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REVIEW ARTICLE

Effects of resistance training with blood flow restriction on haemodynamics: a systematic review

Gabriel R. Neto[1,2,3], Jefferson S. Novaes[2], Ingrid Dias[4], Amanda Brown[2], Jeferson Vianna[5] and Maria S. Cirilo-Sousa[1,3]

[1]Associated Graduate Program in Physical Education, University of Pernambuco/Federal University of Paraíba (UPE/UFPB), João Pessoa, [2]Graduate Program in Physical Education, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, [3]Kinanthropometry and Human Performance Laboratory (UFPB), João Pessoa, [4]Graduate Program in Internal Medicine, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, and [5]Graduate Program in Physical Education, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil

Correspondence
Gabriel Rodrigues Neto, Department of Physical Education, Associate Graduate Program in Physical Education UPE / UFPB, Federal University of Paraíba, University City, Research Center for Human Movement Sciences, Kinanthropometry Laboratory, Room 06 and 08. Castelo Branco. João Pessoa 58051-900, Brazil
E-mail: gabrielrodrigues_1988@hotmail.com

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Summary

This study systematically reviewed the available scientific evidence on the changes promoted by low-intensity (LI) resistance training (RT) combined with blood flow restriction (BFR) on blood pressure (BP), heart rate (HR) and rate-pressure product (RPP). Searches were performed in databases (PubMed, Web of Science™, Scopus and Google Scholar), for the period from January 1990 to May 2015. The study analysis was conducted through a critical review of contents. Of the 1 112 articles identified, 1 091 were excluded and 21 met the selection criteria, including 16 articles evaluating BP, 19 articles evaluating HR and four articles evaluating RPP. Divergent results were found when comparing the LI protocols with BFR versus LI versus high intensity (HI) on BP, HR and RPP. The evidence shows that the protocols using continuous BFR following a LIRT session apparently raise HR, BP and RPP compared with LI protocols without BFR, although increases significantly in BP seem to exist between the HI protocols when compared to LI protocols. Haemodynamic changes (HR, SBP, DBP, MBP, RPP) promoted by LIRT with BFR do not seem to differ between ages and body segments (upper or lower), although they are apparently affected by the width of the cuff and are higher with continuous BFR. However, these changes are within the normal range, rendering this method safe and feasible for special populations.

Introduction

Until 1990s, there were no specific recommendations for progression models in resistance training (RT) (Umpierre & Stein, 2007). However, cardiovascular responses to RT were already discussed in the 1960s (Humphreys & Lind, 1963; Lind & McNicol, 1967). In recent years, RT started to be considered a primary and secondary prevention strategy of different heart diseases, acting positively on cardiovascular risk factors (Bjarnason-Wehrens et al., 2004; Moraes et al., 2005; Braith & Stewart, 2006; Bentes et al., 2015).

The American College of Sports Medicine recommends performing RT with intensities greater than or equal to 70% of one repetition maximum (1RM) to promote strength gains and hypertrophy (ACSM, 2009). However, RT performed at high intensity (HI) may not be viable for people recovering from orthopaedic injuries, for people with some chronic diseases and for the elderly. These individuals may be unable to tolerate an excessive mechanical stress and the associated metabolic changes. Thus, healthcare professionals have sought lower-intensity alternatives for such individuals.

The Japanese developed a low-intensity (LI) RT method (20–50% 1RM) with blood flow restriction (BFR) or KAATSU training for that purpose almost 50 years ago. This method has been proposed for individuals who do not tolerate high 1RM loads (>70% 1RM), including injured athletes, patients undergoing cardiac rehabilitation (Takano et al., 2005) or following surgery of the anterior cruciate ligaments (Takarada et al., 2000; Ohta et al., 2003) and the elderly (Patterson & Ferguson, 2011; Libardi et al., 2015; Vechin et al., 2015), acting positively on muscle atrophy by promoting greater muscle activation. LIRT combined with BFR has also been used to increase strength (Takarada et al., 2002; Laurentino et al., 2012; Silva et al., 2015), muscle hypertrophy (Takarada et al., 2002; Abe et al., 2010; Laurentino et al., 2012), localized muscle resistance (Takarada et al., 2002; Kacin & Strazar, 2011; Gil et al., 2015) and cardiorespiratory endurance (Abe et al., 2010; Park et al., 2010).

A review of the relevant literature showed that some studies evaluated the acute effects of RT with BFR on physiological variables, including systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), heart rate (HR) and rate-pressure product (RPP) (Kacin & Strazar, 2011; Loenneke et al., 2012; Vieira et al., 2013; Araújo et al., 2014; Okuno et al., 2014; Neto et al., 2015; Neto et al., 2016). However, a consensus establishing the real effectiveness of this type of intervention on the changes promoted by RT with BFR in haemodynamics has yet to be reached. Therefore, this review aimed to systematize the available scientific evidence on the changes (acute or chronic) promoted by LIRT combined with BFR on SBP, DBP, MBP, HR and RPP.

Methods

The online databases National Library of Medicine (PubMed), Web of Science™, Scopus and Google Scholar were used to identify the articles to be included in the study, considering the period from January 1990 to May 2015. The selection process of studies is outlined in Figure 1.

The following English keywords/terms/operators were used to perform the searches: ('resistance training' OR 'strength training') AND ('vascular occlusion' OR 'blood flow restriction' OR 'kaatsu') AND ('hemodynamic' OR 'blood pressure' OR 'heart rate'). Furthermore, the following inclusion criteria were adopted: original research articles developed with humans, published in journals indexed in the databases used, samples with an age range of 18–70 years, and that assessed the acute and chronic changes promoted by LIRT combined with BFR. Review articles, articles using protocols with isometric exercises, walking, cycling, treadmill and protocols without exercise, along with comments/expert opinions, chapters or books, validation studies, monographs, dissertations and theses, were excluded from the analysis.

Two researchers conducted the search independently and blinded, their findings were subsequently compared, and any disagreements were solved by consensus with the help of a third reviewer. The titles and abstracts of the articles identified were read to perform the screening. Thus, studies whose titles and abstracts included sufficient information were retrieved. All articles were read in full. A review of the references of those articles was performed for identifying any potentially relevant studies that had not been previously identified during the online search.

This study was conducted according to standardization of PRISMA scale (Liberati et al., 2009). Data analysis was conducted based on a critical review of content, using the following criteria: title, abstract, rationale, objectives, protocol, risk of bias across studies, study characteristics, results of individual studies, limitations and conclusions.

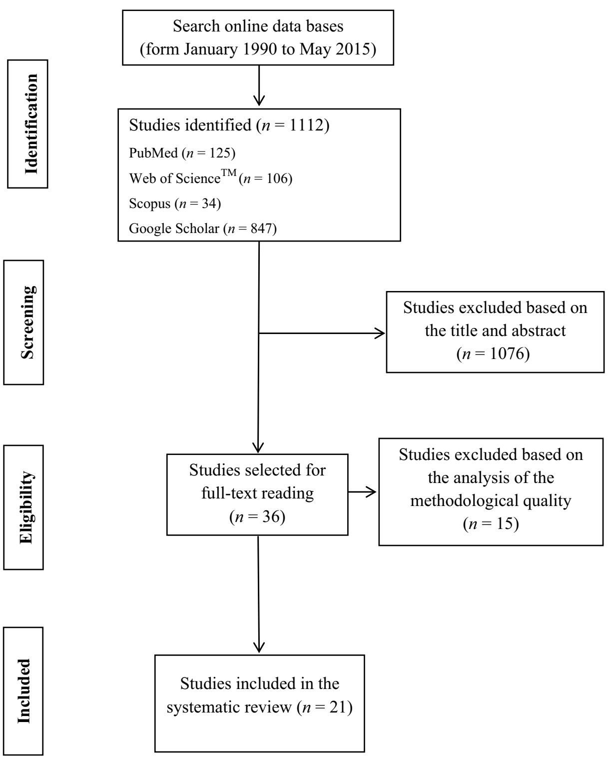

Figure 1 Flow chart of the study selection process.

Results

The summary of the results of the articles was performed based on a structured questionnaire that considered the following components: (i) study author (year), (ii) subjects, (iii) variable, (iv) training protocol, (v) intensity, (vi) training volume, (vii) interval between sets, (viii) BFR pressure during training, (ix) duration of BFR, (x) width of the cuff and (xi) main results.

Of the 1 112 articles identified, 1 076 (96·7%) were excluded based on the title and abstract; thus, 36 articles were selected for full-text reading. Finally, 21 articles were selected after applying the eligibility criteria. This process was performed based on the analysis of the methodological quality of studies. We performed a systematic assessment of changes promoted by LIRT combined with BFR on blood pressure (BP – SBP, DBP, MBP), HR and RPP (Fig. 1).

Assessment of the 21 articles revealed that 14 articles evaluated the acute (Takano et al., 2005; Fahs et al., 2011; Figueroa & Vicil, 2011; Kacin & Strazar, 2011; Rossow et al., 2011, 2012; Vieira et al., 2013; Araújo et al., 2014; Brandner et al., 2015; Poton & Polito, 2014a,b, 2015; Maior et al., 2015; Neto et al., 2015) and two chronic effects of LIRT with BFR on BP and HR (Fahs et al., 2012; Ozaki et al., 2013), two articles on HR and RPP (Poton & Polito, 2014b; Neto et al., 2016), four articles exclusively on HR (Hollander et al., 2010; Loenneke et al., 2010a; Vieira et al., 2013; Okuno et al., 2014) and four articles on RPP (Vieira et al., 2013; Brandner et al., 2015; Poton & Polito, 2014b; Neto et al., 2016). Table 1 presents a summary of the selected manuscripts conducted based on the categories established in the structured questionnaire.

Blood pressure

The following results on BP were found in this review: three studies reported that LIRT sessions (20–40% 1RM) combined with BFR resulted in a significant increase compared with LI protocols without BFR (Takano et al., 2005; Vieira et al., 2013; Poton & Polito, 2014a) and to moderate-intensity protocols (Araújo et al., 2014). However, Kacin & Strazar (2011) reported significant increases with LI without BFR compared to LI with BFR. The studies conducted by Figueroa & Vicil (2011), Fahs et al. (2012) and Ozaki et al. (2013) found no significant differences between the protocols with and without BFR. The study conducted by Rossow et al. (2012) observed a significant increase following the use of different cuff widths. Two studies reported a significant increase with the HI protocol compared with the LI protocol with or without BFR (Poton & Polito, 2014b, 2015). However, three studies observed hypotensive responses following LIRT with BFR (Araújo et al., 2014; Maior et al., 2015; Neto et al., 2015), although three studies found divergent data (Fahs et al., 2011; Rossow et al., 2011; Brandner et al., 2015). The increases in SBP and MBP were higher when using intermittent BFR compared with continuous BFR (Brandner et al., 2015).

Heart rate

In the HR analysis, four articles reported increases with the LI protocol with BFR compared with the LI without BFR and/or HI (Takano et al., 2005; Loenneke et al., 2010a; Vieira et al., 2013; Poton & Polito, 2014a), although the study conducted by Kacin & Strazar (2011) found a significant increase with LI without BFR compared to LI with BFR. Six studies reported increases with the HI protocol compared with LI protocols with or without BFR (Fahs et al., 2011; Rossow et al., 2011; Brandner et al., 2015; Okuno et al., 2014; Poton & Polito, 2014b, 2015). Seven studies found no significant differences between protocols or groups (Figueroa & Vicil, 2011; Fahs et al., 2012; Loenneke et al., 2012; Araújo et al., 2014; Neto et al., 2016). In addition, when analysing cuff width, it was shown that the large model (13·5 cm) may negatively affect HR (Rossow et al., 2012). The increase in HR was higher when using intermittent BFR compared with continuous BFR (Brandner et al., 2015).

Rate-pressure product

The RPP analysis showed that the LI protocol with BFR increased RPP compared to LI without BFR, albeit without significant differences between young people and the elderly (Vieira et al., 2013). However, the study conducted by Neto et al., (2016) detected no significant differences between the protocols. Conversely, the study conducted by Poton & Polito (2014b) found that the HI protocol significantly increased RPP immediately following the second set, and Brandner et al. (2015) reported significant increases with HI compared to LI without BFR in the fourth set.

Exercises, sample, gender and standard used in selected studies

Also noteworthy is the type of exercises used: 57·1% of the studies used lower limb exercises, 23·8% used upper limb exercises, and only 19·0% used exercises for both upper and lower limbs. Considering that sample size and gender may be key criteria in the studies, the review revealed that the sample sizes were small, ranging from seven to 46 subjects. However, the sample in 57% of these articles ranged from seven to 15 subjects. There was a greater predominance of male subjects (66·6% were exclusively men, 28·5% were men and women, and 4·7% were exclusively women). The lack of a training standard was also noted regarding the protocols used (i.e. mode of training, training speed, assessment of exercise pressure, cuff width and duration of BFR application); the standards were apparently established according to the methodological criteria of the researchers and may lead to different responses.

Discussion

This study reviewed the available scientific evidence on the changes promoted by LIRT combined with BFR on SBP, DBP, MBP, HR and RPP. Thus, some studies showed that LIRT with continuous BFR leads to higher HR, SBP, DBP and MBP values than LI protocols without BFR (Takano et al., 2005; Loenneke et al., 2010a; Vieira et al., 2013; Poton & Polito, 2014a). The analysis of the methodology and results of these indicated that these changes may occur even when training is performed using different body parts (upper and lower) if the total volume of exercises is similar. However, these findings contradict Kacin & Strazar (2011), who observed significant increases in HR, SBP, DBP and MBP for the protocol without BFR when compared with BFR. This discrepancy may be explained according to the method used because these authors used a dynamometer at only 15% maximal voluntary muscle contraction (MVC) and standardized the exercise until exhaustion. This method might have promoted a more rapid muscle fatigue for the protocol with BFR. Therefore, the protocol without BFR might have shown a higher volume of work, thus explaining the increase in haemodynamic parameters.

The studies conducted by Figueroa & Vicil (2011), Fahs et al. (2012), Ozaki et al. (2013) and Neto et al., (2016) reported no significant differences in HR, SBP, DBP and MBP between the protocols or groups with and without BFR. These

Table 1 Summary of results from the studies that evaluated the effects of resistance training combined with BFR on (systolic, diastolic and mean) blood pressure, HR and RPP.

			Training protocol				Training volume						
Author (year)	Subjects	Variable	EX	MT	TS	Intensity	Sets	Repetitions	Interval	PADE (mmHg)	BFR between sets	CW (cm)	Results
Takano et al. (2005)	11 men	HR, SBP, DBP and MBP	KE	Bilateral	–	20% 1RM 20% 1RM	BFR = 4 LI = 4	30 × 15 × 15 × 15 30 × 15 × 15 × 15	20 s 20 s	SBP × 1·3	Yes	3·3	LI + BFR ↑ the HR, SBP, DBP and MBP
Hollander et al. (2010)	7 men	HR	AF CE	Unilateral	1 rep/s	30%1RM 70% 1RM	BFR = 3 HI = 3	Exhaustion Exhaustion	60 s 60 s	<20 and >20 SBP	Yes	–	No significant differences between LI + BFR versus HI
Loenneke et al. (2010a)	12 men and women	HR	KE	Bilateral	1 s con 1 s exc	30% 1RM 30% 1RM	BFR = 4 LI = 4	30 × 15 × 15 × 15 30 × 15 × 15 × 15	150 s 150 s	Rubber bands	Yes	7·6	LI + BFR ↑ the HR
Fahs et al. (2011)	11 men	HR, SBP, DBP and MBP	LP, KE, KF, LP	–	–	20%1RM 20%1RM 70% 1RM	BFR = 4 LI = 4 HI = 3	30 × 15 × 15 × 15 30 × 15 × 15 × 15 10 × 10 × 10	30 s 30 s 60 s	120–200	Yes	5·0	HI ↑ HR higher than LI + BFR and LI, albeit with reduced SBP, DBP and MBP compared to LI + BFR and LI
Figueroa & Vicil (2011)	11 men and 12 women	HR, SBP, DBP and MBP	KE KF	Bilateral	2 s con 3 s exc	40% 1RM 40% 1RM	BFR = 3 LI = 3	Exhaustion Exhaustion	60 s 60 s	100	No	–	No significant differences
Kacin & Strazar (2011)	10 men	HR, SBP, DBP and MBP	KE	Unilateral	1 s con 1 s exc	15% MVC 15% MVC	BFR = 4 LI = 4	Exhaustion and Submaximal exercises	120 s	≥230	No	13·0	LI without BFR ↑ HR, SBP, DBP and MBP
Rossow et al. (2011)	10 men	HR, SBP, DBP and MBP	LP, KE, KF, LP	–	–	20% 1RM 20% 1RM 70% 1RM	BFR = 4 LI = 4 HI = 3	30 × 15 × 15 × 15 30 × 15 × 15 × 15 10 × 10 × 10	30 s 30 s 60 s	200	No	5·0	HI ↑ HR until 60 min and↓ SBP and MBP at 60 min
Fahs et al. (2012)	46 men	HR, SBP, DBP and MBP	LP, SSP, AF, AE, KE, KF	–	–	Upper body 50% 1RM for all groups Lower body 20% 1RM 45% 1RM 70% 1RM	BFR = 3 MI = 3 HI = 3	Upper body training with 10 repetitions for all groups Lower body 30 × 15 × 15 × 15 10 × 10 × 10 15 × 15 × 15	60 s 60 s 60 s	160–200	Yes	5·0	No significant differences in HR, SBP, DBP and MBP between the groups after 6 weeks of training
Rossow et al. (2012)	27 men and women	HR, SBP and DBP	KE	–	–	20% 1RM	BFR = 4	30 × 15 × 15 × 15	30 s 60 s	SBP × 1·3	Yes	5·0 versus 13·5	Cuff 13·5 cm ↑ the HR, SBP and DBP
Loenneke et al. (2012)	8 men and 5 women	HR	KE	Bilateral	1 s con 1 s exc	30% 1RM 30% 1RM	BFR = 1 LI = 1	Exhaustion Exhaustion	–	Rubber bands	Yes	7·6	No significant differences
Ozaki et al. (2013)	19 men	HR, SBP and DBP	BP	–	–	30% 1RM 75% 1RM	BFR = 3 HI = 3	30 × 15 × 15 × 15 10 × 10 × 10	30 s 120–180 s	100–160		3·0	No significant differences in HR, SBP and DBP between the groups after 6 weeks of training
Vieira et al. (2013)	15 young people and 12 elderly men	HR, SBP, DBP, MBP and RPP	AF	Unilateral	2 s con 2 s exc	30% 1RM 30% 1RM	BFR = 1 LI = 1	3 min 3 min	–	120	Yes	–	LI + BFR ↑ HR, SBP, DBP and MBP. No differences between ages

Table 1 (continued)

Author (year)	Subjects	Variable	Training protocol			Intensity	Training volume		Interval	PADE (mmHg)	BFR between sets	CW (cm)	Results
			EX	MT	TS		Sets	Repetitions					
Araújo *et al.* (2014)	14 women	HR, SBP, DBP	KE	Bilateral	–	30% 1RM 50% 1RM	BFR = 3 MI = 3	15 × 15 × 15 15 × 15 × 15	45 s 60 s	–	–	18·0	LI + BFR ↑the SBP immediately postexercise compared to MI, albeit ↓
Brandner *et al.* (2015)	12 men	HR, SBP, DBP, MBP and RPP	AF	Unilateral	2 s con 2 s exc	20% 1RM 20% 1RM 20% 1RM 80% 1RM	BFR = 4 BFR = 4 LI = 4 HI = 4	30 × 15 × 15 × 15 30 × 15 × 15 × 15 30 × 15 × 15 × 15 6–8 × 6–8 × 6–8 × 6–8	30 s 30 s 30 s 150 s	80% (91) and 130% (151) of resting SBP	Yes No	10·5 and 8·0	The four protocols ↑ the HR, SBP, DBP, MBP and RPP immediately postexercise
Okuno *et al.* (2014)	09 men	HR	LP	Unilateral	–	40% 1RM 40% 1RM 80% 1RM	BFR = 5 LI = 5 HI = 5	16 × 16 × 16 × 16 + exhaustion 16 × 16 × 16 × 16 + exhaustion 8 × 8 × 8 × 8 + exhaustion	60 s 60 s 60 s	100	Yes	14·0	HI ↑ HR
Poton & Polito (2014a)	10 men 7 women	HR, SBP and DBP	AF	Unilateral	–	20% 1RM 20% 1RM	BFR = 3 LI = 3	15 × 15 × 15 15 × 15 × 15	45 s 45 s	200	Yes	14·5	LI+BFR ↑ the HR, SBP and DBP in the third set compared to the LI protocol
Poton & Polito (2014b)	12 men	HR, SBP, DBP and RPP	KE	Unilateral	–	20% 1RM 20% 1RM 80% 1RM	BFR = 3 LI = 3 HI = 3	15 × 15 × 15 15 × 15 × 15 8 × 8 × 8	45 s 45 s 60 s	167·9	Yes	18·0	HI ↑ a HR, SBP and RPP immediately postexercise in the second set
Poton & Polito (2015)	11 men 6 women	HR, SBP and DBP	LP	Bilateral	–	20% 1RM 20% 1RM 80% 1RM	BFR = 3 LI = 3 HI = 3	15 × 15 × 15 15 × 15 × 15 8 × 8 × 8	45 s 45 s 60 s	144·2	Yes	18·0	HI ↑ the HR, SBP and DBP compared to the LI+BFR protocol
Maior *et al.* (2015)	15 men	SBP, DBP and MBP	AF	Bilateral	No	40% 1RM 80% 1RM	BFR = 3 HI = 3	Exhaustion Exhaustion	60 s 120 s	109·4	Yes	14·0	LI+BFR ↓ SBP, DBP and MBP
Neto *et al.* (2015)	24 men	SBP, DBP and MBP	AF, AE, KE and KF	Bilateral	2 s con 2 s exc	20% 1RM 20% 1RM 80% 1RM	BFR = 4 LI = 4 HI = 4 CONT = without exercise	30 × 15 × 15 × 15 30 × 15 × 15 × 15 8 × 8 × 8 × 8	30s 30s 120 s	arm = 93 leg = 108	No	arm = 6·0 leg = 10·0	LI+BFR, HI and vLI ↓ SBP, LI+BFR ↓ DBP, and HI and LI+BFR ↓ MBP
Neto *et al.*(2016)	24 men	HR and RPP	AF, AE, KE and KF	Bilateral	2 s con 2 s exc	20% 1RM 20% 1RM 80% 1RM	BFR = 4 LI = 4 HI = 4	30 × 15 × 15 × 15 30 × 15 × 15 × 15 8 × 8 × 8 × 8	30 s 30 s 120 s	arm = 93 leg = 108	No	arm = 6·0 leg = 10·0	LI+BFR, HI and LI ↑ HR and RPP immediately postexercise

BF, blood flow restriction; SBP, systolic blood pressure; DBP, diastolic blood pressure; MBP, mean blood pressure; HR, heart rate; RPP, rate-pressure product; EX, exercise; MT, mode of training; TS, training speed; Con, concentric phase; Exc, eccentric phase; CONT, Control; PADE, pressure applied during exercise; CW, cuff width; –, Not reported; ↑, significant increase; AF, arm flexion; AE, arm extension; KE, knee extension; KF, knee flexion; LP, leg press; LP, plantar flexion; CE, calf extension; LP, lat pull-down; SSP, seated shoulder press; BP, bench press; SMVC, sustained maximal voluntary contraction; LI + BFR, low intensity with blood flow restriction; LI, low intensity; HI, high intensity; MI, moderate intensity.

findings might be attributed to the release of BFR pressure between sets, which was not observed in the studies by Poton & Polito (2014a), Takano *et al.* (2005) and Vieira *et al.* (2013) who used continuous BFR. Additionally, the studies performed by Fahs *et al.* (2012) and Ozaki *et al.* (2013) possibly found no significant differences because they examined the chronic effect of RT with and without BFR, and 6 weeks may have been insufficient to reduce HR, SBP, DBP and MBP. However, the studies conducted by Poton & Polito (2015, 2014b) reported significant increases in HR, SBP, DBP and RPP with the HI protocol compared with the LI protocols with or without BFR. These changes may have occurred because the training volume was higher than that in the LI protocols with and without BFR. Another point worth mentioning is the increase in BP and HR for the protocol of LI with continuous BFR when compared to moderate intensity (Araújo *et al.*, 2014). This increase may have occurred due the reduced of blood flow and muscle exercise to promote an increase in the exercise pressor reflex, which in turn contributes to increased autonomic cardiovascular response (Spranger *et al.*, 2015). Furthermore, the study performed by Araujo *et al.* (2014) used only hypertensive women. It is speculated that the response to exercise pressor reflex may occur with more emphasis in this population (Greaney *et al.*, 2014) using continuous BFR. Additionally, there was a significant increase in BP and HR for the protocol of LI with BFR when compared to LI without BFR, but this was only observed in studies using continuous BFR (Takano *et al.*, 2005; Vieira *et al.*, 2013; Poton & Polito, 2014a); no significant differences were observed in studies using intermittent BFR (Figueroa & Vicil, 2011; Neto *et al.*, 2016), which reinforces the safety intermittent BFR. In this context, the study conducted by Brandner *et al.* (2015) found that intermittent BFR seems to increase HR, SBP and MBP more than continuous BFR. However, an important limitation of this study was the application of different pressures for continuous (80% resting SBP) and intermittent BFR (130% resting SBP). It has been suggested that BFR performed continuous or intermittent apparently improves similarly the strength and muscle hypertrophy (Fitschen *et al.*, 2014) and increases muscle activation (Yasuda *et al.*, 2013), with lower pain to intermittent BFR (Fitschen *et al.*, 2014). Thus, intermittent BFR would be a better alternative for practicing this training method because it does not increase haemodynamic responses (Figueroa & Vicil, 2011; Neto *et al.*, 2016), and promotes strength and hypertrophy gains (Fitschen *et al.*, 2014) and muscle activation (Yasuda *et al.*, 2013) with less pain.

Furthermore, a large cuff width (13·5 cm) seems to increase HR, SBP and DBP compared to a small width (5·0 cm) (Rossow *et al.*, 2012). Accordingly, Loenneke *et al.* (2013) report that using a larger cuff width (≥13·5 cm) might be an effective means for promoting a relative (total) occlusion, because a smaller cuff may need a higher pressure to occlude arterial blood flow. And as Rossow *et al.* (2012) used similar pressures between protocols, the stimulus may have been higher for the larger cuff, which could explain a higher pressure exerted on the blood vessels.

Three studies detected hypotensive responses following LIRT with BFR (Araújo *et al.*, 2014; Maior *et al.*, 2015; Neto *et al.*, 2015), although three studies reported otherwise (Fahs *et al.*, 2011; Rossow *et al.*, 2011; Brandner *et al.*, 2015). Thus, when analysing the study methodologies and populations, increased magnitude of hypotension apparently occurs after performing RT with BFR for upper and lower members (agonist–antagonist), in hypertensive individuals (lower limbs) and with loads of 40% 1RM (upper limbs) for apparently healthy young individuals. That is, apparently no hypotensive response occurs when performing LIRT (≤30% 1RM) with BFR in isolated body parts with apparently healthy young individuals, although smaller loads (30% 1RM) may already promote hypotensive responses following LIRT with BFR in hypertensive individuals. Furthermore, performing exercises for upper and lower limbs in the same session may promote greater hypotensive effects than when performing exercises with only one body part, which may be associated with the quantity of muscle mass involved (Lizardo & Simões, 2005). Accordingly, the reduced BP found in the study conducted by Neto *et al.* (2015) may have occurred because of the quantity of muscle mass involved (upper and lower body), which may have caused the increase in endothelial nitric oxide produced by shear stress, which plays a key and protective role on vascular tone (Manini & Clark, 2009; Loenneke *et al.*, 2010b).

Finally, six studies reported an increase in HR with the HI protocol compared with the LI protocols with or without BFR (Fahs *et al.*, 2011; Rossow *et al.*, 2011; Brandner *et al.*, 2015; Okuno *et al.*, 2014; Poton & Polito, 2014b, 2015). These findings may be explained by the fact that the total volume of exercises with the HI protocol was higher. That increase in HR may account for the increased RPP following exercise, whether performed unilaterally or bilaterally (Vieira *et al.*, 2013; Brandner *et al.*, 2015; Poton & Polito, 2014b; Neto *et al.*, 2016). Such an RPP response may be associated with the muscle tension associated with the constriction of blood vessels induced by BFR, which could stimulate muscle and tendon mechanoreceptors (Hayes *et al.*, 2005) and could possibly explain the increased HR and BP (Fisher *et al.*, 2005). Furthermore, the activation of type III muscle fibres and metaboreceptors promoted by BFR seems to promote inhibition of the parasympathetic branch of the autonomic nervous system and chemoreflex stimulation, thus contributing to an increase in cardiovascular responses (Coote & Bothams, 2001; Kaufman & Hayes, 2002).

Conclusion

The protocols using continuous BFR following a LIRT session apparently increase HR, BP and RPP compared with LI protocols without BFR, although increases significantly in BP seem to exist between the HI protocols when compared to LI protocols. Haemodynamic changes (HR, SBP, DBP, MBP, RPP) promoted by LIRT with BFR do not seem to differ between ages and body segments (upper or lower), although they are apparently affected by the width of the cuff and are higher with continuous BFR.

These changes are within the normal range. Thus, this method may be considered safe and viable for special populations, such as the elderly and cardiac patients, among others, because it promotes increased strength and hypertrophy with LI training, albeit without negatively changing haemodynamic measurements. Other noteworthy aspects are that the sample of articles was small and the participation of women was reduced, which could be limiting factors of the studies, especially regarding data extrapolation.

However, different results may be found because of the lack of training standards, which are apparently established according to the methodological criteria of the researchers and may thus prevent the generalization of results. Thus, new controlled and randomized experiments with larger samples must be conducted for examining the effects of LIRT with BFR on SBP, DBP, MBP, HR, RPP in different populations using similar methods. The comparison between different intensities with and without BFR must also be further studied.

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Conflict of interest

The authors have no conflict of interests.

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