the selected studies for this critically appraised topic, there were more physically active male subjects than female subjects included. Of the four studies included, two studies focused on only physically active men, while the other two studies observed both physically active males and females, but both had relatively more men than women within each group.[9-12] Future research on this topic should focus on including more women to increase generalizability of the results to a greater population.

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