RBPFEX
Revista Brasileira de Prescrição e Fisiologia do Exercício

RESISTANCE EXERCISE WITH BLOOD FLOW RESTRICTION ELICITS PERCEPTUAL RESPONSES SIMILAR TO HIGH-LOAD RESISTANCE EXERCISE IN WOMEN WITH TYPE 2 DIABETES: A CROSSOVER AND RANDOMIZED STUDY

Ana Beatriz Alves Martins[1], Nailton José Brandão de Albuquerque Filho[1], Marina Gonçalves Assis[1]
Victor Sabino de Queiros[2], Arthur Wagner da Silva Rodrigues[1], Eliete Samara Batista dos Santos[3]
Breno Guilherme de Araújo Tinôco Cabral[3], Júlio Cesar Gomes da Silva[1,4], Gabriel Rodrigues Neto[1,4]

ABSTRACT

Introduction: Physical training with blood flow restriction (BFR) may provide health benefits for people with diabetes. However, the negative effects cannot be overlooked. Aim: This study aimed to analyze the acute effect of resistance exercise BFR on the rating of perceived exertion (RPE) and subjective perception of pain in untrained women with type 2 diabetes (T2DM). Methods: Ten untrained women with T2DM (56.9 ± 7.4 years; diagnostic time: 10.6 ± 4.1 years) participated in this study. Participants attended a local gym for four non-consecutive days. Initially, predictive values of one maximum repetition (1RM) and arterial occlusion pressure (AOP) were measured. In random order, second, third, and fourth visits were allocated to the following: high-load (HL) exercise (65% 1RM; three sets of 10 repetitions), low-load (LL) exercise (20% of 1RM; three sets of 15 repetitions), and LL exercise with BFR (LL+BFR) (20% 1RM; three sets of 15 repetitions; 50% of AOP). RPE and pain perception were assessed immediately after each set. RPE increased significantly over the sets for all exercise protocols ($p<0.05$). The perception of pain increased significantly throughout the sets only in the HL and LL+BFR exercise protocols ($p<0.05$). LL+BFR and HL exercises showed similar RPE values and pain perception, but significantly higher than the LL exercise ($p<0.05$). We conclude that LL resistance exercise with BFR promotes perceptual responses similar to traditional HL exercise in untrained women with T2DM.

Key word: Diabetes Mellitus. Resistance Training. Physical Exertion.

1 - Coordination of Physical Education, Center for Higher Education and Development (CESED - UNIFACISA / FCM / ESAC), Campina Grande, Paraiba, Brazil.
2 - Graduate Program in Health Science, Federal University of Rio Grande do Norte (UFRN), Natal, Rio Grande do Norte, Brazil.

RESUMO

Exercício resistido com restrição do fluxo sanguíneo provoca respostas perceptivas semelhantes ao exercício resistido de alta carga em mulheres com diabetes tipo 2: um estudo crossover e randomizado

Introdução: Treinamento físico com restrição do fluxo sanguíneo pode propiciar benefícios para saúde de pessoas diabéticas. Contudo, os efeitos negativos não podem ser negligenciados. Objetivo: Analisar o efeito agudo do exercício resistido com RFS na percepção subjetiva de esforço e na percepção subjetiva da dor em mulheres não-treinadas com diabetes tipo 2. Materiais e Métodos: Dez mulheres não-treinadas com DM2 (56,9 ±7,4 anos; tempo de diagnóstico: 10,6 ±4,1 anos) participaram deste estudo. Os participantes frequentaram uma academia local por quatro dias não-consecutivos. Inicialmente, foram medidos os valores preditivos de uma repetição máxima (1RM) e pressão arterial de oclusão (POA). Em ordem aleatória, a segunda, terceira e quarta visitas foram alocadas para o seguinte: exercício de alta carga (AC) (65% de 1RM; três séries de 10 repetições), exercício de baixa carga (BC) (20% de 1RM; três séries de 15 repetições) e exercício BC com RFS (BC + BFR) (20% de 1RM; três séries de 15 repetições; 50% da POA). A PSE e a percepção da dor foram avaliadas imediatamente após cada série. Resultados: A PSE aumentou significativamente ao longo das séries para todos os protocolos de exercício ($p<0,05$). A percepção de dor aumentou significativamente ao longo das séries apenas nos protocolos de exercício AC e BC + RFS ($p<0,05$). Os exercícios BC+RFS e AC apresentaram valores de PSE e percepção de dor semelhantes, mas significativamente maiores que o exercício BC ($p<0,05$). Conclusão: O exercício resistido de BC+RFS promove respostas perceptivas semelhantes ao exercício de AL tradicional em mulheres não-treinadas com DM2.

Palavras-chave: Diabetes Mellitus. Treinamento de Resistência. Esforço físico.

RBPFEX
Revista Brasileira de Prescrição e Fisiologia do Exercício

INTRODUCTION

Blood flow restriction (BFR) artificially induced by the tightening of pneumatic cuffs in the proximal region of the exercised limb can provide low load (LL) resistance training (RT) (i.e., 20%-40% of one repetition maximum [1RM]) potential to promote hypertrophic adaptations and gains in muscle strength in proportions similar to high load (HL) RT (Laurentino et al., 2012).

In addition, RT with BFR sessions can provide a more pronounced hypotensive effect than traditional RT sessions (Domingos, Polito, 2018), and aerobic training programs with BFR can increase skeletal muscle glucose uptake during exercise, a response that is not achieved with aerobic training with comparable work, but without BFR (Christiansen et al., 2019).

The hypotensive and hypoglycemic effect of training with BFR makes this type of strategy an interesting option in the management of diabetes mellitus, considering that the reduction of blood pressure (BP) values and glycemic control were associated with the reduction of the risk for complications related to the disease (Adler et al., 2000; UK Prospective Diabetes Study Group, 1998).

In addition, people with diabetes mellitus may have orthopedic complications (Smith, Burnet, McNei, 2003), therefore, under certain conditions, exercise with high mechanical overload may not be applicable for this group.

Although evidence presented provides support for prescription of training with BFR for diabetic individuals, one cannot neglect the possible adverse effects resulting from this strategy, including severe muscle pain during exercises of this nature.

Currently, literature does not provide studies that evaluated reported pain in exercise with BFR in diabetic people, but a study carried out with healthy individuals found that the application of high restriction pressures elicits higher pain and effort ratings than the HL resistance exercise, while moderate pressures [50% of arterial occlusion pressure (AOP)] promote responses similar to HL resistance exercise (Soligon et al., 2018). This answer may not apply to diabetic individuals, considering that there is a high prevalence of muscle pain in this group (Bair et al., 2010; Menting, Tack, Knoop, 2017).

Muscle pain can compromise adherence of diabetics to physical exercise (Krein et al., 2005) and feeling of tiredness seems to be associated with physical inactivity in this group (Thomas, Alder, Leese, 2004).

Therefore, the clinical relevance of studies that propose to analyze perceptual responses, such as pain and effort, reported by diabetics submitted to different training strategies becomes evident.

Considering that training with BFR can promote interesting responses for this population, our study aimed to analyze the acute effect of resistance exercise with BFR on the rating of perceived exertion (RPE) and subjective perception of pain in untrained women with type 2 diabetes (T2DM).

MATRIALS AND METHODS

Participants

Ten untrained women with T2DM participated in this study. All participants had had a medical diagnosis of T2DM for more than six months.

Characteristics of the sample are reported in Table 1.

Participants were recruited through promoting research on social networks. Inclusion criteria includes the following: (i) age between 35 and 60 years, (ii) with negative answers in all items of the Physical Activity Readiness Questionnaire (PAR-Q), (iii) have not participated in physical training programs for at least six months, and (iv) have no history of lower limbs orthopedic injuries for at least six months.

All participants signed a written consent form to participate in this study. The study was performed in accordance with the ethical standards of the Declaration of Helsinki on human experimentation and approved by the local Research Ethics Committee (protocol no. 3.487.301).

RBPFEX
Revista Brasileira de Prescrição e Fisiologia do Exercício

Table 1 - Subject characteristics.

Variables	Mean ± SD
Age (years)	56.9 ± 7.4
Body mass (kg)	62.9 ± 11.7
Height (cm)	149.0 ± 3.8
BMI (kg/m^2)	27.2 ± 4.2
T2DM Diagnostic Time (years)	10.6 ± 4.1
BPS (mmHg)	130.3 ± 5.5
BPD (mmHg)	83.0 ± 6.1
AOP (mmHg)	190.0 ± 21.6
1RM knee extension (kg)	28.2 ± 6.2

SD = Standard Deviation; n = 10; AOP = Arterial occlusion pressure; BMI = body mass index; T2DM = type 2 diabetes mellitus; 1RM = one repetition maximum; BFR = blood flow restriction.

Experimental design

This is a clinical trial, randomized and crossover compared the perceptual responses reported in low-load (LL), LL + BFR and high-load (HL) resistance exercise. All participants attended a local gym (Campina Grande - PB, Brazil) for four non-consecutive days. Visits took place at the same time and were interspersed for a period of 72-96 hours. Initially, participants underwent an anthropometric assessment (body mass and height), and a hemodynamic assessment that included measurements of blood pressure and arterial occlusion pressure (AOP) of the posterior tibial artery at rest. Subsequently, participants were familiarized with the psychometric scales used in our study and underwent a predictive 1RM test for knee extension exercise (KE).

Second, third, and fourth visits were randomly allocated to the following: (i) HL exercise (65% of predicted 1RM; 10 repetitions), (ii) LL exercise (20% of predicted 1RM; 15 repetitions) or (iii) exercise of LL-BFR (20% of predicted 1RM; 15 repetitions; 50% of AOP).

All exercise protocols consisted in a volume of three sets. Randomization was performed by drawing piece of paper from a bag (i.e., simple randomization). RPE and pain perception were assessed immediately after each set.

We asked participants to avoid prolonged use of activities that required high cognitive demands (e.g., prolonged use of smartphones) in the three hours prior to training sessions.

Participants were instructed to avoid consuming caffeine-based substances (e.g., coffee, chocolates, and cola-type soft drinks) on the days of evaluations and any type of vigorous physical activity 24 hours before experimental sessions.

Determination of blood flow restriction

The restriction pressure (mmHg) was determined using the method proposed by Laurentino et al., (2012). We asked the participant to rest for five mins in a calm and quiet environment, and then the probe of a portable vascular doppler (MedPej®, DF-7001 VN, Ribeirão Preto, São Paulo–Brazil) was fixed above the tibial artery. A pneumatic tourniquet (Dimensions: width of 100 mm and length of 540 mm-Riester®) was attached below the inguinal fold and inflated until the pulse identified by the probe was completely eliminated, finding the arterial occlusion pressure (AOP). The measurement was performed while participants remained seated (position adopted in the exercise).

One repetition maximum (1RM) prediction test

Each participant's load percentage was determined during a session by following the protocol proposed by Brzycki (1993).

Initially, a light warm-up of five to 10 repetitions was performed by employing 40% to 60% of the estimated load of 1RM in accordance with the evaluated participant's self-report.

After a one minute recovery, three to five repetitions were performed with 60% to

80% of the estimated load of 1RM. Subsequently, after one minute, only one attempt was made until exhaustion to identify the value of 1RM.

Participants reached voluntary exhaustion between 5-10 repetitions. The load and the number of repetitions (reps) found were placed in the following equation proposed by Brzycki (1993): 1RM = 100 × load/[102.78 − (2.78 × reps)] to predict 1RM.

Exercise protocols

Experimental sessions consisted of 3 sets of bilateral KE performed following a crossover model. For the LL exercise protocols (with and without BFR), 3 sets of 15 repetitions were performed, interspersed with periods of 30 s, adopting an intensity of 20% of predicted 1RM. In the LL + BFR exercise protocol, a tourniquet was attached to the proximal region of the thigh and inflated to a pressure of 50% of the AOP.

The pressure was maintained throughout the exercise (continuous BFR). For HL exercise, 3 sets of 10 repetitions were performed, interspersed with 90 s of passive recovery, adopting an overload of 65% of predicted 1RM.

All participants were able to complete the pre-defined training volume. The duration of each repetition cycle on the leg extension machine was established at three seconds, divided evenly between the concentric and eccentric phases.

Table 2 - Tested experimental exercise protocols.

	Load	Volume	Interval recovery	% of AOP
Low-load	20% 1RM	15 reps	30 seconds	0
Low-load + BFR	20% 1RM	15 reps	30 seconds	50
High-load	65% 1RM	10 reps	90 seconds	0

1RM = one repetition maximum; BFR = blood flow restriction; AOP = Arterial occlusion pressure.

Perceptual responses

Perceptual responses were assessed immediately after each set, as has been done in previous studies (Counts et al., 2016; Soligon et al., 2018; Lixandrão et al., 2019). Rating of perceived exertion (RPE) was assessed using the OMNI-Resistance Exercise Scales (Robertson et al., 2003).

Before the experimental sessions, participants were informed that the post-set RPE should represent the perceived difficultly, heaviness, and strenuousness of the physical task. We asked that other sensations experienced during exercise, such as discomfort and pain should not be included in the RPE assessment.

Pain perception was assessed using a 10-point visual analog scale, where point 0 represented no pain and point 10 represented maximum pain. Participants were informed that pain classifications should be based on the magnitude of discomfort experienced in the quadriceps.

This method was previously used by Soligon et al., (2018). All participants were previously familiarized with the scales used in the study.

Statistical analysis

Non-parametric statistics were used for data analysis. The Friedman test was used to analyze the median scores in different conditions and time points. The Wicolxon test, followed by the Bonferroni correction, was used to find specific differences. The level of significance was set at p<0.05. All statistical analyses were performed using SPSS statistical software package version 20.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Rate perceived exertion

RPE was different between conditions tested in the first (p=0.044), second (p=0.004), and third sets (p=0.004).

Regarding the LL exercise, the HL exercise promoted higher RPE values in sets 1, 2, and 3 (p=0.035, p=0.005, and p=0.008, respectively), whereas the LL + BFR exercise promoted higher RPE values in sets 2 and 3 (p=0.003 and p=0.002, respectively).

The results did not provide sufficient probability evidence to signify differences between LL + BFR and HL exercises. In all

RBPFEX
Revista Brasileira de Prescrição e Fisiologia do Exercício

conditions tested, the results provided sufficient probability evidence to signify increased RPE from set 1 to set 3. Data are presented in median and variance in Table 3.

Table 3 - Comparative analysis on the rate of perceived exertion (RPE) among the experimental protocols.

Protocols	1st set	2nd set	3rd set
Low load	1.0 (1.5)	2.0 (0.8)*	2.9 (0.9)*,‡
Low load (BFR)	2.0 (0.4)	3.5 (1.9)†,*	5.0 (4.0)†,*,‡
High-load	2.3 (0.8)†	4.0 (1.3)†,*	5.0 (3.1)†,*,‡

† significant difference when compared to the low load exercise protocol; * significant difference when compared to 1st set; ‡ significant difference when compared to the 2nd set.

Perception of Pain

The perception of pain was different between conditions tested in the first (p=0.001), second (p=0.002), and third sets (p=0.002).

In relation to LL exercise, the HL and LL + BFR exercise promoted higher pain classifications in the first (p=0.002 and p<0.001), sencond (p=0.005 and p=0.001), and third sets (p=0.006 and p=0.001).

The results did not provide sufficient probability evidence to signify differences between LL + BFR and HL exercises. For HL and LL + BFR exercises, the results provided sufficient probability evidence to signify that pain perception increased from set 1 to set 3. Data are presented in median and variance in Table 4.

Table 4 - Comparative analysis of pain perception between experimental protocols.

Protocols	1st set	2nd set	3rd set
Low load	0.0 (0.0)	0.0 (0.2)	0.0 (0.5)
Low load (BFR)	1.0 (0.9)†	2.5 (3.7)†,*	3.5 (5.3)†,*,‡
High load	1.5 (2.0)†,*	2.5 (2.9)†,*	3.5 (4.6)†,*,‡

† significant difference when compared to the LL protocol; * significant difference when compared to 1st set; ‡ significant difference when compared to the 2nd set.

DISCUSSION

Our study analyzed the perceptual responses (i.e., RPE and pain perception) reported in LL + BFR, LL, and HL resistance exercise in untrained women with type 2 diabetes. To our knowledge, this was the first study that analyzed this type of response in this population. Results indicate that LL + BFR and HL resistance exercise promoted similar RPE and pain perception, and these responses were notably higher than responses to LL exercise.

RPE is a simple and low-cost method commonly used in the prescription and monitoring of physical exercise in rehabilitation programs (Pageaux, Gaveau, 2016).

RPE provides information on exercise intensity and has an effect on self-regulation of human behavior (Pageaux, Gaveau, 2016).

These aspects, certainly, motivated the performance of a significant number of studies aimed at understanding the modulating factors of RPE during physical exercise.

Previously, it was verified that, under conditions of equalized intervals of recovery and volume, the application of higher loads (70% vs. 40% of 1RM) in RT sessions promoted higher values of RPE in the session (Hiscock, Dawson, Peeling, 2015).

These findings were justified by a possible intensification of the corollary signals sent from the sensory cortex to the motor cortex due to the increased recruitment of motor units (MUs) and the frequency of firing presented in HL RT sessions (Hiscock, Dawson, Peeling, 2015). This mechanism could justify the higher RPE values in the HL exercise and also in the LL + BFR exercise, in relation to the LL exercise, as evidenced in our study. We recognize that the load (% 1RM) applied in the LL + BFR exercise was low (20% 1RM); however, fatigue levels induced by the BFR of the exercised muscle can increase the recruitment of MUs even when an LL is applied in the exercise (Fatela et al., 2019).

In the first set, no diference was found between RPE in the LL and LL + BFR protocol exercise. We speculate that the increase in the recruitment of MUs and the frequency of impulses resulting from the BFR occurred only in the second and third sets; therefore, in these sets, the LL-BFR exercise showed higher values of RPE.

To support our theory, Yasuda et al., (2013) analyzed surface electromyography in LL and LL + BFR exercise using a predefined repetition scheme consisting of 75 repetitions (30-15-15-15) and found that the electromyographic activity were no different in the first 15 repetitions of the first set, but it was higher in the exercise with BFR from the twenty-fifth repetition and remained higher in the final three sets. Although we have not evaluated this type of response, we speculate that a similar behavior was presented in our study; therefore no differences was reported between the RPE in the first set of the LL and LL + BFR exercise. It is worth adding that our BFR RPE results are specific to submaximal exercise protocols (i.e., 3 × 15 repetitions) and that different responses may be observed when exercise is performed to muscle failure (Wernbom et al., 2009; Lixandrão et al., 2019).

Wernbom et al., (2009) did not identify RPE differences between LL + BFR (KE; 30% of 1RM; 3 sets; 100 mmHg) and LL performed to failure indicating that the application of BFR did not seem affect RPE. Lixandrão et al., (2019) found similar RPE for the 45º leg press to failure at LL (30% 1RM) and HL (80% 1RM) and the failure condition responses were higher than those for submaximal LL + BFR exercise (i.e., 4 × 15 repetitions) showing that changes in overload did not seem to affect RPE Together, this evidence suggests that application of BFR and overload (% 1RM) do not seem to have an effect on RPE when the exercise is performed until muscle failure.

The use of sets up to failure also seems to influence the pain classifications reported in exercise with and without BFR. For example, in our study, we found that pain levels were higher in LL + BFR exercise, when compared to traditional LL exercise. These findings are in line with a previously published study that used LL + BFR exercise with a predefined repetition scheme (i.e., 30-15-15-15) (Husmann et al., 2018), but contrasted with studies that used sets until failure (Wernbom et al., 2009; Lixandrão et al., 2019).

Wernbom et al. (2009) found that pain classifications were similar between LL exercise with and without BFR performed until failure, whereas Lixandrão et al., (2019) found that exercise performed to failure (HL and LL) promoted higher pain ratings than a submaximal LL + BFR exercise protocol.

In addition to the characteristics of the prescribed repetition protocol (i.e., failure vs. non-failure), the restriction pressure employed can also affect the pain perception reported in exercise with BFR (Soligon et al., 2018).

Soligon et al., (2018) analyzed and compared the perception of pain reported in LL + BFR exercise (30% of 1RM) associated with different levels of restriction (40%–80% of AOP) and HL exercise (80% of 1RM). Authors found that the exercise performed with 40% and 50% of the AOP promoted a perception of pain similar to HL exercise; however, the application of 60%, 70%, and 80% of the AOP promoted a perception of superior pain. In part, these findings are in line with results presented in our study, since we did not identify any difference in the pain classifications reported in LL exercise performed with 50% of AOP and HL exercise.

These results suggest that LL exercise (20%–30% of 1RM) associated with a BFR of up to 50% of AOP seems to promote a perception of pain similar to HL exercise (~65%–80% of 1RM), but levels of higher BFRs can promote higher pain ratings.

This study has certain limitations that need to be taken into account. Readers should be aware that the 1RM values used to create the LL and HL workloads were based on a predicted 1 RM and not the actual 1RM values of the participants. This will introduce some random error variability in the statistical analysis.

On the other hand, our study relativizes the restriction pressure based on the AOP values obtained through of vascular doppler (gold standard). In addition, this is the first study to include a sample of people with diabetes.

CONCLUSION

HL resistance exercise and LL resistance exercise with BFR promote similar levels of pain and effort, but higher than LL exercise without BFR in untrained women with type 2 diabetes.

It is important to conduct more experiments on diabetic individuals to study both perceived exertion and subjective perception of pain in an acute and chronic way, particularly involving different BFR pressures and different cuff sizes.

REFERENCES

1-Adler, A.I.; Stratton, I.M.; Neil, H.A.W.; Yudkin, J.S.; Matthews, D.R.; Cull, C.A., Wright A.D.; Turner, R.C.; Holman, R.R. Association of systolic blood pressure with macrovascular and microvascular complications of type 2 diabetes (UKPDS 36): prospective observational study. Bmj. Vol. 321. Num. 7258. 2000. p.412-419. DOI: 10.1136/bmj.321.7258.412

2-Bair, M.J.; Brizendine, E.J.; Ackermann, R.T.; Shen, C.; Kroenke, K.; Marrero, D.G. Prevalence of pain and association with quality of life, depression and glycaemic control in patients with diabetes. Diabetic Medicine. Vol. 27. Num. 5. 2010. p. 578-584. DOI: 10.1111/j.1464-5491.2010.02971.x

3-Brzycki, M. Strength testing-predicting a one-rep max from reps-to-fatigue. Journal of Physical Education, Recreation & Dance. Vol. 64. Num. 1. 1993. p. 88-90.

4-Christiansen, D.; Eibye, K.H.; Hostrup, M.; Bangsbo, J. Blood flow-restricted training enhances thigh glucose uptake during exercise and muscle antioxidant function in humans. Metabolism. Vol. 98. 2019. p. 1-15. DOI: 10.1016/j.metabol.2019.06.003

5-Counts, B.R.; Dankel, S.J.; Barnett, B.E.; Kim, D.; Mouser, J.G.; Allen, K.M.; Thiebaud, R.S.; Abe T.; Bemben, M.G.; Loenneke, J.P. Influence of relative blood flow restriction pressure on muscle activation and muscle adaptation. Muscle & Nerve. Vol. 53. Num. 3. 2016. p. 438-445. DOI: 10.1002/mus.24756

6-Domingos, E.; Polito, M.D. Blood pressure response between resistance exercise with and without blood flow restriction: A systematic review and meta-analysis. Life Sciences. Vol. 209. 2018. p. 122-131. DOI: 10.1016/j.lfs.2018.08.006

7-Fatela, P.; Mendonca, G.V.; Veloso, A.P.; Avela, J.; Mil-Homens, P. Blood flow restriction alters motor unit behavior during resistance exercise. International Journal of Sports Medicine. Vol. 40. Num. 09. 2019. p. 555-562. DOI: 10.1055/a-0888-8816

8-Hiscock, D.J.; Dawson, B.; Peeling, P. Perceived exertion responses to changing resistance training programming variables. The Journal of Strength & Conditioning Research. Vol. 29. Num. 6. 2015. p. 1564-1569. DOI: 10.1519/JSC.0000000000000775

9-Husmann, F.; Mittlmeier, T.; Bruhn, S.; Zschorlich, V.; Behrens, M. Impact of blood flow restriction exercise on muscle fatigue development and recovery. Medicine & Science in Sports & Exercise. Vol. 50. Num. 3. 2018. p. 436-446. DOI: 10.1249/MSS.0000000000001475

10-Krein, S.L.; Heisler, M.; Piette, J.D.; Makki, F.; Kerr, E.A. The effect of chronic pain on diabetes patients’ self-management. Diabetes Care. Vol. 28. Num. 1. 2005. p. 65-70. DOI: 10.2337/diacare.28.1.65

11-Laurentino, G.C.; Ugrinowitsch, C.; Roschel, H.; Aoki, M. S.; Soares, A. G.; Neves Junior, M.; Aihara A.Y.; Fernandes Ada R.; Tricoli, V. Strength training with blood flow restriction diminishes myostatin gene expression. Medicine & Science in Sports & Exercise. Vol. 44. Num. 3. 2012. p. 406-412. DOI: 10.1249/MSS.0b013e318233b4bc

12-Lixandrão, M.E.; Roschel, H.; Ugrinowitsch, C.; Miquelini, M.; Alvarez, I.F.; Libardi, C.A. Blood-flow restriction resistance exercise promotes lower pain and ratings of perceived exertion compared with either high-or low-intensity resistance exercise performed to muscular failure. Journal of Sport Rehabilitation. Vol. 28. Num. 7. 2019. p. 706-710. DOI: 10.1123/jsr.2018-0030

13-Menting, J.; Tack, C.J.; Knoop, H. Prevalence and correlates of pain in fatigued patients with type 1 diabetes. Journal of Psychosomatic Research. Vol. 95. 2017. p. 68-73. DOI: 10.1016/j.jpsychores.2017.02.010

14-Pageaux, B.; Gaveau, J. Studies using pharmacological blockade of muscle afferents provide new insights into the neurophysiology of perceived exertion. The Journal of Physiology. Vol. 594. Num. 18. 2016. p. 5049-5051. DOI: 10.1113/JP272585

15-Robertson, R.J.; Goss, F.L.; Rutkowski, J.; Lenz, B.; Dixon, C.; Timmer, J.; Frazee K.; Dube J.; Andreacci, J. Concurrent validation of the OMNI perceived exertion scale for resistance exercise. Medicine & Science in Sports & Exercise. Vol. 35. Num. 2. 2003. p. 333-341. DOI: 10.1249/01.MSS.0000048831.15016.2A

16-Smith, L.; Burnet, S.; McNeil, J. Musculoskeletal manifestations of diabetes mellitus. British Journal of Sports Medicine. Vol. 37. Num. 1. 2003. p. 30-35. DOI: 10.1136/bjsm.37.1.30

17-Soligon, S.D.; Lixandrão, M.E.; Biazon, T.M.P.C.; Angleri, V.; Roschel, H.; Libardi, C. A. Lower occlusion pressure during resistance exercise with blood-flow restriction promotes lower pain and perception of exercise compared to higher occlusion pressure when the total training volume is equalized. Physiology International. Vol. 105. Num. 3. 2018. p. 276-284. DOI: 10.1556/2060.105.2018.3.18

18-Thomas, N.; Alder, E.; Leese, G.P. Barriers to physical activity in patients with diabetes. Postgraduate Medical Journal. Vol. 80. Num. 943. 2004. p. 287-291. DOI: 10.1136/pgmj.2003.010553

19-UK Prospective Diabetes Study (UKPDS) Group. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). The Lancet. Vol. 352. Num. 9131. 1998. p. 837-853.

20-Wernbom, M.; Järrebring, R.; Andreasson, M.A.; Augustsson, J. Acute effects of blood flow restriction on muscle activity and endurance during fatiguing dynamic knee extensions at low load. The Journal of Strength & Conditioning Research. Vol. 23. Num. 8. 2009. p. 2389-2395. DOI: 10.1519/JSC.0b013e3181bc1c2a

21-Yasuda, T.; Loenneke, J.; Ogasawara, R.; Abe, T. Influence of continuous or intermittent blood flow restriction on muscle activation during low-intensity multiple sets of resistance exercise. Acta Physiologica Hungarica. Vol. 100. Num. 4. 2013. p. 419-426. DOI: 10.1556/APhysiol.100.2013.4.6

3 - Graduate Program in Physcial Education, Federal University of Rio Grande do Norte (UFRN), Natal, Rio Grande do Norte, Brazil.
4 - Coordination of Physical Education/Professional Master's in Family Health, Nursing and Medical Schools, Nova Esperança (FACENE /FAMENE), João Pessoa, Brazil.

Authors e-mail:
beatrizalveesm@hotmail.com
nailtonalbuquerquefilho@gmail.com
marinagassis@gmail.com
victorsabino97@ufrn.edu.br
arthur.cabral@unifacisa.edu.br
elietesamarabs@gmail.com
brenotcabral@gmail.com
juliociesar123@gmail.com
gabrielrodrigues_1988@hotmail.com

Corresponding author
Gabriel Rodrigues Neto.
gabrielrodrigues_1988@hotmail.com
Coordination of Physical Education.
Nursing and Medical Schools.
Nova Esperança (FAMENE / FACENE).
Avenida Frei Galvão, 12.
Gramame, João Pessoa, Brazil.
CEP: 58067-695.

Received for publication in 24/03/2023
Accepted in 07/08/2023