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Original empirical article

POST-RESISTANCE EXERCISE HYPOTENSIVE RESPONSES AT DIFFERENT INTENSITIES AND VOLUMES

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Abstract. *The purpose of this study was to investigate the effects of resistance exercise intensity and volume on post-exercise hypotensive responses. Ten normotensive men (aged 22 ± 0.8; height 173.6 ± 2.4 cm and weight 67.2 ± 3.4 kg) participated in this study. The participants performed four ordered sessions of resistance exercise of SHORT volume (3 sets) at LOW intensity (40%1RM) [SL] and HIGH intensity (80%1RM) [SH], LONG volume (6 sets) at LOW intensity (40%1RM) [LL] and HIGH intensity (80%1RM) [LH] (stations: standing two-arm curl, hamstring curl, parallel squat, seated lat pull-down and supine bench press). Blood pressure was measured before the exercises (baseline) and at intervals of 10 min for 90 min after exercise. Systolic blood pressure decreased similarly for 60 min after SL, SH, LL and LH exercise trials, whereas post-exercise diastolic blood pressure presented no change after trials. In conclusion, resistance exercise intensity (40 vs 80%1RM) and volume (3 vs 6 sets) in normotensive men did not influence the magnitude and duration of post-exercise hypotension.*

Key words: *Hypotension; Resistance exercise; Cardiovascular responses; Blood pressure*

INTRODUCTION

The pressure within the cardiovascular system is termed blood pressure. The knowledge of how exercise alters blood pressure has important medical applications, as excessive blood pressure (hypertension) causes the heart to work harder by generating greater pressure to drive the blood throughout the body. This condition is associated with the de-

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velopment of coronary artery disease, acute myocardial infarction, kidney insufficiency, and other pathologic conditions (Thompson et al., 2007; Pescatello et al., 2004). Lowering blood pressure, even in normotensives, is important for reducing the risk of heart disease (Chobanian et al., 2003; Vasan et al., 2001).

The benefits of endurance exercise on the cardiovascular system are well-documented. The results of previous research have shown that, following a single bout of endurance exercise, there is a reduction in blood pressure which has been termed post-exercise hypotension (PEH) (MacDonald 2002; Kelley & Kelley 2000; Hagerman, Walsh, Hikida, Gilders & Murray 2000). However, whether or not resistance exercise results in a post-exercise hypotensive response is relatively unknown. Only a few studies have investigated the PEH response following resistance exercise, and these have shown conflicting results. While some studies show a decrease in blood pressure levels after the exercises Boroujerdi, Rahimi & Noori (2009) others do not report changes Roltsch et al., (2001) or report a blood pressure increase O'Connor, Bryant, Veltri, & Gebhardt, (1993). If resistance training is to be used as a non-pharmacological intervention in the management of blood pressure, more knowledge is required about the different characteristics (i.e. number of sets and repetitions per set, rest between sets and intensity) of the exercise required to evoke PEH, especially the intensity and the volume of the exercise bout. Therefore, in order to minimize cardiovascular risks and maximize the hypotension effects during a resistance exercise program, interactions between these components must be done perfectly.

The experimental protocol, type, volume and intensity of exercise may explain, in part, these discrepancies in post-exercise blood pressure MacDonald et al., (1999). It has been well established that the magnitude of neural and hemodynamic responses during exercise is directly related to exercise intensity and exercise volume (Umpierre & Stein, 2007; Wilkins, Minson, & Halliwill, 2004). Thus, it is possible that different intensities and volumes of exercise also have distinct effects on blood pressure changes after exercise.

Therefore, the purpose of this study was to investigate the effects of resistance exercise intensity and volume on post-exercise hypotensive responses. Although PEH might have clinical relevance in hypertensives, the study was conducted with healthy participants in order to understand its physiology without pathological influences.

METHOD

Participants

Ten normotensive men volunteered to participate in this study. All of the participants were non smokers, had no history of cardiovascular disease, were not taking any medication and engaged in regular physical activity <2 h per week. Subjects who presented a body mass index ≥24 kg/m^2 were excluded. Complete advice about possible risks and discomfort was given to the participants, and all of them give their written informed consent to participate. The Institutional Review Board of the University approved the research protocol. Their physical and cardiovascular characteristics are shown in Table 1.

Table 1. Physical and cardiovascular characteristic of the participants

Participant characteristics	Mean ± SEM
Age (y)	22 ± 1
Weight (kg)	67.2 ± 3
Height (cm)	173.5 ± 2
BMI (kg/m^2)	22.84 ± 1
Systolic blood pressure (mmHg)	109 ± 3
Diastolic blood pressure (mmHg)	68 ± 2
Mean blood pressure (mmHg)	82 ± 3
Heart rate (bpm)	73 ± 4
1 RM two arm curl (kg)	22 ± 7
1 RM hamstring curl (kg)	85 ± 6
1 RM parallel squat (kg)	95 ± 5
1 RM lat pull-down (kg)	55 ± 5
1 RM Supine bench press (kg)	72 ± 6

Blood pressure measurements

After a 5-min rest in the seated position, blood pressure was measured three times during two different visits to the laboratory. On the occasion of each visit, blood pressure was measured by the same experienced observer using a standard mercury sphygmomanometer (ALPK2, Japan), taking the first and the fifth phases of Korotkoff sounds as systolic and diastolic values, respectively. Participants were excluded if the average of the last two values obtained during each visit for systolic and diastolic blood pressures was greater than 139 and 89 mmHg, respectively. We are aware that intra-arterial pressure measurement is considered the golden standard method for assessing blood pressure and that the auscultation method tends to underestimate this parameter. However, the intra-arterial measurement is an invasive procedure that might put participants at risk, which leads to a recommendation to avoid its use in healthy subjects Perloff et al., (1993), Raftery, (1991). Mean blood pressure was calculated by the sum of diastolic blood pressure and one third of pulse pressure.

1RM test

At least 10 days prior to the experiments, participants underwent a 1RM test for the five dynamic constant external resistance exercises (standing two-arm curl, hamstring curl, parallel squat, seated lat pull-down and supine bench press). Resistance exercises were performed using free weights or a universal weight machine station (hamstring curl and seated lat pull-down). Before the test, they underwent four familiarization sessions (3 sets, 20 repetitions of each exercise with the minimum weight allowed by the machines) in non-consecutive days.

Study protocol

Resting protocol: To determine any potential diurnal variations in blood pressure, all of the participants performed a non-exercise control trial three days before the study.

During this trial, the participants were submitted to the same experimental protocol used in the exercise trials, they rested in the seated position for 90 min. Prior to any exercise, the participants visited the laboratory for anthropometric measurements. During this session, height (cm), weight (kg) and resting blood pressure (mmHg) were determined. All of the participants completed four experimental trials (in a randomized determination of intensity and volume per session) exercising at 40 and 80% of 1RM, two sessions at 40% and two sessions at 80% 1RM with different volumes. Each trial was separated by a minimum of four days. Exercise trials were conducted in the early afternoon to control for diurnal variation in blood pressure. Participants were instructed not to exercise 48 h prior to the exercise trials, and to maintain similar activities and meal patterns. Ambient temperature was controlled between 22 and 24°C.

In SHORT volume LOW intensity (SL) and LONG volume LOW intensity (LL) at 40%1RM, the SL performed 3 and LL 6 sets of 20 repetitions of the 5 exercises cited above, with a workload corresponding to 40% of 1RM, and an interval of 30s between the sets and 60s between the exercises. In SHORT volume HIGH intensity (SH) and LONG volume HIGH intensity (LH) at 80% 1RM, the SH performed 3 and LH 6 sets of 10 repetitions with a workload corresponding to 80% of 1RM, with an interval of 50s between sets and 90s between the exercises (Table 2). In each session (before the exercise), participants rested in the seated position on a chair for 20 min (pre-intervention period). After the exercise sessions, the participants rested in a seated position on chair for 90 min, and at this time blood pressure was measured at 10-min intervals. Blood pressure was recorded by the same observer in all the exercise trials. Heart rate was monitored during exercise by Polar (S810).

Table 2. Sessions characteristic

Sessions	Set	Repetition	Rest between sets (s)	Rest between exercises (s)
SL (Short volume, Low intensity)	3	20	30	60
LL (Long volume, Low intensity)	6	20	30	60
SH (Short volume, High intensity)	3	10	50	90
LH (Long volume, High intensity)	6	10	50	90

Statistical analysis

Baseline levels in different exercise trials were analyzed by a one-way analysis of variance for repeated measures. Blood pressure responses after exercise were evaluated by a two-way analysis of variance (ANOVA) for repeated measures, establishing exercise intensity (40 and 80% of 1RM), volume (3 and 6 sets) and recovery stages (baseline, 10-min intervals) as the main factors. When significance was found, the LSD test was employed. $P<0.05$ was accepted as being statistically significant. Data are reported as mean ± SEM.

RESULTS

During resting trial, systolic (−0.2±1.2 mmHg), diastolic (+0.3±1.3 mmHg) and mean blood pressure (+0.1±2.4 mmHg) did not change significantly ($P<0.05$).

Blood pressure. Systolic, mean and diastolic blood pressure changes observed in all the exercise trials are shown in Figure 1. Baseline systolic and diastolic blood pressures were similar in all exercise trials (SL, SH, LL and LH). In comparison with the pre-exercise values, systolic blood pressure decreased similarly for 60 min after SL, SH, LL and LH exercise trials (SL: −6.2±3.4, SH: −7.1±2.8, LL: −6.3±3.2, LH: −6.7±2.5 mmHg, $P<0.05$), while diastolic blood pressure presented no change after any trials. Mean blood pressure decreased similarly for 60 min after SL, SH, LL and LH exercise trials (SL: −4.8±3.7, SH: −4.9±2.1, LL: −4.2±2.5, LH: −4.1±3.5 mmHg, $P<0.05$).

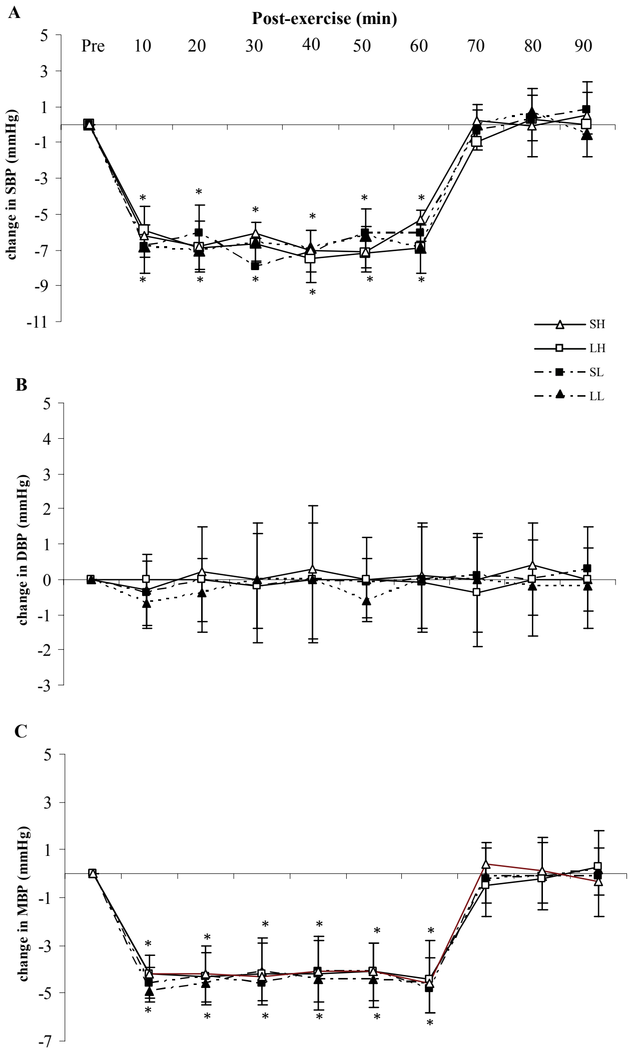

Fig. 1. Post-exercise Systolic (SBP), mean (MBP) and diastolic (DBP) blood pressure changes following SH, LH, SL and LL exercise trials

*Significantly different from pre-exercise ($p<0.05$)

DISCUSSION

The purpose of this investigation was to study the effects of LOW and HIGH intensity, along with SHORT and LONG volume resistance exercise on post-exercise hypotensive responses in normotensive males. The main findings of the present study are: 1) a single bout of resistance exercise provoked PEH in young normotensive humans; however, only systolic blood pressure decreased, which persisted for 60 min; 2) the intensity and the volume of resistance exercise did not play significant roles in determining the occurrence or the magnitude and duration of PEH.

Exercise intensity and volume plays role in hemodynamic, thermoregulatory and neural responses during exercise, and it was expected that different exercise intensities and volumes would determine distinct post-exercise blood pressure responses. However, this was not the case in the present study, in which the exercise performed at an intensity of 40 or 80% of 1RM and volume 3 or 6 sets (per stations) provoked similar hypotension during the recovery period.

The effect of resistance exercise on recovery blood pressure is not well understood. As regards of resistance exercise intensity, Focht & Koltyn (1999) reported systolic blood pressure increased immediately after the session with 80% of 1RM and diastolic blood pressure decreased after the session with 50% of 1RM. Both returned to base line in the 20 min measurement. In a separate study, O'Connor, Bryant, Veltri & Gebhardt (1993) failed to induce a hypotensive response in either systolic blood pressure or diastolic blood pressure following upper and lower-body exercise at 40, 60, and 80% of 1RM. According to study of Rezk, Marrache,Tinucci & Forgaz (2006), systolic blood pressure and diastolic blood pressure decreased for 90 and 30 min, respectively, following resistance exercise at 40% of 1RM. In addition, Simao, Fleck, Polito, Monterio & Farinatti (2005) reported PEH after intense resistance exercise vs low intensity (6RM vs 50% 6RM) which was longer in duration (60 min vs 50 min). Also, as regards of resistance exercise volume, Polito et al.,\, (2003) observed long volume of resistance exercise (12 repetitions) rather than short volume (6 repetitions), provoked a longer decrease in systolic blood pressure (60 min vs 40 min). Similarly, Boroujerdi et al., (2009) reported that the PEH in systolic blood pressure after higher intensity (85%1RM vs 42.5%1RM) was longer in duration (60 min vs 30 min). In contrast, Simao et al., (2005) reported that exercise volume (5 vs 6 exercises) had no effect on PEH. Furthermore, Mediano, Paravidino, Simao, Pontes,\ & Polito (2005) showed that systolic blood pressure decreased for 40 min after 1 series (short volume), 60 min after 3 series (long volume) and diastolic blood pressure decreased after 30 and 50 min after 3 series. However, in the present study, the exercise performed at 40 or 80% of 1RM in 3 and 6 sets provoked similar hypotension during the recovery period. Conflicting results (our results compared to those from previous studies) regarding recovery blood pressure may be related to the investigated population. We used sedentary participants, whereas Boroujerdi et al., (2009), Focht & Koltyn (1999), and Polito et al., (2003), employed trained subjects. Exercise training provokes changes in vasodilator capacity Martin et al., (1991) and the regulation of arterial pressure (Raven & Pawelezyk, 1993) which may influence recovery blood pressure. Also, Mediano et al., (2005) studied older hypertensive humans, while we investigated young normotensive males, it is well understood that older hypertensive subjects have vascular musculature alterations and decreased baroreceptor sensitivity Pescatello et al., (2004); Ebert, Morgan, Barney, Denahan, & Smith (1992), which may modify post-exercise hemodynamic responses. Moreover, resistance protocols typically differ among studies, and these differences may likely be responsible for some of the variations seen in the results. The rest intervals, exercising muscular mass and stations of resistance exercise in the current study differed in regard to Rezk et al., (2006), Simao et al., (2005) and O'Connor et al., (1993) studies. The resulting differences in the degree of metabolic stress produced by these different protocols may be enough to affect recovery blood pressure. In our trial, different exercise intensity had no effect on systolic blood pressure and diastolic blood pressure. This fact had already been reported by Brown, Clemons, He, & Liu (1994), as they have show no significant different between the magnitude and the duration of the post-exercise hypotensive response when present at intensities at 40 to 70% of 1RM.

The mechanism or mechanisms responsible for the post-exercise hypotensive response are unclear. It is thought that PEH is due to reductions in peripheral vascular resistance (Pescatello et al., 2004). Although the mechanisms for the persistent vasodilation underlying PEH are poorly understood, exercise-mediated alterations in sympathetic nervous system function and vasculature responsiveness and baroreflex resetting to a lowering operating blood pressure have been implied Pescatello et al., (2004). MacDonald (2002), Halliwill, Taylor & Eckberg (1996). It was not the purpose of the present study to examine the causal mechanisms of PEH. However, it is apparent from our study that LOW intensity and SHORT volume exercise are a sufficient stimulus to evoke the neural and vascular changes that have been postulated to result in PEH after higher intensity or longer volume exercise. A number of studies reported that release of local substances [potassium (K^+), nitric oxide, prostaglandins, adenosine, ATP], which are effective for peripheral vasodilatation and/or the reduction of blood volume, may be the mechanisms responsible for PEH Wilkins, Minson & Halliwill (2004), MacDonald (2002). The releases of local substances are related to the exercise intensity Wilkins, Minson & Halliwill (2004). Therefore, since in this study PEH was not dependent on exercise intensity, it is unlikely that the release of local substances during exercise is a mechanism of PEH. Also, it is known that the reduction of blood volume is related to the duration of exercise, MacDonald (2002). Since in the present study PEH was not dependent on exercise duration, it would appear unlikely that reductions in blood volume are responsible for PEH. Further work, however, is needed to better clarify how different doses of exercise influence the mechanisms for the immediate blood pressure-lowering effects of resistance exercise.

There is evident that the hypotensive response lasts up to 17 hours following endurance exercise Jones, Pritchard, Keith, Ben, & Atkinson (2008), Pescatello et al., (2004). However, our data as well as previous data indicate that after resistance exercise, the hypotensive response, when present, is less than 10 min long (Brown et al., 1994; O'Connor et al., 1993) or is at most 60 min long (Boroujerdi et al., 2009; Polito et al., 2003; MacDonald et al., 1999). Why the hypotensive response following resistance exercise is substantially shorter in duration compared to endurance exercise is unclear. We studied the impact of acute resistance exercise on hypotensive responses in young male subjects for 90 min. It is known that gender and age might influence hemodynamic and neural responses in certain situations (Rezk et al., 2006; Polito & Farinatti, 2006). It is possible that other intensities or volumes could have distinct effects on post-exercise hypotensive responses. Thus, future studies should address the effect of varying intensity and volume of exercise on post-exercise hypotensive responses in women and other age group for longer periods of time.

CONCLUSION

Although more work is warranted to accurately describe the characteristics of PEH, it seems plausible that acute exercise may aid the non-pharmacological control of hypertension. Vigorous exercise can acutely and transiently increase the risk of sudden cardiac death and acute myocardial infarction in susceptible individuals (Thompson et al., 2007). It appears that the intensity and duration of resistance exercise need not to be greater and longer than 40% of 1RM and average 15 min, respectively. If true resting blood pressure is to be obtained after a resistance training bout, it should not be obtained within 60 min of the last bout. However, given that the our data show a significant systolic hypotensive response with one bout of the resistance exercise protocols at 60 min post-exercise, the practice of not obtaining resting blood pressure until at least several hours after the last exercise bout seems appropriate.

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HIPOTENZIVNI ODGOVOR NA RAZLIČITI INTEZITET I JAČINU VEŽBI OPTEREĆENJA

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Cij ovog istraživanja bio je da se istraže efekti intenziteta i obima vežbi sa opterećenjem na hipotenzivni odgovor na vežbe. Desetorica normotenzivnih muškaraca (starosti 22±0.8; visine 173.6±2.4 cm i težine 67.2±3.4 kg) je učestvovalo u ovom istraživanju. Učesnici su uradili četiri organizovanih sesija vežbi sa opterećenjem KRATKOG obima (3 seta) pri SLABOM intenzitetu (40%1RM) [SL] i VISOKOM intezitetu (80%1RM) [SH], DUGOG obima (6 seta) pri NISKOM intenzitetu (40%1RM) [LL] i VISOKOM intenzitetu (80%1RM) [LH] (vežbe: vežbe za bicpse na nogama, istezanja potkolenice, paralelni čučnjevi, lateralna istezanja u sedećem stavu i potisak na klupi u ležećem stavu). Krvni pristisak meren je pre vežbi (referentne vrednosti) i pri intervalima od 10 min sve do isteka 90 min nakon vežbanja. Sistolni krvni pritisak se isto smanjivao 60 min nakon SL, SH, LL i LH vežbanja, dok se dijastolni pritisak nakon vežbanja nije menjao. Možemo da zaključimo da intenzitet vežbanja sa opterećenjem (40 vs 80%1RM) i obim (3 vs 6 seta) kod normotenzivnih muškaraca nije uticao na jačinu hipotenzije po isteku vežbanja.

Ključne reči: *hipotenzija, vežbanje sa opterećenjem, kardiovaskularni odgovor, krvni pritisak*