Blood flow restriction training promotes hypotensive effect in hypertensive middle-age men

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Recibido: 30.08.2017
Aceptado: 16.11.2017

Summary

Objectives: The purposes of this study were a) to analyze the hemodynamic responses of two methods of resistance training (vascular occlusion vs. traditional) and, b) to demonstrate the effectiveness of vascular occlusion training method on the regulation of blood pressure in hypertensive subjects.
Methods: Ten men of middle age (44.9±5.1 years, 83.7±12. kg, 174.1±8.1cm) performed two different protocols of resistance exercises (3 sets until concentric failure; leg press exercise; 60 sec pause between sets): a) with blood flow restriction (30% of 1RM intensity) and b) high intensity exercise (70% of 1RM intensity). Middle thigh muscle circumference was estimated and hemodynamic variables (heart rate, systolic and diastolic blood pressure) were measured before, immediately after and every 10 min (until 60 min) post exercise. The rate of perceived exertion was also utilized after exercise protocol. All subjects were encouraged not to perform the Valsalva maneuver.
Results: Both protocols showed a significant reduction of systolic, diastolic and mean arterial blood pressure and heart rate post 10 until 60 min compared to values immediately post exercise (p <0.05). The blood flow restriction group showed a significant reduction (p <0.05) of diastolic blood pressure 20 min post-exertion time compared to rest values. In addition, the magnitude of the effect size about diastolic blood pressure revealed a large magnitude of effect at the 20' and 30' post-effort in the blood flow restriction group.
Conclusion: Blood flow restriction protocol promoted a hypotensive effect during 60 min after it is realization.

Key words:
Blood flow restriction.
Resistance training.
Post-exercise hypotension.

Efecto hipotensor producido por entrenamiento de restricción vascular sanguíneo en hipertensos de mediana edad

Resumen

Objetivos: Los objetivos de este estudio fueron: a) analizar las respuestas hemodinámicas de dos métodos de entrenamiento de resistencia (oclusión vascular versus tradicional) y b) demostrar la efectividad del método de entrenamiento de oclusión vascular en la regulación de la presión arterial en sujetos hipertensos.
Métodos: Diez hombres de mediana edad (44,9±5,1 años, 83,7±12 kg, 174,1±8,1 cm) realizaron dos protocolos diferentes de ejercicios de fuerza (3 series hasta el fallo concéntrico, ejercicio de ejercicios de pierna, pausa de 60 segundos entre series): a) Con restricción del flujo sanguíneo (30% de intensidad de 1RM) y b) ejercicio de alta intensidad (70% de intensidad de 1RM). Se estimó la circunferencia muscular media del muslo y se midieron las variables hemodinámicas (frecuencia cardíaca, presión arterial sistólica y diastólica) antes, inmediatamente después y cada 10 min (hasta 60 minutos) después del ejercicio. La escala de esfuerzo percibido también se utilizó después del protocolo de ejercicio. Se animó a todos los sujetos a no realizar la maniobra de Valsalva.
Resultados: Ambos protocolos mostraron una reducción significativa de la presión arterial sistólica, diastólica y media ya frecuencia cardíaca post 10 hasta 60 min en comparación con los valores inmediatamente después del ejercicio (p <0,05). El grupo de restricción del flujo sanguíneo mostró una reducción significativa (p <0,05) de la presión arterial diastólica 20 minutos después del esfuerzo en comparación con los valores de reposo. Además, la magnitud del tamaño del efecto sobre la presión arterial diastólica reveló una gran magnitud de efecto a los 20' y 30' post-esfuerzo en el grupo de restricción de flujo sanguíneo.
Conclusión: El protocolo de restricción del flujo sanguíneo promovió un efecto hipotensor durante 60 minutos después de su realización.

Palabras clave:
Restricción vascular sanguínea.
Entrenamiento de resistencia.
Regulación de la presión arterial.

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Introduction

Cardiovascular disease is associated with primary risk factors that can be controlled, treated or modified, such as high blood pressure (BP). Thus, hypertension is a disease state characterized by increased blood pressure (BP) associated with hemodynamic abnormalities, including elevated systemic vascular resistance index and altered cardiac index[1,2]. The number of individuals with uncontrolled hypertension stage 1 (defined as SBP ≥140 mmHg or DBP ≥90 mmHg) increased from 605 to 978 million because of population growth and aging, consequently, increase risk factor for mortality and morbidity[3]. But a small reduction of 10 mmHg in systolic blood (SBP) and/or 5 mmHg diastolic blood (DBP) pressures can lead to 22% reductions in coronary heart disease events and a 41% reduction in stroke[4]. Physical inactivity is also known as a primary risk factor for cardiovascular disease, and people who are less active and less fit have a 30–50% greater risk for having high BP[5].

Conversely, exercise training decrease risk factor for cardiovascular disease because improve the muscle blood flow to exercising muscle and cause a more normal cardiovascular response to exercise in hypertensive subjects[6]. In this sense, not only aerobic training but also resistance exercises (RE) have been suggested in sports medicine guidelines. A meta-analytical data suggest that resistance exercise (RE) can decrease mean SBP between 10 and 13 mmHg, and 6 and 8 mmHg DBP[7]. Consequently, RE has been prescribed for the control of resting BP in hypertensive and normotensive individuals[8-10]. However, a well understanding methodological about multiple variables to prescription of RE (exercise order, rest periods between sets, specific exercises and session format, weekly frequency, movement velocity, training duration and volume, number of repetitions, sets, type of muscle action and intensity of effort) collaborate to the better control of hemodynamic parameters during and post-exercise[8,10].

Hyperemia is the transient increase in organ blood flow that occurs following a brief period of ischemia (e.g., blood flow restriction), thus, contribute with a vasodilatation by increase in blood flow to a tissue due to the presence of metabolites (adenosine, prostaglandins, and oxide nitric) and myogenic effects[11,12]. But when associated blood flow restriction (BFR) to low-intensity resistance exercise (20%-50% of 1 repetition maximum – RM) promotes an increase in heart rate to maintain cardiac output, because of the decrease in stroke volume, which results from restricted blood flow, and consequently, reduces venous blood return[13,14]. On the other hand, performing RE with the addition of BFR stimulates compensatory adaptations with vascular adaptation to facilitate greater venous return[15]. Besides promote greater shear stress against blood vessel walls on restoration of blood flow that occurs with release of occlusive pressure, which may stimulate greater nitric oxide production to promote vasodilation, and a hypotensive response post-exercise[8,16].

Few studies have evaluated the association between the post-exercise hypotensive response and low-intensity RE combined with BFR in hypertensive subjects[16,17]. But the identification of specific BP responses that might be associated with manipulation of training variables is important to ensure the optimal, and appropriate, prescription of RE for individuals concerned with BP control, such as those with chronic hypertension. Thus, bearing in mind the importance of examining the post-exercise hypotensive response to promote greater efficacy and safety during low-intensity RE with BFR, the purpose of this study was to compare an HIE session vs. low-intensity RE with BFR on the post-exercise hypotensive response in hypertensive middle age subjects.

Material and method

Participants

Ten stage 1hypertensive subjects (age 44.9±5.1 years, body mass 83.7±12.1kg, height 174.1±8.1cm, BMI 27.7±2.3 kg/m^2) with at least one year of recreational RE experience were asked to participate in the current study. All subjects completed the Physical Activity Readiness Questionnaire (PAR-Q). The experimental protocol was in accordance to the declaration of Helsinki and was approved by the local board (CMM/UNISUAM n°63881716.0.0000.5235). All participants were informed about the experimental procedures and gave written informed consent prior to participation[18]. No clinical problems occurred during the study.

The following additional exclusion criteria were adopted: a) use of drugs that could affect cardiorespiratory responses; b) bone-, joint- or muscle-diagnosed problems that could limit the execution of leg press exercise; d) metabolic disease; e) use of exogenous of medication with potential effects on physical performance.

Measures

Volunteers attended the laboratory a total of four times with 48 h between visits. During the first visit, anthropometric and hemodynamic data was collected as well as a 1-RM assessment for the leg press exercise. During the second visit, the 1-RM assessment was repeated; and the RE sessions were performed during the third and fourth visits with or without blood flow restriction. All testing was performed between 1:00 PM and 3:00 PM. Subjects received a light lunch two hours before each lab visit. Coffee, tea, alcohol and tobacco intake were prohibited for 48 hours, and subjects avoided formal and strenuous exercise for 48 hours before each visit.

Body weight was measured using a calibrated physician's beam scale (model 31, Filizola, São Paulo, Brazil), with the men dressed in shorts. Height was determined without shoes using a stadiometer (model 31, Filizola, São Paulo, Brazil) after a voluntary deep inspiration. Body fat percentage (%) was estimated using the seven-site skinfold procedures[19], and performed twice, in circuit. The mean technical error of measurement for skinfold value was 0.31. All biometric measurements were carried out in a climatized room (22±1°C). No clinical problems occurred during the study.

The middle thigh muscle circumference (MC) was estimated by circumference of the bone and muscle portions of the thigh muscle. The thigh skin-fold (TSF) was measured to represent the thickness of the subcutaneous fat that surrounds the muscle. The following formula was used to estimate the muscle-bone cross sectional area[8]:

$$\text{Muscle-Bone CSA} = MC - (\pi \times \text{TSF}/10)$$

Before beginning of each RE session, subjects rested quietly in a supine position for 10 minutes prior to measurement of resting BP. After each RE session, BP was measured immediately post-exercise and in 10-minute intervals for 60 minutes, resulting in a total of seven readings after each RE session. Before and after each session, subjects were fitted with ambulatory BP monitoring equipment in arm (Contec medical, PM50 Monitor, Beijing, China), and this equipment was used for all pre and post-exercise BP measurements. The ambulatory BP equipment was auto calibrated before each use to ensure accuracy. Spurious readings, due to factors such as movement artifact, were automatically edited by the software. During BP rest and post-exercise monitoring, subjects remained in a supine position in a temperature-controlled quiet room (22ºC).

1RM - One-Repetition Maximum Test

Leg press exercise was selected for use in this study due to its common use in RE programs. The 1-RM tests were performed following the anthropometric measurements on the first day. After 48 h, the 1-RM test was repeated to determine test–retest reliability. The heaviest load achieved on either test day was considered the 1-RM. The 1-RM loads were determined in fewer than five attempts with a rest interval of five minutes between attempts[8]. No pause was allowed between the concentric and eccentric phases of a repetition or between repetitions. For a repetition to be successful, a complete range of motion for the exercise had to be completed. The leg press exercise range of motion for a successful repetition was defined as follows: Knees and Hip beginning in full extension followed by half flexion, while maintaining perfect postural alignment with no torso sway.

The 1-RM test has been described previously and for reliability, the following strategies were adopted: a) standardized instructions about the testing procedures were given to subjects prior to test; b) subjects received standardized instructions concerning exercise technique; c) verbal encouragement was provided during tests; d) the mass of all weights and bars was determined using a precision scale.

Resistance exercise sessions and blood flow restriction

The subjects performed a bilateral leg press exercise in a seated position. The two strength training sessions were performed on non-consecutive days and in random order, which included the following: a) three sets of leg press exercise at 70% of 1-RM (HIE protocol); and b) three sets of leg press exercise at 30% of 1-RM with BFR. Both RE protocols utilized 60 sec rest between sets.

In BFR protocol, the proximal portion of both legs was compressed by a specially designed elastic belt (width 100 mm, length 800 mm). The belt contained a small pneumatic bag along its inner surface. To partially occlude muscle blood flow, the cuff was inflated to a pressure of 20 mmHg upper the acute SBP determined after 15 min of semi-recumbent resting. The mean restrictive pressure throughout the period of training was 159.2±12.9 mmHg. The BFR was maintained throughout the session of exercise which lasted 255.2±21.3 sec for BFR protocol and 233.5±20.2 sec for the HIE protocol. The partial occlusion of muscle blood flow was restored immediately following the last RE session. The BFR protocol resulted in a total of 46.2±9.8 repetitions and the HIE protocol, 20.5±5.3 repetitions.

During each RE session, subjects were verbally encouraged to perform all sets to concentric failure, using the consistent definition of a complete range of motion used for the 1-RM test. No attempt was made to control repetition velocity. During all RE sessions, subjects were asked not to perform a Valsalva Maneuver. After both RE session was utilized OMNI scale to quantify work. All of the exercise sessions were preceded by a 10 minutes warm-up on an upper body ergometer (Technogym, New Jersey, USA) with an intensity of 20 watts.

Statistical analysis

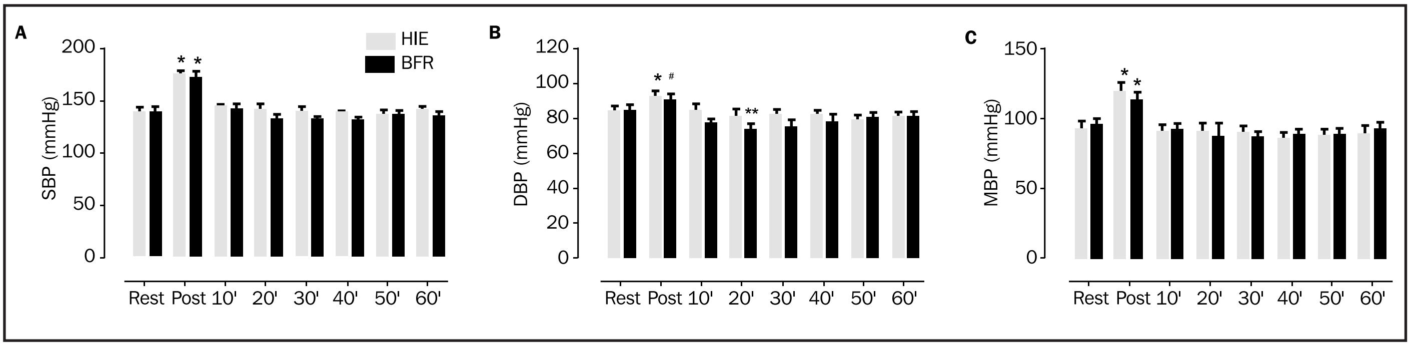
All data are presented as mean ± SD. The statistical analysis was initially performed using the Shapiro–Wilk normality test and the homocedasticity test (Bartlett criterion). To test the reproducibility of the 1-RM load between the test and retest, we used the intraclass correlation coefficient (ICC). To compare potential differences in post-exercise SBP, diastolic blood pressure (DBP), mean blood pressure (MBP), and rating of perceived exertion (OMNI scale) between BFR and HIE protocols, a repeated measures two-way analysis of variance, with Bonferroni post-hoc tests was used. Comparisons within-groups for BP were performed with ANOVA one-way repeated-measures followed by Tukeys post hoc tests. The level of significance was set at $p<0.05$ for all statistical comparisons. The effect size (ES) was calculated for the SBP and DBP responses for each RE session to determine the meaningfulness of the difference[20] and classified as: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0) and very large (>2.0) based on recommendations[21]. The significance level was set at 0.05 and the software used was GraphPad® (Prism 6.0, San Diego, CA, USA).

Results

The ICC for the leg press exercise was 0.95 ($p< 0.001$). Besides, the estimate the muscle-bone cross sectional area no showed statically difference between limbs (right limb = 54±5.1 cm; left limb = 54.3±4.8 cm; $p = 0.17$). Figures 1–3 summarize the acute hemodynamic responses for each protocol (BFR *vs*. HIE). The SBP values were not significantly different between protocols at baseline and post effort at each time point (Figure 1). The SBP and MBP were not significantly different between protocols (Figures 1A and 1B). But both protocols showed significant difference between immediately post-exercise vs. rest and post-exercise measurements ($p<0.05$). However, within the BFR protocol, a significant decrease ($p< 0.05$) in DBP was observed at the 20-minute post-exercise time points compared with baseline (Figure 1B). None significant difference ($p>0.05$) was observed in the rating of perceived exertion (OMNI scale) between BFR and HIE protocols in three sets RE sessions (Figure 2).

Table 1 shows the effect size for SBP, DBP, and MBP each training protocol. The ES statistics presented moderate to large values for SBP at 20, 30, and 40 minutes after the BFR protocol. On the other hand, DBP revealed ES statistics moderate to large values at 10, 20, 30, and 40 minutes after the BFR protocol, while, HIE protocol moderate values only with 50 minutes. MBP showed ES statistics only 30 and 40 minutes after the BFR protocol. Additionally, the ES statistics were generally greater for the BFR protocol at each time point post-exercise.

Figure 1. Systolic blood pressure (SBP), Diastolic blood pressure (DBP), and Mean blood pressure (MBP) at rest, immediately post-exercise, and at 10-minute intervals during 60 minutes after resistance exercise (RE) for the blood flow restricted and High Intensity exercise (HIE) protocols.



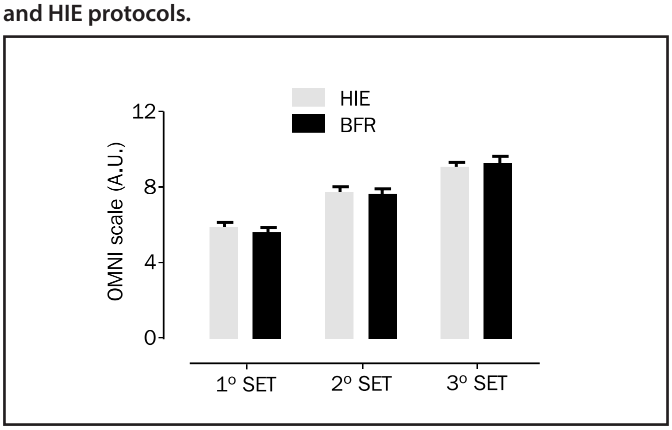
Data are presented as mean ± SD.* and # $p<0.05$ *vs.* rest; ** $p< 0.05$ *vs.* rest

Table 1. Effect Size calculation and classification of blood pressure values compared to rest for high intensity and blood flow restriction protocols during 60 min after exercises.

	10 min	20 min	30 min	40 min	50 min	60 min
Systolic Blood Pressure						
BFR	-0.17	0.57	0.71	0.81	0.26	0.34
	Trivial	Moderate	Moderate	Large	Small	Small
HIE	-0.40	-0.04	0.06	0.27	0.29	0.06
	Small	Trivial	Trivial	Small	Small	Trivial
Diastolic Blood Pressure						
BFR	0.60	0.95	0.82	0.51	0.35	0.28
	Moderate	Large	Large	Moderate	Small	Small
HIE	-0.06	0.32	0.33	0.26	0.54	0.33
	Trivial	Small	Small	Small	Moderate	Small
Mean Blood Pressure						
BFR	0.22	0.55	0.62	0.56	0.44	0.26
	Small	Small	Moderate	Moderate	Small	Small
HIE	0.16	0.09	0.24	0.55	0.41	0.26
	Trivial	Trivial	Small	Moderate	Small	Small

BFR: blood flow restriction protocol; HIE: high-intensity resistance exercise protocol.

Figure 2. Rating of perceived exertion (OMNI scale) between BFR and HIE protocols.



Discussion

The aim of this study was to compare post-exercise hypotensive responses after an HIE session vs. a low-intensity BFR session in stage 1hypertensive subjects and the main findings were that BFR protocol significantly decreases diastolic blood pressure post-exercise compared to high intense exercise. as follows: a) no significant differences between protocols in the SBP, DBP, and MBP responses post-exercise at any time point; b) BFR protocol, significant decreases in DBP occurred at 20-minute post-exercise than compared to rest; c) BFR protocol promoted a moderate to large ES at most time points in SBP, DBP, and MBP post-exercise. These results may suggest that the duration of the hypotensive response might not only be dependent on differences in the rest interval between sets or load intensity (30% in the BFR vs.

70% in the HIE) but rather on the ischemic effects induced during the BFR protocol. This way, after exercise session the ischemic reperfusion mechanism induced by cuff deflation stimulates shear stress, followed by greater vasodilatation and/or enhanced blood flow that can be contribute to hypotensive response[8].

During both RE protocols (BFR *vs*. HIE), significant increases were observed in SBP, DBP, and MBP. The amount of muscle mass recruited during exercise is positively related to the increase in BP because of compression of vascular beds during concentric actions that occludes the circulation and consequently raises vascular resistance[8,22]. Additionally, the application of external compression as in the BFR protocol reduced venous return with concomitant stimulation of group III (mechanosensitive) and group IV (metabosensitive) muscle afferents (according to the temperature, chemical and the mechanical environment) being favorable to a reflex increase in sympathetic nerve activity that promote a greater heart rate and arterial blood pressure to maintain cardiac output[23,24]. Besides, the increased local muscle metabolites (H^+, lactate, and ADP) and heat production seem to contribute for the increased hemodynamic responses after moderate and high intensity exercise[25]. However, current study showed that the BFR protocol promotes a lower hemodynamic response compared to the HIE and LIE performed to muscular failure[25].

Few studies have compared a low-intensity BFR session *vs*. HIE session in hypertensive subjects[17] demonstrated that BFR protocol (three sets; 10 repetitions; 20% 1RM) *vs*. HIE protocol (three sets; 10 repetitions; 65% 1RM) no showed hemodynamic (SBP and DBP) statistically significant differences between exercise protocols. On the other hand, the rating of perceived exertion was significantly higher between sets (1st *vs*. 2nd *vs*. 3rd sets) of the traditional high-intensity resistance exercise than compared to exercise with BFR[17]. Our hemodynamic results were similar to another study[17], even using different load and exercises (knee extension machine *vs*. leg press), which suggests that this response may be associated with potential capacity of BFR in enhancing systemic vascular response and the heart after load[8,14]. Our results to resting perceived exertion was similar no significant differences between protocols. Possibly, hypothesis show that Large muscle groups, used in multi-joint exercises such as leg press, trigger a higher absolute number of neural recruitment and maybe a higher asynchronous recruitment, allowing a better recovery of the muscle fibers, which could reduce the fatigue[26].

Other study compared hypotensive response in hypertensive women between a low-intensity BFR session (three sets; 15 repetitions; 30%1RM) *vs*. HIE session (three sets; 15 repetitions; 80%1RM) in the knee extension exercise[16]. Results showed significant hypotensive response only to SBP in BFR session, but not in the HIE session, between 15- and 60-minutes post exercise. We did a research with normotensive subjects that performed 2 experimental protocols in randomized order: a) 3 sets at 80% of 1 repetition maximum (RM) and 120-second rest between sets (HIE protocol) and b) 3 sets at 40% of 1RM with BFR and 60-second rest between sets. Both protocols the biceps curls exercise was performed to all subjects[8]. The values for SBP, DBP, and mean blood pressure (MBP) at baseline and post-exercise were not significantly different between the HIE *vs*. the BFR protocol. However, within the BFR protocol, significant decreases in SBP occurred at 30 minutes and 40 minutes after exercise when compared with baseline and significant decreases in DBP and MBP occurred at 20 minutes, 30 minutes, and 40 minutes after exercise *vs*. baseline[8]. But the magnitude of the ES was moderate only with 20 minutes post-exercise to DBP[8]. Results of the current study showed that key finding was that the BFR protocol promoted a long-lasting hypotensive DBP response and magnitude of the ES about SBP, DBP, and MBP various from moderate to large. Possible hypothesis to hypotensive DBP response can be that the double leg-press resistance exercise transiently reduces systolic LV mechanics, but increases diastolic mechanics following exercise, suggesting that resistance exercise has a differential impact on systolic and diastolic heart muscle function[27]. Our study showed lower DBP > 10 mmHg between rest (83.3±10.9 mmHg) and 20 minutes post-exercise (73.3±10.4 mmHg). Thus, studies concluded that a decrease =or> 10 mmHg in DBP is associated with 37% lower risk of coronary heart disease events and a 56% lower risk of stroke events[2].

The measurement of BP using the oscillometric method may have been a possible limitation of this study, but care was taken to calculate the appropriate sample size and food recall 24 hours before the collections were performed to increase the internal validity of the research. Additionally, other limiting factors that might be considered in future studies include levels of endothelium-dependent vasodilator agents, local metabolites, autonomic sympathetic activity, and cardiac output, which would provide further insight into the mechanisms behind the observed responses.

Conclusions

Low intensity exercise with blood flow restriction protocols could be performed to promote a post-exercise hypotensive effect in stage 1 hypertensive men. Therefore, it is suggested that either resistance exercise protocols should be used safely and effectively in hypertensive subjects.

Acknowledgements

Dr. Alex Souto Maior is supported by FAPERJ.

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