EFFECTS OF BLOOD FLOW RESTRICTION IN LARGE AND SMALL MUSCLE GROUPS

ORIGINAL ARTICLE
ARTIGO ORIGINAL
ARTÍCULO ORIGINAL

EFEITOS DA RESTRIÇÃO DO FLUXO SANGUÍNEO EM GRUPAMENTOS MUSCULARES GRANDES E PEQUENOS

EFECTOS DE LA RESTRICCIÓN DEL FLUJO SANGUÍNEO EN GRUPOS MUSCULARES GRANDES Y PEQUEÑOS

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ABSTRACT

Introduction: It is known that strength training brings improvements in health and sports performance by causing muscle hypertrophy and increased strength, as well as modifying some hemodynamic and physiological factors. Several strength training methodologies have been developed, one of which is vascular occlusion. There are few studies with large muscle groups due to poor adherence to the training style and the fact that vascular occlusion of large muscle groups is more difficult. Objective: To verify and compare the hemodynamic effects of exercise with and without vascular occlusion in different muscle groups. Methods: Quantitative crossover study, with cross-sectional and field procedures. The sample consisted of 10 physically active healthy male and female subjects between 18 and 30 years of age. With the cross-over design, all the volunteers participated in 3 groups: intervention with vascular occlusion, intervention without vascular occlusion and the control group. Results: Overall, lactate and cholesterol remained elevated after 15 minutes of recovery and blood glucose and blood pressure did not vary among the groups. Conclusion: Vascular occlusion training is an effective method for manipulating hemodynamic variables. ***Evidence level II; Clinical study.***

Keywords: Exercise; Resistance training; Vascular occlusion; Blood flow restriction; Cardiovascular responses.

RESUMO

Introdução: Sabe-se que o treino de força traz melhorias para a saúde e o desempenho esportivo, por ocasionar hipertrofia muscular e aumento de força, além de modificar alguns fatores hemodinâmicos e fisiológicos. Foram desenvolvidos vários métodos de treinamento de força, entre eles, a oclusão vascular. Porém, existem poucos estudos com grandes grupamentos musculares, devido à pouca adesão ao estilo de treino e ao fato de a oclusão vascular de grandes grupos musculares ser mais difícil. Objetivo: Verificar e comparar os efeitos hemodinâmicos do exercício com e sem oclusão vascular em diferentes grupamentos musculares. Métodos: Estudo quantitativo, cruzado, com procedimentos transversais e de campo. A amostra foi composta por 10 indivíduos saudáveis e fisicamente ativos do sexo masculino e feminino, na faixa etária de 18 a 30 anos. Com o desenho cruzado, todos os voluntários participaram de 3 grupos: intervenção com oclusão vascular, intervenção sem oclusão vascular e grupo controle. Resultados: De forma geral, entre grupos, o lactato e o colesterol se mantiveram elevados depois de 15 minutos de recuperação, a glicemia e as pressões arteriais não variaram. Conclusão: O treinamento com oclusão vascular é um método eficaz para manipular as variáveis hemodinâmicas. **Nível de evidência II; Estudo clínico.**

Descritores: *Exercício; Treinamento de resistência; Oclusão vascular; Restrição do fluxo sanguíneo; Respostas cardiovasculares.*

RESUMEN

Introducción: Se sabe que el entrenamiento de fuerza trae mejoras para la salud y el desempeño deportivo, por causar hipertrofia muscular y aumento de fuerza, además de modificar algunos factores hemodinámicos y fisiológicos. Fueron desarrollados varios métodos de entrenamiento de fuerza, entre ellos, la oclusión vascular. Sin embargo, existen pocos estudios con grandes grupos musculares, debido a la poca adhesión al estilo de entrenamiento y al hecho de que la oclusión vascular de grandes grupos musculares grandes es más difícil. Objetivo: Verificar y comparar los efectos hemodinámicos del ejercicio con y sin oclusión vascular en diferentes grupos musculares. Métodos: Estudio cuantitativo, cruzado, con procedimientos transversales y de campo. La muestra fue compuesta por 10 individuos saludables y físicamente activos del sexo masculino y femenino, en el grupo de edad de 18 a 30 años. Con el diseño cruzado, todos los voluntarios participaron en 3 grupos: intervención con oclusión vascular, intervención sin oclusión vascular y grupo control. Resultados: De forma general, entre los grupos, el lactato y el colesterol se mantuvieron elevados después de 15 minutos de recuperación, la glucemia y las presiones arteriales no variaron. Conclusión: El entrenamiento de oclusión vascular es un método eficaz para manipular las variables hemodinámicas. **Nivel de evidencia II; Estudio clínico.**

Descriptores: *Ejercicio; Entrenamiento de resistencia; Oclusión vascular; Restricción del flujo sanguíneo; Respuestas cardiovasculares.*

DOI: http://dx.doi.org/10.1590/1517-8692202127012019_0028
Article received on 08/05/2019 accepted on 09/14/2020

INTRODUCTION

Resistance or strength training promotes improvements in sports performance and health in general, as there is an increase in strength and muscle mass.[1] The magnitude of the strength training responses is measured by the training variables: volume, intensity, rest interval, speed of movement, choice and sequence of exercises.[2]

For adaptations of strength and hypertrophy to occur, there must be acute stimuli planned at high intensities.[3] According to the American College of Sports Medicine,[2] to achieve significant gains in strength and muscle hypertrophy, the training intensity must be between 60% and 80% of a maximum repetition (1RM) in traditional weightlifting exercises. In order to diversify training, there are several methods, such as Bi-set, Drop-Set, FST-7, Blood Flow Restriction (BFR) and many others.[4]

The Kaatsu Training method, known as vascular occlusion, causes a BFR during the training session of a specific muscle. Such a reduction in blood flow does not induce ischemia in skeletal muscles, it only promotes blood restriction in the capillary veins of the limb muscles, so it should not be confused with ischemic conditions of training. Kaatsu Training consists of strength training with low intensity, while a manometer is activated in the proximal part of the upper or lower limbs, ensuring a high superficial vascular pressure in the region. This method of resistance training can improve muscle mass and strength gain.[5]

Scientific evidence has been reported showing that low intensity resistance training (i.e. from 20 to 40% of 1RM) together with vascular restriction may cause positive changes in variables related to training, such as increased strength and resistance, hypertrophy and some hemodynamic effects.[6,7] The mechanisms include greater recruitment of muscle fibers, metabolic substrates accumulation, as well as stimulation of protein synthesis and cell growth.[8]

In this sense, training with vascular occlusion modifies some hemodynamic and physiological factors, such as double product, systolic blood pressure, diastolic blood pressure, oxygen saturation, lactate, and cholesterol.[9,10] In addition, it is considered to be a good technique for cardiovascular improvement and, in certain situations, for rehabilitation.[11]

Moreover, training with vascular occlusion can be a great strength training method to improve physical disabilities. Consequently, it can contribute significantly to prevent an increase in the number of elderly individuals in hospitals.[5] Hence, the use of light and moderate intensities in resistance training has become a great strategy for elderly populations and patients recovering from joint surgery.

Few studies have evaluated the method of BFR in large muscle groups. This is partly due to poor adherence to the training method because the vascular occlusion of large muscle groups is more difficult when compared to small muscle groups. Thus, the aim of the present study is to verify and compare the hemodynamic effects of exercise with and without BFR in different muscle groups.

MATERIALS AND METHODS

This is an applied study with a quantitative approach, with descriptive objectives and with transversal and field procedures, as well as a crossover design. Before any methodological procedure, the study was submitted to and approved by the Research Ethics Committee of UniCEUB (CAAE: 65449517.0.0000.0023). All subjects signed an informed consent form.

Sample

The sample consisted of 10 healthy physically active male and female individuals, age between 18 and 30 years. All were recreational bodybuilding practitioners and were recruited by the semiprobabilistic sampling technique by clusters. None of the participants presented metabolic or osteomioarticular complications. There was no calculation for sample size. Due to the cross-over design of the study, all volunteers went through the 3 groups, namely: intervention with BFR, without BFR (NBFR) and control group (CG).

Study Design

The volunteers were instructed to come to the laboratory for 4 non--consecutive days with 48 hours interval between visits. Time of the visits was set between 11:00 am to 2:00 pm to minimize circadian variations. The first day was to sign the consent form, assess anthropometric and morphological measures, perform the 1RM test and to get familiarized with the exercise protocol.

The second day consisted of collecting data at rest from the CG. In the third day the training protocol was performed in the BFR group. Finally, the fourth day consisted of training and collecting data from the NBFR group.

Study Procedures

Anthropometric and morphological measures (body mass, height, perimetry and skin folds) were evaluated. The following skinfolds were measured in the participants according to the Pollock-3 protocol for men: chest, abdomen, medial thigh; and Pollock-11 for women: tricipital, supra-iliac, medial thigh.[12]

The 1RM tests were performed using the protocol of Uchida and collaborators.[13] The 1RM protocol was used to pre-determine the load used on the training day. The BFR group intensity was set at 20% of 1RM, while the NBFR group intensity was set at 70% of 1RM. The resistance exercise protocol for the NBFR group consisted of performing 4 sets of free squats with the barbell and 4 sets of biceps curls separately at 70% of the 1RM load with 60 seconds of rest interval. Repetitions were performed until the concentric failure.

The resistance exercise protocol used for the BFR group consisted of 4 sets of free squats with the bar and 4 sets of biceps curls with the bar separately at 20% of the 1RM load with 30 seconds of rest interval between sets. Each series was performed until concentric failure. The pressure of the occlusion was based on previous studies, with compression at 100 mmHg.[14-18] Before performing the squat exercise, with the participants standing, the sphygmomanometer was mounted on the lower limbs and positioned in the proximal part of the thighs, just below the gluteal fold and inguinal ligament. For the biceps curl exercise, the sphygmomanometer was mounted on the proximal part of the arm, close to the biceps brachii origin and at the deltoid insertion.

The subjects arrived at the laboratory and remained at rest for 15 minutes to have the following variables collected: (a) systolic and diastolic blood pressure using the auscultatory method; b) glycemia with a digital glucometer (Accu-Chek Active; Roche Diagnostics, USA, and Accu-Chek Softclix® Pro lancing device); (c) total cholesterol (Roche Diagnostics, Accutrend Cholesterol, USA); and (d) lactate (Roche Diagnostics, Accutrend Lactate, USA).

Systolic and diastolic blood pressure was also measured in the following moments: pre-exercise, immediately after exercise, 15, 30, 45 and 60 minutes after exercise. Measurements of blood lactate, total cholesterol and glucose were performed at the moments: pre-exercise, immediately after exercise and 15 minutes after exercise. The CG did not perform any exercise. Participants in this group arrived and lay for a period of 20 minutes.

Statistical analysis

All analyzes were performed using the Statistical Package for Social Sciences (IBM SPSS, IBM Corporation, Armonk, NY, USA, 25.0). Descriptive analysis was used to calculate the mean and standard deviation of all variables. The Shapiro-Wilk test was used to verify the normality of the data, and after confirming the normal distribution of the data, parametric statistics were used. Analysis of variance (ANOVA) in a mixed design with Bonferroni treatment was used to identify significant differences and $p \leq 0.05$ was adopted as the significance level.

RESULTS

Table 1 shows the sample characteristics with mean and standard deviation.

Table 2 shows that the lactate production in the BFR group was significantly higher after 15 minutes of recovery when compared to the NBFR and CG groups.

Blood glucose presented significance only in the NBFR group, in which glycemia showed a significant drop at the Rec60 moment when compared to the Rec15 moment (p = 0.047). For the other groups, there was no statistically significant difference at any time (Table 3).

Table 4 shows that total cholesterol remained significantly higher in the BFR group after 15 minutes of recovery when compared to the NBFR and CG groups.

Both BFR and NBFR groups presented a significantly increased systolic blood pressure at the Final moment in relation to the pre exercise values (p = 0.001), with a subsequent drop at the Rec15 moment (Table 5).

DISCUSSION

The present study examined the acute effects of squat and biceps curl exercises performed with and without occlusion on systolic blood pressure, diastolic blood pressure, blood glucose, total cholesterol, and lactate in young bodybuilders. In general, between groups, lactate and cholesterol remained high after 15 minutes of recovery, while blood glucose and blood pressures did not vary.

Table 1. Sample characteristics.

	(Mean ± SD)
Age (years)	19.40 ± 1.90
Weight (kg)	70.81 ± 18.47
Height (meters)	1.70 ± 0.09
Body Fat (%)	14.29 ± 4.70
Lean Mass (kilograms)	60.56 ± 15.42
1RM Quadriceps	87.80 ± 20.47
1RM Biceps	31.40 ± 10.54

1RM = 1 repetition maximum.

Table 2. Blood lactate (mmol/L).

	BFR	NBFR	CG
Pre	2.53 ± 1.46	3.08 ± 1.19	3.52 ± 1.67
Final	9.01 ± 1.80*	7.75 ± 3.83*	2.47 ± .048Ŧ#
Rec15	7.01 ± 1.85*	4.82 ± 2.25*†Ŧ	2.66 ± 1.00Ŧ#

BFR = Exercise with occlusion. NBFR = Exercise without occlusion. CG = Control group. * = Significant intragroup difference in relation to the pre-moment (p ≤ 0.05). † = Significant intragroup difference in relation to the Final moment (p ≤ 0.05). Ŧ = Significant difference in relation to BFR (p ≤ 0.05). # = Significant difference in relation to NBFR (p ≤ 0.05).

Tabela 3. Blood glucose (mg/dL).

	BFR	NBFR	CG
Pre	92.00 ± 12.50	100.50 ± 17.02	94.60 ± 12.06
Final	92.90 ± 13.40	96.10 ± 17.86	93.10 ± 12.69
Rec15	94.20 ± 10.09	100.80 ± 16.27	89.90 ± 15.13
Rec30	93.80 ± 14.41	92.00 ± 8.89	85.20 ± 11.44
Rec45	87.10 ± 4.43	93.60 ± 8.83	84.70 ± 9.97
Rec60	85.70 ± 13.29	85.90 ± 6.45*	84.20 ± 9.61

BFR = Exercise with occlusion. NBFR = Exercise without occlusion. CG = Control group. * = Significant intragroup difference in relation to the Rec15 moment (p ≤ 0.05).

Table 4. Total cholesterol (mg/dL).

	BFR	NBFR	CG
Pre	2.53 ± 1.46	3.08 ± 1.19	3.52 ± 1.67
Final	9.01 ± 1.80*	7.75 ± 3.83*	2.47 ± .048Ŧ#
Rec15	7.01 ± 1.85*	4.82 ± 2.25*†Ŧ	2.66 ± 1.00Ŧ#

BFR = Exercise with occlusion. NBFR = Exercise without occlusion. CG = Control group. * = Significant intragroup difference in relation to the pre-moment (p ≤ 0.05). Ŧ = Significant difference in relation to BFR (p ≤ 0.05). # = Significant difference in relation to NBFR (p ≤ 0.05).

Table 5. Blood pressure (mmHg).

	BFR	NBFR	CG
Systolic Blood Pressure			
Pre	107.00 ± 6.10	113.50 ± 9.90	108.80 ± 10.47
Final	135.10 ± 25.48*	133.50 ± 12.48*	100.50 ± 9.77#Ŧ
Rec15	104.30 ± 7.72†	111.70 ± 15.61†	101.60 ± 10.29
Rec30	106.90 ± 10.64†	107.70 ± 12.75†	105.50 ± 13.63
Rec45	105.10 ± 16.11†	110.10 ± 7.20†	100.60 ± 10.50
Rec60	104.80 ± 11.85†	106.10 ± 7.02†	107.40 ± 15.12
Diastolic Blood Pressure			
Pre	66.30 ± 6.57	72.40 ± 10.90	60.80 ± 7.95Ŧ
Final	77.10 ± 35.14	86.00 ± 4.59	61.20 ± 9.65Ŧ
Rec15	61.20 ± 3.26	62.90 ± 5.78*†	60.50 ± 7.88
Rec30	65.00 ± 1.01	66.50 ± 2.27	61.40 ± 6.96
Rec45	63.40 ± 13.57	65.20 ± 6.05	60.00 ± 8.54
Rec60	61.10 ± 6.23	62.80 ± 1.75*†	61.30 ± 7.42
Mean Blood Pressure			
Pre	79.85 ± 5.22	86.07 ± 10.33	76.78 ± 8.37
Final	96.41 ± 28.26	101.82 ± 4.04	74.28 ± 7.30#Ŧ
Rec15	75.55 ± 3.20†	79.15 ± 8.64*†	74.19 ± 7.71
Rec30	78.95 ± 9.84†	80.22 ± 4.35†	76.10 ± 8.33
Rec45	77.29 ± 13.59	80.15 ± 5.00†	73.52 ± 8.75
Rec60	75.65 ± 7.28†	77.22 ± 2.75*†	76.65 ± 9.58

BFR = Exercise with occlusion. NBFR = Exercise without occlusion. CG = Control group. * = Significant intragroup difference in relation to the Pre moment (p ≤ 0.05). † = Significant intragroup difference in relation to the Final moment (p ≤ 0.05). # = Significant difference in relation to BFR (p ≤ 0.05). Ŧ = Significant difference in relation to NBFR (p ≤ 0.05).

The squat and biceps curl exercise with and without vascular occlusion altered the subjects' hemodynamic variables after the training session, and increased the production of metabolic by-products during exercise, which may contribute to increase strength and hypertrophy.[19]

Blood lactate in the BFR group remained high at Rec15, being significantly higher compared to the NBFR group. So, it can be assumed that the removal of blood lactate was slower in the BFR group. The production of lactate during high-intensity exercise causes marked changes in muscle cell homeostasis throughout the body.[20] Consequently, it is of great importance to be able to remove lactate, and to restore homeostasis right after exercise.[21,22] A fraction of lactate is removed by the liver, heart and renal cortex, as well as other organs, including skeletal muscles.[23, 24] But the main reason for the delay in lactate removal in the BFR group is unknown. Hence, it would be interesting for further investigate blood lactate kinetics and the Kaatsu Traning method to clarify the main limiting factor for lactate removal after training.

Letieri and colleagues[25] divided the individuals in their study to verify the effects of training in two different groups: with occlusion and without occlusion. They used training intensities similar to the present study. They found a significant difference in the blood lactate response after exercise between groups, corroborating our results. This factor may be due to the use of the BFR method, which generates an accumulation of lactate, and this accumulation is related to the release of growth hormone and muscle hypertrophy.[10, 26]

The results from Silva and colleagues[14] highlight a significant decrease in blood glucose after an exercise session with the same protocol used in this study. This result does not corroborate the results of the present investigation. Because there is a significant effort during the training session with occlusion, glycogen as an energy source was considered a limiting factor for strength. Also, blood glucose changes modify central nervous system functions, which may affect the individual's performance.[27]

In the study by Williams et al.,[28] a significant increase in cholesterol response was shown after training with BFR. In the present study, the BFR and NBFR groups showed significant differences in the responses of total cholesterol in the moment immediately after exercise when compared to the pre-exercise moment. In the BFR group, cholesterol remained significantly higher compared to the other groups at Rec15. With these results, it is plausible to infer that, in the BFR group, the Krebs cycle increased the recruitment of fatty acids. For this reason, the cholesterol remained higher after exercise. Thus, it can be deduced that the Kaatsu training method can promote a greater fats metabolism.[29]

Enzymatic activity is influenced by some factors, one of them is body temperature, which is altered by physical exercise. This is because the three--dimensional structure of the enzymes breaks down, making it impossible to form the enzyme-substrate complex. The activity of lipoprotein lipase appears to raise the levels of circulating HDL cholesterol. Of note, there is a positive correlation between post-heparin lipoprotein lipase activity and HDL-C after exercise.[30,31] It should be noted that the cholesterol fractions were not evaluated in the present investigation, only total cholesterol.

With maximum effort during the BFR training, oxygenation in the muscles is reduced, which causes a local accumulation of metabolites, chemoreceptors stimulation and increased heart rate. All these factors may lead to the systolic blood pressure and diastolic blood pressure observed in the present study.[26] However, double product responses of both BFR and NBFR groups did not show significant changes after the exercise in comparison to the moment at rest. So, we can hypothesize that the volunteers may not have done maximum effort.

In the present study, there was a significant change in systolic blood pressure right after exercise when compared to pre-exercise. The systolic blood pressure results at Rec15, 30, 45 and 60 minutes after exercise were significantly lower than the moment just after exercise. It is believed that the cardiac decrease was not completely balanced by the increase in peripheral systemic vascular resistance, or because there was an increase in the synthesis of nitric oxide that led to positive changes in the endothelium.[11,32,33]

This study has some practical applications. Firstly, the BFR method can be used to manipulate blood glucose and lactate, which can interfere in energy expenditure and in adipose tissue oxidation. Also, the method proves to be effective for the elderly, people with osteoarticular problems, and patients recovering from joint surgery. This is because BFR raises blood pressure to the same values as training without occlusion, allowing to train at the same intensity with lower loads.

The choice of rest intervals and the sample size can be considered limitations of this study. Also, only total cholesterol was assessed. The analysis of HDL, LDL and VLDL fractions could have broadened the results interpretation and the understanding of the training effect with BFR on metabolism. In future studies, it is also suggested to match the recovery interval, increase the sample size, and diversify the choice of exercises.

CONCLUSION

The squat and biceps curl exercises performed separately with and without vascular occlusion provided similar changes in hemodynamic variables. Furthermore, training with BFR delays blood lactate removal and promotes an increase in total cholesterol compared to training without occlusion.

All authors declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: Each author made significant individual contributions to this manuscript. SC: Design, statistical analysis and revision, approval of final version MBSB: Writing, intellectual concept, revision and data analysis, approval of final version. MML: Preparation of the entire research project, approval of the final version. MTD: Data analysis and writing, approval of the final version. GL: Writing and revision, approval of the final version. RAED: Revision, statistical analysis, intellectual concept, approval of the final version. MRM: Coordination and guidance, approval of the final version.

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