Effect of Resistance Exercise with Blood Flow Restriction on Peripheral Oxygen Saturation and Cardiovascular Stress in Untrained Diabetic Women: A Cross and Randomized Study

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Abstract: This study aimed to analyze the effects of high-load (HL) resistance exercise (RE), low-load (LL) RE, and LL RE with blood flow restriction (LL + BFR) in peripheral oxygen saturation level (SpO_2), heart rate (HR), and double product (DP: HR × systolic blood pressure [SBP]) in untrained women with type 2 diabetes (T2DM). Ten untrained women with T2DM (Age = 56.9 ± 7.4 years; BMI = 27.2 ± 4.2 kg/m^2; and Diagnostic time = 10.6 ± 4.1 years) participated in this study. Participants attended a local gym for four non-consecutive days. During the first visit, arterial occlusion pressure (AOP) and predictive values of one maximum repetition (1RM) for knee extension exercise (KE) were assessed. The second, third, and fourth visits were randomly assigned to the following: HL RE (~65% of predicted 1RM in 3 sets of 10 repetitions), LL RE (~20% of predicted 1RM in 3 sets of 15 repetitions), and LL + BFR RE (~20% of predicted 1RM in 3 sets of 15 repetitions; 50% of AOP). HR, SBP e SpO_2 were assessed before and immediately after each protocol. All protocols significantly increased the analyzed variables ($p \leq 0.05$). There were no significant differences in hemodynamic responses between the protocols ($p > 0.05$). Therefore, resistance exercise with BFR seems to promote cardiovascular responses similar to traditional low and high load resistance exercise protocols in untrained diabetic women.

Keywords: Double Product, Heart Rate, Ischemia, Hemodynamics, Kaatsu training, Resistance Training, Therapeutic Occlusion.

INTRODUCTION

Resistance training (RT) with intensity of ≥70% of one maximum repetition (1RM) was recommended for increased strength and muscle hypertrophy (MH) [1]. However, this intensity may not be tolerable for clinical populations, including individuals who recover from musculoskeletal injuries and frail elderly people [2]. Training with blood flow restriction (BFR) appears as an alternative for this population, since RT programs with loads below the recommended (~20%–40% of 1RM), as associated with arterial BFR of the exercised limb, can promote strength gains and MH proportionally similar to high-load (HL) RT; response that is not achieved in conventional low-load (LL) RT programs [2,4].

Recently, training with BFR was pointed out as a possible training strategy for individuals with type II diabetes (T2DM) [5]. BFR training technique is speculated to improve the metabolic profile of this population [5]. Considering that training with BFR can indeed be an interesting strategy for individuals with T2DM, understanding if the technique offers any risk to the health of this population is necessary.

Spranger *et al*. [6] draw attention to the possibility of adverse cardiovascular events in BFR training sessions. Authors speculated that the mechanical or metabolic stimulus provided by BFR exercises may exacerbate the hemodynamic response via an increase in the exercise pressor reflex. This aspect can be a problem for diabetic individuals, considering that some evidence indicates that T2DM can be accompanied by an exaggerated exercise pressor reflex caused by oxidative stress due to the disease [7].

Current literature does not provide studies that analyzed the effect of exercise with BFR on

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cardiovascular stress in individuals with T2DM, so it is not known whether the technique can confer any cardiovascular risk to this public. Bearing in mind that training with BFR can be a valid alternative for T2DM management, it is necessary to evaluate the safety of this training strategy for diabetic individuals. In this context, this study aimed to analyze the effect of low-load resistance exercise with BFR and traditional high and low load exercise on cardiovascular stress and oxygen saturation (SpO_2) in women with type 2 diabetes mellitus.

METHODS

Subjects

Ten untrained women with type 2 diabetes (35-60 years) recruited through virtual media, phone calls and personal invitation. The characteristics of the investigated sample are reported in Table **1**. As inclusion criteria, participants should not meet any of the following: (i) insulin use; (ii) had a lower limbs musculoskeletal injury in the last six months prior to data collection; (iii) positively responded to any of the items on the Physical Activity Readiness Questionnaire/PAR-Q [8]; and (iv) participated a systematic physical training program in the last six months prior to data collection. All participants received oral and written information about the risks and benefits of the study and signed an informed consent form. 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).

Table 1: Subject Characteristics (n=10)

Variables	Mean ± SD
Age (years)	56.99 ± 7.40
Body mass (kg)	62.90 ± 11.74
Height (cm)	149.00 ± 3.85
BMI (kg/m^2)	27.22 ± 4.26
T2DM Diagnostic Time (years)	10.60 ± 4.12
1RM knee extension (kg)	28.20 ± 6.25
AOP (mmHg)	190.00 ± 21.68

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

Experimental Design

This is a crossover and randomized study that aimed to analyze the effect of HL, LL, and LL + BFR exercise on peripheral oxygen saturation level (SpO_2) and cardiovascular stress in untrained women with T2DM. All participants attended a local gym on four occasions. Visits took place at the same time and were interspersed for a period of 72–96 hours. Initially, participants received information about the methodological procedures adopted in the research and, soon after, body mass, height, blood pressure, occlusion pressure of the posterior tibial artery at rest, and values of predicted 1RM were evaluated. Second, third, and fourth visits were randomly allocated to the following: (i) HL exercise (65% of predicted 1RM); (ii) LL exercise (20% of predicted 1RM); (iii) Exercise of LL + BFR (20% of predicted 1RM; 50% of AOP). Before and immediately after exercise, SpO_2, systolic blood pressure (SBP), and heart rate (HR) were assessed (Figure **1**). 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 prior to experimental sessions.

Procedures

Anthropometric Assessment

The anthropometric assessment consisted of verifying body mass on a Filizolascale (Industria Filizola S/A, Brasil). The subject stands in the center of the scale platform, with feet spread sideways and body erect in the Frankfurt plan. To measure height, the participant stood barefoot in an upright posture with feet flat on the platform and heels close together using a stadiometer (Wiso®) INMETRO seal. Height and weight were measured to the nearest 0.5 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated dividing the participant's body mass value by the square of height (kg/m^2).

Determination of Arterial Occlusion Pressure

The level of restriction was relativized using the arterial occlusion pressure (50% of AOP), as previously described by Laurentino *et al*. [3]. Participants were asked to rest for five mins in a calm and quiet environment and, subsequently, a portable vascular Doppler probe was fixed (MedPej®, DF-7001 VN, Ribeirão Preto, São Paulo–Brazil) above the tibial artery. A pneumatic tourniquet (Dimensions: width 100 mm and length 540 mm–Riester®) was fixed below the inguinal region of the thigh and inflated until the auscultatory pulse of the dorsal foot artery was interrupted (AOP). To perform the measurement,

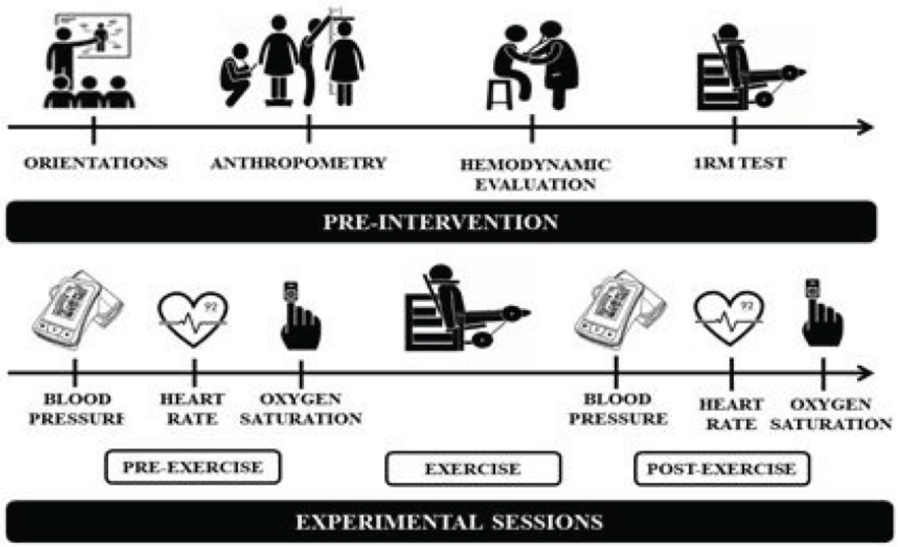

Figure 1: Experimental procedures.

participants remained seated in the position adopted in the exercise, maintaining a hip and knee flexion at 90º.

One Repetition Maximum (1RM) Prediction Test

1RM values for knee extension were determined using a submaximal test. Initially, participants performed a warm-up consisting of 10 repetitions with 40%–60% of the estimated 1RM. After 1 min, participants performed a warm-up consisting of 5 repetitions with 60%–80% of the estimated 1RM load. After a new 1-min interval, the load was adjusted, and participants were asked to perform as many repetitions as possible. The load and number of repetitions were recorded and used to predict values of 1RM using the Brizycki equation [9]: 1RM = 100 × load ÷ (102.78–[2.78 × reps]).

Hemodynamic Variables and Level of Oxygen Saturation

SpO_2, HR and SBP were measured before and immediately after the proposed exercise protocol [10,11]. HR and SBP were measured using a cardiac monitor (Polar®; Vantage M) and an automatic blood pressure monitor (model HEM-705CP 705CP; OMROM®), respectively. The double product (DP) was obtained by multiplying HR and SBP (DP = HR x SBP). Level of oxygen saturation (SpO_2) was assessed using a finger pulse oximeter (G-Tech®; Oled Graph) attached to the right index finger.

Exercise Protocols

Experimental protocols consisted of 3 sets of bilateral KE were performed following a crossover model. For 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, including periods of recovery, thus being characterized as a model of continuous BFR. For the HL exercise protocol, 3 sets of 10 repetitions were performed, interspersed with 90 s of passive recovery, adopting an overload of 65% of predicted 1RM. An execution rate of 1.5 s for the eccentric phase and 1.5 s for the concentric phase was standardized for all tested exercise protocols.

Statistical Analysis

The normality of the data was verified using the Shapiro-Wilk test. H A normal distribution was identified for all variables of interest presented normal distribution, therefore two-way ANOVA for repeated measurements ([3] CONDITION x [2] TIME) was used in data analysis. Bonferroni's post hoc test was used to analyze possible differences in dependent variables. Partial Eta (ɳ2) was used to measure the effect size. The level of significance was set at $p \leq 0.05$. All statistical analyses were performed using SPSS statistical software package version 20.0 (SPSS Inc., Chicago, IL).

RESULTS

HR

No significant interaction effect ($F = 0.051$; $\eta^2 = 002$; and $p = 0.951$) or condition effect ($F = 2.068$; $\eta^2 =$

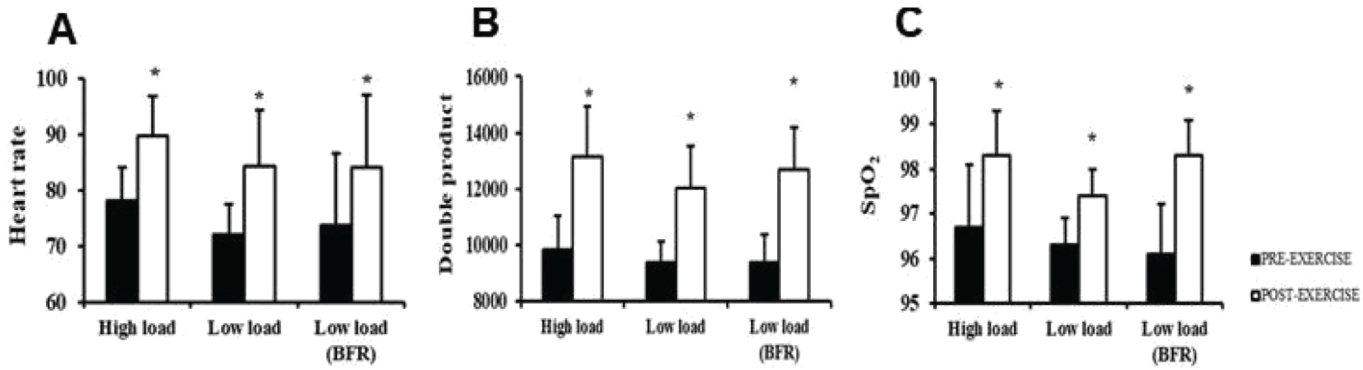

Figure 2: Comparative analysis of hemodynamic responses to the tested exercise protocols.

0.163; and p = 0.071) for HR was found; however, a significant time effect (F = 21.532; η^2 = 0.285; and p < 0.001) was noted. HR increased significantly after all exercise protocols were tested (p = 0.006, p = 0.018, and p = 0.009 for LL, LL + BFR, and HL, respectively) (Figure **2**).

DP

No significant interaction effect (F = 0.440; η^2 = 016; and p = 0.646) or condition effect (F = 1.779; η2 = 0.062; and p = 0.178) for DP was found; however, a significant time effect (F = 83.521; η^2 = 0.607; and p < 0.001) was noted. HR increased significantly after all tested exercise protocols (p < 0.001) (Figure **2**).

SpO_2

No significant interaction effect (F = 1.470; η^2 = 052; and p = 0.239) or condition effect (F = 2.052; η2 = 0.071; and p = 0.138) for SpO_2 was found; however, a significant time effect (F = 38.795; η^2 = 0.418; and p < 0.001) was noted. SpO_2 increased significantly after all tested exercise protocols (p = 0.019, p < 0.001, and p = 0.001 for LL, LL+BFR e HL, respectively) (Figure **2**).

DISCUSSION

This study examined the effects of resistance exercise performed with and without BFR on HR, DP and SpO_2 in untrained women with T2DM. To our knowledge, this was the first study conducted with RE using BFR on diabetic people to analyse this type of response. The main findings are as follows: (i) resistance exercise with BFR promoted an increase in cardiovascular response similar to traditional LL and HL resistance exercise (i.e., without BFR); (ii) All exercise protocols tested were able to increase HR, DP and SpO_2 post-exercise.

The increase in cardiovascular responses (HR and DP) during resistance exercise (RE) protocols tested in our study can be justified, in part, by an increase in the exercise pressor reflex activity due to mechanical or metabolic stimulus provided by exercises of this nature [12]. Previously, it was proposed that exercise with BFR could exacerbate cardiovascular responses, given that this type of exercise has mechanical stimuli and strong metabolic stimulus [6]. This theory was not confirmed in our study. In contrast, Franz *et al*. [12] found that LL + BFR elbow flexion exercise (~30% of 1RM; 50% of AOP) promoted higher post-sets SBP values than a control condition (LL exercise without BFR). It is possible that findings by Franz *et al*. [12] are justified by the repetition protocol used in their study. Authors used a predefined repetition scheme that consisted of 75 repetitions divided into 4 sets (30-15-15-15) and reported that, in the condition of BFR, participants were unable to complete the pre-established number of repetitions, that is, the exercise with BFR was conducted until muscle failure. This aspect must be considered, since the peak of SBP and HR is reached in the last repetitions of maximum sets [13].

Together, HR and SBP measurements, at rest or during exercise, can provide an estimated amount of work done by the myocardium by calculating the DP (i.e., HR multiplied by SBP), a measure that is positively related to the myocardial oxygen consumption (MVO2) [14]. Although this parameter increased significantly in all conditions tested in our study, no differences were reported between protocols. These findings contradict the findings of Poton & Polito [15]. Authors found that in relation to traditional LL exercise (~20% of 1RM) (i.e., without BFR), an LL + BFR KE exercise protocol (~20% of 1RM; 100% of AOP) promoted greater SBP, HR, and DP values during the third set of repetitions. Authors tested the same exercise, intensity (% 1RM), and repetition protocol used in our study, thus it is conjectured that the level of restriction (50% vs. 100% of AOP) may justify, at least in part, the divergence between the present study and the study conducted by Poton & Polito [15]. To support our theory, a previous study found that in the second set of repetitions in a total of four sets (30-15-15-15), the LL + BFR exercise (unilateral elbow flexion; 20% of 1RM) performed with 130% of the brachial SBP promoted higher HR and SBP values than the traditional LL exercise and exercise, whereas the LL + BFR exercise performed with 80% of the brachial SBP promoted a similar hemodynamic response [16].

Divergent results were also identified for the effects of exercise with and without BFR on SpO2, considering that we identified an increase in SpO_2 for all tested protocols, whereas previous studies did not identify changes in the variable [17] or even reduction [11]. Some factors may explain this discrepancy, including the exercised muscle group, number of exercises, duration and level of restriction applied in the studies in question. To illustrate, Picon *et al*. [17] used a restriction level of 30% of AOP in the plantar flexion exercise. Possibly, the muscle mass involved and the level of restriction applied in the study in question were not sufficient to promote changes in SpO2. In addition, the authors used an intermittent restriction model, that is, the pressure was released during the recovery intervals, which attenuated the time under restriction. Previously, a dose-dependent relationship was observed between the time of occlusion and the level of tissue SpO_2 measured by near-infrared spectroscopy (NIRS) (S_{tO2}) [18].

As a limitation, Picon *et al*. [17] did not use any type of control condition, an aspect that makes it difficult to interpret the results presented. In the study by Neto *et al*. [11], authors found a reduction in SpO_2 for all tested exercise protocols (HL, LL and LL-BFR). Unlike the present study, those authors tested four exercises, two for upper limbs and two for upper limbs. Perhaps this training configuration involving different body segments may result in a reduction in SpO_2 levels.

This study has some relevant limitations that warrant emphasis for better results interpretation. (i) Our analyzes were performed immediately after exercise; therefore whether this behavior occurred during exercise is uncertain. (ii) We used a submaximal exercise protocol. Different responses may be observed in exercise protocols conducted until muscle failure. (iii) Our results are specific for KE performed with a moderate level of restriction; thus, it cannot be extrapolated to other exercises and levels of restriction. (iv) Finally, we analyzed a sample of untrained women with T2DM having controlled blood pressure. Different results may be identified in other populations, including hypertensive women with T2DM.

In conclusion, LL RE with BFR seems to promote an increase in HR, DP, and SpO_2 similar to traditional LL and HL RE models in a sample composed of untrained women with T2DM.

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