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Hemodynamic responses to strength exercise with blood flow restriction in small muscle groups

Respostas hemodinâmicas ao exercício de força com restrição de fluxo sanguíneo em pequenos grupos musculares

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Abstract – The aim of this study was to analyze the acute hemodynamic responses to strength exercise with blood flow restriction involving small muscle groups. The sample consisted of 10 male volunteers (22.6 ± 2.07 years, 1.78 ± 0.06 m, 76.32 ± 13.36 kg) who randomly performed two experimental protocols involving the elbow flexion exercise with the dominant arm: strength exercise of the elbow flexors with blood flow restriction (EFBFR) and strength exercise of the elbow flexors without blood flow restriction (EEF). A cross-over design with a seven to ten days interval between the experimental protocols was used. Systolic blood pressure (SBP), diastolic (DBP) and mean (MAP), pulse pressure (PP), heart rate (HR) and double product (DP) were evaluated at rest, immediately after exercise and at 15 minutes of recovery. SBP, DBP and MAP presented a significant increase (p <0.05) immediately after EFBFR when compared to the protocol without blood flow restriction, returning to rest values at the 15 minutes of recovery. DBP significantly reduced (p <0.05) in the recovery period only in the EFBFR experiment and HR increased post-effort in both experiments. The PP and DP did not change between the different times, regardless of the protocol.The results of the present study allow us to conclude that strength exercise with BFR involving small muscle groups was more efficient than exercise without BFR to promote acute changes in hemodynamic responses and that BFR did not represent a cardiovascular risk considering its effects on PP.

Key words: Blood pressure; Exercise therapy; Resistance training.

Resumo – *O presente estudo objetivou analisar as respostas hemodinâmicas agudas ao exercício de força com restrição do fluxo sanguíneo (RFS) realizado com pequenos grupos musculares. A amostra foi composta por 10 voluntários do sexo masculino (22,6 ± 2,07 anos, 1,78 ± 0,06 m, 76,32 ± 13,36 kg), que realizaram de forma aleatória os protocolos envolvendo o exercício de flexão da articulação do cotovelo, com membro dominante (rosca concentrada de bíceps) realizado com (ERFS) e sem restrição do fluxo sanguíneo (ESR). Utilizou-se o desenho cruzado, com intervalo de sete a dez dias entre os experimentos. Foram avaliadas: pressão arterial sistólica (PAS), diastólica (PAD) e média (PAM); pressão de pulso (PP), frequência cardíaca (FC) e duplo produto (DP), em repouso, imediatamente após o esforço, e após o esforço na fase de recuperação de 15 minutos. A PAS, PAD e PAM apresentaram elevação significativa (p <0,05) imediatamente após a realização do ERFS, quando comparadas ao protocolo sem restrição, retornando aos valores de repouso após a recuperação. A PAD reduziu significativamente (p <0,05) na recuperação, apenas no experimento ERFS e a FC elevou no pós-esforço em ambos os experimentos. A PP e o DP não sofreram alterações entre os diferentes momentos de avaliação, independentemente do protocolo. Os resultados do presente estudo permitem concluir que o exercício de força com RFS envolvendo pequenos grupos musculares foi mais eficiente que o exercício sem restrição para promover alterações agudas das respostas hemodinâmicas e que a RFS não representou um risco cardiovascular, considerando seus efeitos sobre a PP.*

Palavras-chave: *Pressão sanguínea; Terapia por exercício; Treinamento de resistência.*

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INTRODUCTION

Strength training (ST) has been recommended for different population groups, mainly because it facilitates strength gains and muscular hypertrophy, directly contributing to the improvement of functional capacity[1] and hemodynamic parameters[2] and has potential therapeutic benefits[3]. However, the traditionally recommended mechanical overload[4] to achieve these goals may represent an important limiting factor for individuals with chronic diseases[3].

ST using low-intensity exercises in combination with blood flow restriction (BFR) produces similar results to the exercises traditionally recommended to promote increases in muscle strength and hypertrophy[4,5]. In addition, it has been shown that ST with BFR reduces cardiac preload[6] and, despite producing lower strength gains than high intensity ST, promotes similar results in relation to muscle hypertrophy[7].

Although the indications of ST with BFR for strength gain and muscle hypertrophy have a consistent basis in the specialized literature, the same does not occur with regard to the acute mechanisms related to the cardiovascular system, which remain largely unknown; this highlights the need for new studies[5].

Despite the increases in systolic (SBP) and diastolic (DBP) blood pressures during exercise with BFR is well documented[7-9] and presents characteristics similar to exercises performed without BFR, the results regarding the behavior of hemodynamic parameters during recovery are variable. While Araújo et al.[9] observed a reduction of SBP only during recovery from exercise with BFR, Neto et al.[10] showed a reduction of SBP and DBP using this protocol. In general, the previously mentioned studies used only strength exercise protocols involving large muscle groups. This study, involving small muscle groups, should provide consistent evidence for interventional studies in which the long-term effects of physical exercise involving small muscle groups and restriction of blood flow can be analyzed considering their potential hypotensive effects. Furthermore, in the published literature, no studies were found that evaluated hemodynamic responses in exercises involving small muscle groups.

Considering the context presented above, the present objective study aimed to analyze the acute hemodynamic responses to strength training with blood flow restriction involving small muscle groups.

METHOD

The present study consisted of a randomized crossover trial in which all subjects performed the two experimental protocols in a randomly determined sequence.

Test subjects

The study sample consisted of 10 young adult male volunteers (age: 22.6

± 2.07 years, height: 1.78 ± 0.06 m, body mass: 76.32 ± 13.36 kg, BMI: 23.34 ± 3,54 kg/m^2). We included male, physically active volunteers who were not under medical treatment and without diagnosis of chronic diseases or musculoskeletal injuries for which the performance of the exercises is contraindicated. The sample size was calculated considering a statistical power of 0.8, with a significance level of 0.05 (two-tailed distribution), a mean standard deviation of the main outcome variables (SBP and DBP) of seven units (based on previous studies of this group) and a real detectable difference between treatments of 9.9 units.

After being informed about the objectives and procedures of the study, subjects signed a free and informed consent agreement. The study was approved by the Ethics Committee on Research Involving Human Beings from Unochapecó University (opinion number 085/12).

Randomization

The exercise and BFR protocols were performed in a random manner by selection from 10 sealed opaque envelopes containing one of the experimental protocols: Five envelopes containing a label with the designation of the exercise of the elbow flexors (EEF), performed unilaterally, without blood flow restriction (bicep curls, 30% 1-RM), and five envelopes containing the same exercise designation, but performed with blood flow restriction (EFBFR). On the first day of the experimental protocol, each subject chose an envelope containing the protocol to be performed, so that five subjects performed the EEF protocol and five performed the EFBFR protocol (Figure 1). In the second trial, with seven-to-ten-days interval, the subjects performed another exercise, different from the one performed in the first trial.

Experimental Protocols

All study participants performed to two experimental protocols with seven-to-ten-days intervals: a) EEF with out blood flow restriction, and b) strength exercise of the elbow flexors (30% 1-RM) with blood flow restriction (EFBFR). The exercise used in both protocols consisted of three sets of 15 repetitions of the elbow flexors (concentration curls) performed with the dominant limb with a load corresponding to 30% of the maximum dynamic strength (1-RM). A 45-second interval between the sets was used and the exercise duration was controlled (1.5 x 1.5 s for the eccentric and concentric phases, respectively) by a digital metronome (Tagima®, São Paulo, Brazil).

For the EFBFR protocol, a pneumatic garret 7.5 x 90 cm (WCS – Cardiomed™, Brazil) was attached to the proximal portion of the arm. The restriction pressure was equivalent to 70% of the measured SBP at rest (Erkamater® E300, Germany) and was released between sets and at the end of the experiment.

All subjects were evaluated individually and were instructed to maintain their normal diet, to abstain from alcoholic beverages and to avoid performance of any kind of physical exercise in the 48 hours preceding each experimental protocol.

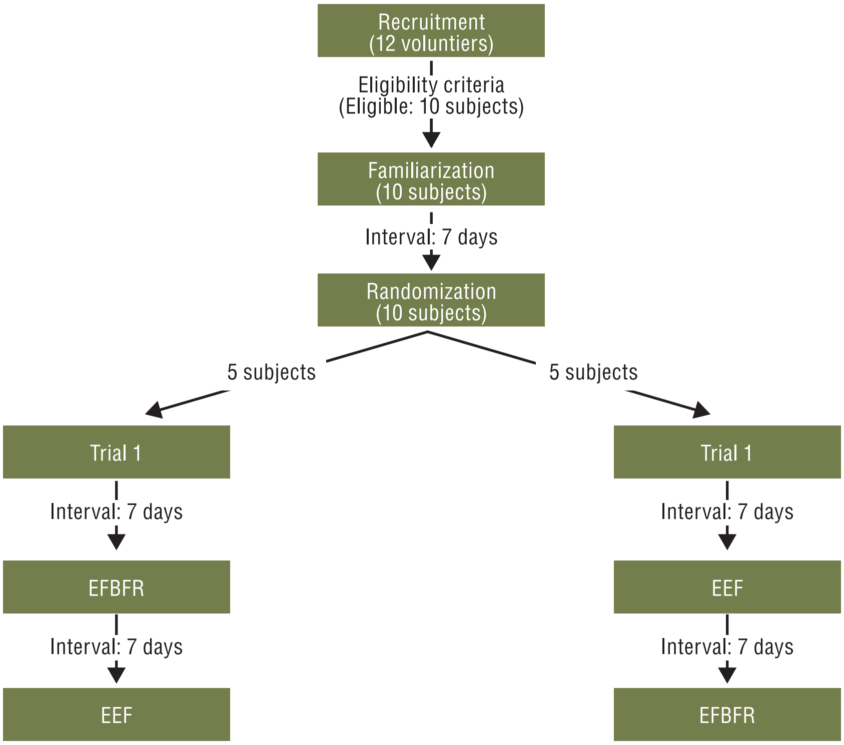

Figure 1. Study flowchart.
Note. EFBFR:Elbow Flexors with Blood Flow Restriction; EEF: Elbow Flexors Exercise.

Procedures

A one-repetition maximum test (1-RM) was conducted according to the recommendations of the American Society of Exercise Physiologists[11]. All the subjects underwent an exercise of flexion and extension of the elbow joint (concentration curls with the dominant limb). First, subjects performed a limb warm-up based on dynamic motions for 25 to 30 seconds. Subsequently, a specific warm up was then performed which consisted of a set of eight to ten repetitions carried out with a load corresponding to 50% of estimated 1-RM. Then, a second set of three repetitions was performed with a load equivalent to 70% of estimated 1-RM. After specific warm-up, the participants rested for three minutes before starting the test, which consisted of performing a single repetition of the concentration curl exercise, starting from the extension of the elbow, performing a complete flexion and returning to the initial position. Between each attempt, a weight increase of approximately 10% was employed in relation to the load of the second specific warm-up set. A maximum of five attempts were allowed to reach the maximum load with an interval of two minutes between attempts. All subjects reached maximal load before the fifth attempt.

Blood pressure (BP) was measured by the auscultatory method[12] using a mercury column sphygmomanometer (Erkamater®E300, Germany). For all measurements, the subjects sat with their arms supported at a height corresponding to the precordium[12]. Hemodynamic responses measurements for both protocols were performed at rest immediately after the completion of the three sets of elbow flexors exercise and after 15 minutes of recovery. All measurements were performed in the non-dominant (and non-exercised) arm.

Heart rate (HR) monitoring was performed using an HR sensor (Polar™ RS-800, Finland). HR was monitored during the 15 minutes of rest, throughout the three sets of exercise and during the 15 minutes of recovery. Data were recorded at 10-second intervals through each experimental protocol and then transferred to a computer for analysis using specific software (Polar ProTrainer5™, Finland).

For the purpose of this study, pulse pressure (PP), mean arterial pressure (MAP) and double product (DP) were calculated. PP was calculated from the difference between SBP and DBP[2] and MAP by the formula MAP = [DBP + 1/3 x (SBP- DBP)][13]. DP was calculated by multiplying the HR by the SBP.

All subjects attended the Laboratory from 7-9 am on four different occasions, with an interval of seven to ten days between visits (Figure 1). During the first visit, the subjects performed the anthropometric evaluation and familiarization with the EEF protocols with and without BFR. During the second visit, the maximum dynamic strength evaluation was performed, and in the third and fourth visits, the experimental protocols were performed according to the sequence determined during the randomization process.

For the accomplishment of the experimental protocols, each subject arrived at the laboratory at the previously scheduled date and time and remained at rest for 15 minutes under HR monitoring, which was maintained until the end of the experiment. As previously described, BP measurements occurred at the following time points: after 15 minutes of rest, immediately after the experiment was performed, and in the recovery phase at 15 minutes post-exertion.

Statistical analysis

Data were presented descriptively by means and standard deviation. The assumptions of normality and homogeneity of variances were tested by the Shapiro-Wilk and Levene's tests, respectively. Two-way ANOVA with repeated measures 2x3 (protocol: EEF and EFBFR *versus* time: rest, post exertion and recovery) was used to compare the effects of the two experimental conditions on the dependent variables and was followed by the Bonferroni multiple comparisons test to identify differences between treatment groups. The significance level was 5%, and all analyses were performed in the statistical program SPSS (version 22.0).

RESULTS

The SBP, DBP and MAP behavior in the two experimental conditions (EFBFR and EEF) are presented in Table 1. Post-exertion, SBP, DBP and MAP presented statistically significant differences compared to the rest and 15-minute recovery phases in both experimental protocols ($p<0.05$).

No statistically significant differences were found between the rest and 15-minute recovery periods for the variables SBP, DBP and MAP in both experimental protocols. Post-exertion SBP, DBP and MAP presented statistically significant differences ($p<0.05$) between the experimental protocols (EEF and EFBFR).

Table 1. SBP, DBP and MAP responses to elbow flexors exercise (concentration curls) performed with the dominant arm with (EFBFR) or without (EEF) blood flow restriction. The results are presented as the means and the standard deviation values are in parentheses.

		Rest	Post-exertion	Recovery (15 min)
SBP	EEF	114^{a}(12)	124^{b} (11)	113^{a}(11)
	EFBFR	120^{a}(10)	136$^{b\#}$(10)	117^{a}(11)
DBP	EEF	81^{a}(8)	83^{a} (11)	84^{a}(9)
	EFBFR	84^{a}(6)	93$^{b\#}$ (6)	85^{a}(6)
MAP	EEF	92^{a}(9)	97^{a} (10)	94^{a}(9)
	EFBFR	96^{a}(7)	107$^{b\#}$ (7)	96^{a}(7)

Note. SBP: systolic blood pressure (mmHg); DBP: diastolic blood pressure (mmHg); MAP: mean arterial pressure (mmHg). EEF: exercise of the elbow flexors; EFBFR: elbow flexors with blood flow restriction. Different lowercase letters, show differences between time points: rest, post-exertion and recovery ($p<0.05$). # Statistically significant difference in relation to the EEF group ($p<0.05$).

PP, HR and DP increased significantly from rest to post-exertion regardless of BFR ($p<0.05$). Except for the HR in the EFBFR protocol, the other analyzed parameters did not present statistically significant differences ($p>0.05$) between rest and 15-minutes of recovery for either experimental protocol.

Table 2. Responses of PP, HR and DP for both experimental exercise protocols (EEF and EFBFR) measured at different time points. The results are presented as the means and the standard deviation values are in parentheses.

		Rest	Post-exertion	Recovery (15 min)
PP	EEF	33^{a} (9)	40^{b} (9)	29^{a} (7)
	EFBFR	36^{a} (6)	43^{b} (7)	33^{a} (10)
HR	EEF	70^{a} (15)	87^{b} (18)	74^{a} (17)
	EFBFR	67^{a} (12)	81^{b} (12)	75^{a} (16)
DP	EEF	8128^{a}(2386)	10855^{b}(2747)	8235^{a}(2511)
	EFBFR	8141^{a}(1910)	11078^{b} (2110)	8863^{a}(2321)

Note. PP: pulse pressure (mmHg); HR: heart rate (bpm); DP: double product (bpm/mmHg). EEF: exercise of the elbow flexors; EFBFR: elbow flexors with blood flow restriction. Different lowercase letters show differences between measurement time points for each parameter.

DISCUSSION

The main finding of the present study was that unilaterally elbow flexion (concentration curls) associated with blood flow restriction resulted in increased SBP, DBP and MAP (9.60, 11.75 and 10.84%, respectively) compared to exercise performed without BFR. Although Poton and Polito[14] has postulated that protocols with high-intensity strength exercises tend to promote greater changes in post-exertion HR, SBP and MAP compared to low-intensity strength training with BFR, when the exercise protocols have the same intensity, as in the present study, there are no differences in post-exercise (recovery period) hemodynamic responses between exercises with and without BFR.

The results of this study show that even a potentially lower stimulus (low intensity elbow flexion exercise), when associated with BFR, promotes cardiovascular stress potentially greater than exercise alone (without BFR). Further, although biochemical markers were not evaluated, it can be postulated that the greater increase in BP in the low-intensity protocol with BFR compared to the protocol without BFR may be associated with hypoxia, increased levels of circulating catecholamines[15], and hyper-reactive stress response[15].

Although the acute increases in SBP, DBP and MBP in response to BFR exercise were more pronounced than in exercise without BFR, these were not persistent, returning to pre-exercise values at 15 minutes of recovery, which may suggest potentiated hypotensive effects of the RFS protocol. Post-exercise hypotension in BFR protocols has already been shown in other studies involving large muscle groups[8,9] with different forms of external compression using intermittent[7] and continuous[9]occlusion pressure; in these two studies, the duration of exercise was greater than in the present study. Exercise duration has been reported in the literature as a determining factor in the magnitude of post-exercise hypotension[17]. As has been demonstrated in other studies, BFR exercises tend to stimulate the production of vasodilators[14] and the sympathetic activation of the cardiovascular system favoring the inhibition of the metaboreflex system[7], factors that affect acute blood pressure responses. Brandner et al.[18] demonstrated that the reduction of hemodynamic variables immediately after the end of exercise suggests that BFR does not induce permanent changes in the autonomic control of hemodynamic responses. In addition, there are reports in the literature[18] that elevated blood pressure in response to BFR exercises present values within the range prescribed for cardiac rehabilitation patients. Such findings provide support for the use of low-intensity exercise protocols with BFR in patients with cardiovascular diseases, either by influencing muscle mass gain and hypertrophy, or through the potential benefits to the cardiovascular system. It should be considered that further studies involving populations with cardiovascular problems, especially hypertensive subjects, are necessary since most of the studies that analyzed hemodynamic responses in low intensity exercise with BFR were performed with healthy subjects.

Another important finding of the present study was the fact that the magnitude of HR, PP and DP responses did not differ between the protocols with and without BFR. The acute HR responses were similar to other studies[7,20], which reported that HR elevation is common in strength protocols with or without BFR. On the other hand, DP was elevated post-exertion and reduced after 15 minutes of recovery for both the EEF and EFBFR groups. These findings indicate that there is similar hemodynamic behavior in low-intensity strength protocols with or without BFR, highlighting the cardiovascular safety of these protocols and reinforcing the cardiovascular protection factor in BFR protocols[20], since the values do not represent a higher myocardial overload than protocols without BFR.

Pulse pressure behavior was similar in the experiments (EEF and EFBFR) at any time point. This is relevant because PP behavior may indicate arterial stiffness[13] and can be a strong predictor of cardiac problems[16]. Nogueira et al.[21] reported that the high PP (values greater than 50 mmHg) is an independent predictor of myocardial infarction and coronary diseases. The findings of the present study suggest that BFR does not increase cardiovascular risk in healthy subjects, considering that the PP values, even post-exertion, were not higher than 45 mmHg and did not differ from the values observed in groupswithout BFR. It should also be noted that strength protocols with mild or moderate intensity have been recommended for populations with cardiac alterations due to their chronic effectiveness for muscle gain and modification of coronary risk factors[22].

Considering that the use of chronic high-intensity strength protocols may be a limiting factor for patients with musculoskeletal or cardiovascular impairment, low-intensity strength protocols with BFR involving small muscle groups may serve as promising alternatives since, as demonstrated in the present study, changes in parameters such as HR, PP and DP did not differ from the protocol without BFR and remained within the ranges considered safe during exercise. It should be noted that in the present study a protocol with high intensity exercise without BFR was not used. This did not allow comparisons of these acute responses between low intensity protocols with BFR and high intensity protocols without BFR. More studies with clinical populations are necessary to confirm this hypothesis.

CONCLUSION

The results of the present study demonstrated that SBP, DBP and MBP increased only in response to strength exercise with BFR, and that these values return to the baseline values 15 minutes after the end of the exercise. In addition, PP values in response to exercise with BFR indicate that the additional load promoted by BFR did not represent a cardiovascular risk for the study subjects.

The observed behavior of the hemodynamic parameters supports the general understanding that protocols with BFR can promote positive alterations in the cardiovascular system.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – Unochapecó University (opinion number 085/12) and the protocol was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: CADS, SLB, MMO. Performed the experiments: CADS, SLB, VSC, MMO. Analyzed the data: CADS, SLB, VSC, MMO, MEDSG, CBS, AGRN. Contributed reagents/materials/analysis tools: CADS, SLB. Wrote the paper: CADS, SLB, VSC, MMO, MEDSG, CBS, AGRN.

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