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Acute Effects of Blood Flow Restricted Resistance Exercise on Heart Rate Variability

Kan Akışı Kısıtlamalı Direnç Egzersizin Kalp Atım Hızı Değişkenliği Üzerine Akut Etkisi

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Abstract: It is recommended that low-load resistance exercise with blood flow restriction be employed as an alternative method for individuals unable to perform traditional high-load resistance exercise. This study investigated the acute effects of low-load resistance exercise with blood flow restriction (BFR-RE) and traditional high-load resistance exercise (HL-RE) on heart rate variability. Sixteen recreational male participants aged 18-24 volunteered to participate in the study and 14 completed the study. Participants were randomly divided into two groups (BFR-RE:8, HL-RE:8). The BFR-RE group performed the leg press exercise (30-15-15-15 reps, 30-seconds rest between sets, 30% of 1RM) with BFR cuffs (60% of arterial occlusion pressure). The HL-RE group performed the same exercise (3 x 12 reps, 90 seconds rest between the sets, 70% 1RM) without BFR cuffs. Heart rate, variability, and time domain parameters were assessed using the POLAR H7 heart rate monitor with the Elite HRV mobile application. Two-way analysis of variance (ANOVA) with 2×2 repeated measures was used to analyze differences between groups. Significance was set at p<0.05. The BFR-RE group exhibited more pronounced statistically significant differences in heart rate variability parameters than the HL-RE group. In conclusion, this study found that BFR-RE exerts a more pronounced effect on cardiac and cardiovascular autonomic function parameters than HL-RE.

Keywords: *Blood flow restriction, strength training, vascular occlusion, autonomic nervous system, cardiovascular*

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INTRODUCTION

In recent years, blood flow restriction training (BFR) has received considerable emphasis from researchers due to its efficacy in enhancing muscle strength and hypertrophy with a relatively lower training load than conventional approaches (Ferguson et al., 2021; Jørgensen et al., 2023; Kamiş et al., 2024). The BFR resistance exercise method, developed by Dr Yoshiaki Sato in 1966, involves partial restriction of arterial inflow and complete restriction of venous outflow in working muscles (Scott et al., 2015). This method, also called "Kaatsu Training," is widely utilized for enhancing athletic performance and facilitating rehabilitation (Ferguson et al., 2021). The physiological mechanisms associated with exercise-induced changes in muscle blood flow have been linked to several processes, including oxygenation, vasomotor responses, metabolic

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stress, and hormonal secretion. In particular, the accumulation of lactate and the reduction in intracellular pH facilitate the onset of muscle relaxation, which stimulates the release of neurotransmitters, particularly those of the type II receptor family (Manoli et al., 2007; Thiel & Dretsch, 2011). The research findings suggest that BFR's high-frequency, low-amplitude magnetic stimulation activates fast-twitch muscle fibers, thereby increasing growth hormone levels and potentially facilitating muscle growth (Loenneke et al., 2013).

BFR has been demonstrated to induce more oxygen demands within the active musculature than would be the case under normal physiological conditions. More functional capillaries are present in the skeletal muscle than anticipated under normal circumstances (Larkin et al., 2012; Loenneke et al., 2012). This results in a higher level of hypoxia, which promotes angiogenesis and increases the production of vascular endothelial growth factor (VEGF). This protein facilitates the growth of new blood vessels. These reactions may improve cardiovascular health and performance (Olfert et al., 2001). It can be posited that the method under discussion has the potential to affect the incidence of coronary artery disease, as there is evidence indicating that it can influence heart rate variability (HRV) in certain demographic sedentary groups (Miller et al., 2022). The research shows that while BFR's aerobic performance indicators are being enhanced, simultaneous improvements in power output could also be observed. This may lead to cardiovascular efficiency improvements, as observed in the improved HRV.

HRV represents the interval between consecutive heartbeats and measures cardiac autonomic regulation. It is an autonomous nervous system function and a marker of general cardiovascular health (Arakaki et al., 2023; Draghici & Taylor, 2016). A higher HRV is typically observed in individuals who exercise regularly, which may indicate more excellent fitness and lower heart function during exercise (Draghici & Taylor, 2016). In a scientific context, the evaluation of the effect of exercise on the cardiovascular system requires determining how the autonomic nervous system responds to a range of physiological stimuli. This is necessary to understand autonomic activity's regulatory mechanisms (Blouin et al., 2019). The primary effects of exercise on heart rate (HR) and HRV can be observed during exercise and the subsequent recovery phase. It can be inferred from the evidence presented that BFR may impact hemodynamic processes in ways that differ from traditional high-intensity aerobic exercise, which could reduce cardiovascular stress. It is emphasized that, particularly in older adults or people with specific health problems, this method may be beneficial in reducing cardiovascular stress (Park et al., 2015). In addition, it has been shown that applying the BFR method in combination with aerobic exercise can reduce hemodynamic responses compared to high-load aerobic exercise performed without BFR (Horiuchi & Okita, 2012).

In this context, BFR training combined with resistance exercise creates a hypoxic environment in the working muscles (Pinto & Polito, 2016), leading to tremendous metabolic stress and muscle fiber recruitment, similar to high-intensity exercise, despite low-intensity training. Even lower exercise intensities can result in significant cardiovascular and muscular benefits in fitness centers. The impact of exercise on HRV is of great consequence, as HRV serves as a crucial marker of autonomic nervous system activity and cardiovascular health. Consequently, elucidating the influence of BFR on HRV may offer valuable insights into its comprehensive impact on overall health (Souza et al., 2021). Universal fitness training methods are focused on muscle hypertrophy. BFR training applied in a single session can positively influence cardiac autonomic responses by improving HRV recovery and reducing cardiovascular stress. It is a valuable training method to enhance cardiovascular health and safety during exercise (Ferreira et al., 2017). For instance, research has demonstrated that low-intensity walking with BFR effectively enhances muscle size and strength in individuals across the age spectrum, including younger and older populations (Clarkson et al., 2017). BFR training effectively increases muscle strength and hypertrophy, especially in populations that cannot tolerate high loads, such as older adults and individuals with musculoskeletal disorders (Yuan et al., 2023). In conclusion, BFR training offers a feasible and potentially safer alternative that can lead to significant gains in strength while positively affecting HRV. The impact on HRV may be considerable, especially in certain groups elderly. The benefits of BFR may be advantageous for endurance athletes, as research indicates that BFR can enhance markers of aerobic performance while concurrently increasing power output, thereby resulting in improved HRV through enhanced cardiovascular efficiency and responses.

The mechanisms underlying the relationship between BFR and HRV are not fully understood. Therefore, this study evaluated the cardiovascular autonomic activity of acute low-load resistance exercise with BFR compared to traditional high-load resistance exercise.

METHOD

Research Design

A repeated-measures design was used to determine the acute effect of low-load resistance exercise with BFR-RE and traditional HL-RE on HR, HRV and time-domain parameters [Root mean square of successive differences between normal heartbeats (RMSSD), Standard deviation of normal-normal (SDNN), Natural log of RMSSD (LN), Percentage of adjacent NN intervals (pNN50), mean R-R Interval (RR)]. The participants were informed about the purpose of the study, the methodology adopted, and the training procedure by the researcher during the initial visit, and their consent was obtained. All participants were informed of the techniques and risks of the study and signed an informed consent form. Sixteen healthy male subjects who met the established inclusion criteria participated in the study voluntarily. Subsequently, two familiarization training sessions were conducted on consecutive days. Following the conclusion of the final acclimatization session, the participants were invited to attend a preliminary measurement session scheduled to take place 72 hours later for full rest (Bishop et.al., 2008). In this preliminary measurement session, the researchers collected anthropometric data, such as the participant's body weight, height, and body mass index. The participants were also instructed to perform a maximum repetition test on the leg press machine. The participants were randomly allocated to the two groups [BFR-RE group (n=7), HL-RE group (n=7)] using a 2-block randomization approach to mitigate selection bias. Intervention measurements were conducted following a 72-hour rest period. The participants were positioned supine for 10 minutes, following which baseline measurements of resting HR, HRV, and blood pressure (BP) were obtained. The arterial occlusion pressure was measured using a cuff while the participants were supine. Participants completed a standardized warm-up protocol of approximately 15 minutes, which included running and dynamic stretching range of motion exercises for the lower extremities before all measurements. Subsequently, the researchers determined the participants' one-repetition maximum loads for the leg press exercise. The leg press was selected as a lower extremity exercise, with only a verbal reminder to participants to keep the knee flexed at 60° for each repetition during 1 RM and exercise reps (Azegami et al., 2007). All tests were performed between 08:30-17:00, and measurements were taken in the gym. Participants were advised to maintain their daily diet and not take additional dietary supplements during the measurement period.

Participants

The sample size was calculated using the G*Power (Version 3.1.9.2, Düsseldorf, Germany) package program with power=.80, a=.05, and d=.38, which indicated that a minimum of 16 participants were required for the study (Castello-Simoes et al., 2013; Junior et al., 2019). The study involved 16 healthy male participants who were students at the University and voluntarily met the inclusion and eligibility criteria. Participants were 16 healthy males aged 18-24 years who were recreationally active at least 3 days a week, without cardiovascular and skeletal muscle disease, no chronic diseases such as hypertension and peripheral vascular disease, not diabetic, not a smoker, and without endothelial dysfunction. Two participants could not continue the study due to personal reasons.

Data Collection

Anthropometric Measurements

Participants' heights were determined using a Seca brand 213 model height meters (Seca et al. Company, Germany). At the same time, body weights were assessed using a Seca brand 813 model scale (Seca et al. Company, Germany).

1 Repetition Maximum Strength Test (1 RM)

Before commencing the test, participants engaged in a general warm-up lasting 5 to 10 minutes, which incorporated dynamic stretching exercises and self-selected intensity jogging. Following the warm-up set of 5 repetitions at 50% of their one-repetition maximum (1RM), participants completed 1-2 sets of 2-3 repetitions at a weight equivalent to 60-80% of their 1RM. After that, the participants performed sets of singular repetitions with progressively greater loads to ascertain their one-repetition maximum. Participants were provided a 3- to 5-minute rest period between each attempt. The one-repetition maximum assessment was completed within five trials, and the process was overseen by qualified personnel (Sheppard & Triplett, 2016). The participants' one-repetition maximum (1RM) values were measured in kilograms (kg) utilizing the leg press exercise equipment. (Diesel 45° Leg Press Xh22, USA).

Blood Pressure (BP)

Blood pressure (BP) was measured with an Omron M3 comfort digital automatic BP device (HEM-7200-E, Omron Healthcare Co Kyoto, Japan). BP was measured in a sitting position at room temperature after resting for 10 minutes. The measurement was taken two times with an interval of one minute, and the average was recorded in mm Hg.

Determination of Arterial Occlusion Pressure

The participants' AOP/LOP (arterial/limb occlusion pressure) values for both legs were obtained in mmHg using the Smart Cuffs Pro elite digital automatic inflation cuff (cuff width: 10.5 cm, SmartCuffs Pro Elite Smart Tools Plus, Strongsville, OH). They were instructed to perform the exercises at 60% AOP. Their AOP values were measured after resting for 10 minutes in the supine position at room temperature.

Heart Rate and Heart Rate Variability

HR and HRV parameters were measured using the Apple iPad Pro 4th Generation device (Apple Inc., USA) with the Elite HRV application using the Polar brand H7 chest strap (Finland). For the resting/Baseline measurement, the subject rested for approximately 20 minutes before the measurement, and then the measurements were taken while the participants were lying down for

10 minutes. For during measurements, participants wore a polar H7 chest strap, and data were recorded during the leg press exercise for both groups (Sun et al., 2011).

High-load resistance exercise (HL-RE):

The HL-RE group performed leg press exercises with 1RM 70%, three sets of 12 repetitions, and 90 seconds of rest between sets without restricting blood flow (Haff & Tripplet, 2016). Exercise tempo was monitored with the iOS-compatible Pro Metronome (Xanin Technology, Berlin, Germany) mobile application as 1 sec concentric-1 sec eccentric (60 BPM). The exercise duration was 4 minutes 12 seconds.

Blood flow restricted resistance exercise (BFR-RE):

The BFR-RE group performed leg press exercises as 30-15-15-15 repetitions, 1RM 30% and 60% AOP/LOP (arterial/limb occlusion pressure), and 30 seconds rest was given between sets (Horiuchi & Okita, 2012). FDA-listed SmartCuffs Pro BFR training device was used in BFR exercise. The tempo of the exercise was monitored with the iOS-compatible Pro Metronome (Xanin Technology, Berlin, Germany) mobile application as in the high-load exercise group, and the tempo was completed in 2 seconds (60 BPM) as 1 second concentric-1 second eccentric. The exercise duration was 5 minutes.

Data Analysis

All statistical calculations were performed using SPSS Statistics 27.0 (IBM, USA). The Shapiro-Wilk test was employed to assess the data's distribution. Means and standard deviations (±SD) for continuous variables for BFR and HL-RT groups are presented as descriptive statistics. The Mann-Whitney U or Independent Sample T-Test was used to determine the possible differences between the leg circumference, resting SBP and DBP, HR, SPO2, and 1 RM groups in the pre-test values obtained before the start of the study. HRV, mean RR, LN, SDNN, RMSSD, and mean HR were used as categorical variables to determine the differences between the resistance training modalities. Two-way analysis of variance (ANOVA) with 2×2 repeated measures was used to analyze differences between groups. All calculations were conducted with a statistical significance level of $p < 0.05$. Effect sizes (ηp^2) were defined as small ($\eta p2>0.01$), medium ($\eta^2>0.06$), and large ($\eta p2>0.14$) (Bakeman, 2005).

Ethical Statement

Ethical approval for this study was given at the local Bandırma University Ethics Committee meeting on 12.07.2024, with the decision number E-77082166-604.01-995086. This study was conducted following the principles of the Declaration of Helsinki.

RESULTS

Fourteen participants successfully completed all experimental trials, and no adverse events were reported. Figure 2 shows the assessed variables' mean and standard deviation values between the BFR and HL-RT interventions and the corresponding effect sizes.

Table 1. Descriptive characteristics of the Participants

Variables	Group	n	Mean	sd	Max	Min.
Height (cm)	BFR-RE	7	173.39	5.71	182.00	164.40
	HL-RE	7	177.90	9.19	192.50	168.00
Weight (kg)	BFR-RE	7	66.13	11.23	87.90	54.30
	HL-RE	7	74.17	14.79	103.30	56.80
Age (years)	BFR-RE	7	20.00	2.08	22.00	17.00
	HL-RE	7	21.00	4.16	30.00	18.00
Circumference (cm)	BFR-RE	7	51.64	5.40	62.50	46.50
	HL-RE	7	53.50	5.10	62.50	48.50
SBP (mm/Hg)	BFR-RE	7	117.14	7.13	127.00	109.00
	HL-RE	7	117.86	10.12	135.00	104.00
DBP (mm/Hg)	BFR-RE	7	65.14	8.15	79.00	57.00
	HL-RE	7	64.57	8.44	80.00	54.00
Resting HR (beat/min)	BFR-RE	7	71.29	14.48	99.00	55.00
	HL-RE	7	62.43	5.32	70.00	54.00
SPO2 (%)	BFR-RE	7	98.14	.90	99.00	97.00
	HL-RE	7	98.57	.53	99.00	98.00
1 RM (kg)	BFR-RE	7	154.53	38.06	225.00	116.70
	HL-RE	7	198.97	41.67	266.70	146.70

BFR-RE: Blood flow restricted resistance exercise; HL-RE: High load resistance exercise; SBP: Systolic blood pressure; DBP: Diastolic blood pressure

Baseline measurements of leg circumference, resting systolic and DBP, resting HR, and oxygen saturation (SpO_2) did not differ between the intervention groups ($p>0.05$). The performance between the intervention groups was comparable, as evidenced by no significant differences (t= -

2.084, p= 0.059) in the one maximum repetition (1 RM). Additionally, the participants' fitness levels and resting states were equivalent at the outset of the exercise protocol (p>0.05).

Table 2. Comparison of the physiological responses exhibited by participants before and during exercise

Variables	Measurement	BFR-RE	HL-RE	F Sig. ES	Time	Time × Group	Group
		mean ± sd ***(min. -max.)***	**mean± sd** ***(min. -max.)***				
RMSSD (ms)	Rest	56.64±21.72	77.29±36.29	F	46.95	0.46	2.82
		(29.58- 84.75)	(26.83-129.82)	p	.005**	.510	.119
	During	7.64± 4.91	17.52±15.07	η_p^2	.796	.037	.190
		(2.86-17.44)	(1.84-46.56)				
SDNN (ms)	Rest	69.85±16.46	75.21±22.40	F	8.58	1.73	5.95
		(49.53-91.60)	(35.58-106.90)	p	.013*	.213	.031*
	During	35.38±7.77	62.10±26.38	η_p^2	.417	.126	.332
		(24.31-50.39)	(34.57-106.30)				
LN (ms)	Rest	3.96±0.43	4.23±0.56	F	70.28	1.83	5.98
		(3.39-4.44)	(3.29-4.87)	p	.001**	.201	.031*
	During	1.87±0.61	2.72±0.71	η_p^2	.854	.132	.332
		(1.05-2.86)	(1.88-3.84)				
mean RR (ms)	Rest	888.10±80.28	1008.11±116.50	F	325.02	.28	9.15
		(754.75-1014.64)	(878.81-1186.31)	p	.001**	.610	.011*
	During	438.89±49.34	532.01±64.45	η_p^2	.964	.022	.432
		(355.11-518.78)	(460.56-624.14)				
average HR (beat/min)	Rest	68.43±6.45	60.43±6.60	F	261.23	3.98	11.55
		(59.00-80.00)	(51.00-68.00)	p	.001**	.069	.005**
	During	139.29±16.30	115.71±12.83	η_p^2	.956	.249	.490
		(116.00-170.00)	(99.00-131.00)				
HRV (ms)	Rest	61.00±6.48	65.14±8.47	F	72.32	1.85	6.10
		(52.00-68.00)	(51.00-75.00)	p	.001**	.199	.030*
	During	28.86±9.48	41.86±10.67	η_p^2	.858	.133	.337
		(16.00-44.00)	(29.00-59.00)				

RMSSD: Root mean square of successive differences between normal heartbeats, SDNN: Standard deviation of normal-normal, HRV: Heart rate variability, LN: Natural log of RMSSD, pNN50: Percentage of adjacent NN intervals, η_p^2: partial eta square, ES: Effect size, RR: RR Interval: *: $p < 0.05$; **: $p < 0.01$

The findings demonstrated that both forms of resistance training elicited a statistically significant acute time-based main effect on the participants' cardiac functional parameters (p<0.05). The exercise interventions resulted in statistically significant acute changes in the participants' cardiac functional parameters, including Root mean square of successive differences between normal heartbeats (RMSSD), Standard deviation of normal-normal (SDNN), mean RR, average HR, and HRV, across both intervention groups. The primary effect findings showed that the exercise interventions significantly impacted RMSSD, SDNN, LN, Mean RR, average HR, and HRV ($p<0.05$). Accordingly, the main effect results were as follows RMSSD (F= 46.95, p= 0.005, η_p^2=0.796), SDNN (F= 8.58, p= 0.013, η_p^2=0.417), LN (F= 70.28, p= 0. 001, η_p^2=0.854), Mean RR (F= 352.02, p= 0. 001, η_p^2=0.964), average HR (F= 261.23, p= 0. 001, η_p^2=0.956) and HRV (F= 72.32, p= 0. 001, η_p^2=0.858). The findings did not reveal statistically significant interaction effects between time and intervention groups for the measured variables ($p > 0.05$).

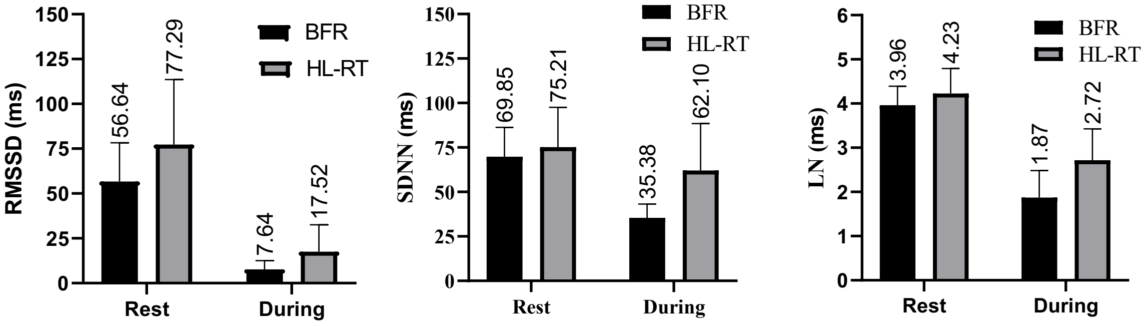

Figure 1. HRV metrics response to acute exercise in milliseconds before and during the exercise.

The findings revealed statistically significant between-group differences, with the BFR group demonstrating more pronounced increases in HRV markers than the high-load resistance training group, with the exception of RMSSD.

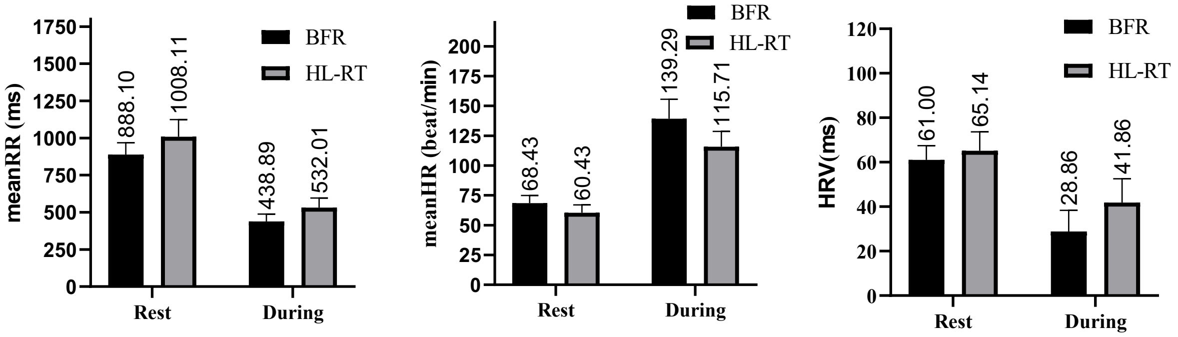

Figure 2. HRV metric, HRV, and HR response to acute exercise in milliseconds before and during the exercise.

The findings revealed statistically significant differences between the two groups in terms of their respective effects, with the BFR intervention group displaying more pronounced enhancements in HRV indicators compared to the high-load resistance training group, with the exception of the

RMSSD variable, for which the p-value was not statistically significant. Accordingly, the between-groups interactions results were as follows SDNN (F= 5.95, p= 0.031, η_p^2=0.332), LN (F= 5.98, p= 0.0031, η_p^2=0.332), Mean RR (F= 9.15, p= 0.005, η_p^2=0.49), and HRV (F= 6.10, p= 0.030, η_p^2=0.337). Furthermore, the heart rate variable showed statistically significant differences in the AVG HR (F= 11.55, p= 0. 005, η_p^2=0.490). No group effect was observed in RMSSD (F= 2.82, p= 0.119, η_p^2=0.190).

DISCUSSION

The primary finding of this study was that resistance exercise with BFR produced a more pronounced impact on cardiac function parameters compared to high-load resistance exercise. The study's central hypothesis was substantiated, as the mean HR and HRV metrics, which function as the kinetic parameters of HRV, exhibited a statistically significant enhancement in the BFR group. Evaluating the magnitude of change showed that the mean RR was 50.58% and HRV was 52.68% in the BFR group, while the mean RR was 47.22% and HRV was 35.73% in the HL-RT group. In the BFR group, the magnitude of changes was more noticeable. The acute training effect was statistically significant in favor of the BFR group for R-R interval and HRV durations ($p<0.05$). During exercise, the autonomic nervous system and cardiovascular functions become more active due to the increased frequency of time differences between heartbeats (Dong, 2016). Shorter RR intervals are often associated with better health, fitness, and willingness to train, while longer intervals may indicate physical or mental stress. Assessing physiological responses to acute exercise on the autonomic nervous system and cardiovascular functions via HRV has provided an innovative approach to optimizing exercise intensity and physiology during exercise (Dong, 2016; Hautala et al., 2009). The study's findings may therefore indicate that resistance exercise combined with BFR has a greater acute effect on cardiac kinetics than high-load resistance exercise.

This study provides evidence to support the literature's view that exercise with BFR may lead to a complex interplay between the sympathetic and parasympathetic nervous system responses and may potentially enhance HRV through improved cardiovascular regulation (Clarkson et. al.,2017).

HRV markers indicate potential increases or decreases depending on factors like exercise intensity, duration, and the individual's training status. Some studies have observed no significant changes in HRV markers like RMSSD, SDNN, and pNN50 immediately after BFR exercise (Lopes et al., 2021). Some studies have reported a decrease in HRV markers after BFR exercise (Ferreira et al., 2019; Schamne et al., 2019). The cardiovascular load and sympathetic activation during BFR may contribute to this (Crisafulli et al., 2018). These studies do not support our results. Only RMSSD accepts this content. All HRV markers provide more information about cardiovascular responses to BFR exercise as a whole. Other research that provides further insights into the cardiovascular responses to BFR training has indicated that BFR, particularly when combined with high-intensity resistance training, could potentially increase HRV and all HRV markers (Crisafulli et al., 2018). This may be due to the increased muscle activation and metabolic stress associated with BFR, which could lead to improved autonomic regulation over time (Holmes et al., 2022). The inconsistencies in the literature may stem from variations in BFR protocols (e.g., cuff pressure, exercise selection, intensity), the timing of HRV measurements (rest, during exercise), and the characteristics of the study participants (e.g., age, training status, health conditions). The protocol we used in the research, BFR training, may be a safer and more available option to enhance muscle strength and size while potentially improving the cardiovascular system for long-term training adaptations.

The evidence from the literature suggests that BFR training has been widely reported to be beneficial for gaining strength and increasing muscle mass (Yasuda et al., 2011). BFR training has attracted attention for its potential effects on HRV in the short and long term. Studies have shown that BFR training can cause acute hemodynamic responses such as increased BP and HR (Horiuchi & Okita, 2012; Reina-Ruiz et al., 2022). Research indicates that BFR training at low intensity leads to a more moderate increase in maximum HR, ranging from 11% to 13%, compared to traditional heavy resistance training. This result shows acute BFR training can lead to changes in the kinetics of the HR and the recovery of the HR (Bazgir et al., 2016). A study investigating BFR gait training found significant changes in these parameters and demonstrated an immediate autonomic response following BFR training (Chen et al., 2024).

Physiological functional mechanics have been shown to affect cardiovascular markers, including HRV while increasing muscle adaptations (Miller et al., 2021). However, it has also been emphasized that there may be effects on heart muscle condition and cardiovascular risk. Therefore, some research groups consider exercise with BFR potentially risky for cardiovascular health (Patterson et al., 2019). This highlights its potential to serve as a beneficial exercise modality, especially for those at risk, such as those who are obese and have associated cardiovascular insufficiency. A meta-analysis has shown that exercise combined with BFR can lead to significant changes in resting BP and heart rate, which may be a risk for individuals with pre-existing cardiovascular disease (Park et al., 2015).

The study found that participants engaging in the two distinct resistance training exercises demonstrated a markedly elevated mean HRV with the BFR training approach compared to the high-load resistance training approach. Additionally, the mechanics of HRV were considerably more favorable for BFR. These findings align with previous research on the topic. However, some literature suggests that resistance training with BFR and traditional high-intensity resistance training may be practical but not significantly affect HRV in certain groups. For example, a study of inactive older adults with conditions such as diabetes and hypertension found no changes in HRV after resistance training (Centner et al., 2019). Further research shows that BFR can reduce SBP without affecting coagulation markers (Bazgir et al., 2016; Parati & Ochoa, 2012). This suggests that BFR may be safe and effective in specific clinical populations (Thomas et al., 2018).

In contrast, the results obtained in our study group suggest that BFR provides a higher level of HRV response. BFR may reduce cardiac stress while maintaining a stable HRV and may be a more effective form of exercise in such a sample group. BFR can lead to significant improvements in performance metrics. A study found that futsal players who underwent BFR during small-sided games significantly improved mean power output (Neto et al., 2017). Data analysis from several studies showed that BFR uses increased heart rate and BP during exercise, suggesting that BFR can effectively improve the internal training load (Cerqueira et al., 2021). In this respect, our findings make an essential contribution to the literature.

The findings are essential because traditional high-intensity resistance exercise is generally thought to cause more dramatic changes in BP, HR, and cardiac output compared to low-intensity BFR exercise . This is due to the increased cardiovascular strain associated with high-intensity training. However, the BFR training method effectively produces a more significant muscular workload and physiological response at a substantially lower relative exercise intensity (Bazgir et al., 2016; Park et al., 2015). This is a significant advantage, as it allows individuals who may not be able to tolerate or access high-intensity resistance training, such as the elderly or those recovering from injury, still to achieve meaningful muscular adaptations through the BFR technique. Additionally, research has indicated that BFR exercise may benefit cardiovascular health, including reductions in BP, without adversely impacting coagulation markers or HRV (Bazgir et al., 2016; Park et al., 2015). These findings suggest that BFR training may be a safer and more accessible option for improving muscular strength and size while potentially providing cardiovascular protective effects.

CONCLUSION

The autonomic nervous system undergoes considerable acute modifications at low intensities of BFR. The acute effects of BFR on HRV markers are still not elucidated, and further research on different exercise methods and different measurement methods [measuring device used, measured time-dependent (short-medium-long), time-domain, frequency-domain, and non-linear parameters] is needed to draw firm conclusions. The available evidence suggests that acute changes, if any, may be small and depend on various factors. When interpreting these findings, it is important to consider the specific BFR protocol and individual characteristics. These findings suggest that BFR training may be a safer and more accessible option for improving muscle strength and size while providing cardiovascular protective effects. This is an important advantage because it allows individuals who cannot tolerate or access high-intensity resistance training, such as the elderly or those recovering from injury, to achieve meaningful muscle adaptations through the BFR technique.

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