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Research article

Effects 0f Acute Upper and Lower Body Resistance Exercise on Cardiovascular Response in Adult Women Through Blood Flow Restriction

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Abstract

The purpose of this study was to compare and contrast cardiovascular responses during acute upper body resistance exercise (UBRE) and lower body resistance exercise (LBRE) and resting with or without blood flow restriction (BFR) in adult women. The subjects were 18 adult women (21.5 ± 2.0 years old) and it was a cross-over experimental design. Resistance exercise consisted of 20% 1-RM, 10 repetitions, and 4 sets. For UBRE, arm curl and bench press exercise, and LBRE squat and leg extension exercise were performed. The change in cardiovascular response during exercise and recovery with or without BFR was significantly different between UBRE (diastolic blood pressure: DBP, mean arterial pressure: MAP, total peripheral resistance: TPR) and LBRE (DBP, MAP, heart rate: HR, Cardiac output: CO) ($p < .05$). In non-BFR, DBP, MAP, SV, HR, CO, there was a difference in TPR ($p < .05$). It was concluded LBRE with BFR had a positive effect on the cardiovascular response of the cardiovascular system during exercise and recovery.

Key words: Blood flow restriction, Cardiovascular response, Resistance exercise.

Introduction

Currently, a wide variety of exercise training methods are used to improve physical fitness, muscular strength, and endurance for fitness programs and rehabilitation programs. Among them, blood flow restriction (BFR) training was reported to have significant benefits to increase skeletal muscle mass strength (Yasuda et al., 2015). This exercise practice with low-intensity workloads has generated considerable interest in recent years due to its positive effects comparable to traditional protocols with higher intensity resistance training (i.e., ~70-85% of a one-repetition max (1-RM) (Slysz et al., 2016). BFR uses an inflatable cuff or tourniquet placed proximally to the exercising muscle to partially that fully occlusion blood flow in order to stimulate neuromuscular adaptations (Iida et al., 2011). It produces partial restriction of arterial inflow and full occlusion of venous outflow of the extremity to which the external cuff pressure is applied (Loenneke et al., 2012; Partsch and Partsch, 2005). This maneuver elicits health benefits of the normal physiological adaptations to exercise due to accumulated metabolites which increase muscle growth (Yasuda et al., 2015).

BFR training provides health benefits to the young and the elderly as well as individuals with cardiovascular disease (Lowery et al., 2014; Yasuda et al., 2015; Zhao et al., 2021). Moreover, previous research suggested BFR combined with low load resistance training, or cardiovascular endurance training can be utilized as a potential therapeutic alternative in the rehabilitation of patients who may be incapable of performing high load resistance training (e.g., elderly, recovering athletes) (Centner et al., 2019; Mouser et al., 2019). Known beneficial effects are an improvement in VO_{2max} (de Oliveira et al., 2016; Held et al., 2020) aerobic capacity (Cardoso et al., 2020), carotid arterial compliance (Ozaki et al., 2011), and microvascular filtration capacity of skeletal muscles (Evans et al., 2010). A big advantage of BFR training produces is that it similar benefits of high-intensity resistance exercise even though low-loads are used.

However, even though side effects with BFR were minimal, studies have reported potential negative cardiovascular effects such as an increase in blood clots, ischemia-reperfusion, and muscle damage (Cristina-Oliveira et al., 2020; Loenneke et al., 2011; Patterson et al., 2019). Particularly, among the side effects associated with BFR training is the muscle metaboreflex (MMR)-induced cardiovascular abnormalities. Continued research is required to determine if the exercise pressor reflex is altered. This MMR (a component of the exercise pressor reflex) rases blood pressure (BP) due to an increase in metabolites produced by mismatch between metabolic demand and supply within exercising skeletal muscle. Evidence showed BFR training was positively effective in reducing BP in both normotensive and hypertensive individuals (Araujo et al., 2014; Neto et al., 2015). On the other hand, BP responses were exaggerated in hypertensive individuals, which is partially associated with abnormal metaboreflex (Chant et al., 2018). Furthermore, Araujo and colleagues (Araujo et al., 2014) reported BFR exercise-induced BP response was substantially elevated compared to exercise without BFR. Thus, more research is needed to reveal a protocol which can be used safely without excessive increase in BP during BFR training sessions. However, with regard to negative effects most studies focused on exercising BP responses during lower body mainly BFR exercise. Our study would be relevant to providing exercise professionals, as well as healthy individuals, that the use of BFR during exercise can cause negative impacts to the body. Thus, we examined whether upper body resistance exercise (UBRE) with BFR evoked excessive cardiovascular responses. It was hypothesized that lower body resistance exercise (LBRE) with BFR would result in higher BP responses during exercise and recovery compared to the UBRE with BFR.

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Methods

Participants

A total of 18 apparently healthy sedentary women college students aged between 20 and 30 years were recruited in this study. Subjects were normotensive, non-medicated, non-smokers, and free of cardiovascular diseases that could affect physiological responses to exercise and post-exercise. Subjects were considered to be sedentary since none of them had participated in at least 30 min moderate intensity physical activity on three days per week for at least three months as assessed by health history questionnaire (American College of Sports Medicine, 2021). They are informed of the pretesting guidelines and reviewed the experimental procedures and signed an informed consent form containing the risk and benefits prior to participating in this study. The study was approved by World Health Beauty Institutional Research Board (1-20170113119-AB-N-01-09).

Exercise test protocol

All subjects reported to the laboratory for the baseline measurement and BFR exercise. The experimental protocol consisted of measurements of cardiovascular responses during and after the UBRE and LBRE with or without BFR. Each subject completed workouts with or without BP cuff inflated on their arms or legs. All exercise tests were performed at the same time of day to reduce diurnal variation. They were asked to refrain from consuming alcohol and strenuous physical activity for 48 h, and caffeine for three hours prior to each test. In all experiments, each exercise was measured over a total of 4 visits. Each protocol was separated by three days. Resting BP was measured at least twice in a seated position via a sphygmomanometer and pressure cuff. For the relative exercise intensities for the resistance exercise used in this study, the one-repetition maximum (RM) test was conducted to determine the maximal weight each subject can perform with one repetition. The following day, subject completed four bouts of UBRE and LBRE at a 20% workload of their predetermined 1RM with and without BFR. The body composition, including height, weight, body mass index, fat mass, and percent body fat was measured using a body composition analyzer (MC190-EM; Tanita,Tokyo, Japan) (Table 1).

Resistance exercise

The resistance exercise program consisted of a three minutes warm-up exercise on cycle ergometer with low intensity, followed by exercise for the upper and lower limbs (squat and arm curl). The trial was performed with loads corresponding to the 20% of 1 RM without BFR. Under resting conditions, the maximum number of repetitions was examined several times to obtain exact values for one-repetition maximum (1RM). If they were able to perform more than 10 repetitions, then a heavier weight was provided. Whenever the maximum number of repetitions was ≤10, the weight was considered submaximal weight and the 1RM was calculated as follows: estimated 1RM (kg) = submaximal weight (kg)/(102.78 - 2.78×maximum number of repetitions)/100 (Shimizu et al., 2016). Determination of 1-RM involved performing 5 - 10 repetitions with a light load (40-60% of estimated 1RM). After 3 minutes of rest, subjects performed 3 to 5 repetitions with increased load (50 to 70% of estimated 1-RM). After resting for another 3 minutes, the exercise was repeated 2 to 3 times with a load of 60 to 80% of the estimated 1-RM. After these submaximal repetitions, 1-RM was determined within 5 repetitions, including 3 minutes of rest. All repetitions were performed at the same movement speed and range of motion were identical between measurements. Final weight was recorded as the participant's 1-RM (Lowery et al., 2014). If the subject failed to complete 5 repetitions, 1-RM was estimated using Epley's formula (1-RM = load [kg] × (1 + [0.033 × number of repetitions]) (Shimizu et al., 2016).

1RM (kg) = (1-RM = load [kg] × (1 + [0.033 × number of repetitions])

The exercise intervention was repeated 10 times at the speed of 1 second with 4 sets. Rest times between sets used during acute resistance training with BFR are generally short and BFR is maintained. A study on acute resistance exercise used rest periods of 150 seconds (Loenneke et al., 2010), but was not found to increase metabolic responses. The resting time between sets was 30 seconds. The BP was measured at rest, and during exercise and recovery using an automated Omron JPN 500 device (Omron Healthcare, Japan). All subjects were instructed to adhere to their normal living and dietary routines throughout the study.

Table 1. Characteristic of subjects. (M±SD)

Variable	n = 18
Age (yr)	21.5 ± 2.0
Height (cm)	162.4 ± 4.3
Weight (kg)	57.5 ± 7.6
Body mass index (kg/cm^2)	21.7 ± 2.2
Fat free mass (kg)	40.5 ± 4.3
Fat mass (kg)	16.9 ± 4.7
Body fat (%)	29.1 ± 4.7
Heart rate (beats/min)	77.0 ± 11.0
Systolic blood pressure (mmHg)	111.1 ± 6.7
Diastolic blood pressure (mmHg)	76.4 ± 5.8
Mean arterial pressure (mmHg)	87.9 ± 5.5
1 Repetition maximal-Upper (kg)	22.8 ± 5.8
1 Repetition maximal-Lower (kg)	47.8 ± 12.1

Blood flow restriction

Although muscle adaptation was achieved by applying the same pressure to each individual in a prior study, it was found that higher BFR pressure can increase cardiovascular response (Mattocks et al., 2017). We employed the cuff pressure of 80% arterial occlusive pressure during low-load resistance training. This training induced hypertrophic and strength responses comparable to traditional high-load training (Laurentino et al., 2012). The cuff was placed in the most proximal part of both legs and arms using pneumatic and stretchable bands size (50 mm for lower limbs and 40 mm for upper limbs, respectively) (KAATSU Global Inc., USA). The arterial occlusion pressure was equal to the systolic pressure in the upper limbs and twice the systolic pressure in the lower limbs (Iida et al., 2011). The BFR was applied immediately before the squat set and used only during the exercise, releasing during each rest interval.

Measurement of cardiovascular responses

Stroke volume (SV) and heart rate (HR) were obtained continuously via impedance cardiography (Physioflow, Manatec Biomedical, Paris, France) from the rest throughout the recovery. This non-invasive device measures real-time cardiac output (CO) data and has been used to quantify cardiac parameters in healthy subjects (Dillon et al., 2021; Lee et al., 2015; Tordi et al., 2004). For the SV measurement, two electrodes were placed on the supraclavicular fossa at the base of the left side of the neck, two electrocardiography (ECG) electrodes used for recoding single lead ECG, and two electrodes were placed at the xiphoid process. The Physioflow is a thoracic bioimpedance technique that detects the change in impedance by injecting a high frequency (75 kHz) alternating electrical current of low magnitude (1.8 mA peak to peak) via two skin electrodes positioned on the neck and another two positioned on xiphoid process (Bougault et al., 2005). By detecting the difference of thoracic impedance over time, this device noninvasively measures the SV (Charloux et al., 2000). CO was calculated by the formula (HR x SV x BSA). HR is measured from the ECG, SV is SV index (i.e., SV/BSA), and BSA is body surface area. It has well known that this transthoracic bioimpedance technique is valid against the direct Fick method at rest and during exercise (Charloux et al., 2000; Richard et al., 2001). Mean arterial pressure (MAP) was calculated using the formula: MAP = [(SBP-DBP) x 1/3)] + DBP. Total vascular conductance (TVC) was cal culated as CO/MAP.

Statistical analysis

Data analysis was performed using SPSS PC+ for Windows (version 26.0). Based on Cohen's D power equation, in order to maintain the effect size of 0.95 and power of 0.8, a minimum 18 participants was needed. Data are expressed as the mean ± standard deviation (SD). Mean values of SBP, DBP, MAP, HR, SV, CO, and TVC for each 30 seconds interval at rest and during exercise and recovery used for comparison between two resistance exercises with and without BFR. A 2 x 2 x 6 repeated measures ANOVA was used to test the effects of resistance exercise groups (UBRE and LBRE) on cardiovascular response across condition (with and without BFR) and across time (Rest, last minute of exercise, R10, R20, R30, and R40). Statistical significance was set at $p < 0.05$.

Results

Table 2 indicates the comparison of cardiovascular responses during UBRE and recovery according to BFR and non-BFR. There were significant interactions between time and group effects in both DBP and MAP. BFR resulted in greater DBP and MAP only during exercise compared to without BFR. SV was significantly increased at only 10 min recovery compared to the exercise. HR and CO were significantly decreased at 10 min recovery from exercise and this reduction remained during 20 min, 30 min, and 40 min recovery. There was significant interaction effect in TPR. BFR had greater TPR during exercise compared to the without BFR.

Table 3 indicates the comparison of cardiovascular responses at LBRE and recovery according to BFR and non-BFR. SBP significantly decreased from exercise throughout the recovery in both conditions. There were significant interactions between time and group effects in both DBP and MAP. BFR resulted in greater DBP and MAP only during exercise compared to without BFR. SV was significantly increased at 10 min, 20 min, 30 min and 40 min recovery compared to the exercise. There were significant interactions between time and group effects for in both HR and CO. HR and CO were significantly decreased at 10 min recovery from exercise and this reduction remained at 20 and 40 min of recovery. There was significant interaction effect in TPR. BFR had greater TPR during exercise compared to the without BFR. There were no differences in TPR in both conditions.

Table 4 indicates comparison of cardiovascular responses according to UBRE, LBRE, and BFR during recovery. SBP significantly decreased from exercise throughout the recovery in both conditions. There were significant interactions between time and group effects in both DBP and MAP. LBRE with BFR resulted in greater DBP and MAP only during exercise compared to UBRE with BFR. There were significant interactions for HR, SV, and CO. There were significantly differences in HR and SV between UBRE and LBRE with BFR and at 10 min, 20 min, and 30 min recovery. CO was significantly higher during LBRE with BFR and recovery compared to the UBRE. There was significant interaction effect in TPR. BFR had greater TPR during exercise compared to the without BFR. There were no differences in TPR in both conditions. There was significant interaction in TPR between LBRE with BFR. TPR was significantly decreased in LBRE with BFR compared to the UBRE with BFR and this reduction remained throughout the recovery.

Discussion

BFR stimulates the exercise pressor reflex (EPR) in response to tissue hypoxia, and there are concerns about how reduced blood flow affects cardiovascular function (Spranger et al., 2015). BFR is an exercise method with a low load that may induce muscle hypertrophy. Since it artificially reduces the amount of blood returning to the heart, subject's cardiovascular response must be monitored. When the working muscles need more oxygen, the central nervous system responds by attenuating the parasympathetic nerve activation and facilitating the sympathetic nerve activation (Smith and Fernhall, 2011). This causes the body to increase HR to try to pump more blood to deoxygenated tissues, which increases the cardiac load and the heart requires more amount of oxygen to the myocardium (Smith and Fernhall, 2011).

In this study, the cardiovascular response according to BFR showed an interaction between DBP, MAP, and CO of UBRE and LBRE during exercise and recovery ($p < .05$). SBP showed no difference in both UBRE and LBRE during exercise and recovery regardless of BFR, but significantly decreased after 10 minutes of exercise. This result may have been attributed to the post-exercise hypotensive effect (PHE) effect. The reason for this is the decrease in CO that is not completely explained by increased systemic peripheral vascular resistance (Maior et al., 2015). In this study, DBP decreased according to BFR (19.1%, 22.2%) and non-BFR (17.0%, 17.4%) 10 minutes after UBRE and LBRE recovery, respectively. Previously, similar results were also suggested by Maior et al. (2015) and Neto et al. (2015).

Recently, interest in the exercise pressor reflex (EPR) of skeletal muscle has been demanded as a physiological phenomenon requiring attention in BFR exercise (Spranger et al., 2015). In exercise physiology, it was suggested that the EPR determines the cardiovascular response when performing physical activity such as BFR exercise. This response is characterized by hypersensitivity of the sympathetic nervous system, which may explain the increase in HR and BP (Mitchell, 2017). Metaboreflex and muscle mechanoreflex are regulators of EPR, which are both increased during BFR exercise by skeletal muscle cuff pressure (Renzi et al., 2010).

Most previous studies showed no change in SBP for at least 10 minutes immediately after LBRE using BFR (Tomschi et al., 2018). The increase in SBP during exercise is thought to be from EPR, which occurs even under conditions of BFR due to the stimulation of mechanical reflexes (vascular compression) and metabolic reflexes (metabolite accumulation) known as Groups III and IV (Kaufman et al., 1984). However, it is very difficult to compare changes in SBP because the degree of change in SBP can vary depending on the exercise parameters (e.g., intensity, volume, and cuff pressure and width).

Table 2. Comparison of cardiovascular response during upper body resistance exercise (UBRE) and recovery following BFR or without BFR.

		UBRE			**p**
		non-BFR	**non-BFR**		
SBP (mmHg)	rest	99.8 ± 5.8	100.0 ± 4.2	Time Group Time×Group	.000* .950 .528
	exercise	118.3 ± 8.8	120.7 ± 7.6		
	recovery 10 min	101.3 ± 4.4	101.5 ± 5.0		
	recovery 20 min	100.3 ± 5.6	99.2 ± 5.1		
	recovery 30 min	99.4 ± 6.0	98.7 ± 5.0		
	recovery 40 min	98.1 ± 4.6	97.7 ± 5.2		
DBP (mmHg)	rest	68.5 ± 5.2	67.4 ± 4.6 ^{b}	Time Group Time×Group	.528 .279 .000*
	exercise	73.5 ± 8.0 ^{c,d,e,f}	83.5 ± 6.7 ^{a,c,d,e,f}		
	recovery 10 min	64.6 ± 4.7 ^{b}	66.1 ± 5.2 ^{c}		
	recovery 20 min	66.2 ± 5.6 ^{b}	65.2 ± 3.6 ^{b}		
	recovery 30 min	65.8 ± 4.7 ^{b}	65.4 ± 4.2 ^{b}		
	recovery 40 min	65.5 ± 5.1 ^{b}	65.8 ± 5.2 ^{b}		
MAP (mmHg)	rest	78.9 ± 4.7 ^{b}	78.3 ± 3.4 ^{b}	Time Group Time×Group	.000* .540 .000*
	exercise	88.5 ± 5.9 ^{a,c,d,e,f}	94.3 ± 8.9 ^{a,c,d,e,f}		
	recovery 10 min	76.8 ± 3.7 ^{b}	77.9 ± 4.2 ^{b}		
	recovery 20 min	77.6 ± 5.0 ^{b}	76.6 ± 3.4 ^{b}		
	recovery 30 min	77.0 ± 4.8 ^{b}	76.5 ± 3.6 ^{b}		
	recovery 40 min	76.4 ± 4.4 ^{b}	76.4 ± 4.5 ^{b}		
SV (ml)	rest	79.9 ± 10.6	78.5 ± 8.6	Time Group Time×Group	.002* .513 .964
	exercise	78.4 ± 9.6	77.7 ± 11.3		
	recovery 10 min	83.7 ± 12.0	81.1 ± 12.0		
	recovery 20 min	79.1 ± 11.2	76.8 ± 11.7		
	recovery 30 min	79.0 ± 11.4	75.9 ± 11.6		
	recovery 40 min	78.0 ± 10.6	75.4 ± 11.6		
HR (beats/ min)	rest	61.0 ± 10.8	59.0 ± 8.0	Time Group Time×Group	.000* .472 .629
	exercise	90.3 ± 12.2	84.1 ± 22.0		
	recovery 10 min	61.3 ± 8.9	61.1 ± 7.7		
	recovery 20 min	59.8 ± 9.6	61.0 ± 8.5		
	recovery 30 min	79.0 ± 11.4	75.9 ± 11.6		
	recovery 40 min	59.3 ± 8.0	60.1 ± 8.4		
CO (l/min)	rest	4.8 ± 0.6	4.6 ± 0.5	Time Group Time×Group	.000* .697 .254
	exercise	7.0 ± 0.8	6.7 ± 0.8		
	recovery 10 min	5.0 ± 0.4	5.0 ± 0.6		
	recovery 20 min	4.6 ± 0.4	4.7 ± 0.6		
	recovery 30 min	4.5 ± 0.4	4.5 ± 0.5		
	recovery 40 min	4.5 ± 0.3	4.5 ± 0.5		
TPR (mmHg/l/ min)	rest	16.7 ± 2.5 ^{b}	17.2 ± 2.1 ^{b}	Time Group Time×Group	.000* .005 .028*
	exercise	12.7 ± 1.5 ^{a,c,d,e,f}	14.2 ± 2.3 $^{a,d,e,f\ \#}$		
	recovery 10 min	15.3 ± 1.4 ^{b,d,e,f}	15.6 ± 1.7 ^{e}		
	recovery 20 min	16.8 ± 1.7 ^{b,c}	16.3 ± 2.0 ^{b}		
	recovery 30 min	16.8 ± 1.4 ^{b,c}	16.8 ± 1.7 ^{b,c}		
	recovery 40 min	16.8 ± 1.6 ^{b,c}	16.8 ± 1.7 ^{b}		

Values are mean ± standard deviation, SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, SV: stroke volume, HR: heart rate, CO: cardiac output, TPR: total peripheral resistance. a: rest, b: recovery 10 min, c: recovery 20 min, d: recovery 30 min, e: recovery 40 min. a, b, c, d, e f: different alphabet appear significant difference stage. #*p* < .05, significant different between groups effects. **p* < .05, significant different main or interaction effects.

Table 3. **Comparison of cardiovascular response of lower body resistance exercise (LBRE) and recovery according to BFR or without BFR.**

		UBRE		p	
		non-BFR	**non-BFR**		
SBP (mmHg)	rest	102.1 ± 5.6	99.5 ± 5.1		
	exercise	123.2 ± 12.4	126.2 ± 11.4	Time	.000*
	recovery 10 min	105.8 ± 4.8	104.0 ± 5.1	Group	.928
	recovery 20 min	103.1 ± 5.4	102.0 ± 4.0	Time×Group	.220
	recovery 30 min	102.0 ± 5.4	102.0 ± 4.9		
	recovery 40 min	99.7 ± 5.6	101.5 ± 6.0		
DBP (mmHg)	rest	71.8 ± 5.2 $^{b,c,d.e,f}$	71.2 ± 5.1 ^{b,f}		
	exercise	82.7 ± 6.6 ^{a,c,d,e,f}	91.6 ± 8.9 ^{a,c,d,e,f}	Time	.000*
	recovery 10 min	67.5 ± 3.9 ^{a,b}	68.3 ± 6.4 ^{b}	Group	.130
	recovery 20 min	67.5 ± 4.4 ^{a,b}	68.6 ± 5.1 ^{b}	Time×Group	.000*
	recovery 30 min	66.8 ± 3.9 ^{a,b}	68.2 ± 5.7 ^{b}		
	recovery 40 min	65.8 ± 5.0 ^{a,b}	67.2 ± 4.1 ^{a,b}		
MAP (mmHg)	rest	81.9 ± 4.7 ^{a,f}	80.6 ± 4.6 ^{a}		
	exercise	96.2 ± 7.3 ^{a,c,d,e,f}	102.5 ± 8.8 ^{a,c,d,e,f}	Time	.000*
	recovery 10 min	80.2 ± 3.7 ^{b,f}	80.2 ± 5.2 b	Group	.332
	recovery 20 min	79.4 ± 4.3 ^{b}	79.7 ± 4.5 b	Time×Group	.002*
	recovery 30 min	78.5 ± 3.9 ^{b}	79.5 ± 5.1 b		
	recovery 40 min	77.1 ± 4.6 ^{a,b,c}	78.6 ± 4.4 b		
SV (ml)	rest	77.8 ± 12.0	76.5 ± 14.7		
	exercise	87.4 ± 11.7	88.6 ± 14.9	Time	.000*
	recovery 10 min	85.8 ± 10.5	87.3 ± 14.3	Group	.849
	recovery 20 min	79.1 ± 10.9	81.2 ± 13.6	Time×Group	.659
	recovery 30 min	79.5 ± 11.3	79.6 ± 15.4		
	recovery 40 min	76.8 ± 11.1	77.9 ± 14.4		
HR (beats/min)	rest	61.5 ± 7.7 ^{b,c,d}	61.2 ± 7.8 ^{b,c,d,e}		
	exercise	100.6 ± 19.4 ^{a,c,d,e,f}	115.3 ± 17.5 ^{a,c,d,e,f}	Time	.000*
	recovery 10 min	68.7 ± 7.0 ^{a,b,e,f}	74.1 ± 12.1 ^{a,b,d,e,f}	Group	.101
	recovery 20 min	65.7 ± 7.6 ^{a,b,f}	68.6 ± 9.3 ^{a,b,c}	Time×Group	.000*
	recovery 30 min	63.6 ± 8.3 ^{b,c}	67.4 ± 9.1 ^{a,b,c}		
	recovery 40 min	61.7 ± 7.6 ^{b,c,d}	65.7 ± 9.3 ^{b,c}		
CO (l/min)	rest	4.7 ± 0.7 ^{b,c,d}	4.6 ± 0.7 ^{b,c,d,e}		
	exercise	8.7 ± 1.6 ^{a,c,d,e,f}	10.2 ± 2.2 ^{a,c,d,e,f}	Time	.000*
	recovery 10 min	5.8 ± 0.7 ^{a,b,d,e,f}	6.3 ± 0.9 ^{a,b,d,e,f}	Group	.100
	recovery 20 min	5.1 ± 0.7 ^{a,b,c,f}	5.5 ± 0.8 ^{a,b,c,f}	Time×Group	.000*
	recovery 30 min	5.0 ± 0.6 ^{b,c,d,f}	5.2 ± 0.9 ^{a,b,c}		
	recovery 40 min	4.7 ± 0.6 ^{b,c,d,f}	5.0 ± 0.9 ^{b,c,d}		
TPR (mmHg/l/min)	rest	17.6 ± 3.2	17.8 ± 2.5		
	exercise	11.4 ± 2.3	10.6 ± 2.6	Time	.000*
	recovery 10 min	13.8 ± 1.7	12.8 ± 1.8	Group	.484
	recovery 20 min	15.6 ± 2.3	14.8 ± 2.4	Time×Group	.536
	recovery 30 min	15.9 ± 2.0	15.5 ± 3.0		
	recovery 40 min	16.6 ± 2.5	16.1 ± 3.4		

Values are mean ± standard deviation, SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, SV: stroke volume, HR: heart rate, CO: cardiac output, TPR: total peripheral resistance. a: rest, b: recovery 10 min, c: recovery 20 min, d: recovery 30 min, e: recovery 40 min. a, b, c, d, e f: different alphabet appear significant difference stage. *$p < .05$, significant different main or interaction effects.

In this study, DBP significantly decreased during recovery after LBRE regardless of BFR, and returned to resting levels after 10 minutes of recovery. Figueroa and Vicil (2011) reported that SBP and DBP increased immediately after LBRE regardless of BFR, but returned to the resting level during 30 minutes of recovery. Elevated MAP after exercise was significantly higher in the BFR group compared to the non-BFR group. CO increased similarly between the two sessions, but SV did not change and HR increased during exercise with BFR. It is believed this result may provide circulatory difficulties to people with cardiovascular disease.

In this study, cardiovascular responses between UBRE and LBRE of BFR showed significant differences in DBP, MAP, SV, HR, CO, and TPR ($p < .05$). This result shows that a significant difference in SBP after UBRE with BFR. This supports the study by Tomschi et al. (2018) who reported no change, suggesting that a change in SBP is not dependent on intensity, rest interval, or ischemia. Additionally, the significant decrease in DBP at 10 min after BFR may be due to decreased TPR and BP (Coote, 2010). In this study, the BFR group showed a significant increase in HR compared to the non-BFR group in UBRE and LBRE. In particular, the difference that induced higher HR during LBRE compared to UBRE could be attributed to the baroreflex (Spranger et al., 2015). Therefore, low-intensity LBRE (20 - 40% 1-RM) with BFR is thought to be related to an acute increase in cardiovascular response.

Table 4. Comparison of cardiovascular responses of UBRE and LBRE during exercise and recovery using BFR.

		UBRE			
		non-BFR	non-BFR		*p*
SBP (mmHg)	rest	100.5 ± 4.2	99.5 ± 5.1	Time Group Time×Group	.000* .077 .070
	exercise	120.7 ± 7.6	126.2 ± 11.4		
	recovery 10 min	101.5 ± 5.0	104.0 ± 5.1		
	recovery 20 min	99.2 ± 5.1	102.0 ± 4.0		
	recovery 30 min	98.7 ± 5.0	102.0 ± 4.9		
	recovery 40 min	97.7 ± 5.2	101.5 ± 6.0		
DBP (mmHg)	rest	67.4 ± 4.6 ^{b}	71.2 ± 5.1 ^{b,f}	Time Group Time×Group	.000* .019* .005*
	exercise	83.5 ± 6.7 ^{a,c,d,e,f}	91.6 ± 8.9 $^{a,c,d,e,f\#}$		
	recovery 10 min	66.1 ± 5.2 ^{b}	68.3 ± 6.4 ^{b}		
	recovery 20 min	65.2 ± 3.6 ^{b}	68.6 ± 5.1 ^{b}		
	recovery 30 min	65.4 ± 4.2 ^{b}	68.2 ± 5.7 ^{b}		
	recovery 40 min	65.8 ± 5.2 ^{b}	67.2 ± 4.1 ^{a,b}		
MAP (mmHg)	rest	78.3 ± 3.4 ^{a}	80.6 ± 4.6 ^{b}	Time Group Time×Group	.000* .017* .005*
	exercise	94.3 ± 8.9 ^{a,c,d,e,f}	94.3 ± 8.9 ^{a,c,d,e,f}		
	recovery 10 min	77.9 ± 4.2 ^{b}	80.2 ± 5.2 $^{b\#}$		
	recovery 20 min	76.6 ± 3.4 ^{b}	79.7 ± 4.5 ^{b}		
	recovery 30 min	76.5 ± 3.6 ^{b}	79.5 ± 5.1 ^{b}		
	recovery 40 min	76.4 ± 4.5 ^{b}	78.6 ± 4.4 ^{b}		
SV (ml)	rest	78.5 ± 8.6	76.5 ± 14.7 ^{b,c,d}	Time Group Time×Group	.000* .277 .002*
	exercise	77.7 ± 11.3	88.6 ± 14.9 ^{a,d,e,f}		
	recovery 10 min	81.1 ± 12.0 ^{d,e,f}	87.3 ± 14. ^{a,d,e,f}		
	recovery 20 min	76.8 ± 11.7 ^{c}	81.2 ± 13.6 ^{a,b,c,f}		
	recovery 30 min	75.9 ± 11.6 ^{c}	79.6 ± 15.4 ^{b,c,d}		
	recovery 40 min	75.4 ± 11.6 ^{c}	77.9 ± 14.4 ^{b,c,d}		
HR (beats/min)	rest	59.0 ± 8.0 ^{b}	61.2 ± 7.8 ^{b,c,d,e}	Time Group Time×Group	.000* .001* .000*
	exercise	84.1 ± 22.0 ^{a,c,d,e,f}	115.3 ± 17.5 $^{a,c,d,e,f\#}$		
	recovery 10 min	61.1 ± 7.7 ^{b}	74.1 ± 12.1 $^{a,b,d,e,f\#}$		
	recovery 20 min	61.0 ± 8.5 ^{b}	68.6 ± 9.3 $^{a,b,c\#}$		
	recovery 30 min	59.8 ± 7.7 ^{b}	67.4 ± 9.1 $^{a,b,c\#}$		
	recovery 40 min	60.1 ± 8.4 ^{b}	65.7 ± 9.3 ^{b,c}		
CO (l/min)	rest	4.6 ± 0.5 ^{b,c}	4.6 ± 0.7 ^{b,c,d,e}	Time Group Time×Group	.000* .000* .000*
	exercise	6.7 ± 0.8 ^{a,c,d,e,f}	10.2 ± 2.2 $^{a,c,d,e,f\#}$		
	recovery 10 min	5.0 ± 0.6 ^{a,b,d,e,f}	6.3 ± 0.9 $^{a,b,d,e,f\#}$		
	recovery 20 min	4.7 ± 0.6 ^{b,c}	5.5 ± 0.8 $^{a,b,c,f\#}$		
	recovery 30 min	4.5 ± 0.5 ^{b,c}	5.2 ± 0.9 $^{a,b,c\#}$		
	recovery 40 min	4.5 ± 0.5 ^{b,c}	5.0 ± 0.9 $^{b,c,d\#}$		
TPR (mmHg/l/min)	rest	17.2 ± 2.1 ^{b}	17.8 ± 2.5	Time Group Time×Group	.000* .030* .000*
	exercise	14.2 ± 2.3 ^{a,d,e,f}	10.6 ± 2.6 $^{\#}$		
	recovery 10 min	15.6 ± 1.7 ^{e}	12.8 ± 1.8 $^{\#}$		
	recovery 20 min	16.3 ± 2.0 ^{b}	14.8 ± 2.4 $^{\#}$		
	recovery 30 min	16.8 ± 1.7 ^{b,c}	15.5 ± 3.0		
	recovery 40 min	16.8 ± 1.7 ^{b}	16.1 ± 3.4		

Values are mean ± standard deviation, SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, SV: stroke volume, HR: heart rate, CO: cardiac output, TPR: total peripheral resistance. a: rest, b: recovery 10 min, c: recovery 20 min, d: recovery 30 min, e: recovery 40 min. a, b, c, d, e f: different alphabet appear significant difference stage. $^{\#}p < .05$, significant different between groups effects. $^{*}p < .05$, significant different main or interaction effects.

In this study, healthy sedentary women college students aged between 20 and 30 were recruited. Most studies have not stratified men and women for analysis or simply have omitted women completely. In fact, females are often underrepresented in terms of scientific evaluation, largely attributed to the dynamic hormonal fluctuations of the menstrual cycle (Hunter, 2016), which may alter their responses or increase variability to exercises used in the studies. Our study should consider potential limitations. The current study included healthy and physically active individuals. The study cannot be applicable to other populations such as older adults, sedentary populations, and patients. Another limitation is the fact that this study did not evaluate the effects of the BFR during exercise over longer durations.

Conclusion

In conclusion, in resistance exercise with BFR, CO increased due to increase in HR and SV during exercise, and blood pressure response was stable due to a significant decrease in TPR during exercise. That could be the cause of the action of metabolic receptors due to BFR during resistance exercise. Therefore, it was judged that low-intensity resistance exercise with BFR had a positive effect on the hemodynamic response of the cardiovascular system during exercise and recovery. It will be necessary to conduct a long-term training study to confirm the differences in cardiovascular responses of UBRE and LBRE exercise according to BFR in the future. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

ACSM's Guidelines for Exercise Testing and Prescription. (2021) American College of Sports Medicine. Liguori, G., Feito, Y., Fountaine, C., Roy, B., Eds.; Eleventh edition.; Wolters Kluwer: Philadelphia.https://www.acsm.org/education-resources/books/guidelines-exercise-testing-prescription

Araujo, J.P.; Silva, E.D., Silva, J., Souza, T., Lima, E.O., Guerra, I. and Sousa, M.S. (2014) The acute effect of resistance exercise with blood flow restriction with hemodynamic variables on hypertensive subjects. *Journal of Human Kinetics* **43**, 79-85. https://doi.org/10.2478/hukin-2014-0092

Bougault, V.; Lonsdorfer-Wolf, E., Charloux, A., Richard, R., Geny, B. and Oswald-Mammosser, M. (2005) Does thoracic bioimpedance accurately determine cardiac output in COPD patients during maximal or intermittent exercise? *Chest* **127(4)**, 1122-1132. https://doi.org/10.1016/s0012-3692(15)34456-1

Cardoso, R.K., Araujo, A.M., Del Vechio, F.B., Bohlke, M., Barcellos, F.C., Oses, J.P., de Freitas, M.P. and Rombaldi, A.J. (2020) Intradialytic exercise with blood flow restriction is more effective than conventional exercise in improving walking endurance in hemodialysis patients: A randomized controlled trial. *Clinical Rehabilitation* **34**, 91-98. https://doi.org/10.1177/0269215520945660

Centner, C., Wiegel, P., Gollhofer, A. and Konig, D. (2019) Effects of Blood Flow Restriction Training on Muscular Strength and Hypertrophy in Older Individuals: A Systematic Review and Meta-Analysis. *Sports Medicine* **49**, 95-108. https://doi.org/10.1007/s40279-018-0994-1

Chant, B., Bakali, M., Hinton, T., Burchell, A.E., Nightingale, A.K., Paton, J.F.R. and Hart, E.C. (2018) Antihypertensive Treatment Fails to Control Blood Pressure During Exercise. *Hypertension* **72**, 102-109. https://doi.org/10.1161/hypertensionaha.118.11173

Charloux, A., Lonsdorfer-Wolf, E., Richard, R., Lampert, E., Oswald-Mammosser, M., Mettauer, B., Geny, B. and Lonsdorfer, J. (2000) A new impedance cardiograph device for the non-invasive evaluation of cardiac output at rest and during exercise: comparison with the "direct" Fick method. *European Journal of Applied Physiology* **82**, 313-320. https://doi.org/10.1007/s004210000226

Coote, J.H. (2010) Recovery of heart rate following intense dynamic exercise. *Experimental Physiology* **95(3)**, 431-440. https://doi.org/10.1113/expphysiol.2009.047548

Cristina-Oliveira, M., Meireles, K., Spranger, M.D., O'leary, D.S., Roschel, H. and Pecanha, T. (2020) Clinical safety of blood flow-restricted training? A comprehensive review of altered muscle metaboreflex in cardiovascular disease during ischemic exercise. *American Journal of Physiology Heart and Circulatory Physiology* **318**, 90-109. https://doi.org/10.1152/ajpheart.00468.2019

de Oliveira, M.F., Caputo, F., Corvino, R.B. and Denadai, B.S. (2016) Short-term low-intensity blood flow restricted interval training improves both aerobic fitness and muscle strength. Scand. *Journal of Science and Medicine in Sport* **26(9)**, 1017-1025. https://doi.org/10.1111/sms.12540

Dillon, K., Shariffi, B., Gillum, T., Boyer, W., Sullivan, S. and Kim, J.K. (2021) Effects of chronic dietary grape seed extract supplementation on aortic stiffness and hemodynamic responses in obese/overweight males during submaximal exercise. *European Journal of Sport Science* **22(6)**, 1-26. https://doi.org/10.1080/17461391.2021.1923815

Evans, C., Vance, S. and Brown, M. (2010) Short-term resistance training with blood flow restriction enhances microvascular filtration capacity of human calf muscles. *Journal of Sports Science* **28**, 999-1007. https://doi.org/10.1080/02640414.2010.485647

Figueroa, A. and Vicil, F. (2011) Post-exercise aortic hemodynamic responses to low-intensity resistance exercise with and without vascular occlusion. *Scandinavian Journal of Medicine & Science in Sports* **21(3)**, 431-436. https://doi.org/10.1111/j.1600-0838.2009.01061.x

Held, S., Behringer, M. and Donath, L. (2020) Low intensity rowing with blood flow restriction over 5 weeks increases VO2maxin elite rowers: A randomized controlled trial. *Journal of Science and Medicine in Sport* **23**, 304-308. https://doi.org/10.1016/j.jsams.2019.10.002

Hunter, S.K. (2016) The relevance of sex differences in performance fatigability. *Medicine & Science in Sports & Exercise* **48**, 2247-2256. https://doi.org/10.1249/mss.0000000000000928

Iida, H., Nakajima, T., Kurano, M., Yasuda, T., Sakamaki, M., Sato, Y., Yamasoba, T. and Abe, T. (2011) Effects of walking with blood flow restriction on limb venous compliance in elderly subjects. *Clinical Physiology and Functional Imaging* **31**, 472-476. https://doi.org/10.1111/j.1475-097x.2011.01044.x

Kaufman, M.P., Rybicki, K.J., Waldrop, T.G. and Ordway, G.A. (1984) Effect of ischemia on responses of group III and IV afferents to contraction. *Journal of Applied Physiology* **57**, 644-650. https://doi.org/10.1152/jappl.1984.57.3.644

Laurentino, G.C., Ugrinowitsch, C., Roschel, H., Aoki, M.S., Soares, A.G., Neves, M., Aihara, A.Y., Fernandes, A.D.R.C. and Tricoli, V. (2012) Strength training with blood flow restriction diminishes myostatin gene expression. *Medicine & Science in Sports & Exercise* **44**, 406-412. https://doi.org/10.1249/mss.0b013e318233b4bc

Lee, J.S., Stebbins, C.L., Jung, E., Nho, H., Kim, J.K., Chang, M.J. and Choi, H.M. (2015) Effects of chronic dietary nitrate supplementation on the hemodynamic response to dynamic exercise. *American Journal of Physiology Regulatory, Integrative and Comparative Physiology* **309**, 459-466. https://doi.org/10.1152/ajpregu.00099.2015

Loenneke, J.P., Kearney, M.L., Thrower, A.D., Collins, S. and Pujol, T.J. (2010) The acute response of practical occlusion in the knee extensors. *The Journal of Strength & Conditioning Research* **24**, 2831-2834. https://doi.org/10.1519/jsc.0b013e3181f0ac3a

Loenneke, J.P., Balapur, A., Thrower, A.D., Barnes, J.T. and Pujol, T.J. (2011) The perceptual responses to occluded exercise. *International Journal of Sports Medicine* **32**, 181-184. https://doi.org/10.1055/s-0030-1268472

Loenneke, J.P., Fahs, C.A., Rossow, L.M., Sherk, V.D., Thiebaud, R.S., Abe, T., Bemben, D.A. and Bemben, M.G. (2012) Effects of cuff width on arterial occlusion: implications for blood flow restricted exercise. *European Journal of Applied Physiology* **112**, 2903-2912. https://doi.org/10.1007/s00421-011-2266-8

Lowery, R.P., Joy, J.M., Loenneke, J.P., De Souza, E.O., Machado, M., Dudeck, J.E. and Wilson, J.M. (2014) Practical blood flow restriction training increases muscle hypertrophy during a periodized resistance training programme. *Clinical Physiology and Functional Imaging* **34**, 317-321. https://doi.org/10.1111/cpf.12099

Maior, A.S., Simao, R., Martins, M., De Salles, B.F. and Willardson, J. (2015) Influence of blood flow restriction during low-intensity resistance exercise on the postexercise hypotensive response. *The Journal of Strength & Conditioning Research* **29(10)**, 2894-2899. https://doi.org/10.1519/jsc.0000000000000930

Mattocks, K.T., Jessee, M.B., Counts, B.R., Buckner, S.L., Grant Mouser, J., Dankel, S.J., Laurentino, G.C. and Loenneke, J.P. (2017) The effects of upper body exercise across different levels of blood flow restriction on arterial occlusion pressure and perceptual responses. *Physiology & Behavior* **171**, 181-186. https://doi.org/10.1016/j.physbeh.2017.01.015

Mitchell, J.H. (2017) Abnormal cardiovascular response to exercise in hypertension: contribution of neural factors. *American Journal of Physiology Regulatory, Integrative and Comparative Physiology* **312(6)**, 851-863. https://doi.org/10.1152/ajpregu.00042.2017

Mouser, J.G., Mattocks, K.T., Dankel, S.J., Buckner, S.L., Jessee, M.B., Bell, Z.W., Abe, T. and Loenneke, J.P. (2019) Very-low-load resistance exercise in the upper body with and without blood flow restriction: cardiovascular outcomes. *Applied Physiology, Nutrition, and Metabolism* **44**, 288-292. https://doi.org/10.1139/apnm-2018-0325

Neto, G.R., Sousa, M., Costa, P.B., De Salles, B.F., Novaes, G. and

Novaes, J. (2015) Hypotensive effects of resistance exercises with blood flow restriction. *The Journal of Strength & Conditioning Research* **29(4)**, 1064-1070. https://doi.org/10.1519/jsc.0000000000000734

Ozaki, H., Miyachi, M., Nakajima, T. and Abe, T. (2011) Effects of 10 weeks walk training with leg blood flow reduction on carotid arterial compliance and muscle size in the elderly adults. *Angiology* **62**, 81-86. https://doi.org/10.1177/0003319710375942

Partsch, B. and Partsch, H. (2005) Calf compression pressure required to achieve venous closure from supine to standing positions. *Journal of Vascular Surgery* **42**, 734-738. https://doi.org/10.1016/j.jvs.2005.06.030

Patterson, S.D., Hughes, L., Warmington, S., Burr, J., Scott, B.R., Owens, J., Abe, T., Nielsen, J.L., Libardi, C.A., Laurentino, G., Neto, G.R., Brandner, C., Martin-Hernandes, J. and Loenneke, J. (2019) Blood Flow Restriction Exercise: Considerations of Methodology, Application, and Safety. *Frontiers in Physiology* **10**, 533. https://doi.org/10.3389/fphys.2019.00533

Renzi, C.P., Tanaka, H. and Sugawara, J. (2010) Effects of leg blood flow restriction during walking on cardiovascular function. *Medicine & Science in Sports & Exercise* **42(4)**, 726-732. https://doi.org/10.1249/mss.0b013e3181bdb454

Richard, R., Lonsdorfer-Wolf, E., Charloux, A., Doutreleau, S., Buchheit, M., Oswald-Mammosser, M., Lampert, E., Mettauer, B., Geny, B. and Lonsdorfer, J. (2001) Non-invasive cardiac output evaluation during a maximal progressive exercise test, using a new impedance cardiograph device. *European Journal of Applied Physiology* **85**, 202-207. https://doi.org/10.1007/s004210100458

Shimizu, R.; Hotta, K., Yamamoto, S., Matsumoto, T., Kamiya, K., Kato, M., Hamazaki, N., Kamekawa, D., Akiyama, A., Kamade, Y., Tanaka, S. and Masuda, T. (2016) Low-intensity resistance training with blood flow restriction improves vascular endothelial function and peripheral blood circulation in healthy elderly people. *European Journal of Applied Physiology* **116(4)**, 749-757. https://doi.org/10.1007/s00421-016-3328-8

Slysz, J., Stultz, J. and Burr, J. F. (2016) The efficacy of blood flow restricted exercise: A systematic review & meta-analysis. *Journal of Science and Medicine in Sport* **19**, 669-675. https://doi.org/10.1016/j.jsams.2015.09.005

Smith, D.L. and Fernhall, B. (2011) Advanced Cardiovascular Exercise Physiology. Champaign, IL: Human Kinetics. https://link.gale.com/apps/doc/A268309974/AONE?

Spranger, M.D., Krishnan, A.C., Levy, P.D., O'Leary, D.S. and Smith, S.A. (2015) Blood flow restriction training and the exercise pressor reflex: a call for concern. *American Physiological Society* **309**, 1440-1452. https://doi.org/10.1152/ajpheart.00208.2015

Thomson, J.S., Watson, P.E. and Rowlands, D.S. (2009) Effects of nine weeks of beta-hydroxy-beta- methylbutyrate supplementation on strength and body composition in resistance trained men. *The Journal of Strength & Conditioning Research* **23(3)**, 827-835. https://doi.org/10.1519/jsc.0b013e3181a00d47

Tomschi, F., Koster, P., Predel, H., Lay, D., Bloch, W. and Grau, M. (2018) Acute effects of lower and upper body-resistance training on arterial stiffness, peripheral, and central blood pressure in young normotensive women. *Sport Sciences for Health* **14**, 357-363. https://doi.org/10.1007/s11332-018-0440-7

Tordi, N., Mourot, L., Matusheski, B. and Hughson, R.L. (2004) Measurements of cardiac output during constant exercises: comparison of two non-invasive techniques. *International Journal of Sports Medicine* **25**, 145-149. https://doi.org/10.1055/s-2004-819949

Yasuda, T., Fukumura, K., Uchida, Y., Koshi, H., Iida, H., Masamune, K., Yamasoba, T., Sato, Y. and Nakajima, T. (2015) Effects of low-load, elastic band resistance training combined with blood flow restriction on muscle size and arterial stiffness in older adults. *The Journal of Gerontology. Series A, Biological Sciences and Medical Sciences* **70**, 950-958. https://doi.org/10.1093/gerona/glu084

Zhao, Y., Lin, A. and Jiao, L. (2021) Eight Weeks of Resistance Training with Blood Flow Restriction Improve Cardiac Function and Vascular Endothelial Function in Healthy Young Asian Males. *International Health* **13**, 471-479. https://doi.org/10.1093/inthealth/ihaa089

Key points

- The purpose of this study was to compare and contrast cardiovascular responses during acute upper body resistance exercise (UBRE) and lower body resistance exercise (LBRE) and resting with or without blood flow restriction (BFR) in adult women.
- It was concluded that LBRE using BFR had a positive effect on the cardiovascular response of the cardiovascular system during exercise and recovery.
- Our study would be relevant to providing exercise professionals, as well as healthy individuals, that the use of BFR during exercise can cause negative impacts to the body.

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