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Original Article

ACUTE EFFECTS OF STRENGTH EXERCISE WITH BLOOD FLOW RESTRICTION ON THE ARTERIAL RESISTANCE INDEX

EFEITOS AGUDOS DO EXERCÍCIO DE FORÇA COM RESTRIÇÃO DO FLUXO SANGUÍNEO SOBRE O ÍNDICE DE RESISTÊNCIA ARTERIAL

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RESUMO
O presente estudo objetivou avaliar o comportamento agudo do índice de resistência da artéria braquial (IRAB) e da artéria poplítea (IRAP) em resposta a exercícios de força de baixa intensidade envolvendo pequenos (PGM) e grandes grupos musculares (GGM), realizado com e sem restrição de fluxo sanguíneo. Onze homens (idade 23 ± 3,29 anos) realizaram um experimento randomizado, cruzado, com quatro braços: Exercício para pequenos grupos musculares (PGM), pequenos grupos musculares com restrição de fluxo sanguíneo (PGM+RFS), grandes grupos musculares (GGM) e grandes grupos musculares com restrição de fluxo sanguíneo (GGM+RFS). O comportamento de IRAB e IRAP foi avaliado em repouso, mediatamente após o exercício, e aos 15 e 30 minutos da recuperação. A análise dos dados mostrou uma redução significativa do IRAB do repouso para o pós-exercício apenas nos protocolos de PGM com ou sem RFS (p <0,05). Protocolos envolvendo GGM, independentemente do BFR, não afetaram o IRAP (p> 0,05), porém, foram eficientes para promover aumentos significativos do IRAB (p <0,05) imediatamente após o exercício. Nossos achados indicam que os exercícios envolvendo PGM, independentemente da BFR, são capazes de promover a vasodilatação local (artéria braquial), porém, sem efeitos sistêmicos. Nenhum dos protocolos analisados afetou o comportamento do IRAP.
Palavras-chave: Oclusão vascular. Terapia por exercício. Vasodilatação.

ABSTRACT
The present study aimed to evaluate the acute behavior of the brachial artery resistance index (BARI) and popliteal artery resistance index (PARI) in response to low intensity strength exercises involving small (SMG) and large muscle groups (LMG) performed with and without blood flow restriction. Eleven men (age 23 ± 3.29 years) underwent a four-arm, randomized, cross-over experiment: Small muscle group exercise (SMG), small muscle groups with blood flow restriction (SMG+BFR), large muscle groups (LMG) and large muscle groups with blood flow restriction (LMG+BFR). The behavior of BARI and PARI was evaluated at rest, immediately after exercise, and at 15 and 30 minutes during recovery. Data analysis showed a significant reduction of the BARI from rest to post-exercise only in the protocols involving SMG, regardless of the BFR (p <0.05). Protocols involving LMG, with or without BFR, did not affect PARI (p> 0.05), but were efficient to promote significant increases in BARI (p <0.05) immediately after exercise. Our findings indicate that the exercises involving SMG, regardless of BFR, are efficient to promote local vasodilatation (brachial artery), but without systemic effects. None of the analyzed protocols affected the PARI behavior.
Keywords: Vascular Occlusion. Exercise Therapy. Vasodilatation.

Introduction

Strength exercises, in addition to benefits associated with sports performance, also promotes important physiological adaptations related to human health[1], and have been positively associated with the treatment and prevention of chronic degenerative diseases, especially those related to cardiovascular function[2-4]. In addition, physical exercise is also recognized as an efficient non-pharmacological measure for cardiovascular disease therapy[5] and the cardiovascular responses are dependent on the muscle mass involved[6]. However, the intensities necessary recommended[7] to promote such adaptations are not always possible to be applied to a considerable part of the population, particularly those with functional limitations, or cardiovascular and chronic diseases[8].

Alternatively, low intensity strength exercise with blood flow restriction (BFR) has been proposed as an effective intervention since it produces acute and chronic responses similar to those obtained with high intensity exercises without BFR[9].

Despite advances in research involving in hemodynamic responses to strength exercise with BFR[10] and vascular adaptations[11], this vascular response in the low-intensity strength exercise comparing of small and large muscle groups with and without blood flow restriction still poorly understood and studies related to the subject are rare. Authors[12] recommend the use of Doppler ultrasonography in the diagnosis of hemodynamic dysfunctions or cardiovascular diseases, and the resistance index (IR) has been used as an important indicator of local vasodilation, as well as for the diagnosis of proximal or distal vascular obstructions[13].

No study was found comparing vascular responses to BFR strength exercise in small and large muscle groups in the literature that was accessed. In this study, we evaluate the acute behavior of the brachial artery resistance index (BARI) and popliteal artery resistance index (PARI) in response to strength exercises involving small muscle groups (SMG) and large muscle groups (LMG), both with and without BFR. Our hypothesis is that BARI and PARI respond differently to low-intensity strength exercise protocols involving muscle groups of different sizes, and we believe that RFS at 70% at systolic blood pressure may potentiate vasodilation.

Methods

Subjects

As shown in Figure 1, the study sample consisted of 15 male university students (age: 23.00 ± 3.29 years, maximum dynamic force for barbell and Machine of 37.27 ± 8.82 and 119.71 ± 23.42 kg, respectively), not involved in exercise programs in the three months prior to the beginning of the study, had no clinical restrictions for physical exercise, were not undergoing drug treatment, had no diagnosed comorbidities, and were not restricting caloric intake. Participants were informed about the benefits and possible risks and related to the experimental protocol and signed a consent form agreeing to their participation in the study. Throughout the study, three subjects were excluded because they could not participate in one of the data collection steps (Figure 1). The study followed all the requirements of National Health Council Resolution (466/CNS/2012 of December 12, 2012) and was approved by Unochapecó Ethics Committee Involving Human Beings (Protocol No. 1,309,614).

Volunteers (n=32)	
↓	Exclusion based on criteria (n = 2)
Ramdonized (n=15)	
First trial (n=15)	
Second trial (n=15)	
↓	Excluded for not attending at least one experiment (n = 2)
Thrid trial (n =11)	
↓	Excluded for not attending at least one experiment (n = 2)
Forth trial (n=11)	

Figure 1. Organization chart of the study
Source: Authors

Experimental Design

Before starting the data collection, the subjects performed two familiarization sessions, in which all the exercises included in the study protocol were performed: strength exercise involving small muscle groups (biceps) without and with BFR, and exercise of force involving large muscle groups (Machine) with and without BFR. Three days after the last familiarization session, subjects performed strength assessment (1-RM test), following the recommendations of the American Society of Exercise Physiologists[14] and were randomly assigned to perform the exercise protocols. In subsequent weeks, each subject performed the four experimental protocols in random order (determined from a quadruple Latin square). Over the course of four sessions, and in relation to the 1-RM test, an interval of five to seven days was maintained.

The randomization was realized by a blinded independent research that generated fifteen experimental sequences with four trials determined from a quadruple latin square. Each experimental sequence was placed individually in a non-transparent sealed envelope. On the first day of data collection, each subject chose an envelope that contained the sequence of the four experiments to be performed upon arrival at the exercise physiology and biochemistry laboratory. The envelope was opened by the researcher and the order of the experiments was not informed to the subjects until the beginning of each trial.

Subjects were instructed not to perform physical exercises for 24 hours prior to each session, to maintain typical eating habits, and to avoid the use of drugs, caffeine, alcohol, or tobacco on exercise days and on the last day of the experiment. At the time scheduled for each of the four trials, the subjects attended the laboratory between 8:00 and 9:00 p.m., they remained seated at rest for 15 minutes before blood pressure measurement. After this period each subject lay on a stretcher (in a dorsal decubitus) for five minutes before the measurements of blood pressure, BARI, PARI and RI in the lower and upper limbs. For the measurements of blood pressure, BARI, PARI and RI were used a portable vascular doppler (Toshiba - PLT-704ST), with the probe positioned at an angle between 45º and 60º, as recommended by Pellerito and Polak[13]. Resistance index and upper limb blood pressure were measured in the brachial artery with the probe positioned between the biceps aponeurosis and the biceps muscle, with the subject lying on a bed in the dorsal decubitus position.

The measurement of lower limb RI and blood pressure in the popliteal artery was performed with the subject lying down in the ventral decubitus position, with the transducer positioned at the anatomical point corresponding to the popliteal cavus. Immediately after assessment of resting RI, the exercise protocol was performed according to the order determined at random. RI for brachial and popliteal arteries was measured immediately after exercise, and again after 15 and 30 min of recovery (Figure 2).

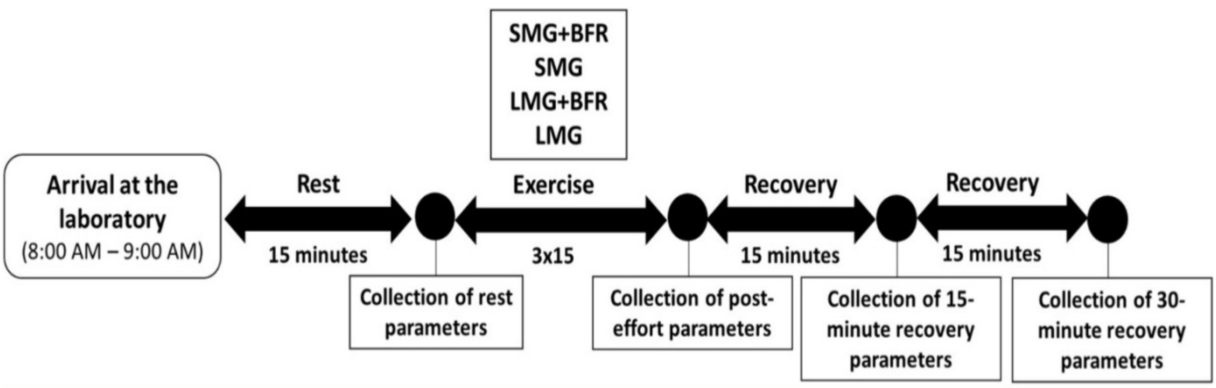

Figure 2. Experimental protocol
Source: Authors

All strength exercises were performed with a load corresponding to 30% of 1-RM. Three sets of 15 repetitions were performed with a 45 second recovery interval between sets and an execution speed of three seconds (1.5 seconds for the concentric phase and 1.5 seconds for the eccentric phase). A digital metronome (Sanny®, Personal Counter®, São Bernardo do Campo, SP, Brazil) was used to control the execution speed of the exercise, the number of repetitions and the interval between the series.

Four experimental protocols were performed: 1) Strength exercise for small muscle groups (SMG): barbell; 2) Strength exercise for small muscle groups with blood flow restriction (SMG+BFR): barbell with BFR. For BFR upper limbs, two 7 x 45.5 cm pneumatic sticks (Missouri, Mikatos, SP) were positioned at the arms near to shoulder joint; 3) Strength exercise for large muscle groups (LMG): Machine (Physicus™, Auriflama, SP) and: 4) Strength exercise for large muscle groups with blood flow restriction (LMG+BFR): Machine with BFR. For BFR lower limb, two 9.5 x 92 cm pneumatic sticks (Missouri®, Mikatos, SP) were positioned in the thighs near to gluteal line.

For both experiments using RFS (SMG+BFR and LMG+BFR), the occlusion pressure used corresponded to 70% of the systolic blood pressure, measured at rest. The occlusion pressure used in all trials ranged from 74 to 109 mmHg (89.97± 9.20 mmHg).

Statistical analysis

The Shapiro-Wilk test was used to evaluate the data normality. A 4X4 factorial ANOVA was used for comparisons between times (rest, immediately after exercise and after 15 and 30 min of recovery) and between experimental protocols (SMG; LMG; SMG+BFR and LMG+BFR). A Sidak test was used for multiple comparisons, and the value of $p \leq 0.05$ was used as the threshold for statistical significance. Statistical Package Social Science, version 20.0 (SPSS® Inc., Chicago, USA) was used for all analyses.

Results

The characteristics of the sample for age, body mass, height, body fat and lean body mass are presented in Table 1.

Table 1. Characteristics of the sample

Variable	Mean	Standard Deviation	Minimun	Maximun
Age (years)	23.00	3.29	20.00	29.00
Body mass (kg)	70.67	7.26	61.60	84.30
Height (m)	1.72	0.04	1.66	1.77
Body fat (%)	23.98	2.50	8.00	25.80
Lean body mass (kg)	54.48	2.68	50.20	58.70

Source: Authors

The analysis of the behavior of resistance indices (BARI and PARI) in response to exercise involving LMG and SMG both with and without BFR are presented in Figure 3. The post-exercise BARI presented statistically significant differences between the exercises involving small and large groups in exercises with BFR ($p < 0.05$). No statistically significant differences were found for the BARI in exercises performed without BFR involving small and large muscle groups ($p > 0.05$). However, the PARI in the exercises performed with BFR showed statistically significant differences between the protocols involving small and large muscle groups ($p < 0.05$).

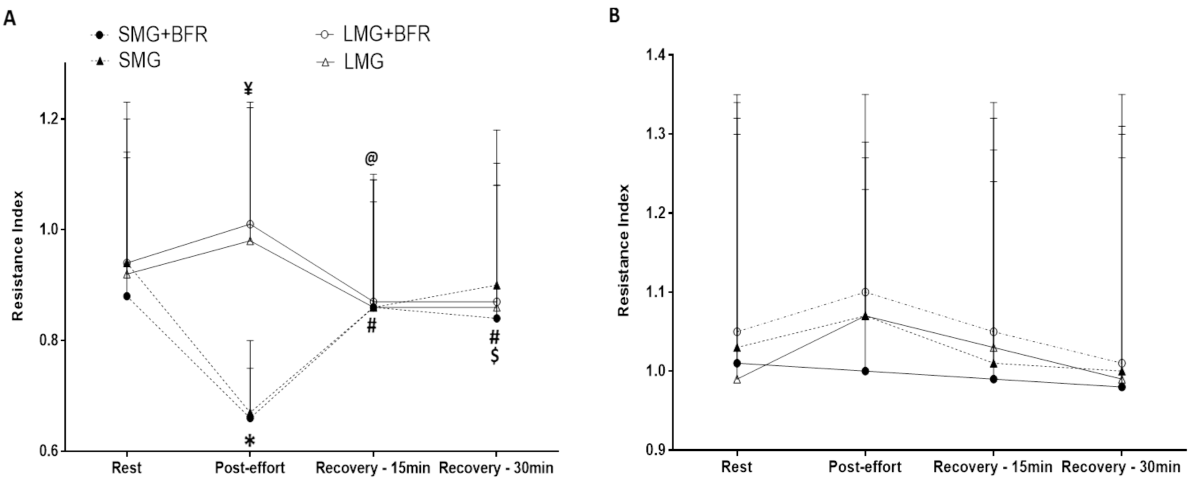

Figure 3. Analysis of the acute behavior of the resistance index of brachial (A) and popliteal arteries (B)
Source: Authors

Discussion

To our best knowledge, this is the first study to evaluate the acute responses of popliteal and brachial artery resistance indices with low intensity strength exercise involving small and large muscle groups with and without blood flow restriction. The main findings of this study were: a) low intensity strength exercises involving SMG, independent of BFR, reduced BARI immediately after exercise, and PARI was not affected by any of the exercise protocols. This indicates that vasodilation occurred in response to our exercise protocols, specifically a localized response without systemic reflexes. This agrees with the other studies[15], which investigated this type of response in a unilateral manual grip protocol. The authors of the study demonstrated that with SMG exercise, vasodilation occurs only in the exercised muscle group without responses in the non-exercised contralateral limb. Although they showed that vasodilation is a localized response with SMG exercise, the mechanisms behind the response are not yet fully elucidated.

In the present study, evaluation of the acute behavior of BARI and PARI in response to LMG exercise showed no local or systemic vasodilation, contrary to results for SMG. The increase in BARI indicated vasoconstriction in the upper limbs (a muscular group not involved in the exercise). One possible mechanism for this behavior is well described in the scientific literature, which is vasoconstriction of musculature that is not active in the exercise to promote higher availability of blood to the active musculature, this response is characteristic of exercises involving LMG[16]. The fact that BFR did not change outcomes for the BARI and PARI may be due to the occlusion pressure used in this study and the size of the active muscle group.

An occlusion pressure equivalent to 70% of SBP, as used in the present study, represents a different BFR when applied to SMG versus LMG. This is because in addition to the size of the muscle group occluded during exercise[17], other factors[18] such as the amount of pressure applied, the duration of pressure application[10,19] and the vascular anatomy of the region subjected to external compression[13] may interfere with the amount of blood given to the exercising muscles. It has also been reported that the circumference of the thigh and lean mass modulate the magnitude of the BFR, i.e. a larger lean mass and thigh circumference, decrease the effect of the occlusion pressure applied to the area, which effectively promotes restriction of blood flow[17].

Our results may also be explained by mechanical load used. Regardless of BFR, the exercise intensity for LMG was likely not sufficient to produce the metabolic and hemodynamic changes in active musculature necessary for local or systematic reduction of RI. Other studies using BFR have been fundamentally characterized by the use of low intensities, where occlusion pressure is the factor that promotes physiological responses comparable to high-intensity exercise[20,21]. In the present study, BFR pressure corresponding to 70% of SBP did not promote additional responses in LMG, at least not acute responses.

The results of this study point to the need for new research using combinations of different mechanical loads and occlusion pressures. The objective of future studies should be development of an ideal protocol, characterized by a low intensity that is greater than 30% of 1-RM and an occlusion pressure that allows comfortable performance of exercises with greater than 70% SBP; these conditions should promote desirable hemodynamic responses when performing LMG exercises. It is important to consider that very high occlusion pressures for long periods of time should be avoided[22].

Another factor that should be considered in BFR studies is the position of the subject for evaluation of SBP at rest. In the present study, resting BP measurements were performed with the subject in the dorsal position[13]. However, in the case of upper limbs BP measurements should be done with the subject standing in the exercise position. For lower limbs, systolic pressure should be measured with the subject standing using a portable Doppler. Results from the current study suggest that adoption of these measures will provide resting pre-exercise parameters more coherent with the exercise hemodynamic condition, which will allow establishment of a more reliable occlusion pressure percentage for the intended physiological stress.

Most studies involving BFR for upper or lower limbs positioned the sticks in the same manner employed in this study. We note that the positioning of the sticks in relation to the anatomical position of the collateral pathways of the great arteries in the arms and legs may limit BFR, even with high occlusion pressures. In strength exercises with SMG, the BFR apparatus was positioned at a height corresponding to the main arterial trunk, before the brachial artery and deep brachial artery division. The sticks in the LMG exercise protocol (Machine) were in an anatomical position (sanding position) at which pressure could block or markedly restrict blood flow in the superficial femoral artery. However, the deep femoral artery leading the blood to the distal portion of the lower limbs is only subjected to light pressure, or none at all; this likely maintains normal or adequate blood nourishment for the lower limbs[13].

The results of this study provide support for the development of future research, particularly regarding lower limb strength exercises with blood flow restriction. These findings may aid in the development of protocols or BFR devices capable of reducing blood flow to the active musculature, thus achieving the desired levels of physiological stress while ensuring the safety of the subjects.

Conclusion

The exercises involving SMG were efficient to promote local vasodilation without systemic effects independently of BFR. The exercises involving LMG did not cause localized or systemic vasodilation, however, they did produce vasoconstriction in musculature that was not involved in the exercise (i.e. arms). Evaluation of the RI behavior in response to exercises involving small or large muscle groups using BFR suggested that the occlusion pressures used in the study were not sufficient to promote changes in PARI or BARI.

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