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Does Acute Blood Flow Restriction with Pneumatic and Non-Pneumatic Non-Elastic Cuffs Promote Similar Responses in Blood Lactate, Growth Hormone, and Peptide Hormone?

by
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Blood flow restriction (BFR) can be used during resistance training (RT) through pressure application with pneumatic (pressurized) cuffs (PC) or non-pneumatic (practical) cuffs (NPC). However, PC are expensive and difficult to use in the gym environment compared to NPC. The main aim was to compare, correlate, and verify the hormonal and metabolic responses between PC and NPC during a low-load BFR during RT of the upper-body. The secondary aim was to compare blood lactate (BLa) concentration between pre- and post-exercise (2-min into recovery), as well as growth hormone (GH) and insulin-like growth factor 1 (IGF-1) concentration before, 10-min, and 15-min post exercise. Sixteen trained men randomly and alternately completed two experimental RT protocols of the upper-body : A) RT with BFR at 20% 1RM using PC (RT-BFR-PC) and (B) RT with BFR at 20% 1RM using NPC (RT-BFR-NPC) in the bench press, wide-grip lat pulldown, shoulder press, triceps pushdown, and biceps curl exercises. There was no significant difference in BLa 2-min post exercise (p=0.524), GH 10-min (p=0.843) and 15-min post exercise (p=0.672), and IGF-1 10-min (p=0.298) and 15-min post exercise (p=0.201) between RT-BFR-PC and RT-BFR-NPC. In addition, there was a moderate correlation, satisfactory ICCs, and agreement between both protocols in metabolic and hormonal responses. The experimental sessions promoted significant increases in GH and BLa, but not in IGF-1 (p<0.05). The absence of a significant difference between RT-BFR-PC and RT-BFR-NPC in metabolic and hormonal responses highlight the applicability of NPC as a low-cost and easy-to-use tool for BFR upper-body RT.

Key words: *katsu training, resistance exercise, GH, lactate, IGF-1.*

Introduction

Blood flow restriction (BFR) is a training method that aims to fully restrict arterial flow and partially restrict venous flow of active muscles during exercise (Scott et al., 2016). This training method uses a technique that involves applying external pressure through a tourniquet cuff (McEwen et al., 2019) on the most proximal region of the upper and/or lower limbs, and when this cuff is inflated, a severe restriction in the venous blood flow occurs (Patterson et al., 2019). Currently, low-load resistance training (20-50% 1RM) associated with BFR has been shown to be effective in increasing muscle hypertrophy and strength in several populations (Lixandrao et al., 2018; Krzysztofik et al., 2019), such as athletes (Wilk et al., 2018), older adults (Centner et al., 2019), and individuals in physical therapy

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(McEwen et al., 2019).

Although few studies have found positive responses of resistance training (RT) with BFR for muscle hypertrophy (Hill et al., 2018; Sudo et al., 2017; Maszczyk et al., 2020), the underlying mechanisms responsible for this effect remain unknown (Pearson and Hussain, 2015; Staniszewski et al., 2020). One of the hypertrophic effects of this training method is associated with the rise in metabolic stress levels caused by the ischemic pressure that induces an increase in blood lactate concentrations (BLa) (Loenneke et al., 2011). The low pH environment induced by the metabolic stress is known to stimulate growth hormone (GH) secretion, which exerts an interactive possible effect on muscle protein synthesis (West and Phillips, 2012). On the other hand, some studies have demonstrated that the elevation of GH may raise the rates of insulin-like growth factor 1 (IGF-1) (Loenneke et al., 2012), which could be locally produced within peripheral muscle tissue as well as systematically synthesized by the liver in response to GH (Pearson and Hussain, 2015). Pneumatic (PC) (Dankel et al., 2017) and non-pneumatic cuffs (NPC) (Luebbers et al., 2014; Yamanaka et al., 2012) made of elastic and non-elastic (nylon) materials (Patterson et al., 2019) may be used to restrict blood flow during the application of this training method.

Although there are different methodologies for applying pressure to the elastic cuffs around the limb (Behringer et al., 2017; Esmaeilzadeh et al., 2018; Loenneke et al., 2010), these methods often vary widely with regard to the applied pressure and the amount of restricted blood flow, which causes difficulties in instrument standardization among participants (Abe et al., 2019). Current recommendations highlight that cuff application should be based on arterial occlusion pressure (Patterson et al., 2019). On the other hand, as most RT practitioners do not have access to the instruments to evaluate BFR, some studies have been based on the individual perception of tightness to cause BFR (Loenneke et al., 2010; Lowery et al., 2014), despite the fact that these scales provide some estimation errors if they are not correctly applied (Bell et al., 2019). Nevertheless, recently, Abe et al. (2019) observed similar decreases in blood flow between a practical elastic cuff and a traditional pressurized nylon cuff. This study highlighted the importance of practical cuffs as a low-cost tool for RT with BFR, however, to date, there are no studies that have compared PC and NPC in metabolic and hormonal responses during RT.

In this way, considering that practical cuffs are easy-to-use and inexpensive compared to pressurized cuffs, being more accessible to the general population (Abe et al., 2019), the main aim of this study was to compare, correlate, and verify the hormonal and metabolic responses between PC and NPC during a low-load upper-body RT-BFR session. The secondary aim was to compare the behavior of BLa concentration between pre and 2-min post-exercise moments, GH and IGF-1 among pre, 10-min and 15-min post-exercise evaluations.

Methods

Experimental approach to the problem

The study was divided into six evaluation sessions, separated by a period of 48-96 hours. All evaluations were performed at the same time of the day to control for daily variation of hormonal measurements. Coffee, tea, alcohol, and tobacco consumption, and physical exercise were prohibited for 24-hour before the experimental procedures. In the first and second sessions, anthropometric measures, and PC pressure adjustment with NPC were performed. In the third and fourth sessions, participants randomly and alternately performed the one repetition maximum (1RM) tests (test and retest) in the bench press (BP), wide-grip lat pulldown (LP), shoulder press (SP), triceps pushdown (TP), and biceps curl exercises (BC). During the fifth and sixth sessions, the participants randomly and alternately performed two training sessions: (A) RT-BFR at 20% 1RM using PC (RT-BFR-PC) and (B) RT-BFR at 20% 1RM using NPC (RT-BFR-NPC). In these sessions, they performed the BP, LP, SP, TP, and BC exercises. Blood lactate concentration (BLa) was obtained before the beginning of the experimental training session and 2-min after the last exercise. Hormonal (GH and IGF-1) measurements were performed before the beginning of the experimental session, as well as 10-min and 15-min after the last exercise.

Participants

Sixteen healthy males (27.06 ± 5.00 years, 77.71 ± 10.60 kg, 1.73 ± 0.06 m, 25.8 ± 3.364 m^2 kg^{-1},

7.76 ± 5.58% fat) with at least six months experience in RT volunteered to participate in the study. To be included in the research, the participants had to meet the following criteria: (A) have no cardiac or metabolic diseases; (B) have no bone, joint, or muscle injuries that compromised physical performance; (C) use or have used in the last 12 months anabolic steroids, drugs or medications with potential impact on physical performance (self-reported). All procedures were approved by the local ethics committee following the Declaration of Helsinki. All participants signed a consent form for their participation in the study.

Evaluation

Anthropometric measures

Body mass and height were measured using a medical scale with a stadiometer (Health-O-Meter®, model 402EXP, Badger Scale Inc., Milwaukee, United States), with subjects wearing only underwear. Body fat percentage (%) was estimated by the skin fold method at three locations (Jackson and Pollock, 1978), and the circumference of the relaxed arm was measured with a tape considering the midpoint between the scapular acromion and the elbow.

One-repetition maximal testing

1RM test and retest were performed for the following exercises: BP, LP, SP, TP, and BC. The 1RM test protocol was performed according to the recommendations of the National Association of Strength and Conditioning (Baechle and Earle, 2008) and the following recommendations were adopted: a) standardized instructions on the test procedures, as well as the technique used to perform the exercises; b) verbal encouragements; and c) feedback regarding technique and movement cadence during the test. First, the participants performed a general warm-up (3-5 minutes of light activity, such as walking, unloaded joint mobility and light static stretching involving the tested muscle group, followed by a specific warm-up (1 set of 10-12 repetitions with 30% of body weight). After that, all participants executed a set of five repetitions of each exercise at 50% 1RM, followed by two to three repetitions with a load corresponding to 60% and 80% 1RM as a specific warm-up. The participants executed a set of single repetitions with increasing load to determine 1RM, and 5-min rest intervals between attempts. The 1RM was tested using five maximal and progressive attempts. These procedures were followed during all proposed exercises. A 5-min recovery interval was used between exercises with the order randomized. The 1RM retest was performed 48-hours after the first test (Schoenfeld et al., 2016). During all exercises, movement speed (cadence) was maintained at (1.5/0/1.5/0), i.e. a 1.5-s eccentric phase, 0-s i.e., no break in the transition phase, and a 1.5-s concentric phase, and 0-s i.e., no rest before the next repetition (Wilk et al., 2020a; Wilk et al., 2020b) using a digital metronome (DM90, Seiko®, Tokyo, Japan).

Blood Flow restriction determination and equalization between PC and NPC

BFR was performed using two instruments: a PC of 9.0-cm x 57.0-cm (komprimeter Riester®, Jungingen, Germany) and a NPC of 5.0-cm x 47.0-cm, both placed in the proximal portion of the arm, below deltoid. The contact area of the instruments (air tube of the PC and NPC) was 5.0-cm (Abe et al., 2019). A predetermined pressure of 150-mmHg was used to adjust and equalize the pressure of PC with NPC, where cuff pressure was similar to previous studies (Dankel et al., 2017; Takano et al., 2005). At this moment, the objective was to verify the percentage of NPC length reduction, based on tourniquet pressure, using pain perception (Ferreira-Valente et al., 2011) as a comparison variable. Participants reported the perception of pain in one arm (PC) 150-mmHg, with the cuff reduction in cm on the other arm (NPC). The arm circumference was measured and the length reduction to achieve the same perception of arm pain with the NPC. The instruments for the restriction (PC and NPC) were used in a randomized and alternated form (Table 1). We also asked the participants how they perceived the pain produced by the pressure of the tourniquet on a scale of 1 to 10 (Lalonde and Curnier, 2014). This procedure aimed to promote equal BFR pressures between both instruments. A portable vascular Doppler (Df7001 vn Medpej, Ribeirão Preto, São Paulo) was used in the radial artery to verify blood flow during all interventions, thus ensuring that blood flow was not occluded.

Measurements

Blood Sample

Venous blood samples (10 ml averaged for each measurement point) were obtained with

participants sitting in a slightly reclined position. All blood sampling was performed at the same time of day to reduce the effects of any diurnal variation in hormone concentrations. The resting blood sample was obtained after a 20-min equilibrium period. The experimental session started 10-min after the withdrawal of the first blood sample. After the experimental sessions, without BFR instruments, the blood samples were obtained within 2-min, 10-min and 15-min post-exercise. All blood samples were processed and stored at -20°C until analysis.

Biochemical Analysis

Plasma lactate concentrations were measured with the Lactate Bioclion kit (ref K084-Enzymatic UV Test, for in vitro use only). The hormone concentrations (GH e IGF-1) were determined by the chemiluminescence method through the LumiQuest® line.

Procedures

Before starting the strength exercises, the participants performed a warm-up procedure similar to those described in the 1RM testing. Two experimental sessions were performed for the upper-body, using five bilateral strength exercises: BP, LP, SP, TP, and BC. For BP and SP, a barbell measuring 1.8-m and a specific adjustable bench were used. For LP and TP, a specific pulley equipment was used. To perform the BC, a barbell measuring 1.2-m was used. For BP, SP, and BC exercises bumper plates with different weights were used. All equipment used were (Physicus®, Auriflama, Brazil) branded products. Participants randomly completed RT-BFR-PC and RT-BFR-NPC protocols with loads adjusted to 20% 1RM. For the RT-BFR-PC protocol a pressure of 150-mmHg was used. For RT-BFR-NPC protocol the same reduction in cm in the cuff (obtained in the determination and equalization session) was used individually for each participant. The experimental session was performed with the same pressure during the execution of each exercise and released during the intervals (Neto et al., 2018). All participants performed a set of 30 repetitions for each exercise, followed by three sets of 15 repetitions, with a rest interval of 30-s between all sets and one minute between exercises (Loenneke et al., 2012; Patterson et al., 2019). The speed of movement was the same as the one used during the 1RM session.

Statistical Analysis

To verify the normality and homogeneity of variances, Shapiro-Wilk and Levene's tests were adopted, respectively. After attending the assumptions of normality and homogeneity of variances, dependent sample T-test was applied to compare the responses of [2-min post-exercise in blood lactate concentrations (BLa)], [10-min, and 15-min post-exercise in growth hormone (GH)], and [10-min, and 15-min post-exercise in peptide hormone (IGF-1)] between RT-BFR-PC and RT-BFR-NPC protocols. Paired sample T-tests were applied to compare pre- and post-exercise BLa concentration. Two-way repeated-measures ANOVA with Bonferroni's post-hoc tests were applied to compare pre, 10-min, and 15-min post-exercise in GH and IGF-1 concentrations during the protocols. The correlation interpretation followed the following classification criteria: 0 – 0.3 negligible; 0.3 – 0.5 weak; 0.5 – 0.7 moderate; 0.7 – 0.9 strong and 0.9 – 1.0 very strong. The ICC was determined using the following classification criteria: < 0.4 poor; 0,4 – < 0,75 satisfactory; ≥ 0.75 excellent. To evaluate the agreement between RT-BFR-PC and RT-BFR-NPC the visual analysis of the Bland-Altman plot was used, being considered a bias of 5%. For all statistical data, the significance level (α) of 5% was adopted, the statistical analyses were performed with SPSS software (25.0, IBM, Armonk, USA).

Results

The intra-class correlation coefficients (ICCs) were calculated for the 1RM test and retest for all exercises (mean values/ICCs): horizontal bench press (0.977/0.955-0.984), wide-grip lat pulldown (0.969/0.949-0.979), shoulder press with the barbell (0.976/0.971-0.989), triceps pushdown on a pulley (0.970/0.972-0.991) and biceps curl with a barbell (0.991/0.980-0.997). The analysis of metabolic and hormonal variables showed no significant difference between (p>0.05) RT-BFR-PC and RT-BFR-NPC protocols. The results regarding significance (p), correlation (r), intra-class correlation coefficient (ICC) values in comparison between RT-BFR-PC and RT-BFR-NPC protocols are shown in table 2.

The agreements determined by the Bland-Altman plot are represented in the figures below. There was an agreement between RT-BFR-PC and RT-BFR-NPC protocols, with differences between

protocols within the 95% confidence interval, except for one of the participants in all evaluated variables.

The results showed significant differences between pre and 2-min post-exercise values of BLa during RT-BFR-PC (p=0.001) and RT-BFR-NPC (p=0.001) protocols. Also, a significant difference in the concentration of GH was found between 10-min post and pre-exercise (p=0.001), 15-min post and pre-exercise (p=0.001), as well as 10-min and 15-min post-exercise (p=0.001) in RT-BFR-PC protocol, as well as between 10-min post and pre-exercise (p= 0.001), 15-min post and pre-exercise (p=0.001), as well as 10-min and 15-min post-exercise (p= 0.011) in RT-BFR-NPC protocol. For IGF-1, no significant difference was found between 10-min post and pre-exercise (p= 1.000), 15-min post- exercise and resting values (p=1.000), as well as between 10-min and 15-min post-exercise (p= 1.000) in RT-BFR-PC protocol, and between 10-min post and pre-exercise (p= 0.759), 15-min post and pre- exercise (p=0.937), and 10-min and 15-min post- exercise (p=1.000) in RT-BFR-NPC protocol.

Discussion

The main findings of the present study showed no significant difference in BLa concentration 2-min post-exercise, GH, and IGF-1 10-min and 15-min post-exercise between RT-BFR-PC and RT-BFR-NPC. In addition, there was a moderate correlation between protocols for BLa concentration 2-min post-exercise, GH 10-min and 15-min post-exercise, and IGF-1 15-min post-exercise, with the ICCs, considered satisfactory in these variables between the protocols. Bland-Altman plot analysis showed agreement between RT-BFR-PC and RT-BFR-NPC in metabolic and hormonal variables, except for one of the participants. The BLa concentration showed a significant increase between pre and 2-min post-exercise in both protocols. The GH also showed a similar trend showing a significant increase between pre, 10-min and 15-min post-exercise. On the other hand, IGF-1 did not show significant changes between the different moments during both protocols.

Table 1

Equalization of the BFR pressure between PC and NPC.

RA Circ (cm)	LA Circ (cm)	RA %Red (cm)	LA %Red (cm)	RA PC Pain	LA NPC Pain	RA PC Pain	LA NPC Pain
34.5±3.34	34.41±3.36	4.64±1.31	4.71±1.50	5.38±1.15	5.31±1.14	5.38±1.15	5.31±1.14

Note: Values expressed mean ± standard deviation. RA Circ: right arm circumference; LA Circ = left arm circumference; RA %Red: right arm percentage of reduction; LA %Red: left arm percentage of reduction; RA PC Pain: right arm with pneumatic cuff, pain; LA NPC Pain: left arm with non-pneumatic cuff, pain; RA PC Pain: right arm with pneumatic cuff, pain; LA NPC Pain: left arm with non-pneumatic cuff, pain.

Table 2

Comparison between RT-BFR-PC and RT-BFR-NPC in the metabolic and hormonal variables

RT-BFR-PC	RT-BFR-NPC	Significance	Correlation	Significance correlation	Correlation significance	ICC	ICC classification
2-min post-session BLa (mmol.l^{-1})							
11.45 ± 0.35	11.15 ± 0.54	*p*= 0.529	r= 0.60*	*p*= 0.014	Moderate	0.714	Satisfactory
10-min post-session GH (ng/mL)							
9.03 ± 1.33	9.34 ± 1.86	*p*= 0.843	r= 0.58*	*p*= 0.020	Moderate	0.719	Satisfactory
15-min post-session GH (ng/mL)							
7.23 ± 4.31	7.77 ± 5.80	*p*= 0.672	r= 0.56*	*p*= 0.025	Moderate	0.706	Satisfactory
10-min post-session IGF-1 (ng/mL)							
269.69 ± 15.3	249.50 ± 18.7	*p*= 0.298	r= 0.41	*p*= 0,114	Weak	0.571	Satisfactory
15-min post-session IGF-1 (ng/mL)							
268.88 ± 14.8	248.19 ± 16.4	*p*= 0.201	r= 0.51*	*p*= 0.043	Moderate	0.664	Satisfactory

p< 0.05 for the correlation between RT-BFR-PC and RT-BFR-NPC protocols

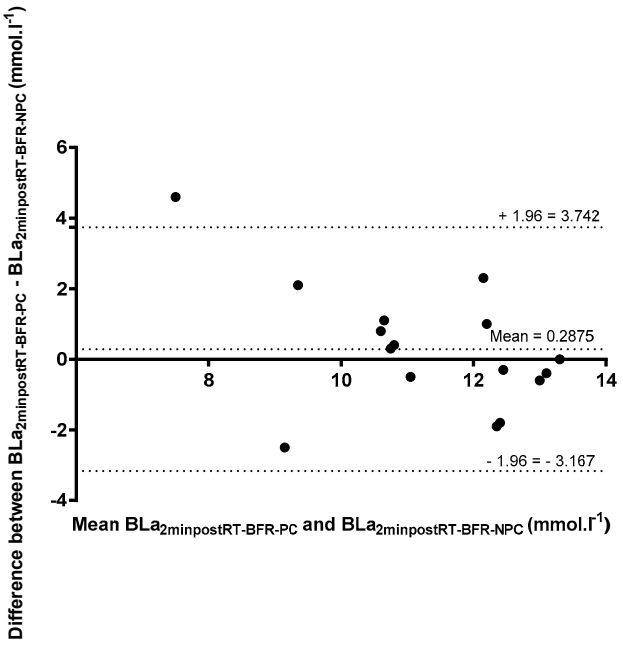

Figure 1

Agreement between RT-BFR-NPC and RT-BFR-PC 2-min post-session in BLa (mmol.l^{-1}).

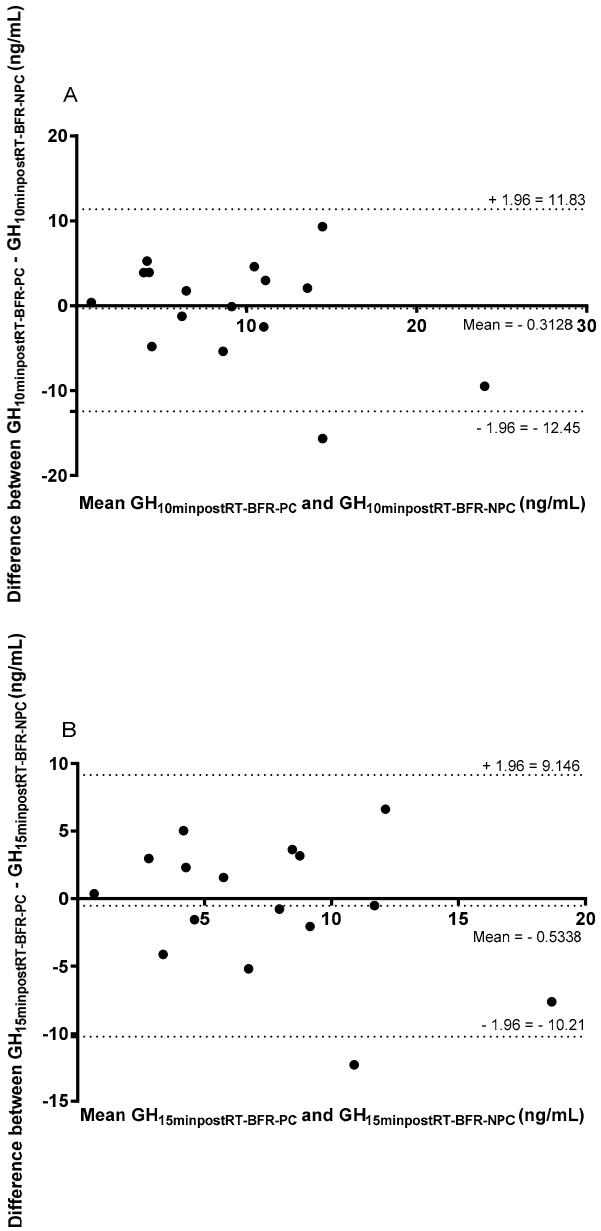

Figure 2

Agreement between RT-BFR-NPC and RT-BFR-PC 10-min (Figure 2A) and 15-min (Figure 2B) post-session in GH (ng/mL).

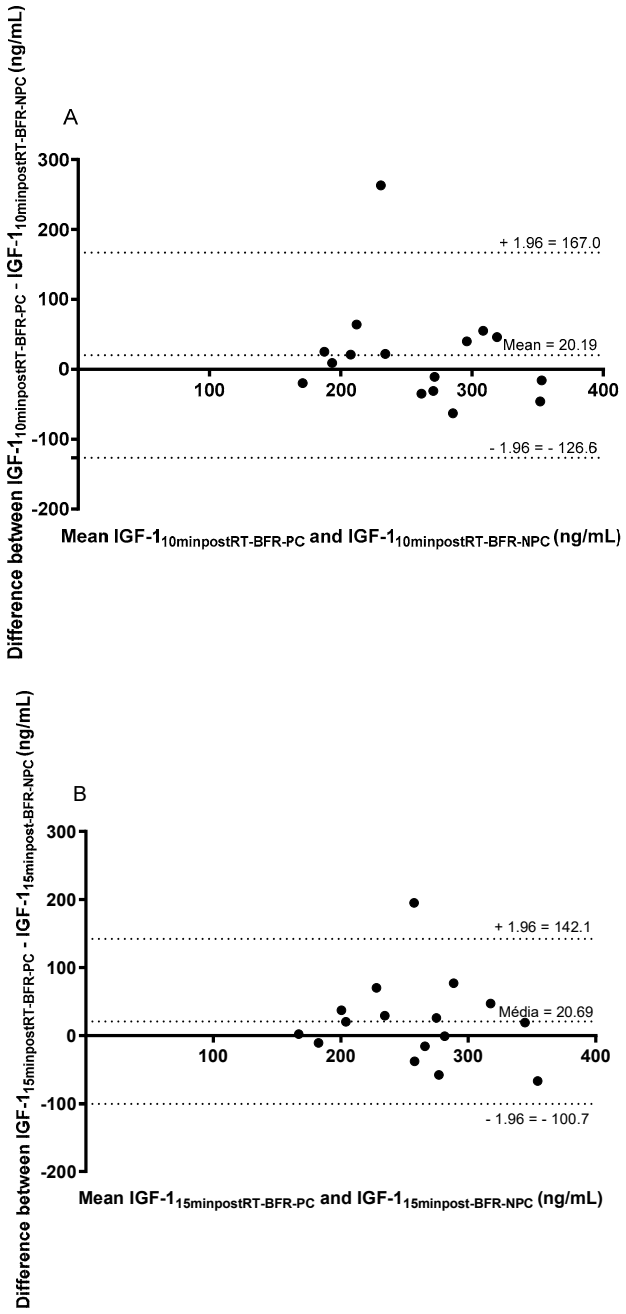

Figure 3

Agreement between RT-BFR-NPC and RT-BFR-PC 10-min (Figure 3A) and 15-min (Figure 3B) post-session in GH (ng/mL).

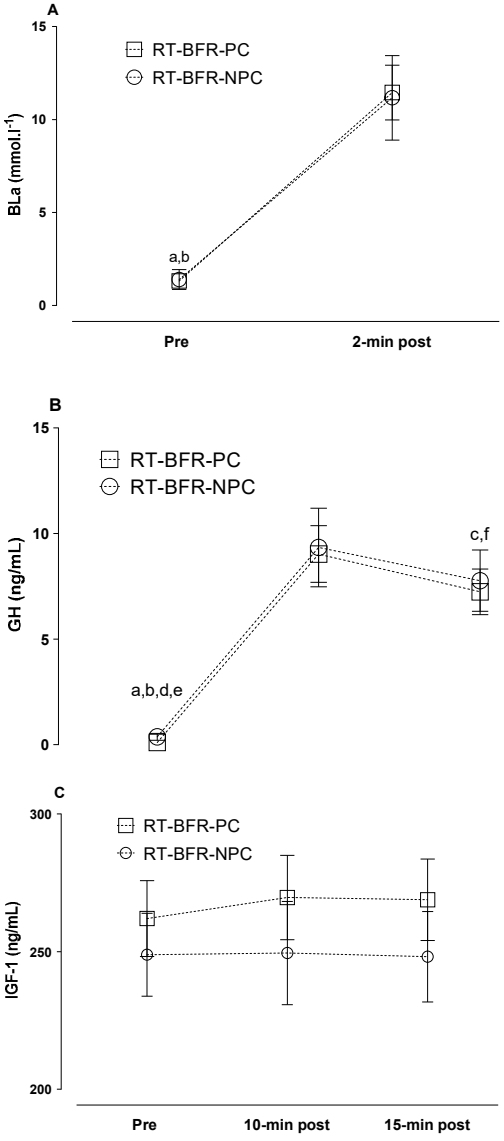

Figure 4

Comparison of blood lactate, growth hormone, and peptide hormone at pre, 2-min, 10-min, and 15-min post-session moments in RT-BFR-PC and RT-BFR-NPC protocols. [a, b] *p≤ 0.05, (a) significant difference between pre x 2-min post-session in RT-BFR-PC, (b) significant difference between pre x 2-min post-session in RT-BFR-NPC (Figure 4A).* [a, d] *p≤ 0.05, (a) significant difference between pre x 10-min post-session in RT-BFR-PC, (d) significant difference between pre x 10-min post-session in RT-BFR-NPC.* [b, e] *p≤ 0.05, (b) significant difference between pre x 15-min post-session in RT-BFR-PC, (e) significant difference between pre x 15-min post-session in RT-BFR-NPC.* [c, f] *p≤ 0.05, (c) significant difference between 10-min x 15-min post-session in RT-BFR-PC, (f) significant difference between 10-min x 15-min post-session in RT-BFR-NPC (Figure 4B). For IGF-1, there was no significant difference among the different moments in both protocols (Figure 4C).*

In an attempt to use inexpensive tools and easy applicability to perform BFR in a practical way, several studies have sought to apply wraps at the proximal end of the lower limb (at the top of the thigh, near the inguinal crease) (Behringer et al., 2017; Loenneke et al., 2010; Luebbers et al., 2014; Wilson et al., 2013; Yamanaka et al., 2012) and at the proximal end of the upper limbs (above the bicep, below the deltoid) (Luebbers et al., 2014). Some research has shown the validity of wraps to increase performance (Behringer et al., 2017; Luebbers et al., 2014; Yamanaka et al., 2012), muscle activation and muscle thickness (Wilson et al., 2013), others do not support its use as a practical alternative to perform BFR training (Loenneke et al., 2010). In order to approximate the restriction pressure applied on PC , Wilson et al. (2013) and Behringer et al. (2017) used practical wraps with a perceived pressure of seven (moderate) on a scale from zero to ten, although in our study we found a lower perception value, five on a scale of 0 to 10, and this value seems to have been sufficient for the application of the method. Wilson et al. (2013) has shown that the perceived pressure resulted in complete occlusion of the veins, another study highlights that it is a very subjective measure, and likely, differs among individuals and may vary greatly depending on the day (Luebbers et al., 2014). Thus, the use of these models has a greater limitation since there is no equalization between practical wraps and PC that are normally applied to BFR training. Recently, Abe et al. (2019) demonstrated similar decreases in blood flow between a practical elastic cuff and a traditional pressurized nylon cuff in an experimental study, in which the authors emphasized the possibility of using practical cuffs as a low-cost tool for RT-BFR. However, our study appears to be the first in the literature to equalize NPC with PC, and subsequently, to verify the metabolic and hormonal responses of both during a RT session for upper-body.

BLa concentration showed significantly higher values in post-exercise conditions that are corroborated by other studies of RT-BFR (Takarada et al., 2000). Metabolic accumulations throughout the training session with BFR may contribute to increased recruitment of fast-twitch motor units (Pearson and Hussain, 2015). The intramuscular acidic environment has been shown to stimulate sympathetic nerve activity through chemoreceptive reflex mediated by intramuscular metaboreceptors and afferent fibers of group III and IV (Loenneke et al., 2012; Pearson and Hussain, 2015), this is one of the possible potential mechanisms for muscle hypertrophy in RT-BFR (Pearson and Hussain, 2015).

This same pathway of chemoreception has shown an important role in the regulation of pituitary GH secretion (Gosselink et al., 1998). Thus, there was a significant increase in GH between pre, 10-min and 15-min post-exercise in both protocols. Some studies corroborated these findings (Gosselink et al., 1998; Pierce et al., 2006; Sato et al., 2005). In the study by Takarada et al. (2000), BFR training elevated GH baseline levels about 290 times, suggesting that low-load RT-BFR stimulates GH secretion without considerable tissue damage. Sato et al. (2005) and Pierce et al. (2006), also demonstrated that plasma concentrations of GH may be higher in RT-BFR. Pierce et al. (2006) observed high GH plasma concentrations, approximately nine times the baseline value, in RT-BFR when combined with low-load (20% 1RM). Similarly, to our study, Sato et al. (2005) also found significant increases in GH immediately, 15-min and 60-min post-exercise in arm and leg RT.

Similar to Kawada and Ishii's (2005) study, we did not find significant increases in IGF-1 for RT-BFR. On the other hand, Takano et al. (2005) found increases in IGF-1 activity in response to RT with low-load BFR. These divergences can be explained due to differences in intensity levels or frequency of training programs found between studies. In this sense, Hwang and Willoughby (2019) claim that there are many conflicts between BFR training protocols, inducing different responses in IGF-1 levels post-exercise (Abe et al., 2005; Kawada and Ishii, 2005).

As a limitation of the study, it is important to note that we did not measure the stretching capacity of the PC and NPC materials used in our study, although they are marketed as non-elastic materials. However, to ensure that NPC produced the same venous restriction found in the PC we used the same contact area with the limb, i.e. 5.0-cm (Abe et al., 2019). This procedure was performed to produce similar restrictions on venous blood flow in both instruments used for the training session (Laurentino et al., 2016).

However, the 150-mmHg pressure used in the present study was apparently not sufficient to induce PC and NPC deformation, as well as the NPC due mainly to its size.

Conclusions

The present study showed no significant difference, moderate correlations, satisfactory ICCs and agreements between RT-BFR-PC and RT-BFR-NPC at practically all post-exercise moments in the hormonal and metabolic variables. We encourage further research to test different materials for the manufacture of NPC to find those that most closely match the response caused by PC. As short-term BFR has shown increases in muscular strength and power (Wilk et al., 2020c; Wilk et al., 2020d), it would be interesting to verify the practical applicability of NPC for this type of training. In addition, other studies must verify the hypertrophic response of using NPC for chronic upper-body adaptive responses to RT.

Practical Applications

Considering the beneficial effects of RT-BFR for hypertrophy and strength, it is important to develop equipment that is low-cost and easy-to-use for coaches and practitioners in the gym environment. In this sense, NPC presents a great advantage over frequently used PC. In this sense, a practical way to use our non-elastic NPC would be to measure the highest circumference point on the practitioner's biceps, and then reduce by about 5% in length the graduated cuff to perform BFR training session for upper-body.

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