Article

Acute Effects of Resistance Exercise With Continuous and Intermittent Blood Flow Restriction on Hemodynamic Measurements and Perceived Exertion

Gabriel R. Neto[1,2,3]**, Jefferson S. Novaes**[3]**,
Verônica P. Salerno**[3,4]**, Michel M. Gonçalves**[3,5]**,
Bruna K. L. Piazera**[4,6]**, Thais Rodrigues-
Rodrigues**[2]**, and Maria S. Cirilo-Sousa**[1,2]

Abstract

This study compared the acute effects of low-intensity resistance exercise (RE) sessions for the upper limb with continuous and intermittent blood flow restriction (BFR) and high-intensity RE with no BFR on lactate, heart rate, double product (DP; heart rate times systolic blood pressure), and perceived exertion (RPE). Ten recreationally trained men (1–5 years strength training; age mean $= 19 \pm 0.82$ years) performed three experimental protocols in random order: (a) low-intensity RE at 20%

[1]Department of Physical Education, Federal University of Paraíba, João Pessoa, Brazil
[2]Department of Physical Education, Kinanthropometry and Human Development Laboratory, João Pessoa, Brazil
[3]Department of Gymnastics, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil
[4]Department of Bioscience of Physical Activity, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil
[5]Brazilian Army Research Institute of Physical Fitness, Rio de Janeiro, Brazil
[6]Department of Medicine, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil

Corresponding Author:
Gabriel R. Neto, Department of Physical Education, Federal University of Paraíba, University City, Castelo Branco, João Pessoa 58051-900, Brazil.
Email: gabrielrodrigues_1988@hotmail.com

one-repetition maximum (1RM) with intermittent BFR (LI + IBFR), (b) low-intensity RE at 20% 1RM with continuous BFR (LI + CBFR), and (c) high-intensity RE at 80% 1RM. The three RE protocols increased lactate and DP at the end of the session ($p < .05$) and increased heart rate at the end of each exercise ($p < .05$). However, greater local and general RPE was observed in the high-intensity protocol compared with LI + IBFR and LI + CBFR in the lat pull-down, triceps curl, and biceps curl exercises ($p < .05$). A greater percentage change in DP and lactate was observed for continuous BFR compared with intermittent BFR; however, RPE was lower for intermittent BFR. In conclusion, intermittent BFR appears to be an excellent option for physical training because it did not differ significantly from continuous BFR in any variable and promoted a lower percentage change in DP and RPE.

Introduction

Low-intensity resistance exercise (RE; 20% and 30% one-repetition maximum; 1RM) in combination with blood flow restriction (BFR) has been used to increase strength (Laurentino et al., 2012; Silva et al., 2015; Vechin et al., 2015), hypertrophy (Laurentino et al., 2012; Vechin et al., 2015), functional capacity (Araujo et al., 2015), and local muscle endurance (Gil et al., 2015; Kacin & Strazar, 2011), and it has been found safe with respect to hemodynamics (Araújo et al., 2014; Fahs et al., 2011; Neto, Novaes, et al., 2016; Neto et al., 2015; Neto, Sousa, et al., 2016; Takano et al., 2005; Vieira, Chiappa, Umpierre, Stein, & Ribeiro, 2013). This training method may be used on different special populations because it reduces impact on the joints (Loenneke, Wilson, Marín, Zourdos, & Bemben, 2012; Scott, Loenneke, Slattery, & Dascombe, 2015) and enables gains in muscle strength and hypertrophy similar to those resulting from high-intensity (HI) training (Laurentino et al., 2012; Takarada, Takazawa, et al., 2000).

When applying the BFR method, several methodological procedures in the use of the occlusion device (tourniquet) should be standardized, such as cuff size, pressure, and the form of BFR application (continuous or intermittent) during exercise. One study compared the effect of continuous and intermittent BFR on muscle activation (Yasuda, Loenneke, Ogasawara, & Abe, 2013), another compared their effects on metabolic stress and recruiting of fast-twitch fibers (Suga et al., 2012), and yet another investigated strength and lean body mass (Fitschen et al., 2014). However, the best option for upper limb training with BFR (continuous vs. intermittent) remains unclear.

A review of the literature indicated that only one study compared the acute effect of low-intensity (LI) RE (unilateral elbow flexion) with continuous and intermittent

BFR on heart rate (HR) and double product (DP; systolic blood pressure [SBP] times rather; Brandner, Kidgell, & Warmington, 2014). That study found that intermittent BFR significantly increased HR compared with continuous BFR and revealed no differences in DP, perhaps due to the different pressures used for BFR.

Other studies have assessed the effect of RE with continuous BFR on lactate (Fujita et al., 2007; Loenneke, Kearney, Thrower, Collins, & Pujol, 2010; Loenneke, Wilson, Balapur, et al., 2012; Pierce, Clark, Ploutz-Snyder, & Kanaley, 2006; Poton & Polito, 2014; Reeves et al., 2006; Takano et al., 2005; Takarada, Nakamura, et al., 2000; Vieira et al., 2015), HR (Loenneke, Kearney, et al., 2010; Loenneke, Wilson, Balapur, et al., 2012; Poton & Polito, 2014; Takano et al., 2005; Vieira et al., 2013), DP (Poton & Polito, 2014; Vieira et al., 2013), and perceived exertion (RPE; Loenneke, Balapur, Thrower, Barnes, & Pujol, 2011; Loenneke, Kearney, et al., 2010; Poton & Polito, 2014; Vieira et al., 2015), as well as the effect of intermittent BFR on HR (Figueroa & Vicil, 2011; Kacin & Strazar, 2011; Neto, Sousa, et al., 2016; Rossow et al., 2011) and DP (Neto, Sousa, et al., 2016). However, no studies have evaluated the acute effect of a LI RE session for upper limb training with continuous and intermittent BFR on lactate, HR, DP, and RPE.

Continuous or intermittent BFR is being used to show improved strength and hypertrophy, but the best form of restriction to use is still unknown. Thus, it is important to understand BP stimuli to verify the degree of change and safest method of BFR (continuous vs. intermittent) during an RE session. It is necessary to conduct these studies in healthy populations (e.g., youth and adults), with safe procedures and methods before extending research to special populations.

Therefore, this study compared the acute effects of a session of RE for the upper limb with continuous and intermittent BFR on lactate, HR, DP, and RPE in a small sample of physically fit military men. Given past research findings, the present study hypothesized that the hemodynamics and RPE responses would be similar for LI RE with continuous and intermittent BFR.

Methods

Participants

The study included 10 normotensive and recreationally trained (1–5 years strength training; Rhea, 2004) military men (19 ± 0.82 years old; 78.80 ± 10.89 kg; 174.60 ± 5.48 cm; $25.79 \pm 2.75 \, m^2 \, kg^{-1}$; SBP $= 123.83 \pm 9.70$ mm Hg; Diastolic Blood Pressure (DBP) $= 79.8 \pm 8.35$ mm Hg). An a priori analysis of the needed sample size was estimated with G*Power 3.1 software (Faul, Erdfelder, Lang, & Buchner, 2007), based on a power assumption of 0.80, $\alpha = 0.05$, correlation coefficient of 0.5, nonsphericity correction of 1, and an effect size of 0.45. From these values, a sample size of 10 subjects was calculated using procedures suggested by Beck (2013).

The following exclusion criteria were used: (a) responding positively to any items of the Physical Activity Readiness Questionnaire (Shephard, 1988), (b) missing any of the exercise sessions, (c) having any musculoskeletal injury in the arms, and (d) engaging in smoking. After explaining the risks and benefits of the study, participants signed an informed consent form prepared in accordance with the Declaration of Helsinki. The study was approved by the local Ethics Committee (protocol number 0476/13).

Experimental Design

During the first visit to the laboratory, anthropometric parameters and muscle strength were measured. After that visit, participants returned to the laboratory on three occasions, 72 to 96 hours apart, during which they completed the three protocols in random order (crossover design): (a) low-load RE at 20% 1RM combined with intermittent BFR (LI + IBFR), (b) low-load RE at 20% 1RM combined with continuous BFR (LI + CBFR), and (c) high-load RE at 80% 1RM (HI). All three protocols were performed at the same time of day to control for the diurnal variation in hemodynamic parameters. Lactate, HR, and RPE measurements were performed prior to and after each session, and HR and RPE were assessed at the end of each exercise.

During the study, participants were instructed to refrain from exhaustive exercise, avoid caffeine, chocolate, nutritional supplements, and alcohol intake before and after the study and sleep for a minimum of 6 hours on the night prior to the exercise session. In addition, participants were instructed to maintain the same eating habits during the study period and during all RE sessions, and the individuals were instructed not to perform the Valsalva maneuver (forced expiratory effort against a closed glottis).

Procedures

Anthropometric evaluation. A stadiometer and scale (model 31, Filizola, São Paulo, Brazil) were used to measure participants' height and body mass to the nearest 0.5 cm and 0.1 kg, respectively. These measurements were then used in an equation to obtain the body mass index in $m^2 kg^{-1}$.

Lactate assessment. Blood samples from each participant were collected in ethylenediaminetetraacetic acid tubes (5 ml) 20 minutes prior to and immediately after (~60 seconds to 90 seconds) the exercise. Blood was taken through the antecubital vein, placed on ice, and centrifuged at 1500g at 4°C for 15 min; blood plasma was extracted and stored at −80°C. The plasma lactate was measured using the Bioclin® commercial kit (lactate enzymatic UV test; K084) following the manufacturer's specifications.

BP, HR, and double product. Prior (15 minutes) to and after (∼30 seconds to 60 seconds) each RE session, BP was measured with a stethoscope (3 M, Littmann® Cardiology, USA) and a Tycos® DuraShock™ aneroid sphygmomanometer (Welch Allyn Inc., NY, USA, Model DS-44). The cuff was fully wrapped around the right arm, covering at least two thirds of the upper arm. This device was used for all measurements prior to and after each exercise session. All measurements were performed according to the guidelines of the American Heart Association (Pickering et al., 2005). HR was continuously monitored prior to and after each exercise (Polar T31 coded™ transmitter). DP was obtained by multiplying the HR (bpm) × SBP (mm Hg) prior to and after each session.

Determination of BFR. Following assessment of BP with the traditional sphygmomanometer (120 mm in width, 500 mm in length), the participants remained seated and a standard BP sphygmomanometer (pneumatic komprimeter tourniquet for hemostasis in the extremities; Riester) for the arm (60 mm in width, 470 mm in length) was set in the axillary fold to assess BP prior to beginning each continuous and intermittent BFR protocol. The total BFR was obtained by multiplying the SBP × 1.3 (Brandner et al., 2014; Suga et al., 2010; Takano et al., 2005). The cuff was inflated or deflated between sets.

One-repetition maximum test. The following exercises were performed bilaterally: bench press, lateral pull-down, triceps curl with pulley, and biceps curl with pulley. To warm up, each individual performed a set of 5 to 10 repetitions at 40% and 60% of the maximum perceived strength with 1 minute of rest between sets. After a 1-minute interval, a second set was concluded with three to five repetitions at 60% to 80% of the maximum perceived strength. After 1 minute of rest, the strength assessment was initiated and measured in up to five attempts and the load was adjusted prior to each new attempt. The recovery time between attempts was standardized at 3 to 5 minutes with an interval of 20 minutes for recovery between different exercises. The test was interrupted when the individual failed to properly execute the movement, and the maximum load considered was the load moved in the last successful attempt.

Trial sessions. Four REs were performed with bilateral execution: bench press (with conventional barbells and calibrated weights), lat pull-down, pulley triceps curl, and pulley biceps curl (on conventional machines—Physicus®, Brazil). All participants performed three protocols in random order: four RE at 20% 1RM combined with intermittent BFR (LI + IBFR), four RE at 20% 1RM combined with continuous BFR (LI + CBFR), and four RE at 80% 1RM (HI). For the LI protocols with continuous and intermittent BFR, the participants completed 30 reps, followed by three sets of 15 reps, at 20% 1RM, with 30 seconds of rest

between all sets and 1 minute between exercises while wearing a standard BP sphygmomanometer (pneumatic komprimeter tourniquet for hemostasis in the extremities; Riester) on the arms (60 mm in width, 470 mm in length) fixed at the proximal region. For the LI + IBFR protocol, the cuff was deflated between sets, and for the LI + CBFR protocol, the cuff remained inflated between sets but was always fully deflated at the end of each exercise. For the HI protocol, participants completed three sets of eight reps at 80% 1RM, with 2 minutes of rest between all sets and 1 minute between exercises. The execution speed was set at 3 seconds (1.5 for the concentric muscle action and 1.5 for the eccentric muscle action) and controlled by a metronome.

Perceived exertion. Prior to beginning the study, the participants attended two familiarization sessions with the OMNI-RE Scale (Robertson et al., 2003). The RPE (0–10) was measured at the end of each exercise (local and general perception).

Total exercise volume. The total load was multiplied by the number of sets and reps completed in the four exercises (Load × Sets × Reps) to obtain the total exercise volume.

Statistical analyses

All statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL). The Shapiro–Wilk test for normality and Levene's test for homogeneity were performed first. The variables exhibited normal distribution and homogeneity ($p > .05$). The reproducibility test was conducted between the first and second BP measurement at rest prior to beginning each protocol (intraclass correlation coefficient). One-way analysis of variance (ANOVA) with post hoc Bonferroni tests were performed to compare the total exercise volume between protocols, and a paired *t* test was performed to compare the two BFR pressures used in the LI + IBFR and LI + CBFR protocols. Two-way ANOVA, followed by post hoc Bonferroni tests, were performed to analyze possible differences in lactate and DP. Two-way repeated measures ANOVA, followed by post hoc Bonferroni tests, were performed to analyze possible differences in HR. Nonparametric Friedman and Wilcoxon tests were used to conduct the RPE analysis. The percentage change ($\Delta\%$) was used to express differences between significant changes. The significance level was set at $p \le .05$.

Results

The mean pressure used throughout the intermittent and continuous BFR exercise protocols was 163.80 ± 10.52 and 160.95 ± 12.92 mm Hg, respectively. The BP intraclass correlation coefficients were as follows: LI + IBFR = .975,

LI + CBFR = .966, and HI = .959. The paired t test showed no significant differences between the two BFR pressures used during the LI + IBFR versus LI + CBFR protocol ($p = .444$). A significant difference was observed in the sum of the total volume of the four exercises between the protocols, LI + IBFR and LI + CBFR (4,131.0 ± 608.2) versus HI (5,598.7 ± 836.7), $p < .001$, but no significant differences were observed between LI + IBFR versus LI + CBFR ($p = 1.000$).

For comparative analysis of lactate by two-way ANOVA, there were no significant interactions between Protocols × Time, $F(2, 6) = 2.774$; $\eta^2 = 0.170$; $p = .080$. A significant difference was observed between LI + IBFR versus HI ($p = .032$) at the end of the exercise sessions. Significant increases in lactate were observed prior to and after the exercise session for all protocols, LI + IBFR ($p < .001$, $\Delta = 4.4\%$), LI + CBFR ($p < .001$, $\Delta = 5.0\%$), and HI ($p < .001$, $\Delta = 5.2\%$; Figure 1).

For comparative analysis of HR by two-way ANOVA, there were significant interactions between Protocols × Time, $F(2, 6) = 5.720$; $\eta^2 = 0.298$; $p < .001$, between protocols, $F(2, 6) = 10.149$; $\eta^2 = 0.429$; $p = .001$, and time, $F(2, 6) = 214.000$; $\eta^2 = 0.888$; $p < .001$. A significant difference was observed between LI + IBFR versus HI ($p = .007$; $p < .001$; $p < .001$) and LI + CBFR versus HI ($p = .005$; $p < .001$; $p = .002$) at the end of the bench press, lat pull-down, and triceps curl exercises, respectively. However, a significant difference in HR was only evident between LI + IBFR versus HI ($p = .035$) at the end of the biceps curl exercise (end of session). Significant increases in HR were observed prior to
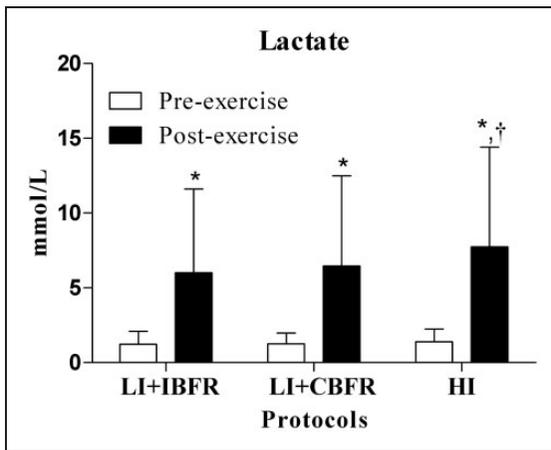

Figure 1. Comparative analysis of lactate pre- and immediately postexercise session between the study protocols.
[†]Significant difference between LI + IBFR versus HI; *significant difference pre- versus immediately post-exercise. LI + IBFR = low intensity combined with intermittent blood flow restriction; LI + CBFR = low intensity combined with continuous blood flow restriction; HI = high-intensity protocol.

and after the exercise session for all protocols, LI + IBFR ($p < .001$, $\Delta = 1.1\%$), LI + CBFR ($p < .001$, $\Delta = 1.08\%$), and HI ($p < .001$, $\Delta = 1.3\%$). Significant increases in HR were observed between the end of the bench press exercise versus biceps curl, lat pull-down versus biceps curl, and triceps curl versus biceps curl ($p < .001$; $p < .001$; $p < .001$, respectively) for the LI + IBFR protocol. For the LI + CBFR protocol, significant increases in HR were observed between the end of the bench press versus lat pull-down, bench press versus triceps curl, bench press versus biceps curl, lat pull-down versus biceps curl, and triceps curl versus biceps curl exercises ($p = .021$; $p = .001$; $p < .001$; $p < .001$; $p < .001$, respectively). For the HI protocol, significant increases in HR were observed between the end of the bench press versus lat pull-down, bench press versus triceps curl, bench press versus biceps curl, lat pull-down versus biceps curl, and triceps curl versus biceps curl exercises ($p = .005$; $p < .001$; $p < .001$; $p = .001$; $p = .004$, respectively; Table 1).

The nonparametric Friedman test revealed significant differences between the protocols ($p < .001$; $p < .001$, respectively) in local and general RPE. The Wilcoxon test indicated greater local RPE in the HI protocol compared with the LI + CBFR protocol ($p = .016$) for the bench press exercise. In the lat pull-down exercise, greater local ($p = .005$; $p = .011$) and general ($p = .005$; $p = .007$) RPE was observed for the HI protocol compared with the LI + IBFR and LI + CBFR protocols, respectively. In the triceps curl exercise, greater local ($p = .007$) and general ($p = .008$) RPE were observed for the HI protocol compared with the LI + IBFR protocol. In the biceps curl exercise, greater local ($p = .034$) and general ($p = .020$) RPE were observed for the HI protocol compared with the LI + IBFR protocol, as well as greater local RPE ($p = .026$) for the HI protocol compared with the LI + CBFR protocol (Table 2).

For comparative analysis of DP by two-way ANOVA, there were no significant interactions between Protocols × Time, $F(2, 6) = 2.831$; $\eta^2 = 0.173$; $p < .077$,

Table 1. Comparative Analysis of Heart Rate (HR) With Each Exercise Between the Study Protocols.

HR	Before	Bench press After	Lat pull-down After	Triceps curl After	Biceps curl After
LI + IBFR	71.0 ± 9.4	111.3 ± 13.4[c]	117.1 ± 14.3[c]	118.7 ± 20.4[c]	152.2 ± 19.1[c]
LI + CBFR	74.5 ± 13.2	109.9 ± 14.4[c]	123.7 ± 18.4[c]	129.9 ± 21.7[c]	155.5 ± 20.4[c]
HI	71.2 ± 5.8	136.8 ± 27.4[a,b,c]	154.2 ± 13.6[a,b,c]	159.2 ± 14.1[a,b,c]	168.9 ± 8.1[a,b]

LI + IBFR = low intensity combined with intermittent blood flow restriction; LI + CBFR = low intensity combined with continuous blood flow restriction; HI = high-intensity protocol.
[a]Significant difference between LI + IBFR versus HI.
[b]Significant difference between LI + CBFR versus HI.
[c]Significant difference between pre versus immediately post each exercise.

and between protocols, $F(2, 6) = 2.373$; $\eta^2 = 0.149$; $p = .112$; however, there was a significant interaction effect in time tempo, $F(2, 6) = 483.127$; $\eta^2 = 0.947$; $p < .001$. A significant increase was evident between before versus after the exercise session measurements for all protocols, LI + IBFR ($p < .001$, $\Delta = 1.6\%$), LI + CBFR ($p < .001$, $\Delta = 1.8\%$), and HI ($p < .001$, $\Delta = 2.2\%$; Figure 2).

Discussion

This study compared the acute effects of RE for the upper limb with continuous and intermittent BFR on lactate, HR, DP, and RPE in military men. To our knowledge, this was the first study to compare hemodynamics and RPE after an upper limb RE session with continuous and intermittent BFR. The main findings were as follows: (a) the three RE protocols increased lactate and DP at the end of the session and increased the HR at the end of each exercise; (b) higher local and general RPE was observed in the HI protocol compared with the LI + IBFR and LI + CBFR protocols in the lat pull-down, triceps curl, and biceps curl exercises; and (c) a higher percentage variation in DP and lactate was observed for continuous compared with intermittent BFR, but mean RPE values were lower for intermittent BFR. These data support our hypothesis of no difference in RPE and hemodynamic variables when BFR is continuous versus intermittent.

Although no study has compared the effect of continuous and intermittent BFR on lactate, some studies have evaluated the effect of RE with isolated continuous BFR (Loenneke, Kearney, et al., 2010; Loenneke, Wilson, Balapur, et al., 2012; Poton & Polito, 2014; Reeves et al., 2006; Vieira et al., 2015). The mean values of lactate in those studies were lower than those observed here (7.23 ± 0.93 mmolL^{-1}, Loenneke, Kearney, et al., 2010; 2.7 ± 1.4 mmolL^{-1}, Loenneke, Wilson, Balapur, et al., 2012); and lactate lower

Table 2. Comparative Analysis of Perceived Exertion (RPE) of Each Exercise Between the Study Protocols.

	Bench press		Lat pull-down		Triceps curl		Biceps curl	
RPE after	Local	General	Local	General	Local	General	Local	General
LI + IBFR	5.2 ± 2.4	4.5 ± 2.7	3.8 ± 1.9	3.4 ± 2.6	5.8 ± 2.5	4.5 ± 2.6	7.6 ± 2.0	6.8 ± 2.8
LI + CBFR	4.3 ± 2.4	4.6 ± 1.8	4.3 ± 2.3	4.3 ± 2.2	7.2 ± 3.2	6.8 ± 3.1	7.7 ± 3.0	7.5 ± 3.2
HI	6.8 ± 1.8[b]	6.3 ± 2.2	7.5 ± 1.9[a,b]	7.2 ± 1.8[a,b]	8.7 ± 2.1[a]	8.0 ± 2.2[a]	9.4 ± 1.5[a,b]	9.2 ± 1.3[a]

LI + IBFR = low intensity combined with intermittent blood flow restriction; LI + CBFR = low intensity combined with continuous blood flow restriction; HI = high-intensity protocol.
[a]Significant difference between LI + IBFR versus HI.
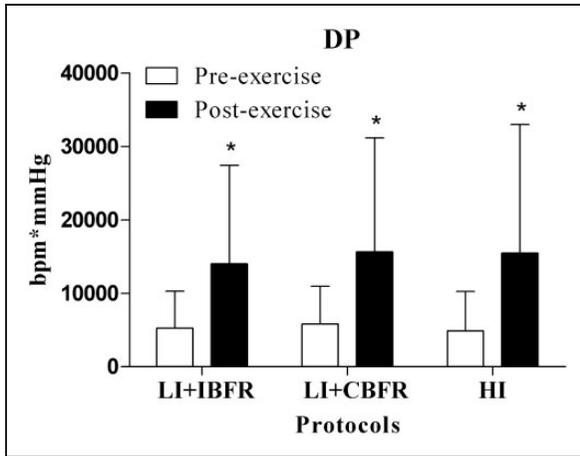[b]Significant difference between LI + CBFR versus HI.

Figure 2. Comparative analysis of double product (DP) pre- and immediately after postexercise session between the study protocols.
*Significant difference between pre- versus immediately postexercise. LI + IBFR = low intensity combined with the intermittent blood flow restriction; LI + CBFR = low intensity combined with continuous blood flow restriction; HI = high-intensity protocol.

than $3 \, mmolL^{-1}$ (Reeves et al., 2006; Vieira et al., 2015)], perhaps because prior studies used only single-joint exercises (unilateral or bilateral knee extension and unilateral elbow flexion or plantar flexion). In addition, the exercise volume was higher in the present study, as four exercises were completed (one exercise session) with bilateral, unilateral, and multiple joint execution. Of those five prior studies, three compared the lactate or HR and DP responses between continuous BFR and HI protocols (Poton & Polito, 2014; Reeves et al., 2006; Vieira et al., 2015). The results of these studies corroborate our findings regarding increases in lactate (Poton & Polito, 2014; Reeves et al., 2006; Vieira et al., 2015), HR, and DP (Poton & Polito, 2014) for the HI protocol, as well as for LI with continuous BFR protocol immediately postexercise, with no significant differences between these protocols; however, the mean values were higher for the HI protocol. Unlike the lactate or HR and DP data, Poton and Polito (2014) and Vieira et al. (2015) obtained different results for RPE than those obtained here. Those studies found a higher RPE in the protocol with continuous BFR compared with the HI protocol, which may be due to continuous BFR showing a higher tension time which increases the levels of H^{+} ions (Loenneke, Wilson, & Wilson, 2010; Manini & Clark, 2009), making the muscle involved in the BFR too acidic and leading to a stronger RPE response. However, the high mechanical stress caused by the HI protocols may be responsible for the higher increase in lactate, HR, and DP, regardless of exercise volume (one exercise or one session), and the metabolic stress promoted by continuous BFR may be responsible

for the increase in RPE due to the increased hyperemia, H^+ ions, and lactate, which can be verified with low exercise volume (only one exercise).

Moreover, in the present study, a significant increase in lactate was observed for the HI protocols compared with the LI protocol with intermittent BFR, which may be due to the release of the cuff pressure having promoted less metabolic stress and consequently, less muscle fatigue, leading a lower increase in mean DP and RPE compared with the LI protocols. Another explanation is that intermittent BFR promotes lower levels of muscle pain compared with continuous BFR (Fitschen et al., 2014), which could cause less strain on the muscles involved.

Other studies have assessed the effect of intermittent BFR on only HR (Figueroa & Vicil, 2011; Kacin & Strazar, 2011; Neto, Sousa, et al., 2016; Rossow et al., 2011) and DP (Neto, Sousa, et al., 2016); only two studies (Neto, Sousa, et al., 2016; Rossow et al., 2011) have compared intermittent BFR with HI. The study by Rossow et al. (2011) corroborates our findings, as it found a significant increase in HR in the HI protocol compared with LI with intermittent BFR after only one leg RE session. However, Neto, Sousa et al. (2016) found no significant difference in HR or DP between the HI and LI with intermittent BFR protocols after one session of arm and leg (agonist and antagonist) RE. Regarding RPE, the findings of Neto, Sousa et al. (2016) differ from the results obtained here. That study found that the RPE was higher for intermittent BFR compared with the HI protocol. Thus, when reviewing the results of studies on RPE (Loenneke, Kearney, et al., 2010; Neto, Sousa, et al., 2016; Poton & Polito, 2014; Vieira et al., 2015), the use of isolated exercises with continuous or intermittent BFR leads to higher RPE compared with the HI protocol. However, when considering one training session in only one body segment (upper or lower), RPE appears to be higher for the HI protocol, which may be due to the higher exercise volume in this condition compared with the BFR conditions. Additionally, local RPE appears to increase more after continuous and intermittent BFR of the muscles involved in the BFR (e.g., biceps and triceps) compared with the muscles not involved in BFR (e.g., pectoral and dorsal), which occurs due to hyperemia and H^+ ion concentrations increasing more on the occluded site, promoting increased RPE (Loenneke, Wilson, et al., 2010). However, there may be an increase in muscle strength (6%), triceps muscle mass (8%), and pectoralis major mass (16%) after 2 weeks of training in the bench press exercise (30% 1RM; 4 sets; 30 reps in the first set; 15 reps in the second, third and fourth sets; 30 seconds of rest between sets; Yasuda, Fujita, Ogasawara, Sato, & Abe, 2010).

The study by Brandner et al. (2014), the first to compare the effect of RE (unilateral elbow flexion) with continuous and intermittent BFR on HR and DP, showed that the intermittent BFR protocol promoted a significant increase in HR at the end of the second set compared with continuous BFR; however, no significant differences in HR and DP were observed at the end of the fourth set

between continuous and intermittent BFR. In contrast, the mean HR and DP values in the intermittent BFR protocol were higher than those of continuous BFR, which may have occurred due to some methodological limitations of the study. The authors compared the acute effect of RE for arms in four conditions: HI (80% 1RM; four sets of 6–8 reps; 150 seconds rest between sets) without BFR, LI (20% 1RM; 4 sets; 30 reps in the first set; 15 reps in the second, third, and fourth sets; 30 seconds rest between sets) without BFR, and two LI protocols with application of continuous (91 mm Hg) and intermittent BFR (151 mm Hg) with a cuff width of 10.5 cm. The increased HR and DP values at the end of exercise may have occurred due to the use of different pressure levels for the continuous (80% resting SBP) and intermittent (130% resting SBP) BFR and only one single-joint exercise (arm flexion), performed unilaterally. Therefore, the methodology of the present study is closer to a real training situation because we used bilateral, single- and multijoint exercises, which enabled a higher training volume than in the study by Brandner et al. (2014); we used four exercises, which strengthen the comparison of the continuous and intermittent BFR results.

An analysis of these findings suggests that intermittent BFR can be an excellent training option for healthy participants due to the increase in muscle activation (Yasuda et al., 2013), gain in muscle strength, and lean body mass (Fitschen et al., 2014) and increase in lactate, HR, and DP, all of which are similar between continuous and intermittent BFR conditions. However, intermittent BFR had lower RPE, which may be of fundamental importance for lowering pain, motivating participants, and helping them adhere to training protocols. This study contributes to the BFR training literature and assists a more complete understanding of the efficiency and safety of this technique.

Declaration of Conflicting Interests

Funding

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Author Biographies

Gabriel R. Neto is a PhD student in the Department of Physical Education – Associate Graduate Program in Physical Education UPE / UFPB. His research interests involve the resistance exercise with blood flow restriction with different objectives in different populations.

Jefferson S. Novaes is an assistant professor (PhD) at the Department of Gymnastics, Federal University of Rio de Janeiro (UFRJ), Physical Education Graduate Program. His research interests involve the resistance exercise with blood flow restriction with different objectives in different populations.

Verônica P. Salerno is an assistant professor (PhD) at the Department of Gymnastics, Federal University of Rio de Janeiro (UFRJ), Physical Education Graduate Program.

Michel M. Gonçalves is MD at the Department of Gymnastics, Federal University of Rio de Janeiro (UFRJ), Physical Education Graduate Program.

Bruna K. L. Piazera is MD at the Department of Medicine, Federal University of Rio de Janeiro (UFRJ), Endocrine Medicine Graduate Program.

Thais Rodrigues-Rodrigues is a research assistant in Kinanthropometry and Human Development Laboratory in Federal University of Paraíba (UFPB).

Maria S. Cirilo-Sousa is an assistant professor (PhD) in the Department of Physical Education – Associate Graduate Program in Physical Education UPE / UFPB. His research interests involve the resistance exercise with blood flow restriction with different objectives in different populations.