Artigo Original

ISSN 0103-1716

Are there differences in the activation of the agonist and antagonist muscles during resistance training sessions with continuous or intermittent blood flow restriction?

Existem diferenças na ativação dos músculos agonista e antagonista durante sessões de treinamento de força com restrição de fluxo sanguíneo contínua ou intermitente?

RODRIGUES NETO G, SANTOS HH, PEREIRA NETO EA, BRASILIANO MM, SILVA JCG, NOVAES JS, TAHERI M, CIRILO-SOUSA MS. Are there differences in the activation of the agonist and antagonist muscles during strength training sessions with continuous or intermittent blood flow restriction? R. bras. Ci. e Mov 2019;27(3):139-149.

***ABSTRACT*:** Resistance training (RT) with blood flow restriction (BFR) has been used to increase muscle strength and hypertrophy, however, the best strategy to perform BFR (continuous or intermittent) has not yet been established. The aim of this study was to analyze the chronic effect of RT with continuous or intermittent blood flow restriction (CBFR or IBFR) on muscle activation. A total of 24 men with RT experience were randomly divided into three experimental groups: low-load exercises at 20% of one repetition maximum (1RM) combined with CBFR (LL + CBFR), low-load exercises at 20% of 1RM combined with IBFR (LL + IBFR), or low-load exercises at 20% of 1RM without BFR (LL). Twelve RT sessions were performed for 6 weeks, twice a week. A comparative analysis of the activation of the biceps and triceps brachial muscles after the bench press, triceps pulley, and biceps pulley exercises did not reveal group × evaluations × sets, group × evaluations, group × sets, or evaluations × sets interactions with regard to group, evaluation, or sets ($p > 0.05$). However, the evaluations showed a significant increase in the LI+IBFR group after the 1st, 2nd, and 4th sets ($p < 0.05$) only with regard to biceps muscle activation. It was concluded that the muscle activations of the biceps and triceps are similar with regard to the bench press, triceps pulley, and biceps pulley exercises when CBFR is compared with IBFR; however, IBFR improved the muscle activation of the biceps brachial only with regard to the front pull down exercise.

Key Words: Electromyography; Therapeutic occlusion; Physical exercise; Resistance training.

RESUMO: O treinamento de força (TF) com restrição de fluxo sanguíneo (RFS) tem sido utilizado para o aumento da força e hipertrofia muscular, entretanto, ainda não foi estabelecido a melhor estratégia para realizar a RFS (contínua ou intermitente). O objetivo do estudo foi analisar o efeito crônico do TF com a RFS, contínua ou intermitente, sobre ativação muscular. Participaram do estudo 24 homens com experiência em TF que foram divididos aleatoriamente em três grupos experimentais: a) exercícios de baixa carga a 20% de 1RM combinado com a RFS contínua (BC + RFSC), b) exercícios de baixa carga a 20% de 1RM combinado com a RFS intermitente (BC + RFSI), c) exercícios de baixa carga a 20% de 1RM sem a RFS (BC). Foram realizadas 12 sessões de TF (duração de seis semanas, sendo duas vezes por semana). Na primeira e na última sessão foi avaliada a ativação muscular do bíceps e tríceps nos quatro exercícios (supino reto, puxada frontal, rosca tríceps e rosca bíceps, respectivamente). Na análise comparativa da ativação muscular do bíceps e do tríceps braquial nos exercícios: supino reto, rosca tríceps e rosca bíceps, observou-se que não existiram interações entre grupo × avaliações × séries, grupo × avaliações, grupo × séries, avaliações × séries, no grupo, nas avaliações e nas séries ($p > 0,05$); entretanto, nas avaliações houve aumento significativo no grupo BC+RFSI, na 1ª, 2ª e 4ª séries ($p < 0,05$) apenas na ativação muscular do bíceps. Conclui-se que a ativação muscular do bíceps e tríceps parecem ser semelhantes nos exercícios supino reto, rosca tríceps e rosca bíceps quando comparada a RFS contínua *vs.* intermitente, porém, a RFS intermitente parece melhorar a ativação muscular do bíceps braquial apenas no exercício puxada frontal.

Palavras-chave: Eletromiografia; Oclusão terapêutica; Exercício físico; Treinamento de resistência.

Gabriel Rodrigues Neto[1,2,3,4]
Heleodório H. Santos[1,2]
Elísio A. Pereira Neto[1,2,5]
Marlon M. Brasiliano[1,2]
Júlio Cesar G. Silva[1,2,3,4]
Jefferson Silva Novaes[6,7]
Morteza Taheri[8]
Maria S. Cirilo-Sousa[1,2,9]

[1]Universidade Federal da Paraíba
[2]Universidade de Pernambuco
[3]Faculdades Nova Esperança
[4]Unifacisa - Centro Universitário
[5]University of South Australia
[6]Universidade Federal do Rio de Janeiro
[7]Universidade Federal de Juiz de Fora
[8]Imam Khomeini International University
[9]Universidade Regional do Cariri

Contato: Gabriel Rodrigues Neto - gabrielrodrigues_1988@hotmail.com

Recebido: 06/09/2018
Aceito: 31/01/2019

Introduction

Low-load (LL) resistance training (RT; i.e., 20-30% of one repetition maximum [1RM]) combined with blood flow restriction (BFR) emerged in the 1960s but gained greater notoriety in the 2000s[1] as an alternative method for individuals who cannot perform high-intensity exercises (i.e., ≥ 65% of 1RM). In this context, this training method has been shown to effectively increase muscle strength[2-5], muscular hypertrophy[2,5], localized muscular endurance[4,6,7], isometric force[8], and functional capacity[9]. Furthermore, it has been shown to be safe in relation to hemodynamics[10-14].

In the last 20 years, this form of intervention has gained more prominence in the academic community, thus, several researches have been carried out aiming to understand all the procedures inherent in its application, with respect to safety, efficacy and adherence. In this direction, it is observed that studies were developed to understand all the methodological procedures involved in the applicability of this training method (i.e., intensity[15], most efficient cuff size[16], and training pressure[17]. However, BFR mode (continuous or intermittent; CBFR or IBFR)[18-24] might be the most important methodological procedure. Yasuda *et al.*[24] compared BFR modes only during the acute phase, and they did not observe differences in muscle activation between these modes after performing a unilateral elbow flexion exercise. Similarly, Fitschen *et al.*[19] showed that CBFR promotes a greater sensation of pain than IBFR and that this characteristic can influence adherence to training among individuals, especially those with special needs.

Therefore, it is relevant to develop an investigation towards the comparison of BFR modes in healthy individuals, to later conduct studies in clinical populations. Thus, these data will raise important information for those who wish to carry out a training program with this training methodology and professionals who use this method for rehabilitation or improvement of physical performance. In addition, a review of the relevant literature verified that the chronic effect of RT with CBFR or IBFR has not been investigated with regard to muscle activation after upper limb training sessions.

Considering the above, the present study hypothesized that the modes of CBFR and IBFR would not promote significant differences in the activation of the elbow agonist and antagonist muscles. Thus, the present study compared the chronic effect of RT with BFR, between continuous and intermittent modes, on the activation of the elbow agonist and antagonist muscles in healthy young men.

Materials and methods

Participants

The procedures suggested by Beck[26] were followed to calculate the adequate sample size a priori using the G*Power 3.1[25]. Thus, considering a power of 0.8, a significance level of 5% and an effect size (ES) of 0.35, it was found that 24 participants would be enough to provide 0.821 statistical power.

Therefore, 24 men between 18 and 36 years old, with a minimum RT experience of 2 months and a maximum of 12 months, participated in this study (Table 1). Participants were eligible for inclusion if they 1) were between 18 and 40 years old; 2) responded negatively to all items of the Physical Activity Readiness Questionnaire (PAR-Q)[27]; 3) had a body mass index (BMI) of less than 30 $m^2.kg^{-1}$; 4) did not present with a history of musculoskeletal lesions in the upper limbs over the last 6 months; and 5) were not smokers.

After meeting the inclusion criteria and being explained about the risks and benefits of the research, the participants signed the informed consent document prepared based on the Helsinki Declaration. The local ethics committee approved this study under protocol n° 0476/13 and CAAE: 20355013.2.0000.5188.

Table 1. Anthropometric and muscular strength characteristics (1RM) of participants.

	LL + CBFR (9 participants)	LL + IBFR (7 participants)	LL (8 participants)	p
Age (years)	26.1 ± 5.0	23.1 ± 5.6	22.2 ± 3.5	0.277
Body mass (kg)	67.5 ± 9.7	81.0 ± 8.5	78.0 ± 10.9	0.045
Height (m)	1.71 ± 0.05	1.75 ± 0.08	1.75 ± 0.06	0.443
BMI (kg.m^2)	22.8 ± 2.2	26.5 ± 2.7	25.2 ± 2.4	0.054
PRBFLA (mmHg)	108.8 ± 9.2	117.1 ± 10.3	-	0.090
Bench press (1RM)	77.6 ± 17.2	75.9 ± 12.4	75.5 ± 11.9	0.808
Front pull Down (1RM)	69.0 ± 13.0	67.3 ± 14.4	63.8 ± 12.3	0.722
Triceps pulley (1RM)	31.3 ± 6.8	31.6 ± 4.6	32.3 ± 4.8	0.852
Biceps pulley (1RM)	34.4 ± 5.9	35.1 ± 8.1	32.7 ± 5.9	0.860

Note: BMI = body mass index; PRBFLA = mean pressure used in blood flow restriction of the left arm; LL + CBFR = low-load combined with continuous blood flow restriction; LL + IBFR = low-load combined with intermittent blood flow restriction; LL = low-load.

Study Design

On the first visit to the laboratory, the participants underwent an anthropometric assessment. Five minutes later, the BFR point was determined. After another 15 to 20 minutes, participants' isometric muscle strength (IMS) was measured. Three to 5 minutes later, the maximal dynamic muscle strength (1RM) of each exercise (bench press, front pull down, triceps pulley, and biceps pulley) was assessed (see Figure 1). The training period lasted 6 weeks, twice a week, totalizing 12 sessions. On the first and last sessions, the muscle activation of the four sets was assessed with regard to all of the exercises (Figure 1), and the first session occurred 72 hours after the first visit. The three separate groups of the study performed the following training protocols: a) LL + CBFR = low-load RT (20% of 1RM) combined with CBFR; b) LL + IBFR = low-load RT (20% of 1RM) combined with IBFR; or c) LL = low-load RT (20% of 1RM] without BFR. Throughout the study, participants were instructed to refrain from exercising their upper limbs or ingesting nutritional supplements.

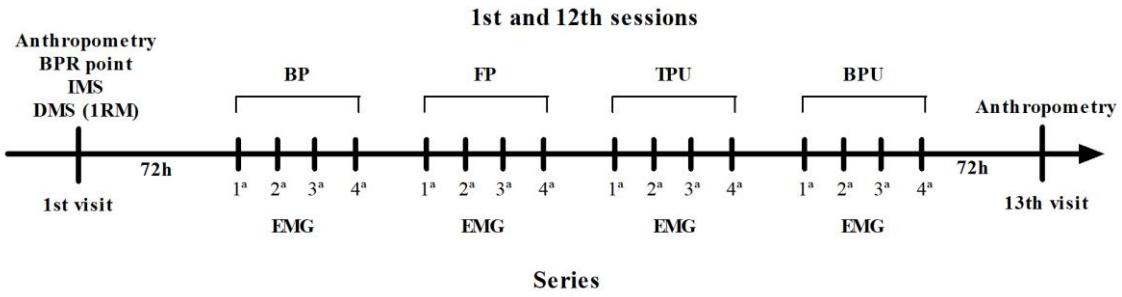

Figure 1. Experimental design.
Note: BFR = blood flow restriction; IMS = Isometric muscle strength; DMS = dynamic muscle strength; BP = Bench press; FP = Front pull down; TPU = triceps pulley; BPU = biceps pulley; EMG = electromyography

Procedures

Anthropometry

A scale with a precision of 0.1 kg (model 7755 - Soehnle Professional®, Germany) was used to assess body mass, a portable stadiometer with a precision of 0.5 cm (WCS, Cardiomed®, Brazil) was used to evaluate height and the BMI was subsequently calculated.

Evaluation of BFR

After the anthropometric measurements the participants were instructed to lie down on their backs and an experienced researcher placed a standard blood pressure sphygmomanometer (60 x 470 mm; a Riester pneumatic tourniquet komprimeter to restrict blood flow in the limbs) in the region of the axillary fold (right and left arms). Sequentially, the cuff was inflated to the point where the auscultatory pulse of the radial artery, which was captured by the vascular Doppler probe (MedPeg® DV - 2001, Ribeirão Preto, SP, Brazil), was discontinued and that was considered as the BFR pressure (mmHg). For each participant, the cuff pressure used during the exercises was determined at 80% of the complete BFR pressure during the resting state[2].

Maximal Dynamic Muscle Strength (1RM)

The maximal dynamic muscle strength to determine the training load was assessed by the 1RM test, following the recommendations of the ACSM[28]. Thus, all the participants performed the 1RM test across the four bilateral exercises (i.e., bench press, front pull down, triceps pulley, and biceps pulley). A recovery time of 5 minutes was adopted between each exercise based on the studies by Rodrigues Neto *et al*.[20-22].

Surface Electromyography (EMG)

An electromyography acquisition device (W4X8 model, Biometrics Ltd., UK) with eight wireless channels and the following technical characteristics was used to record the electrical signal of the triceps and biceps brachial muscles during the execution of the four exercises: 12-bit analog-to-digital (A/D) conversion plate; amplifier gain, 1,000x; bandpass filter, 20 to 500 Hz (second-order *Butterworth*); common mode rejection ratio (CMRR), > 100 dB; signal noise rate, < 3 mV root mean square (RMS); and impedance, 10^9 Ohms. Surface, bipolar, active, and simple differential electrodes were used, preamplified 20 times. DataLOG software was used for the sampling and analysis of the signals at a sampling frequency of 1,000 Hz. Before the electromyographic signal was captured, trichotomy, abrasion, and skin cleaning with 70% alcohol were performed to decrease tissue impedance.

The capture electrodes were fixed with double-sided adhesive tape, micropore, and elastic bands at specific points of each muscle. To ensure that the electrodes were placed at the same points for all evaluations, the volunteers were tagged with a long-lasting henna dye, and a new layer was applied when the mark had almost disappeared.

The entire process for capturing the EMG signals of the biceps and triceps brachial muscles across the four exercises was based on the recommendations of the *Surface Electromyography for the Non-invasive Assessment of Muscles* (SENIAM). For the brachial biceps, the electrode was fixed at 1/3 of the distance between the cubital fossa and acromium, whereas for the brachial triceps (lateral portion) the electrode was placed at 50% of the distance between the posterior portion of the acromion and the olecranum (laterally this point)[29]. The recording of the electromyographic signal was stored on a memory card and then analyzed and processed using the DataLog software that came with the equipment, considering the RMS of 15 repetitions for each set.

The electromyographic signal was measured only on the arm that presented greater isometric strength, which was measured via a manual dynamometer (CROW®, Brazil). For this procedure, the following standardization was

adopted. Each participant performed three hand grip attempts on a manual dynamometer in each hand; thus, only the limb that presented the greatest isometric strength was considered for electrode placement. The reference electrode was fixed at the radial styloid processes, on the arm with less strength. To record the electromyographic signal, the participants assumed the correct positions for each of the four exercises.

For purpose of signal processing and statistical calculations, the mean and RMS peak of the five central repetitions (i.e., the 6th, 7th, 8th, 9th, and 10th repetitions) were considered for each of the four sets based on the 15 repetitions performed, and normalization of the EMG signal was performed based on the peak. Regarding the windowing time, three seconds (1.5 s for concentric phase and 1.5 s for eccentric phase) were used.

Training Sessions

A total of 72 hours after the first visit, the participants were randomly divided into three experimental groups: a) four exercises at 20% of 1RM combined with CBFR (LL + CBFR); b) four exercises at 20% of 1RM combined with IBFR (LL + IBFR); and c) four exercises at 20% of 1RM without BFR (LL). Twelve sessions were performed with the following bilateral exercises: bench press (with a conventional bar and calibrated weights), front pull down, triceps pulley, and biceps pulley (using conventional equipment). The joint amplitude of the shoulder ranged from 90° to 120° for the bench press exercise (lying in the supine position) and from 180° to 45° for the front pull down exercise (sitting). The joint amplitude of the elbow ranged from 90° to 0° for the triceps pulley exercise (standing) and from 0° to 145° for the biceps pulley exercise (standing). The participants of the three groups completed four sets of 15 repetitions using 20% of 1RM with 30-second intervals between all of the sets and a 1-minute interval between exercises. The groups with BFR used a standard blood pressure cuff (a Riester pneumatic tourniquet komprimeter) to restrict blood flow in the in the arms (width 60 mm, length 470 mm), which was placed in the most proximal region. For the LL + CBFR group, the cuff was kept inflated between sets; however, it was always deflated at the end of each exercise, whereas the cuff was deflated between sets for the LL + IBFR group. The execution speed for the three groups was established at 3 seconds (1.5 for the concentric muscle action and 1.5 for the eccentric muscle action) controlled by a metronome.

Total Training Volume

The total volume (V_T) of any intervention (12 sessions) was verified by multiplying the load by the number of sets and complete repetitions of all of the sessions of the four exercises (sessions x load x sets x repetitions).

Statistical Analysis

Initially, the Shapiro-Wilk normality test and Mauchly's sphericity test were used. The variables showed a normal distribution ($p > 0.05$); however, because the sphericity assumption was not met, Greenhouse-Geisser correction values were adopted ($p < 0.05$). The characteristics of the sample (age, body mass, height, and BMI), the mean pressure used for the BFR of the left arm and the 1RM test of the four exercises (bench press, front pull down, triceps pulley, and biceps pulley) were verified with One-way ANOVA. One-way ANOVA with Bonferroni post hoc test was used to compare the V_T of the exercises between groups. Student's independent-samples t-test was employed to compare the BFR pressures used for the LL + CBFR and LL + IBFR groups. A three-way repeated-measures ANOVA composed of group (LL + CBFR *vs.* LL + IBFR *vs.* LL) × evaluation (pre-test *vs.* post-test) × sets (first *vs.* second *vs.* third *vs.* fourth), followed by Bonferroni post hoc test, was used to analyze the possible differences in the dependent variable. The ES was used to verify the magnitude (trivial < 0.50, small = 0.50-1.25, moderate = 1.25-1.9, and large > 2.0] of the significant changes between the assessments of the study groups[30]. The level of significance was set at $p < 0.05$. All statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL).

Results

The analysis of the total training volume of the 12 sessions did not reveal significant differences among the groups (LL + CBFR [30,585.6 ± 5,629.1] *vs.* LL + IBFR [30,251.3 ± 5,236.1] *vs.* LL [29,447.1 ± 4,724.2], p = 0.902). The analysis of BFR measured at the left arm did not reveal a significant difference between the LL + CBFR and LL + IBFR groups (p = 0.128).

EMG of the Bench Press Exercise

The comparative analysis of the muscle activation of the biceps and triceps brachial muscles did not show group × evaluations × sets, group × evaluations, group × sets, or evaluations × sets interactions for the group, evaluations, or the sets with regard to the bench press exercise (p > 0.05; see Table 2).

Table 2. Comparison of normalized EMG signal means in the biceps and triceps brachial muscles across the four sets of bench press exercises.

Muscles	**LL + CBFR (n = 9)**		**LL + IBFR (n = 7)**		**LL (n = 8)**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Biceps						
1st Set	0.136 ± 0.05	0.165 ± 0.13	0.181 ± 0.07	0.176 ± 0.08	0.187 ± 0.05	0.170 ± 0.10
2nd Set	0.122 ± 0.03	0.131 ± 0.07	0.179 ± 0.09	0.154 ± 0.12	0.178 ± 0.04	0.152 ± 0.05
3rd Set	0.137 ± 0.04	0.139 ± 0.09	0.142 ± 0.04	0.133 ± 0.11	0.196 ± 0.04	0.189 ± 0.10
4th Set	0.137 ± 0.05	0.140 ± 0.08	0.146 ± 0.04	0.149 ± 0.08	0.187 ± 0.04	0.143 ± 0.04
Triceps						
1st Set	0.154 ± 0.02	0.184 ± 0.13	0.132 ± 0.05	0.404 ± 0.32	0.160 ± 0.05	0.245 ± 0.07
2nd Set	0.155 ± 0.03	0.151 ± 0.07	0.159 ± 0.02	0.857 ± 1.81	0.156 ± 0.05	0.208 ± 0.04
3rd Set	0.152 ± 0.07	0.152 ± 0.07	0.146 ± 0.02	0.529 ± 0.98	0.147 ± 0.03	0.195 ± 0.05
4th Set	0.150 ± 0.03	0.138 ± 0.08	0.144 ± 0.06	0.462 ± 0.76	0.160 ± 0.03	0.196 ± 0.04

Note: LL + CBFR = low-load combined with continuous blood flow restriction; LL + IBFR = low-load combined with intermittent blood flow restriction; LL = low-load.

EMG of the Front Pull Down Exercise

The comparative analysis of the muscle activation of the biceps brachial muscle did not show group × evaluations × sets, group × evaluations, group × sets, or evaluations × sets interactions for the group or the sets with regard to the front pull down exercise (p > 0.05); however, significant interactions were observed for the evaluations (p = 0.005). For the effect evaluations, a significant increase was observed only with regard to the LL + IBFR group at the 1st (p = 0.017, ES = 4.47), 2nd (p = 0.002, ES = 6.07), and 4th sets (p = 0.027, ES = 5.23; see Table 3). The comparative analysis of the triceps brachial muscle activation did not find group × evaluations × sets, group × evaluations, group × sets, or evaluations × sets interactions for the group, evaluations, or sets with regard to the bench press exercise (p > 0.05; see Table 3).

Table 3. Comparison of normalized EMG signal means in the biceps and triceps brachial muscles across the four sets of front pull down exercises**.**

Muscles	LL + CBFR (n = 9)		LL + IBFR (n = 7)		LL (n = 8)	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Biceps						
1st Set	0.152 ± 0.10	0.196 ± 0.17	0.110 ± 0.04	0.289 ± 0.21*	0.160 ± 0.03	0.224 ± 0.13
2nd Set	0.120 ± 0.04	0.164 ± 0.14	0.129 ± 0.04	0.372 ± 0.26*	0.146 ± 0.07	0.230 ± 0.14
3rd Set	0.110 ± 0.05	0.141 ± 0.14	0.128 ± 0.04	0.331 ± 0.24	0.152 ± 0.08	0.357 ± 0.49
4th Set	0.115 ± 0.05	0.128 ± 0.11	0.125 ± 0.03	0.282 ± 0.19*	0.136 ± 0.07	0.211 ± 0.20
Triceps						
1st Set	0.114 ± 0.02	0.240 ± 0.24	0.209 ± 0.04	0.458 ± 0.38	0.148 ± 0.05	0.232 ± 0.28
2nd Set	0.114 ± 0.05	0.155 ± 0.12	0.160 ± 0.04	0.212 ± 0.13	0.148 ± 0.07	0.280 ± 0.30
3rd Set	0.160 ± 0.05	0.164 ± 0.12	0.179 ± 0.05	0.235 ± 0.20	0.142 ± 0.06	0.265 ± 0.22
4th Set	0.161 ± 0.05	0.173 ± 0.11	0.180 ± 0.03	0.229 ± 0.16	0.148 ± 0.05	0.293 ± 0.95

Note: * Significant difference when compared with the pre-test; LL + CBFR = low-load combined with continuous blood flow restriction; LL + IBFR = low-load combined with intermittent blood flow restriction; LL = low-load

EMG of the Triceps Exercise

The comparative analysis of the muscle activation of the biceps and triceps brachial muscles did not reveal group × evaluations × sets, group × evaluations, group × sets, or evaluations × sets interactions for the group, evaluations, or sets with regard to the triceps pulley exercise ($p > 0.05$; see Table 4).

Table 4. Comparative analysis of the normalized mean EMG signal in the biceps and triceps brachial muscles across the four sets of triceps pulley exercises.

Muscles	LL + CBFR (n = 9)		LL + IBFR (n = 7)		LL (n = 8)	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Biceps						
1st Set	0.338 ± 0.48	0.156 ± 0.08	0.222 ± 0.12	0.282 ± 0.21	0.165 ± 0.10	0.132 ± 0.07
2nd Set	0.173 ± 0.02	0.145 ± 0.05	0.156 ± 0.02	0.178 ± 0.06	0.165 ± 0.12	0.118 ± 0.07
3rd Set	0.216 ± 0.12	0.148 ± 0.05	0.161 ± 0.03	0.194 ± 0.04	0.168 ± 0.06	0.181 ± 0.12
4th Set	0.262 ± 0.273	0.153 ± 0.06	0.175 ± 0.06	0.155 ± 0.05	0.175 ± 0.07	0.202 ± 0.17
Triceps						
1st Set	0.211 ± 0.05	0.159 ± 0.09	0.184 ± 0.02	0.186 ± 0.18	0.170 ± 0.07	0.203 ± 0.04
2nd Set	0.208 ± 0.05	0.135 ± 0.06	0.172 ± 0.07	0.164 ± 0.10	0.188 ± 0.03	0.189 ± 0.05
3rd Set	0.208 ± 0.05	0.151 ± 0.09	0.184 ± 0.02	0.159 ± 0.10	0.160 ± 0.06	0.198 ± 0.05
4th Set	0.199 ± 0.05	0.146 ± 0.08	0.190 ± 0.02	0.142 ± 0.09	0.192 ± 0.09	0.220 ± 0.06

Note: LL + CBFR = low-load combined with continuous blood flow restriction; LL + IBFR = low-load combined with intermittent blood flow restriction; LL = low-load.

EMG of the Biceps Pulley Exercise

The comparative analysis of the muscle activation of the biceps and triceps brachial muscles did not reveal

group × evaluations × sets, group × evaluations, group × sets, or evaluations × sets interactions for the group, evaluations, or sets with regard to the biceps pulley exercise ($p > 0.05$; see Table 5).

Table 5. Comparison of the normalized muscle activation (EMG) means of the biceps and triceps brachial muscles across the four sets of biceps pulley exercises.

	LL + CBFR (n = 9)		LL + IBFR (n = 7)		LL (n = 8)	
Muscles	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Biceps						
1st Set	0.203 ± 0.03	0.217 ± 0.11	0.198 ± 0.03	0.179 ± 0.07	0.184 ± 0.02	0.250 ± 0.19
2nd Set	0.203 ± 0.04	0.215 ± 0.13	0.235 ± 0.04	0.190 ± 0.07	0.199 ± 0.04	0.241 ± 0.18
3rd Set	0.206 ± 0.04	0.213 ± 0.14	0.253 ± 0.05	0.212 ± 0.11	0.206 ± 0.04	0.240 ± 0.17
4th Set	0.214 ± 0.04	0.210 ± 0.12	0.259 ± 0.05	0.228 ± 0.11	0.187 ± 0.08	0.249 ± 0.19
Triceps						
1st Set	0.182 ± 0.03	0.436 ± 0.59	0.169 ± 0.01	0.207 ± 0.09	0.188 ± 0.11	0.179 ± 0.05
2nd Set	0.280 ± 0.23	0.192 ± 0.12	0.148 ± 0.02	0.224 ± 0.10	0.156 ± 0.05	0.171 ± 0.05
3rd Set	0.232 ± 0.20	0.287 ± 0.29	0.169 ± 0.04	0.233 ± 0.10	0.150 ± 0.04	0.206 ± 0.13
4th Set	0.179 ± 0.03	0.249 ± 0.30	0.255 ± 0.19	0.248 ± 0.14	0.165 ± 0.05	0.227 ± 0.11

Note: LL + CBFR = low-load combined with continuous blood flow restriction; LL + IBFR = low-load combined with intermittent blood flow restriction; LL = low-load

Discussion

The present study analyzed the chronic effect of RT with CBFR or IBFR on the activation of the agonist and antagonist muscles of the upper limbs of healthy men. According to the literature, this was the first study to analyze the chronic adaptations of RT combined with CBFR or IBFR on the electrical activity of the upper limbs. The main findings were that the BFR modes (continuous or intermittent) were similar regarding the activation of the biceps and triceps brachial muscles for the bench press, triceps pulley, and biceps pulley exercises. However, a significant increase in biceps muscle activation was observed in the LL + IBFR group among the 1st, 2nd, and 4th sets.

Although no study had analyzed the chronic effects of CBFR or IBFR on muscle activation, one study evaluated the acute effect of strength exercise combined with CBFR or IBFR on muscle activation[24]. Our findings corroborate those of Yasuda *et al.*[24] and reinforce the present hypothesis because those authors did not find significant differences between CBFR and IBFR. In that study, the participants performed only one exercise with unilateral execution (arm flexion), the load used was 20% of 1RM, and four sets were performed (30 x 15 x 15 x 15 repetitions with 30-second intervals) with a training pressure of 160 mmHg. After analyzing the data of the present study and those of Yasuda *et al.*[24], it appears that no significant differences exist between CBFR and IBFR, and this finding was independent of acute or chronic adjustments, training volume (one *vs.* four exercises), execution mode (unilateral *vs.* bilateral), and mean restriction pressure (high = 160 mmHg [Yasuda *et al.*[24]] *vs.* moderate = 108 or 117 mmHg [present study]).

In this context, Sousa *et al.*[4] analyzed the 6-week effect of RT combined with CBFR on the muscle activation of the knee extensors across four groups (high intensity, LL + CBFR, high intensity and LL + CBFR, and LL). Although these authors did not find differences among the groups, they observed higher values for the two groups that used CBFR. Our results corroborate those of that study in that differences among groups were not observed with regard to muscle activation, showing higher magnitudes for IBFR.

In addition, other studies have analyzed the acute effect of strength exercise combined with CBFR on muscle

activation[31,32], observing that BFR increased the muscle activation compared with the condition without BFR, and with greater chronic muscle activation during the concentric phase[33]. This increase in muscle activation may lead to acute changes that are observed due to the increased volume and swelling of the muscle cell, which might be important factors for the promotion of muscle hypertrophy in chronic adaptation[33]. Moreover, this increase in muscle activation during CBFR compared with the condition without BFR diverges from our study where no differences were found. One possible explanation is that Yasuda *et al*.[31,32] analyzed muscle activation in the same participants (crossover study), whereas groups were used in the present study. Furthermore, the different physical characteristics of the participants might have interfered directly with the electromyographic signal, which is a limitation of the present study. To respond to the proposed objective; however, it was necessary to use this study design.

The increase in the muscle activation of the biceps brachial muscle in the IBFR group seemed to be an effective form of intervention and the best intervention using the training method. CBFR and IBFR are similar with regard to the neuromuscular adaptations of the muscle activation in its acute[24] and chronic form, muscular strength and hypertrophy[19], heart rate and double product[22], and oxidative stress and muscle damage[21]; however, no consistency exists with regard to metabolic stress[22,23]. However, IBFR has a lower perception of effort[22,24] and is associated with less pain[19], which might enable greater adherence and permanence among the people who practice this training method, either for rehabilitation or muscular performance.

Finally, this study has limitations. The muscle activity of the pectoralis and back was not verified because the heart beat might have interfered with the electromyographic signal. The BFR pressure used was verified for the dorsal decubitus, but the positions of the four exercises were performed in different positions; however, these procedures are commonly performed in the literature[2-4,6,8,11,12].

Conclusions

The results of the present study showed that CBFR and IBFR appear to generate similar chronic adaptations to the activation of the biceps and triceps brachial muscles during the bench press, triceps pulley, and biceps pulley; however, IBFR seems to improve biceps muscle activation only for the front pull down exercise. Therefore, research should be developed and aimed at comparing the two forms of BFR on the activation of different muscle groups across different exercises, intensities, and BFR percentages.

Acknowledgements

The authors thank the Brazilian Federal Agency for their Support and Evaluation of Graduate Education (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior; CAPES).

References

1. Sato Y. The history and future of KAATSU training. Int J Kaatsu Train Res. 2005; 1(1): 1-5.

2. Laurentino GC, Ugrinowitsch C, Roschel H, Aoki MS, Soares AG, M. NJ, *et al*. Strength training with blood flow restriction diminishes myostatin gene expression. Med Sci Sports Exerc. 2012; 44(3): 406-12.

3. Silva JCG, Rodrigues Rodrigues Neto G, Freitas E, Elísio Neto, Batista G, Torres M *et al*. Chronic effect of strength training with blood flow restriction on muscular strength among women with osteoporosis. J Exerc Physiol Online. 2015; 18(4): 33-41.

4. Sousa JBC, Rodrigues Neto G, Santos HH, Araújo JP, Silva HG, Cirilo-Sousa MS. Effects of strength training with blood flow restriction on torque, muscle activation and local muscular endurance in healthy subjects. Biol Sport. 2017; 34(1): 83-90.

5. Vechin FC, Libardi CA, Conceição MS, Damas FR, Lixandrão ME, Berton RPB, *et al*. Comparisons between low-

intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly. J Strength Cond Res. 2015; 29(4): 1071-6.

6. Gil ALS, Rodrigues Neto G, Sousa MSC, Dias I, Vianna J, Nunes RAM, *et al*. Effect of strength training with blood flow restriction on muscle power and submaximal strength in eumenorrheic women. Clin Physiol Funct Imaging. 2017; 37(2): 221-8.

7. Kacin A, Strazar K. Frequent low-load ischemic resistance exercise to failure enhances muscle oxygen delivery and endurance capacity. Scand J Med Sci Sports. 2011; 21(6): 231-41.

8. Chaves E, Rodrigues Neto G, Cirilo-Sousa MS, Miranda H, Araújo CO, Vianna JM *et al*. Effect of strength training with blood flow restriction on isometric strength during different phases of the menstrual cycle. Med Sports 2016; 69(3): 331-43.

9. Araujo JP, Rodrigues Neto G, Loenneke JP, Bemben MG, Laurentino G, Batista G, *et al*. The effects of water aerobics in combination with blood flow restriction on strength and functional capacity in post-menopausal women. AGE. 2015:10.1007/s11357-015-9851-4.

10. Rodrigues Neto G, Novaes JS, Dias I, Brown A, Vianna J, Cirilo-Sousa MS. Effects of resistance training with blood flow restriction on hemodynamics: a systematic review. Clin Physiol Funct Imaging; 2016. doi: 10.1111/cpf.12368.

11. Rodrigues Neto G, Sousa MSC, Costa PB, Salles BF, Novaes GS, Novaes JS. Hypotensive effects of resistance exercises with blood flow restriction. J Strength Cond Res. 2015; 29(4): 1064-70.

12. Rodrigues Neto G, Sousa MSC, Silva GVC, Gil ALS, Salles BF, Novaes JS. Acute resistance exercise with blood flow restriction effects on heart rate, double product, oxygen saturation and perceived exertion. Clin Physiol Funct Imaging. 2016; 36(1): 53-9.

13. Vilaça-Alves J, Rodrigues Neto G, Morgado NM, Saavedra F, Lemos R, Moreira TR *et al*. Acute effect of resistance exercises performed by the upper and lower limbs with blood flow restriction on hemodynamic responses. J Exerc Physiol Online. 2016; 19(3): 100-9.

14. Bazgir B, Valojerdi MR, Rajabi H, Fathi R, Ojaghi SM, Meybodi MKE *et al*. Acute cardiovascular and hemodynamic responses to low intensity eccentric resistance exercise with blood flow restriction. Asian J Sports Med. 2016; 7(4): e38458.

15. Suga T, Okita K, Morita N, Yokota T, Hirabayashi K, Horiuchi M *et al*. Dose effect on intramuscular metabolic stress during low-intensity resistance exercise with blood flow restriction. J Appl Physiol. 2010; 108(6): 1563-7.

16. Rossow LM, Fahs CA, Loenneke JP, Thiebaud RS, Sherk VD, Abe T *et al*. Cardiovascular and perceptual responses to blood flow restricted resistance exercise with differing restrictive cuffs. Clin Physiol Funct Imaging. 2012; 32(5): 331-7.

17. Sumide T, Sakuraba K, Sawaki K, Ohmura H, Tamura Y. Effect of resistance exercise training combined with relatively low vascular occlusion. J Sci Med Sport. 2009; 12(1): 107-12.

18. Brandner CR, Kidgell DJ, Warmington SA. Unilateral bicep curl hemodynamics: Low pressure continuous vs high pressure intermittent blood flow restriction. Scand J Med Sci Sports. 2015; 25(6): 770-7.

19. Fitschen PJ, Kistler BM, Jeong JH, Chung HR, Wu PT, Walsh MJ, *et al*. Perceptual effects and efficacy of intermittent or continuous blood flow restriction resistance training. Clin Physiol Funct Imaging. 2014; 34(5): 356-63.

20. Rodrigues Neto G, Novaes JS, Gonçalves M, Batista GR, Mendonça RMSC, Miranda HL *et al*. Hypotensive effects of resistance exercise with continuous and intermittent blood flow restriction. Motriz: J Phys Ed. 2016; 22(3): 198-204.

21. Rodrigues Neto G, Novaes JS, Salerno VP, Gonçalves MM, Batista GR, Cirilo-Sousa MS. Does a resistance exercise session with continuous or intermittent blood flow restriction promote muscle damage and increase oxidative stress? J Sports Sci. 2017:doi: 10.1080/02640414.2017.1283430.

22. Rodrigues Neto G, Novaes JS, Salerno VP, Gonçalves MM, Piazera BKL, Rodrigues-Rodrigues T *et al*. Acute effects of resistance exercise with continuous and intermittent blood flow restriction on hemodynamic measurements and perceived exertion. Percept Mot Skills. 2017; 124(1): 277-92.

23. Suga T, Okita K, Takada S, Omokawa M, Kadoguchi T, Yokota T *et al*. Effect of multiple set on intramuscular metabolic stress during low-intensity resistance exercise with blood flow restriction. Eur J Appl Physiol. 2012; 112(11): 3915-20.

24. Yasuda T, Loenneke JP, Ogasawara R, Abe T. Influence of continuous or intermittent blood flow restriction on muscle activation during low-intensity multiple sets of resistance exercise. Acta Physiol Hung. 2013; 100(4): 419-26.

25. Faul F, Erdfelder E, Lang AG, Buchner A. G* Power 3: A flexible statistical power analysis program for the social,

behavioral, and biomedical sciences. Behav Res Meth. 2007; 39(2): 175-91.

26. Beck TW. The importance of a priori sample size estimation in strength and conditioning research. J Strength Cond Res. 2013; 27(8): 2323-37.

27. Shephard RJ. PAR-Q, Canadian Home Fitness Test and exercise screening alternatives. Sports Med. 1988; 5(3): 185-95.

28. ACSM. Manual do ACSM para avaliação da aptidão física relacionada à saúde. 3. ed. Rio de Janeiro: Guanabara Koogan; 2011.

29. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol. 2000; 10(5): 361-74.

30. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use the effect size. J Strength Cond Res. 2004; 18(4): 918-20.

31. Yasuda T, Brechue WF, Fujita T, Sato Y, Abe T. Muscle activation during low-intensity muscle contractions with varying levels of external limb compression. J Sports Sci Med. 2008; 7(4): 467-74.

32. Yasuda T, Fukumura K, Fukuda T, Iida H, Imuta H, Sato Y, *et al*. Effects of low intensity, elastic band resistance exercise combined with blood flow restriction on muscle activation. Scand J Med Sci Sports. 2014; 24(1): 55-61.

33. Yasuda T, Loenneke JP, Thiebaud RS, Abe T. Effects of blood flow restricted low-intensity concentric or eccentric training on muscle size and strength. Plos One. 2012; 7(12): e52843.