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The Long-Term Impact on Ankle-Brachial Index from Low Intensity Resistance Exercise with Blood Flow Restriction Technique: A Systematic Review

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Abstract: *This comprehensive review delves into the impact of low-intensity resistance training coupled with blood flow restriction (BFR) on arterial stiffness, evaluated through the ankle-brachial index (ABI). This assessment seeks to discern any discernible alterations in arterial stiffness attributed to this unique training approach. Employing systematic search via PubMed and Google Scholar databases, this review examined research articles focusing on the chronic effects of resistance training with BFR on the ABI. Inclusion criteria encompassed studies assessing this effect across various age groups while concentrating on healthy individuals and publications in the English language. Among the extensive array of studies, a selective inclusion of 5 research articles formed the foundational basis of this analysis. Synthesizing analyses from these studies illuminated the safety of BFR training, particularly at intensities around 20-30% or using elastic bands. Intriguingly, these modalities exhibited no significant impact on alterations in the ABI, notably observed within elderly subjects. However, a notable scarcity in studies focusing on young subjects warrants a more comprehensive investigation into this specific demographic. The findings of this review underscore the safety and efficacy of BFR resistance training methodologies, especially protocols utilizing 20-30% 1RM or incorporating elastic bands of 75-repetition-scheme, showcasing no significant impact on the ankle-brachial index, particularly in the elderly population over intervention periods not exceeding 12 weeks. Encouraging practitioners, these established methodologies offer safe practices for the elderly. However, the evident research gap in young subjects necessitates more expansive investigations.*
Keywords: *Ankle-brachial index, Blood flow restriction, Resistance training*

INTRODUCTION

In recent years, blood flow restriction (BFR) resistance training has gained considerable traction within sports coaching and physiotherapeutic practices for its purported benefits in enhancing training adaptations and aiding rehabilitation (Cuffe et al., 2022). The versatile nature of BFR training is exemplified through its varied applications: coaches harness its potential for athletic performance (Wortman et al., 2021), optimizing muscle hypertrophy (May et al., 2022) and strength gains (Lopes et al., 2022); physiotherapists utilize it as an effective tool for injury rehabilitation (Killinger et al., 2019), aiding in muscle recovery and functional restoration (Cognetti et al., 2022); additionally, it finds utility among elderly individuals who may not tolerate high-load exercises, allowing for enhanced muscle activation and maintenance (Cook et al., 2017).

However, amidst its increasing popularity, concerns have been raised regarding its safety (Nakajima et al., 2006), particularly in relation to the vascular system. This apprehension is centered around the external compression applied to muscles via cuffs (Wortman et al., 2021), potentially impacting vascular function. Notably, the assessment of arterial stiffness through the Ankle-Brachial Index (ABI) serves as a crucial method for evaluating vascular health (Aboyans et al, 2012). The ABI is a simple yet crucial diagnostic tool. It involves measuring and comparing the blood pressure in the ankle to that in the arm. By dividing the ankle systolic pressure by the arm systolic pressure, this index provides a numerical value that reflects the ratio of blood pressure in these two areas. The meta-analysis of 4 studies comprising 922 limbs demonstrated that the test of ABI score of less than or equal to 0.90 could be a non-invasive method to identify the serious peripheral arterial disease, such as peripheral artery disease or atherosclerosis, aiding in the diagnosis and monitoring of vascular conditions (Xu et al. 2013; Casey et al. 2019). The ABI serves as a quick and non-invasive method to evaluate blood flow and arterial health, offering valuable insights into a patient's vascular status.

Given these considerations, this systematic review aims to comprehensively review the available data pertaining to the

safety aspects of low-intensity resistance training combined with BFR, particularly focusing on the chronic impact on the Ankle-Brachial Index change. By evaluating existing evidence, this review should provide insights into the potential effects and safety profile of this training modality on vascular function, informing future practices in training and rehabilitation.

MATERIALS AND METHODS

Eligibility Criteria

This systematic review incorporated studies that met stringent inclusion criteria: (1) measurement of pre- and post-training Ankle-Brachial Index, (2) implementation of resistance training accompanied by blood flow restriction techniques, (3) emphasis on chronic training effects (over a duration exceeding 4 weeks), and (4) inclusion of participants classified as possessing a healthy status. Solely peer-reviewed publications in English, available in reputable journals, were taken into account. Exclusion criteria encompassed study cohorts characterized by physical ailments such as cancer or diabetes. Furthermore, populations with mental health conditions such as depression, schizophrenia, or dementia were deliberately omitted from this comprehensive analysis.

Search Strategy

The databases such Google Scholar and Pubmed were searched for papers published between 2010 to 2023. The search term consisted of "Blood flow restriction" OR "Blood Flow-restricted" OR "BFR" AND "Low intensity" AND "Resistance training" OR "Resistance exercise" AND "Arterial stiffness" OR "Ankle Brachial Index" AND "Healthy" AND "Older" OR "adult"

Study Selection

The study selection process followed a meticulous approach in adherence to the predefined inclusion and exclusion criteria outlined in section 2.1. Initially, retrieved articles from Google Scholar and PubMed databases, encompassing publications dated between 2010 to 2023, underwent a rigorous screening process. This involved an initial screening of titles and abstracts to identify relevant studies meeting the specified criteria. Subsequently, selected studies underwent a full-text assessment for comprehensive scrutiny against the predetermined eligibility criteria. The final selection included studies meeting all predefined criteria outlined in section 2.1 and aligned with the specific focus of this systematic review on blood flow restriction and its chronic impact on arterial stiffness evaluated through the Ankle-Brachial Index among healthy adult populations.

Quality Assessment

The methodological quality of the studies was evaluated utilizing the Physiotherapy Evidence Database (PEDro) scale, as detailed by Morton et al. (2009). In order minimizing subjectivity and enhancing the objectivity of the quality assessment, the appraisal step underwent an evaluation by independent experts in filed of sport science and sport rehabilitation to mitigate the potential risk of bias and uphold the rigor of the evaluation. This PEDro scale encompasses rigorous assessment criteria including Eligibility criteria, Random allocation, Concealed allocation, Baseline comparability, Blind subjects, Blind therapists, Blind assessors, Adequate follow-up, Intention-to-treat analysis, Between-group comparisons, and Point estimates and variability. Each study was appraised on a scale ranging from 0 to 10, with higher scores indicative of superior methodological quality (Cashin & McAuley, 2020). The PEDro scale serves as a comprehensive tool for evaluating the rigor and reliability of research methodologies employed in the assessed studies.

RESULTS

A total of 5 articles meeting the specified inclusion criteria were identified, involving a combined total of 96 healthy subjects, with 44 individuals allocated to the BFR training group. The resistance training interventions encompassed exercises with an external load ranging from 20% to 30% of the subjects' one-repetition maximum (Clark et al, 2011: Yasuda et al, 2014), and in some cases, incorporated the use of elastic bands (Yasuda et al, 2015; Yasuda et al, 2015; Yasuda et al, 2016). The duration of these interventions varied from 4 to 16 weeks.

Notably, studies focusing on elderly participants uniformly employed a training frequency of two sessions per week (Yasuda et al, 2014; Yasuda et al, 2015; Yasuda et al, 2015; Yasuda et al, 2016). Conversely, one study (Clark

et al. 2011) involving healthy young participants utilized a training regimen comprising three sessions per week. Regarding the targeted muscle groups, four studies (Clark et al. 2011; Yasuda et al, 2014; Yasuda et al, 2016) concentrated on lower body resistance training, while two studies (Yasuda et al, 2015; Yasuda et al, 2015) centered their interventions on upper body resistance exercises.

Table 1. *Effect of blood flow restriction resistance training on ankle-brachial index*

Study	Duration and Training Frequency	Subjects	BFR-RT Intensity	Arterial occlusion pressure	Training intervention	Exercises	Primary outcome on Ankle-Brachial Index of BFR-RT
Yasuda et al. 2014	12 weeks 2days /week	19 healthy elder men and women	20-30%1RM 4sets of 75 repetitions scheme (30, 20, 15, and 10 reps)	120-270mmHg	Low intensity BFR RT (n=9) Control (n=10)	1-Leg press 2-Knee extension	There was no significant change from pre to post observed in ABI value from pre 1.13 unit to post intervention 1.15 unit in BFR training group.
Yasuda et al. 2015	12 weeks 2days /week	17 healthy elder women	Elastic bands 4sets of 75 repetitions scheme (30, 15, 15, and 15 repetitions)	180-270mmHg	Low intensity BFR RT (n=9) Control (n=8)	1-Arm Curl 2-Triceps Pressdown	There was no significant change from pre to post observed in ABI value from pre 1.17 unit to post intervention 1.14 unit in BFR training group.
Yasuda et al. 2015	12 weeks 2days /week	14 healthy elder women	Elastic bands 4sets of 75 repetitions scheme (30, 15, 15, and 15 repetitions)	230-270mmHg	Low intensity BFR RT (n=7) Control (n=10)	1-Arm curl 2-Triceps Pressdown	There was no significant change from pre to post observed in ABI value from pre 1.14 unit to post 1.12 unit in BFR training group.
Yasuda et al. 2016	12 weeks 2days /week	30 healthy elder women	Elastic bands 4sets of 75 repetitions scheme (30, 15, 15, and 15 repetitions)	160-200mmHg	Low intensity BFR RT (n=10) High intensity RT (n=10) Control (n=10)	1-Bilateral squat 2-Knee extension	There was no significant change from pre to post observed in ABI value from pre 1.14 to post 1.15 unit in BFR training group.
Clark et al. 2011	4 weeks 3days/week	16 young healthy men and women	30%1RM 3sets x 30-50 repetition to failure 80%1RM 3sets x 8-12repetition	130% above the resting brachial SBP	Low intensity BFR RT (n=9) High intensity RT (n=7)	1-Knee extension	There was no significant change from pre to post observed in ABI value from pre 1.15 to post 1.09 unit in BFR training group.

For a comprehensive overview of the interventions and outcomes of the included studies, refer to Table 1. Additionally, Table 2 provides the individual PEDro scores for each study, offering an assessment of methodological quality. Of 5 studies included, two studies were classified as "good quality" while the rest of three were classified as "fair quality".

Table 2. *PEDro scale*

		Yasuda et al. 2014	Yasuda et al. 2015	Yasuda et al. 2015	Yasuda et al. 2016	Clark et al. 2011
	Eligibility	Yes	Yes	Yes	Yes	Yes
1	Random allocation	1	0	1	1	1
2	Concealed allocation	1	0	0	1	0
3	Baseline comparability	1	1	1	1	0
4	Blind subjects	0	0	0	0	0
5	Blind therapists	0	0	0	0	0
6	Blind assessors	0	0	0	0	1

7	Adequate follow-up	1	1	1	1	1
8	Intention-to-treat analysis	1	1	1	1	1
9	Between-group comparisons	1	1	0	0	0
10	Point estimates and variability	0	1	1	1	0
	Scores	6/10	5/10	5/10	6/10	4/10
	Quality	"Good"	"Fair"	"Fair"	"Good"	"Fair"

DISCUSSION

The key outcomes of this comprehensive review underscore several critical points. First, our analysis revealed a lack of evidence indicating a significant impact of low-intensity resistance training with BFR on the ABI score. Second, our findings suggest that in elderly individuals aged over 60, BFR training demonstrates a notable safety profile concerning this vascular index. This safety was particularly evident when utilizing an external load range between 20-30% of 1 repetition maximum in conjunction with 75-repetition schemes. Third, the limited available data, notably from a solitary study involving healthy young subjects over a short duration of 4 weeks, impedes making conclusive statements about the safety of BFR training for this specific demographic. Consequently, establishing robust conclusions about this cohort's safety necessitates further research and deeper investigation.

The arterial occlusion pressure, notably exceeding 200mmHg, emerged as a seemingly safe threshold, even among elderly individuals, warranting consideration and potential adoption in the practice of this technique. Among the four studies that incorporated low-intensity resistance training with BFR, the recorded pressure ranged between 120-270mmHg (Yasuda et al., 2014; Yasuda et al., 2015; Yasuda et al., 2015; Yasuda et al., 2016). Nevertheless, the recent recommendation on the guideline practice of how much pressure to be applied suggested the use of individual arterial occlusion pressure (Rolnick et al., 2020). However, it's pivotal to consider the duration of training as a crucial factor. The studies reviewed this time followed a pattern involving four sets with 75-repetition schemes, with each set interspersed by a mere 30-second rest interval, resulting in a total exercise duration of approximately 10-15 minutes (Yasuda et al., 2015) which is in accordance with the guideline for appropriate time of application of BFR (Patterson et al., 2019). The extension of application time becomes a focal point of concern when contemplating additional sets or exercises for the elderly. Careful consideration is warranted for longer application times, especially when incorporating more sets or exercises, to ensure optimal safety and efficacy among this demographic.

In our analysis, it became evident that resistance training targeting both lower and upper body muscles appears to maintain safety concerning the ABI among the elderly population which is in accordance with the current recommendation (Patterson et al., 2019). Existing studies have implemented isolated exercises like knee extensions alongside compound lower body movements such as squats and leg presses, all of which demonstrated safety in relation to the vascular index. However, it's noteworthy that while lower body exercises have been studied (Yasuda et al., 2014; Yasuda et al., 2016), the impact of compound exercises on the upper body remains unexplored within this context. As such, future research endeavors should prioritize investigating the effects of chronic resistance training with BFR utilizing compound upper body exercises like bench presses or seated rows. This exploration aims to discern whether these exercises might influence the ABI, thus contributing to a more holistic understanding of the implications of such training regimens.

Given the scarcity of studies involving young, healthy individuals, drawing definitive conclusions and formulating precise recommendations for this age group is currently constrained by the presence of only one fair-quality study investigating this specific vascular index. To bridge this gap in our understanding, it is imperative that future research endeavors focus on augmenting this body of knowledge. Expanding the duration of studies beyond the current 4 weeks scope to obtain the insights into the safety profile associated with training modality among this demographic. This extension in study duration stands to enrich our understanding and provide a more nuanced perspective on the implications and safety considerations pertinent to young, healthy subjects engaged in this form of training.

CONCLUSION

This review highlights the lack of evidence on low-intensity resistance training with BFR affecting ABI scores. For the elderly (age >60), BFR training, using 20-30% of 1RM and 75-repetition schemes, appears notably safe. However, limited data, especially for young, healthy individuals, impedes solid conclusions. Further research, extending beyond 4 weeks, is crucial to fully comprehend the safety of BFR training in this demographic. Considering

arterial occlusion pressures over 200mmHg as seemingly safe, cautious extension of exercise duration is advised, particularly for additional sets or exercises among the elderly. Future studies should explore compound upper body exercises' impact on ABI, complementing the existing focus on lower body movements in BFR training research.

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