OPEN ACCESS

Exercise and Quality of Life Journal
DOI: 10.31382/preprint.000005

REVIEW ARTICLE

Blood flow restriction endurance exercise and endurance performance in athletes

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Received: 30. January 2025 | Accepted: 21. April 2025 | Published: 22. April 2025

Abstract

The development and advancement of sports training over time have been accompanied by continuous innovations, which significantly contribute to improving athletic performance. In this process, research has played a crucial role in understanding the effectiveness of various training methods, including blood flow restriction (BFR) exercise, which is increasingly gaining attention due to its potential to enhance athletic performance. BFR training can be implemented in both: resistance exercise and endurance exercise. The studies discussed indicate a growing interest in the application of BFR through endurance type of exercise to enhance aerobic capacity. This narrative review examined the role of BFR training in enhancing endurance performance by reviewing relevant literature. We performed a comprehensive search on PubMed and Google Scholar using keywords such as "Blood Flow Restriction," "endurance exercise," "aerobic capacity," and "athletes." The focus was on peer-reviewed articles published in the last decade that investigated the effects of BFR training on endurance and aerobic capacity, specifically within athletic populations. Studies included in this review were selected based on their relevance to BFR training and its impact on endurance performance, while those not directly related to BFR or involving non-athlete populations were excluded. Key findings concerning BFR training protocols and their impact on endurance metrics were summarized. This review aims to provide an overview of the current evidence regarding the effectiveness of BFR training in endurance exercise and its potential implications for optimizing athletic performance. These investigations adopting BFR training show promising results, with several studies reporting significant improvements in key physiological parameters such as maximal oxygen consumption (VO2 max) and muscular endurance. Overall evidence suggests that integrating BFR training into endurance exercise training regimens holds potential for optimizing aerobic capacity in athletes.

Keywords: blood flow restriction · aerobic capacity · endurance exercise · athletes

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EQOL Journal
Exercise and Quality of Life

Abbreviations:
BFR = blood flow restriction
VO2 max = maximal oxygen consumption
OBLA = onset of blood lactate accumulation
BFR-EE = blood flow restriction endurance exercise
HIIT = high intensity interval training
AOP = arterial occlusion pressure

1.0 Introduction

The development and advancement of sports training over time have been accompanied by continuous innovations, which significantly contribute to improving athletes' performance. In this process, research has played a crucial role in understanding the effectiveness of various training methods, including innovative blood flow restriction (BFR) type of training, which is increasingly gaining attention due to its potential to enhance athletic performance (Cook et al., 2014; Doma et al., 2020).

The BFR method involves the use of a restrictive device, most commonly an inflatable cuff, that is applied to the proximal part of a limb to reduce arterial blood flow and prevent venous return (Wilk et al., 2018). This compression leads to inadequate oxygen supply (hypoxia) within the muscle cell. Achieving the correct pressure for occlusion is critical for effective BFR training. Typically, the pressure is set as a percentage of the arterial occlusion pressure (AOP), which is determined using a handheld doppler ultrasound or similar device to identify the pressure at which arterial blood flow is completely occluded. Common percentages used include 40% to 80% of AOP, depending on the specific protocol and individual tolerance (Wilk et al., 2018). When the supply of oxygen is limited due to the hypoxic environment created by BFR, muscle cells must shift toward anaerobic pathways to generate ATP, which are less efficient and produce lactate as a byproduct (Behrendt et al., 2023).

BFR type of training has gained considerable attention in recent years as elicit similar adaptations as higher-load type of exercise training. This is particularly beneficial for older individuals and those with injuries who cannot tolerate the higher mechanical stress caused by high-intensity exercise (Centner et al., 2019). The effects of BFR training on muscle strength and hypertrophy are well researched, with extensive literature available in the form of systematic reviews and meta-analyses (Centner et al., 2019; Rolnick et al., 2020). For the purpose of gaining strength and induce hypertrophy in the skeletal muscle, BFR is typically performed in combination with resistance training between 20 and 40% of one repetition maximum (Lixandrão et al., 2015).

On the other hand, BFR training can also be performed in combination with endurance type of exercise to improve markers of aerobic capacity such as maximal oxygen uptake (VO2max), onset of blood lactate (OBLA) and running economy (RE). Generally, VO2max is expressed in millilitres of oxygen per kilogram of body weight per minute (ml/kg/min) and represents the highest rate at which the body can transport and utilize oxygen during physical exertion. Whereas OBLA is the exercise intensity at which blood lactate production exceeds clearance, indicating a shift from aerobic to anaerobic metabolism during volitional exercise. Lastly, RE can be defined as the energy demand for a given velocity and expressed as VO2 at a given velocity. Collectively, these markers are robust predictors of endurance exercise performance (McLaughlin et al., 2010).

Recent reviews have identified a growing body of evidence supporting the use of BFR in combination with endurance-type exercise (BFR-EE) as a viable strategy to enhance both cardiovascular and muscular performance in athletes. For example, Muller et al. (2024) demonstrated that aerobic training with BFR can lead to greater improvements in muscle hypertrophy and strength than aerobic training alone. Similarly, Yang et al. (2024) reported that BFR training improved multiple fitness parameters in athletes, including endurance, strength, and body composition. Yin et al. (2025) further emphasized that interval training combined with BFR significantly enhanced VO2 max and sprint performance, particularly when training protocols were tailored to individual athlete characteristics.

Nevertheless, there is still paucity of evidence in relation to BFR endurance type of training (BFR-EE) and its impact on VO2 max, OBLA and RE and endurance exercise performance. Therefore, this review aims to elucidate the empirical evidence surrounding BFR training and its application in the context of endurance exercise training to improve athletic performance.

1.1 BFR and endurance exercise

BFR-EE is typically performed during activities such as walking (Sugimoto et al., 2021; Clarkson et al., 2017), cycling (Behrendt et al., 2023; Gonzales et al., 2024), and running (de Queiros et al., 2024;

Paton et al., 2017). The intensities used during BFR-EE vary, ranging from 40 % of VO2 max (Abe et al., 2010; Conceição et al., 2019) to 45 % -70 % heart rate reserve (Amani et al., 2018; Chen et al., 2022), which is the difference between maximum heart rate and resting heart rate, and in some cases have not been standardized (Clarkson et al., 2017; Park et al., 2010). BFR-EE has proven to be effective in improving strength and hypertrophy in both young and older populations through systematic reviews and meta-analyses (Centner et al., 2019; Slysz et al., 2016). Additionally, in a study involving 19 sedentary older man and woman, 24 walking training sessions of low-intensity using BFR were implemented, comprising 4 training sessions per week. Both BFR and control group performed 10 min walking at 4 km/h. Following six-week intervention, BFR-EE resulted in 2.5-4.5-fold greater improvement in performance on all measures of physical function compared with control group among these older adults (Clarkson et al., 2017). This demonstrates how can addition of BFR increase the quality of simple walking exercise for populations that may be contraindicated to heavy-load resistance training.

The impact of BFR type of training on endurance exercise capacity has been investigated by several research groups (Paton et al., 2017; Amani et al., 2018; de Oliveira et al., 2016; Held et al., 2020). For instance, the effects of BFR training were examined in a four-week study involving 37 young individuals who participated in four different interval-training protocols. The study showed that four weeks of low-intensity BFR-EE improved VO2 max by 6-9 %, OBLA by 16-25 %, and muscular strength by 11-15 % (de Oliveira et al., 2016). Similar results were also observed in trained individuals (Amani et al., 2018; Held et al., 2020). For instance, BFR-EE was demonstrated to improved VO2 max in endurance athletes by 9% more than in the control group (Held et al., 2020). In addition to these changes, BFR-EE can also lead to significant improvements in endurance performance in young (Formiga et al., 2020), older (Clarkson et al., 2017), and even athletic populations (Park et al., 2010).

Recent evidence continues to support the use of BFR-EE in enhancing endurance-related parameters in athletes across different performance levels and disciplines. A meta-analysis by Castilla-López et al. (2022) reported that the inclusion of BFR in training sessions led to consistent improvements in key endurance metrics, including a 7 % increase in VO2 max, 24 % in RE, 17 % in time to exhaustion, and 58 % in sport-specific performance. Noteworthy, however, among trained athletes, these enhancements are not superior to those observed after the same training sessions without BFR. It is important to note the limitations of this study, including the reduced number of studies, small sample sizes, and concerns regarding the risk of bias. Ultimately, however, a recent meta-analysis examined the effects of BFR on overall sport performance in athletes and reported improvements in VO2 max ranging between 3.6 and 11.6 % (Li et al., 2024). Complementing these findings, a more recent meta-analysis by Dong et al. (2025), focusing specifically on athletic populations, concluded that BFR-EE induces moderate improvements in VO2max and substantial gains in lower limb strength, while its effects on anaerobic power and sport-specific performance appear relatively modest. Together, these findings suggest that BFR-EE may be particularly effective when the primary goal is to improve aerobic capacity and muscular strength, especially in scenarios where high mechanical loading is not feasible or desirable.

The meta-analysis suggests that endurance exercise training with BFR leads to significantly greater improvements in aerobic capacity compared to endurance exercise without BFR, especially at low-to-moderate intensity levels. However, this enhancement is not observed with high-intensity aerobic exercise (Held et al., 2020). Despite BFR-EE being somewhat inferior to high intensity interval training or HIIT, VO2 was greater during BFR-EE compared with EE without BFR, indicating that this training method could replace HIIT and still significantly increase VO2 max (Silva et al., 2021).

2.0 Impact of BFR-EE on endurance performance in athletes

To improve transparency, the studies included in this narrative review were identified through a systematic search of PubMed and Google Scholar using keywords related to BFR, endurance exercise, and athletic performance. Studies were included if they reported specific performance or physiological outcomes (e.g., VO2 max, lactate threshold, running economy). Only peer-reviewed articles involving trained or elite athlete populations were considered. Notably, the application of BFR in the context of endurance exercise is a relatively recent area of investigation, and therefore, all relevant studies were published within the last 15 years. Participant selection within the included studies typically involved trained or elite athletes, and in most cases, inclusion criteria were based on years of training experience or sport-specific competition level.

Variables such as VO2 max were measured using indirect calorimetry, while performance metrics were derived from time trials or sport-specific tests. A narrative review was chosen due to the heterogeneity in study designs, BFR protocols, and outcome measures, allowing for more flexible and context-rich interpretation of the findings.

Research on the impact of BFR on endurance performance in athletes is still a relatively unexplored area. One of the early studies involved an intervention with 12 elite college basketball players, which involved walking with BFR compared to a control group without BFR (Park et al., 2010). All participants began the same walk training which comprised five bouts of 3-min walking (4 km/h at 5% grade) on a treadmill and with 1-min rest between walk-sets. The walking speed was increased up to 6 km/h in the BFR-walk group, while it remained constant throughout the training period in the control group. Over a 2-week period, participants engaged in 6 weekly training sessions. The BFR group reported significant improvements in VO2 (11.6%) and maximal minute ventilation (10.6%), while the control group did not show improvement. Based on findings of this study, it is suggested that BFR walk training could be beneficial in the rehabilitation of athletes seeking to maintain or enhance endurance (Park et al., 2010). However, one limitation of this study was the absence of individualized prescription of walking speed for participants. By relying on absolute values instead of considering individual fitness levels or abilities, the study may not adequately address potential variations among participants, potentially constraining the applicability of the findings to a broader population of athletes.

Later on, a 2-week study involving 20 young soccer players with at least 7 years of playing experience was conducted by dividing them into three groups: a control group, a group that performed the intervention with BFR, and a group that performed the intervention without BFR. The intervention consisted of 3 sets (first week) and 4 sets (second week) of 400 meters with 60-80 seconds of rest at 60-70% of maximum heart rate reserve. The group of researchers found that VO2 max significantly increased in both intervention groups. However, the BFR group reported greater gains in VO2 max (+ 3.7 %) compared to the non-BFR group (+ 1.4 %). This study has shown that using BFR-EE can improve VO2 max without manipulating the distance and speed of training (intensity factors during aerobic energy system training) (Amani et al., 2018).

In 2020, a study involving 31 elite rowers was conducted to assess the impact of BFR on endurance performance. The intervention was sport-specific, as both groups, the BFR group and the control group, engaged in low-intensity rowing training. The intervention lasted for 5 weeks, with 3 training sessions per week for both the BFR group and the control group. During the training sessions, the BFR group wore cuffs on their lower limbs for 2 sets of 10 minutes with a 10-minute rest in between. The results showed significant improvements in VO2 max for the BFR group (+ 9.1 %) compared to the control group (+ 2.5 %). The study concluded that 15 sessions of BFR, amounting to 5 hours over the 5-week period, led to a significant increase in VO2 max , suggesting that BFR could be a promising method for enhancing aerobic performance in highly trained elite rowers (Held et al., 2020).

More recently, a study involving 50 masters road cyclists (aged between 35 and 49 years) investigated the effects of different training protocols on VO2 max and endurance performance. The participants were divided into 3 groups: a control group (continuous cycling for 75 minutes at 65-70% of peak power output), HIIT group (4x4-minute intervals at 80% peak power output, alternated with 2 minutes at 30% of peak power output), and BFR interval training group (1st and 3rd series at 80% of peak power output, 2nd and 4th series at 60% of peak power output). The study lasted 12 weeks with 2 training sessions per week. The aim was to determine differences in VO2 max over a 40 km trial before and after an intervention. VO2 max increased in the HIIT (+ 7.1 %) and BFR interval training (+ 7.8 %) groups, accompanied by significant improvements in maximal cardiac output (+5.9 %; + 4.2 %) and stroke volume (+ 5.6 %; + 3.6 %). Additionally, performance in the 40 km time trial improved across all three groups (HIIT and BFR interval training by 4 % and control group by 1 %) with changes correlating with corresponding alterations in VO2 max (Tangchaisuriya et al., 2022). These findings suggest that integrating a combination of HIIT and BFR training into the regular regimen provides masters road cyclists with multiple additional physiological adaptations that are beneficial for their performance.

In a subsequent study, elite male swimmers undertook 15 training sessions over a 5-week period, with 2 sessions of 10 minutes of occlusion per training. In comparison to the control group, the group performing occlusion showed a divergence in VO2 peak of 6% favouring the group performing occluded training. The study concluded that 15 sessions of low-intensity training swimming (amounting to 5 hours over 5 weeks) with BFR application resulted in additional improvements in VO2 peak compared to LIT swimming without BFR (Held et al., 2023a).

This sport-specific approach was also implemented in a study involving 12 male futsal players who underwent BFR-EE intervention. The intervention involved ten sessions of a 3-a-side game every other day on half of the futsal court. Results indicated significantly greater improvements in run time to fatigue (7.1%) and running economy (-22.7%) in the group performing futsal with occlusion. Although there was an improvement in VO2 max in the occlusion group (+ 10.7 %) compared to the other group (+ 7.3 %), it did not reach statistical significance potentially due to a smaller sample size (Amani-Shalamzari et al., 2020).

To further explore the impact of BFR on muscular endurance across various athletic disciplines, we examine three distinct studies conducted on different athlete populations. One of the studies investigated the impact of BFR-EE on 21 endurance-trained male runners. Participants were assigned to either running interval training with BFR or without BFR. Each participant completed 5 sets of 3-minute intervals with 1-minute rests at 50% of their heart rate reserve. Results revealed that the BFR group exhibited a significantly greater increase in VO2 max (+ 12 %) and knee extensor endurance (+ 8.5 %) after 24 training sessions compared to the non-BFR group (+ 4 %; - 2 %). These findings suggest that running interval training with BFR may offer a viable approach for enhancing muscular fitness and endurance running performance in distance runners (Chen et al., 2022).

Another sport-specific study involved 19 semi-professional soccer players. Both groups underwent identical activities during a 6-week preseason training regimen, including soccer-specific drills, plyometrics, small-sided games, and continuous running. Significantly larger improvements were observed in the BFR group compared with the non-BFR group in both aerobic endurance, assessed using the 20-m multistage fitness test (+ 54.1 %; + 24.7 %) and soccer-specific endurance, measured by the Hoff test (+ 58.4 %; + 22.7 %). These findings indicate that team sport training with BFR can enhance physical qualities related to performance in youth soccer players (Hosseini Kakhak et al., 2022).

One of the most recent studies included in this review examined a sample of 15 climbers who were divided into a BFR and a non-BFR group. They performed low-intensity climbing training (2 times 10 minutes per session; 3 times per week) over a period of 5 weeks. The measured parameters were static-intermitted finger hang (GripEndurance) and bent arm hang (ArmEndurance). The analysis revealed statistically significant results in the BFR group compared to the non-BFR group, specifically indicating increased GripEndurance (+ 15,4 %) and ArmEndurance (+ 6,9 %). This study contributes valuable insights into the application of BFR within the context of climbing training, offering a novel approach to improving endurance-specific performance metrics in climbers (Held et al., 2023b).

In elite sport contexts, Thompson et al. (2024) conducted a quasi-experimental study to examine the impact of BFR training within a low-intensity training block in elite and world-class rowers. The intervention took place during a 4-week non-competitive training period and included 11 BFR-specific rowing sessions. Each session consisted of 2 × 10 minutes of rowing at a workload corresponding to a blood lactate concentration of approximately 2 $mmol \cdot L^{-1}$, a marker of submaximal aerobic intensity. Notably, no high-intensity training was performed during this block, allowing for isolated observation of BFR-EE effects. Performance was assessed via 2000-meter rowing ergometer time trial, alongside physiological measurements including VO_2 max, hemoglobin mass, and lactate thresholds (~2 and ~4 $mmol \cdot L^{-1}$). Following the intervention, both male and female athletes demonstrated statistically significant improvements in time trial performance (1.09 % in females, 1.17 % in males), which is noteworthy given the elite status of the participants and the short duration of the training block. VO2max increased in female rowers, while both sexes showed improvements in submaximal power output at lactate thresholds. However, no change in hemoglobin mass was detected. Interestingly, performance gains were not significantly correlated with changes in physiological variables, suggesting that the benefits of BFR in this context may be partially attributable to neuromuscular or technical adaptations not captured by traditional markers of aerobic performance.

3.0 Physiological processes in BFR-EE

There are various physiological responses proposed in relation to the mechanism of action of BFR training such as specific muscle fibre recruitment, metabolic response, cellular swelling, anabolic hormone response and myofibrillar hypertrophy (Saraf et al., 2022).

3.1 Cell swelling

BFR training causes cell swelling, leading to an acute increase in muscle thickness due to fluid accumulation in the limb from reduced venous return (Loenneke et al., 2012). Fluid shifts from plasma to muscle cells due to osmolality differences (Tranum-Jensen et al., 1981), driven by decreased oxygen availability, metabolite accumulation, and increased reactive hyperaemia (Loenneke et al., 2012). In turn, environment facilitates earlier recruitment of type II muscle fibres during exercise (Ilett et al., 2019). BFR training has been shown to significantly increase cell swelling compared to work-matched controls (Yanagisawa et al., 2017), similar to the levels seen in high-load training (Freitas et al., 2017) and exercise to failure (Wernbom et al., 2019). The swelling activates an intrinsic volume sensor in muscle fibres, initiating the muscle protein synthetic response through stressed cytoskeletal matrices and anabolic signalling pathways, which in turn may contribute to skeletal muscle hypertrophy (Loenneke et al., 2012).

3.2 Metabolic stress

Metabolite-induced accelerated fatigue occurs when BFR is applied to an exercising limb, where metabolic substrates and byproducts of muscular contractions, such as lactate, hydrogen ions (H+), ATP, and inorganic phosphates, accumulate because they cannot exit the limb through the venous system due to the restrictive cuff (Loenneke et al., 2012). These metabolites disrupt the excitation-contraction mechanism, leading to earlier recruitment of type II muscle fibres compared to the same exercise in free-flow conditions (Wernbom et al., 2019). As metabolic stress builds, muscle contraction velocity slows and muscle activation increases, stimulating anabolic processes (Takarada et al., 2000). Metabolites also activate group III-IV afferents in and around the muscle fibres during contractions, promoting increased blood flow to reduce peripheral fatigue accumulation. Group III-IV afferents are types of sensory nerve fibers that play a crucial role in the perception of muscle activity and the regulation of blood flow during exercise (Amann et al., 2014). These afferents may stimulate additional motor unit recruitment to maintain force during repeated contractions and are believed to increase the perception of effort during exercise, correlating with type II muscle fibre recruitment (Pageaux et al., 2016).

Further supporting the role of metabolic stress in low load training, Burd et al. (2010) found that resistance exercise at 30 % 1RM performed to failure led to 199% increase in myofibrillar protein synthesis at 24 hours post exercise – significantly more than both high load and work-matched low load protocols. This condition also showed the highest activation of anabolic signalling pathways, including p70S6K and 4E-BP1, as well as elevated MyoD and myogenin expression. Although BFR was not used, the physiological stress closely mimics that of BFR-EE, highlighting how low-load, high-fatigue exercise can drive muscle adaptation.

Metabolic stress, characterized by an elevated ADP/ATP ratio and the accumulation of metabolites such as lactate, hydrogen ions, and inorganic phosphate, plays a central role in promoting muscular adaptations during BFR training. Studies show that this internal environment accelerates fatigue, leading to the earlier and increased recruitment of type II muscle fibers—fibers with greater hypertrophy potential. When combined with exercise, BFR has been shown to acutely stimulate muscle protein synthesis and promote muscle hypertrophy, likely through enhanced metabolic stress and cell swelling. However, BFR in the absence of muscle contraction appears insufficient to stimulate muscle protein synthesis, highlighting the importance of combining BFR with active exercise to elicit adaptive responses (Flewwelling et al., 2025).

3.3 Hormonal response

BFR training creates a hypoxic environment in the skeletal muscle cells, leading to decrease in blood pH. This acidic environment activates peripheral mechanoreceptors, specifically type III and IV efferent nerves, which conveys information to the hypothalamus. In response to that, the hypothalamus signals the anterior pituitary gland to release growth hormone. This increase in growth hormone, along with insulin-like growth factor 1, promotes muscle synthesis, which ultimately contributes to hypertrophy of the skeletal muscle (Saraf et al., 2022).

Combining endurance exercise with BFR leads to positive acute and chronic changes in both metabolic and hemodynamic variables. Acutely, BFR-EE results in increased oxygen consumption compared to endurance exercise without BFR, indicating heightened metabolic demands (Ozaki et al., 2010). Additionally, studies demonstrate higher energy expenditure during exercise with BFR (Loenneke et al., 2011; Karabulut et al., 2015). Moreover, BFR-EE significantly elevates excessive post-exercise oxygen consumption compared to sessions without BFR at the same intensity (Mendonca et al., 2015).

The amount of pressure applied during BFR-EE significantly impacts physiological responses. Proper selection of cuff pressure is crucial for safety and effectiveness, with 60-80% of AOP recommended. Higher pressures may increase venous occlusion and metabolite accumulation but also cause significant pain and fatigue, potentially limiting exercise duration. With that said, 60% of AOP is more tolerable, making it a preferable option for sustained BFR-EE. Also, BFR-EE acutely reduces maximal voluntary isometric contraction torque by ~18% with 60% AOP and ~40% with 80% AOP. Reductions in torque were influenced by peripheral mechanisms, such as reduced blood flow and metabolite accumulation inhibiting muscle contraction (Kilgas et al., 2022).

Chronically, BFR-EE can lead to a 10% increase in VO2 max, maximum power (+15%), and lactate threshold (+16%) (Park et al., 2010; de Oliveira et al., 2015). On a similar note, research suggests a linear increase in heart rate with rising exercise intensity, with higher BFR pressure correlating with elevated heart rate values during exercise (Ozaki et al., 2010; Karabulut et al., 2015). Furthermore, studies indicate that stroke volume during exercise with BFR is lower compared to exercise without BFR (Kumagai et al., 2012; Sugawara et al., 2015). Additionally, BFR-EE leads to significant increases in systolic blood pressure, mean arterial pressure, and diastolic blood pressure compared to endurance exercise without BFR (Ozaki et al., 2010; Karabulut et al., 2015; Sugawara et al., 2015). These hemodynamic changes are observed both immediately after and during endurance type of exercise, with mean arterial pressure particularly elevated at higher exercise intensities. Nonetheless, blood pressure levels typically return to resting levels within 30 to 50 minutes post-exercise, indicating a temporary hypotensive effect (Wilk et al., 2018; Silva et al., 2018).

The acute application of BFR during HIIT elicits various physiological responses and performance outcomes. BFR during HIIT triggers metabolic processes such as vascular and oxygenation responses, impacting muscle oxygen delivery and extraction, thereby subjecting muscles to higher metabolic stresses. However, this acute intervention also accelerates central and peripheral neuromuscular fatigue mechanisms, leading to a temporary reduction in performance metrics such as the number of sprints, work accomplished, and jump height compared to HIIT without BFR. Specifically, oxygenation responses reveal an increased demand for muscle oxygen utilization, while neuromuscular responses indicate heightened levels of peripheral fatigue. Moreover, when BFR is applied to the lower limbs during HIIT, it exacerbates central fatigue, affecting the central nervous system's ability to efficiently drive muscle contractions. Overall, while BFR during HIIT may enhance certain metabolic responses, it concurrently induces faster onset of fatigue, impacting performance temporarily (Chua et al., 2022).

4.0 Conclusion

The studies discussed indicate a growing interest in the application of BFR through endurance type of exercise to enhance endurance performance across various sports disciplines. These investigations show promising results, with several studies reporting significant improvements in key physiological parameters such as VO2 max, muscular endurance, lactate threshold and running economy following BFR interventions. However, it is important to note that some studies indicate insignificant changes in certain performance metrics, possibly due to small sample sizes or other methodological limitations.

Nevertheless, the overall conclusion suggests that integrating BFR into endurance type of training regimens holds potential for optimizing endurance-related qualities in athletes. In practical terms, these findings support the inclusion of BFR-EE in athletic training programs as a time-efficient and adaptable method to enhance aerobic capacity and muscular performance, particularly in periods where high mechanical loading my not be feasible.

Future research should continue to explore the optimal combination of intensity, cuff pressure, and session frequency across different sports disciplines, as well as the long-term safety and performance outcomes of BFR integration in elite-level periodization models. Further research with larger sample sizes and more rigorous methodologies is needed to confirm and extend these initial findings, providing a deeper understanding of the efficacy and mechanisms of BFR-induced adaptations in athletic performance.

5.0 Future recommendations

Future recommendations for research in the field of BFR-EE in athletes should address several key areas to enhance the understanding and applicability of this training method. First and foremost, it's crucial to acknowledge the challenge of small sample sizes in many studies. Additionally, future studies should strive for greater diversity in participant demographics, including various age groups, genders, and athletic backgrounds, to ensure findings are applicable to a broader range of athletes. Furthermore, there is a need for the development of standardized methodologies for implementing BFR-EE protocols in athletes. Currently, there is variability in the application of BFR techniques, including cuff pressures, exercise intensities, and training durations, across different studies. Establishing standardized protocols will facilitate comparison between studies and enable researchers to determine the most effective and safe BFR training strategies for athletes.

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