EFFECT OF CONCURRENT EXERCISE ON POST-EXERCISE HYPOTENSION IN BORDERLINE HYPERTENSIVE WOMEN: INFLUENCE OF EXERCISE INTENSITY

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Abstract:

The aim was to investigate the effects of concurrent exercise at moderate (MO) and light (LI) intensity on post-exercise hypotension (PEH). Ten women with borderline hypertension were submitted to the experimental procedure consisting of three sessions. In the MO session, the participants ran on the treadmill for 22 minutes at 65% of HR_{max} and then performed 5 resistance exercises against resistance corresponding to 65% of 1RM. In the LI trial, they performed a similar sequence but with intensity of 40% of HR_{max} and 1RM for the endurance and resistance exercise, respectively. The participants rested in a non-exercise control trial (C). The blood pressures were assessed prior and post exercising after 15, 30, 60, 90 and 120 minutes, and after four, five and six hours of recovery. A significant PEH of systolic blood pressure from the resting value was observed after the MO exercise bout at all time points, while the systolic blood pressure following the LI exercise trial decreased significantly only after the fourth hour compared to the resting value. PEH of diastolic blood pressure occurred after both LI and MO for 120 minutes and 5 hours compared to pre-exercise values, respectively. Blood pressure responses were not significantly altered during the C trial. This study suggests that a bout of concurrent endurance and resistance exercise provoked PEH in borderline hypertensive women up to six hours after exercise. However, concurrent exercise at MO intensity resulted in a longer PEH for both systolic and diastolic blood pressure compared to LI intensity.

Key words: *concurrent exercise, post-exercise hypotension, exercise intensity*

Introduction

Hypertension is one of the most important public health risks worldwide and is regarded as one of the most significant cardiovascular risk factors (Ljubotina, et al., 2011). Although pharmacological intervention is the primary treatment for hypertension, physical training is considered to be an important factor of management and therapy (Taylor, et al., 2010; Pescatello, et al., 2004a; Lizardo, Silveira, Vassallo, & Oliveira, 2008).

Recently, researchers' attention has been paid not only to the benefits of the cardiovascular effects of exercise training, but also to the effects resulting from a single acute exercise session (Lizardo, et al., 2008). It has been shown that after a bout of physical exercise, blood pressure levels decrease within minutes and persist so lowered for hours in relation to pre-exercise levels (MacDonald, 2002; Pescatello, et al., 2004a). This phenomenon in either systolic or diastolic blood pressure is called post-exercise hypotension (PEH). The PEH has been widely investigated because it is of great importance for the treatment and prevention of hypertension (MacDonald, 2002). If this is the case, an acute bout of exercise, which is repeated regularly, might become an important non-pharmacological tool in the management of hypertension (Cornelissen & Fagard, 2004). The PEH mechanism/mechanisms are poorly understood. PEH may be due to a barorreflex resetting itself to a lower operating blood pressure and a reduction in the α-adrenergic vasculature responsiveness (Pescatello, et al., 2004a). On the other hand, PEH may be the result of vasodilator metabolites released from skeletal muscles, which may precipitate a lowered peripheral vascular resistance (Brown, Clemons, He, & Liu, 1994). The vasodilatory effect may also be precipitated by increasing some vasodilating hormones, the core temperature and acidity resulting from exercise (McArdle, Katch, & Katch, 1991; Halliwill, 2001).

Some studies have focused on the PEH in normotensive individuals (Boroujerdi, Rahimi, & Noori, 2009; Mohebbi, Rahmani-Nia, Sheikholeslami, & Faraji, 2010; Faraji, Bab, & Ardeshiri, 2010; Simao, Fleck, Polito, Monterio, & Farinatti, 2005; Forjaz, Matsudaira, Rodrigues, Nunes, & Negaro, 1998) and reported that PEH may last for as long as two hours in their subjects, whereas other studies found that PEH lasts several hours in hypertensive individuals (Quinn, 2000; Pescatello, et al., 2004b; Pescatello, Fargo, Leach, & Scherzer, 1991; Marceau, Kouame, Lacourciere, & Cleroux, 1993). Evidences showed that the magnitude and duration of PEH may be affected by the exercise intensity and duration/volume, the population (normotensive or hypertensive) and the exercise type (endurance or resistance exercise) (MacDonald, 2002; Pescatello, et al., 2004a; Halliwill, 2001).

Previous studies have reported that PEH can be detected after several exercise modalities, such as cycle ergometry, treadmill running and resistance exercises (Mohebbi, et al., 2010; Vriz, et al., 2002; Cornelissen & Fagard, 2004). Most of these research studies measured only the blood pressure in normotensive humans and/or for a short-time period in the range of one to four hours. To our knowledge, however, the impact of concurrent exercise in borderline hypertensive individuals on PEH for a long time (over four hours) has not been reported yet. In recent years, concurrent resistance and endurance exercise have received much attention as a form of training. Concurrent exercise, in which resistance and endurance exercises are combined or included in the same training sessions or programmes, has been studied in the search for new methods to enhance with positive changes in body composition, the development of strength and aerobic capacity, as well as cardiovascular adaptations (Chtara, et al., 2008; Davis, Wood, Andrews, Elklind, & Davis, 2008). However, only one study has investigated hypotensive response after a combined arm and leg ergometry exercise for 60 minutes (MacDonald, MacDougall, & Hogben, 2000). Nevertheless, in order to use concurrent exercise as a non-pharmacological tool in the management of hypertension, more knowledge in this context is required to evoke PEH.

In view of these considerations, our primary aim was to investigate the effect of concurrent exercise on PEH in borderline hypertensive women. The secondary aim was to investigate the role of the concurrent exercise intensity during PEH, since PEH may be affected by exercise intensity (Cornelissen & Fagard, 2004).

Methods

Subjects

Our sample consisted of 10 borderline hypertensive women (aged 37.6±6.5 years; 80.8±6.2 kg; 170.2±6.9 cm). Based on previous studies, the responses of PEH to exercise were conducted to ensure that this number of participants would be adequate to yield significant results (MacDonald, et al., 2000; Boroujerdi, et al., 2009).

According to previous medical screening of four measurements after a 10-minute rest in the sitting position, the participants were classified as borderline hypertension (systolic blood pressure higher than 135 mmHg and lower than 150 mmHg, diastolic blood pressure higher than 85 mmHg and lower than 95 mmHg) in agreement with the American College of Sport Medicine's (ACSM) Position on Blood Pressure (Pescatello, et al., 2004a). The subjects had exercise experience of at least six months. This study was limited to females to reduce the gender variation in blood pressure response to the exercise (Hayward & Kelly, 1997). The study design was approved by the university's institutional Review Board before data collection. All the subjects were properly informed about the study procedures and gave a signed written consent. The blood pressure of the participants was controlled pharmacologically during the study. Two subjects were taking beta-blockers agents, but the other participants did not take any medication. The subjects were asked to avoid smoking, alcohol, medications and exercise 48 hours prior to the exercise trials, and to maintain light and similar meal patterns and activities.

Exercise protocols

During the first visit to the laboratory, the subjects performed one repetition maximum (1RM), for the purpose of determining their lower and upper body maximal strength.

The 1RM test was perfected for each of the five resistance exercises and 65% of 1RM selected as represented workload used in the experimental sessions. The subjects then completed three sets of 15 repetitions of five different resistance exercises at 60% of 1RM as a familiarization session. The order of resistance exercises was as follows: shoulder press, lat pull-down, leg press, knee extension and leg curl.

The subjects carried out three experimental sessions in a randomized design. Each session started at 9:00 a.m., on distinct days and with a minimum of 72-hour intervals. Three experimental sessions were: moderate concurrent exercise (MO), light concurrent exercise (LI) and a control session without exercise (C).

In the MO session, the participants ran on the treadmill for 22 minutes at 65% of the maximum heart rate (HR_{max}), calculated from *220 – age* equation, and then performed a resistance exercise as three sets of 12 repetitions of the five exercises cited previously, with a workload corresponding to 65% of 1RM, with intervals of 50 s and 60 s between the sets and exercises, respectively. In the separate trial

(LI), the subjects performed a similar sequence but with the intensity of 40% of HR_{max} and 1RM (for endurance and resistance exercise, respectively). The treadmill velocity and heart rate were controlled continually during the exercise. Verbal encouragement was provided during the testing procedure.

Control session. To control any variations in the blood pressure status that may have occurred as a result of the diurnal variations, the subjects performed a non-exercise control (C) session. During the C session, they rested in a seated position for the period corresponding to the exercises.

In each session (MO and LI or C), the systolic and diastolic blood pressure were measured before and after exercise at 15, 30, 60, 90 and 120 minutes in a sitting position on a chair. These blood pressure assessments were also performed after lunch at four, five and six hours of recovery. During the afternoon period, the participants were allowed to walk or sit in the laboratory. Resting systolic and diastolic blood pressure was obtained every five minutes (until 20 minutes). Blood pressure was recorded by a standard mercury sphygmomanometer (Yamasu, Japan) and heart rate (HR) was automatically monitored (Polar, S810). All measurements were taken by the same experienced investigator. The laboratory temperature was controlled between 22 and 25°C.

Statistical analysis

The Statistical Package for Social Sciences (SPSS v. 14®, Inc. Chicago, IL) was used for all descriptive statistics. A two-way repeated-measures analysis of variance (ANOVA) was used to determine the training-related effects in each of the dependent variables over a period of time. When significant differences were found, the Bonferroni *post-hoc* test was used. The results are reported as means±standard deviation. The level of significance was set at $p<.05$.

Results

Changes in the systolic and diastolic blood pressure from baseline values (pre-exercise) to six hours post-exercise in all groups are presented in Figure 1. Baseline systolic and diastolic blood pressures were similar in all the experimental trials.

During the control trial, systolic (+1.8±4 mmHg) and diastolic blood pressure (+0.7±3 mmHg), did not change significantly ($p>.05$).

A significant PEH of systolic blood pressure ($p<.05$) was observed after the MO bout (−11.6±8 mmHg) at all time points from the resting value (139.3±10 mmHg), while the systolic blood pressure following the LI trial decreased significantly (−11.8±13 mmHg) only after the fourth hour compared to the resting value (140.8±11 mmHg) ($p<.05$).

Regarding the control session, the systolic blood pressure levels in the MO bout were significantly different at all time points. However, this difference was prolonged after 120 minutes following the LI bout.

Post-exercise hypotension of diastolic blood pressure occurred after both LI (−10.9±10 mmHg) and MO (−10.6±9 mmHg) for 120 minutes and five hours compared to pre-exercise resting values, respectively ($p<.05$).

Discussion and conclusions

In the field of exercise and hypertension, PEH is important to help the control of blood pressure, especially in hypertensive patients (Pescatello, et al., 2004a). Scientific evidence demonstrates that the average PEH was approximately 8/9 mmHg in the normotensive humans, 14/9 mmHg in the borderline hypertensive subjects and 10/7 mmHg in the hypertensive population (MacDonald, 2002). Therefore, assessing the blood pressure responses to exercise with different characteristics in order to define better prescription strategies for subjects with cardiovascular disease is important.

The current research investigated the effect of concurrent exercise at moderate (MO) and light (LI) intensity on PEH in borderline hypertensive women. The main findings of this study were: (a) concurrent exercise evoked PEH in borderline hypertensive humans and (b) the intensity of the concurrent exercise plays a significant role in the duration of PEH in the period afterwards.

Although previous studies reported PEH after endurance or resistance exercise separately (Boroujerdi, et al., 2009; Mohebbi, et al., 2010; Faraji, et al., 2010; Simao, et al., 2005; Forjaz, et al, 1998; Quinn, 2000; Pescatello, et al., 2004b; 1991; Marceau, et al., 1993), we have shown that PEH can also be evoked if resistance and endurance exercises were combined. This result is novel and indicates the public health benefits that could be realized by people with borderline hypertension if they habitually engage in concurrent exercise.

Despite the fact that PEH can be detected in normotensive individuals, it was found to be much less consistent and of lesser magnitude than in hypertensive individuals (MacDonald, 2002; Pescatello, et al., 2004a; Halliwill, 2001). However, in this work, PEH was observed after both MO (systolic: −11.6±8 mmHg; diastolic: −10.6±9 mmHg) and LI (systolic: −11.8±13 mmHg; diastolic: −10.9±10 mmHg) bouts in borderline hypertensive humans. In this study, the mean PEH values were close to that reported by previous research studies in the borderline hypertensive subjects (14/9 mmHg). A decrease in systolic and diastolic blood pressure, even at small levels (2 mmHg), decreases the risk of stroke by 14% and 17% and the risk of coronary artery disease by 9% and 6%, respectively (Whelton, et al., 2002).

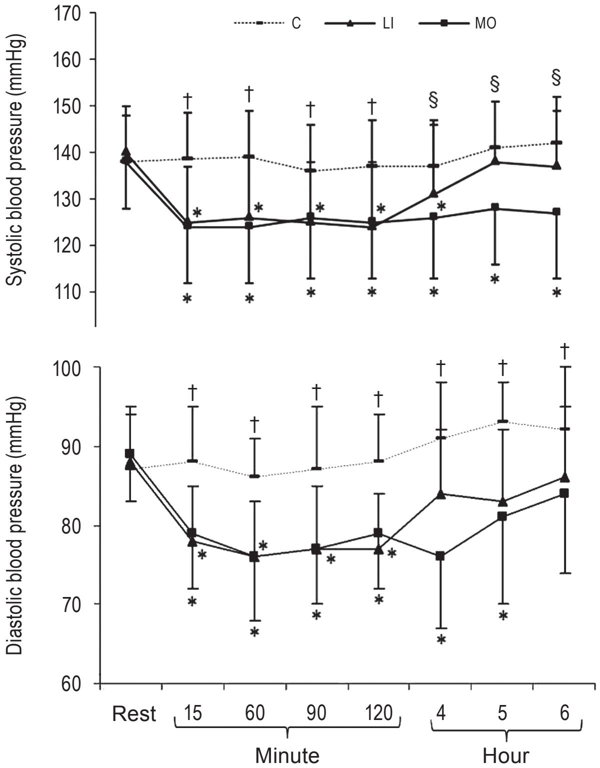
In this study we employed endurance training before strength training, since previous researchers found that conducting endurance training before strength training in a concurrent chronic exercise protocol improved the cardiovascular adaptations more than the reverse sequence in both men and women (Kraemer, et al., 2001; Davis, et al., 2008). In addition, the previous data of ours had shown that endurance before resistance exercise vs reverse exercise form resulted in a greater PEH for systolic blood pressure (Delavar & Faraji, 2011).

Because of the scarcity of literature about the effect of acute concurrent exercise on PEH responses, it is difficult to compare results obtained in the present research with other data (acute endurance or resistance exercise separately). However, the reduction in blood pressure levels after a single exercise bout is in agreement with the results reported by the previous studies regarding PEH after endurance (i.e. treadmill or cycle ergometer) and resistance exercise for normotensive, borderline hypertensive and hypertensive subjects (Boroujerdi, et al., 2009; Mohebbi, et al., 2010; Faraji, et al., 2010; Simao, et al., 2005; Forjaz, et al, 1998; Quinn, 2000; Pescatello, et al., 2004b; Pescatello, et al., 1991; Marceau, et al., 1993).

In the present research, the effect of concurrent exercise at light and moderate intensity was examined on PEH among women with borderline hypertension. Although some researchers reported that exercise intensity did not influence the magnitude and duration of PEH in healthy normotensive women, it has shown that higher intensity exercises may evoke a more pronounced PEH response than moderate ones in the same group (Quinn, 2000; Rezk, Marrache, Tinucci, Mion, & Forjaz, 2006). Furthermore, some studies suggest that a slightly higher exercise intensity elicits a greater effect on blood pressure than a lower intensity. Quinn (2000) suggested that 75% of maximum oxygen uptake (VO_{2max}) appears to offer a more sustained and substantial reduction in both systolic and diastolic blood pressure compared to a 50% work bout in 16 hypertensive patients. In fact, the 75% exercise intensity significantly reduced the systolic blood pressure for 10.5 hours (15.4 hours) versus 5.8 hours (2.7 hours) for the 50% intensity exercise in the hypertensive men (women), and diastolic blood pressure for an average of 11.9 hours (9.8 hours) versus 5.5 hours (2.9 hours), respectively. In another study, Pescatello et al. (2004b) examined the influence of one bout of light exercise (40% of VO_{2max}) and of moderate exercise (60% of VO_{2max}) in 49 middle-aged men with high normal to stage one hypertension on PEH. They observed, for the first five hours after exercise, that the PEH was greater after moderate exercise. However, for the remainder of the day, light exercise appeared to be as effective as moderate exercise in evoking PEH. In addition, Marceau et al. (1993) showed that a higher intensity of exercising (70% of VO_{2max}) produced greater benefits, especially during the evening and sleeping hours, compared to a lower intensity exercising (50% of VO_{2max}) in eleven sedentary subjects with mild to moderate hypertension. In the current research, the MO exercise bout was more effective in decreasing both the systolic and diastolic blood pressure than the LI exercise. We observed a significant PEH of systolic blood pressure after MO at all measurement time points, while LI trial provoked PEH in systolic blood pressure for up to four hours. Also, a decrease in the diastolic blood pressure following MO was prolonged to five hours, but LI evoked PEH of the diastolic blood pressure for 120 minutes. Although we used concurrent exercise in this study, a convergence of the cited results for an acute effect of exercise intensity on PEH is noteworthy, and suggests that higher intensity exercises may have stronger effects on both systolic and diastolic blood pressure than light exercises.

The reasons for these observations are unclear, and it was not the aim of this study to examine the causal mechanisms of PEH. However, one possible explanation as suggested by Pescatello et al. (2004b), would be the sympathetic inhibition or functional sympatholysis, defined as an intensity-dependent blunting of responsiveness to α and β-adrenergic receptor stimulation and/or reduced noradrenaline releases which are more pronounced after moderate exercise than light exercise over this time period (Cornelissen & Fagard, 2004). Another possible explanation may reside in the proposed mechanisms for PEH which include exercise-induced alterations in baroreceptor function, i.e. either a shift to a lower blood pressure operating point or an increased responsiveness to changes in the blood pressure during the post-exercise period (Hallliwill, 2001). It is possible that exercise-induced alterations in baroreceptor function contributed similarly to the lowering of the blood pressure of either MO or LI initially. However, over a period of time other PEH mechanisms became operative that augmented the blood pressure benefits of MO for the remainder of the hours afterwards. In addition, it is possible that the observed longer PEH after higher intensity (MO vs LI) was related to higher vasodilating hormones, metabolic stress, core temperature and acidity induced by the MO exercise bout. For better explanation of these different exercise responses of blood pressure to different intensities more research is needed, and it is also necessary to examine the possible mechanisms.

In the case of the C session, blood pressure levels rose (+2.5±4 mmHg) afterwards compared to the initial levels (Figure 1). This increase was not significant, but it is possible that this phenomenon has been due to the higher activity of the sympathetic nervous system and the higher levels



* Significantly different in comparison with pre-exercise (p<.05)
† Significantly different in comparison with LI or MO
§ Significantly different in comparison with MO

Figure 1. Post-exercise changes in systolic and diastolic blood pressure following concurrent exercise at light (LI) and moderate (MO) intensity, and control session (C)

of catecholamine observed at the end of the session (Park, et al., 2006). Despite the fact that the diastolic blood pressure after LI session was not below the compared resting level afterwards, it remained significant below the C condition. However, despite any influence of the diurnal variations in the blood pressure, it becomes clear from this result that concurrent exercise was able to attenuate the subjects' blood pressure over a period of time.

Limitations: Two subjects were using beta-blockers agents during the study course. However, the medication intake was the same in all the experimental sessions, and it is verified that exercise associated to medications, such as beta-blockers, did not impair the PEH (Wilcox, Bennet, Macdonald, Broughton, & Baylis, 1987).

We studied the influence of acute concurrent exercise on blood pressure responses in middle-aged borderline hypertensive women for six hours. It is possible that gender, resting blood pressure levels, and age might influence the hemodynamic and neural responses in certain situations (MacDonald, 2002). Moreover, other exercise characteristics such as different concurrent exercises, intensity and duration of exercise could have distinct effects on the PEH responses. On the other hand, we examined the PEH up to six hours of recovery. Thus, we do not know whether the decreased systolic blood pressure after MO exercise persists longer than six hours. However, previous data about the extended impact of physical activity showed that the hypotensive response could persist for up to ten (Melo, Alencar, Tinucci, Mion, & Forjaz, 2006) and twenty-two hours (Pescatello, et al., 2004a) following resistance and endurance exercise in hypertensive individuals, respectively.

In conclusion, this study revealed that a bout of combined endurance and resistance exercise provoked PEH in borderline hypertensive women up to six hours after exercise. This effect may aid the non-pharmacological control of hypertension and prevent the risk factors associated with cardiovascular disease. However, concurrent exercise with moderate intensity resulted in a longer PEH for both systolic and diastolic blood pressure compared to light intensity exercise.

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UČINCI PRIMJENE KONKURENTNOG TRENINGA NA POJAVU HIPOTENZIJE NAKON VJEŽBANJA U GRANIČNO HIPERTENZIVNIH ŽENA: UTJECAJ INTENZITETA VJEŽBANJA

Cilj je ovog istraživanja bio istražiti učinke konkurentnog treninga provedenog umjerenim (MO) i laganim (LI) intenzitetom na pojavu hipotenzije nakon tjelesnog vježbanja. U istraživanje, koje se sastojalo od tri eksperimentalne trenažne jedinice, bilo je uključeno deset granično hipertenzivnih žena. Na treningu koji je bio proveden umjerenim intenzitetom ispitanice su 22 minute trčale na pokretnom sagu intenzitetom od 65% maksimalne frekvencije srca (FS_{max}) te su nakon toga provele trening s opterećenjem (5 vježbi) u kojemu je trenažno opterećenje bilo 65% 1RM. Na drugom treningu, koji je bio proveden laganim intenzitetom, ispitanice su izvodile iste vježbe istim redoslijedom samo opterećenjem od 40% FS_{max} u trčanju na pokretnom sagu, odnosno 40% 1RM u dijelu treninga s opterećenjem. Ispitanice su se odmarale tijekom treće, kontrolne, trenažne jedinice. Krvni tlak je mjeren prije i nakon vježbanja, i to: 15, 30, 60, 90 i 120 minuta te 4, 5 i 6 sati tijekom odmora. Značajna hipotenzija sistoličkog tlaka zabilježena je nakon vježbanja umjerenim intenzitetom u svim vremenskim mjernim točkama, dok je nakon vježbanja laganim intenzitetom sistolički krvni tlak bio značajno ispod razine zabilježene u mirovanju tek nakon četvrtog sata odmora. Hipotenzija dijastoličkog tlaka, u odnosu na vrijednosti u mirovanju, zabilježena je nakon oba tipa treninga i to 120 minuta i pet sati nakon vježbanja za trening laganim odnosno umjerenim intenzitetom. Vrijednosti krvnog tlaka nisu se značajno mijenjale tijekom kontrolne trenažne jedinice. Ovo istraživanje sugerira da i akutni konkurentni trening može izaziva hipotenziju u granično hipertenzitivnih žena u trajanju do 6 sati nakon vježbanja. Ipak, konkurentni trening proveden umjerenim intenzitetom rezultirao je dužim trajanjem hipotenzije i sistoličkog i dijastoličkog tlaka u usporedbi s istim treningom provedenim laganim intenzitetom.

Ključne riječi: *konkurentna vježba, hipotenzija nakon vježbanja, intenzitet vježbanja*

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