ORIGINAL ARTICLE

Hypotensive Response to Continuous Aerobic and High-Intensity Interval Exercise Matched by Volume in Sedentary Subjects

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Abstract

Background: Systemic arterial hypertension (SAH) is one of the main risk factors for heart disease. Among the benefits linked to different modalities of physical exercise, post-exercise hypotension (PEH) is a key point for exercise prescription in this condition.

Objective: To investigate and compare PEH in response to continuous aerobic exercise (CONT) and high-intensity interval exercise (HIIE), matched by volume, in sedentary individuals.

Methods: A randomized cross-over study, composed of sedentary, healthy male subjects submitted to two acute physical exercise protocols matched by volume, HIIE and CONT, on a treadmill. Hemodynamic measures for the evaluation of PEH were performed pre, immediately after exercise and every five minutes thereafter, during one hour of recovery. Two-way ANOVA with repeated measurements was used for comparisons between groups and Bonferroni post hoc test as appropriate. $P < 0.05$ was considered significant.

Results: Both exercise protocols promoted significant PEH, with reductions in systolic blood pressure (SBP) and mean arterial pressure (MAP). HIIE promoted a reduction of SBP and MAP at the 15th minute, whereas the same effect was observed at the 30th following CONT.

Conclusion: Both HIIE and CONT, matched by volume, promote PEH of similar magnitude. However, PEH occurs earlier following HIIE, suggesting a better time / effectiveness ratio, and an additional beneficial effect of this modality. (Int J Cardiovasc Sci. 2019;32(1)48-54)

Keywords: Hypertensio/physiopathology; Cardiomegaly; Sedentarsm; Adherence Guidelines; Blood Pressure; Post –Exercise hypotension; Exercise; High-Intensity Interval Exercise.

Introduction

Systemic arterial hypertension (SAH) is a multifactorial chronic disease associated with metabolic and hormone dysfunctions, myocardial hypertrophy and lifestyle.[1] There is an exponential increase in the risk of cardiovascular events when systolic blood pressure (SBP) and diastolic blood pressure (DBP) are above 115 and 75 mmHg, respectively. Increments of 20 mmHg in SBP or 10 mmHg in DBP increase the risk for cardiovascular events by 100%.[2]

Nonpharmacological, low-cost strategies for prevention and treatment of SAH include regular physical exercise and interventions supported by national and international guidelines as primary strategy for the treatment of SAH.[3,4] Physical exercise cause physiological changes including post-exercise hypotension (PEH), which can effectively attenuate myocardial overload in SAH.[5]

Studies have demonstrated the occurrence of PEH in response to continuous aerobic exercise (CONT),[5] resistance exercise,[6] and more recently, to high-intensity

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interval exercise (HIIE).[7] In fact, both aerobic and resistance exercises have similar effects on PEH, with slightly stronger effects of CONT.[8] Besides, interval exercise protocols have drawn attention from scientific community, as they promote an increase in peak oxygen consumption, insulin sensitivity and mitochondrial enzymes, at the same proportion as observed with traditional continuous exercises in sedentary subjects, although these types of exercises require five-fold higher exercise volume as compared with HIIE.[9]

Regardless of the type of exercise, volume seems to be determinant for the magnitude of cardiovascular responses, influencing PEH. In this context, the effects of CONT and HIIE, adjusted for equivalent volumes, on hemodynamic variables are unknown. Therefore, the current study aims to investigate and compare PEH in response to HIIE and to CONT, matched by volume, in young sedentary individuals.

Methods

Subjects

Thirteen men aged 20-30 years, with sedentary lifestyle for at least six months[10] and no history of diseases, were recruited by convenience through print media and online social media. The following exclusion criteria were used: (1) individuals unable to exercise due to physical or psychological limitations; and (2) individuals using ergogenic aids or tobacco.

The study was approved by the local ethics committee (approval number 2.202.349) and performed according to the Helsinki Declaration.

Experimental design

This randomized crossover study consisted of three days of evaluations separated by 72 hours. On day 1, measurements of blood pressure (BP), heart rate (HR) and body mass index (BMI) using a scale and a stadiometer were obtained, and ergometric test was performed to determine maximal heart rate (maxHR). On days 2 and 3, patients underwent two exercise sessions – HIIE or CON in a random sequence. The website www.randomizer.org was used for randomization of the experimental conditions.

Hemodynamic measurements

BP measurements were taken using a digital sphygmomanometer (Omron, HEM-907, Japan) previously validated.[11] Measures were taken with individuals in sitting position at rest. Resting BP was measured on the first day of evaluation, following the VII guidelines for hypertension of the Brazilian Society of Cardiology.[4] BP measurements were taken on exercise test days before, immediately after and every five minutes thereafter during a 60-min resting period. HR was measured using a heart rate monitor (Polar Electro Oy, V800, Finland) every time BP was taken. Double product (DP) was calculated by the formula DP = SBP x HR at predetermined time points.

Ergometric test and peak oxygen consumption (peak VO_2)

Maximal effort ergometric test was performed on a treadmill (Imbramed, ATL 10200, Brazil), following the Conconi protocol.[12] Initial velocity was set at 5 km/h, with increments of 1 km/h/minute. The tests were interrupted when two of the following criteria were met – HR above that predicted for age (220-age), perceived exertion ≥ 20 on Borg's scale[13] or voluntary exertion. Peak oxygen consumption was predicted using a formula previously validated for the Brazilian population.[14] All volunteers were verbally encouraged to reach maximal exertion during the tests.

Exercise protocol

Exercise protocols were conducted using a treadmill (Imbramed, ATL 10200, Brazil). The protocols were equalized by volume, or distance covered, i.e., in both protocols, the distance covered was 5 km.[15]

Continuous aerobic exercise (CONT)

After a 5-minute warm-up, treadmill velocity was adjusted to 70% of the maximal heart rate reached during the ergometric test. This velocity was maintained until the volunteers ran a total of 5 km.[15]

High-intensity interval exercise (HIIE)

After a 5-minute warm-up, the volunteers performed an intermittent 5-km running test, consisting of a 1-minute running at 90% of maximal heart rate followed by a 1- minute resting period at 60% of maximal heart rate.[15]

Statistical analysis

Normality of data distribution was analyzed by the Shapiro-Wilk test. Two-way ANOVA (conditions vs. time points) test for repeated measures was used for within-group and between-group comparisons, followed by post-hoc Bonferroni test as appropriate. A $p < 0.05$ was set as statistically significant. All data were analyzed using the Statistical Package for Social Sciences (SPSS) 20 software. Data were expressed as mean ± standard deviation.

Results

Characteristics of the sample are described in Table 1. No significant differences were found in SAP, DAP, mean arterial pressure (MAP) or HR between the exercise protocols at the pre-exercise moment. Higher HR was found in HIIE immediately after exercise as compared with CONT ($p = 0.02$). Exercise duration was shorter for HIIE compared with CONT ($p = 0.04$). Other descriptive variables of each experimental condition are described in Table 1.

Both conditions caused significant PEH. A significant reduction in SAP ($p = 0.01$) and MAP ($p < 0.01$) was observed at the 15th minute after HIIE, persisting until one hour thereafter. A significant reduction in SAP ($p = 0.04$) and MAP ($p = 0.01$) was observed at the 35th and 30th minute, respectively, after CONT, and hence the beneficial effect of PEH occurred later after CONT than HIIE. No significant changes in DAP were found during the exercise tests. Also, no significant differences were found between SAP, MAP and DAP between the conditions. Changes in BP in response to different exercise protocols are shown in Figure 1.

No differences were found in DP over the study period, except for the time immediately after the exercise, in which DP was higher in HIIE than in CONT ($p = 0.03$) (Figure 2).

Table 1 - Characteristics of the study group and exercise conditions

Variables	Mean ± standard deviation	
Age (years)	22.7 ± 2.6	
BMI (kg/m²)	25.3 ± 2.7	
Peak VO_2 (mL/kg/min)	35 ± 1.4	
Resting SBP (mmHg)	125.7 ± 7.8	
Resting DBP (mmHg)	80 ± 9.2	
Resting heart rate (bpm)	69.6 ± 5.6	
Maximal heart rate (bpm)	192.7 ± 6.3	
	HIIE	**CONT**
Pre SBP (mmHg)	127.9 ± 7.5	124.9 ± 7.2
Post SBP (mmHg)	141.8 ± 6.1	142 ± 8.1
Pre DBP (mmHg)	81.3 ± 7.4	82.7 ± 8.7
Post DBP (mmHg)	72.9 ± 6.8	78.8 ± 10.1
Minimum SBP (mmHg)	110 ± 6.7	111.5 ± 8
Minimum DBP (mmHg)	72.1 ± 10	73.5 ± 9.6
Pre-exercise heart rate (bpm)	84± 9.7	88.7 ± 12.3
Post-exercise heart rate (bpm)*	160.2 ± 17.7	139.2 ± 13.7
Session duration (min)#	35.4 ± 4.2	44.2 ± 2.1

*BMI: body mass index; peakVO_2: peak oxygen consumption; SBP: systolic blood pressure; DBP: diastolic blood pressure; CONT: continuous aerobic exercise; HIIE: high-intensity interval exercise; *: p = 0.02 between the groups; #: p = 0.04 between the groups.*

Discussion

In the present study, we evaluated blood pressure behavior after two exercise conditions, matched by volume – CONT and HIIE. The main findings were: 1) both conditions promoted PEH; 2) HIIE promoted PEH at the 15th minute and thereafter, while the onset of PEH occurred only at the 30th minute following CONT.

PEH has been systematically investigated, showing important effects on prevention and treatment of SAH.[5,7,8,16] The sum of the acute hypotensive effects in response to each exercise protocol promotes a long-term, protective effect on cardiovascular system, attenuating the risk for negative outcomes.[17,18] Therefore, manipulation of the type, volume and intensity of exercise is important for the selection of efficient and clinically applicable strategies.

Previous studies have suggested that the effects of HIIE on PEH were slightly superior than CONT. Angadi et al.,[7] have shown that PEH occurs in both exercise conditions (HIIE and CONT, not matched by volume) during the first post-exercise hour in normotensive subjects. Nevertheless, PEH persisted for three hours after HIIE.[7] In the study by Dantas et al.,[19] HIIE significantly reduced ambulatory BP in normotensive individuals. This effect persisted for 5 hours after the session, and no changes were found in asleep BP. Nevertheless, the study[19] did not include an aerobic condition, which made it impossible to compare both conditions. Carvalho et al.,[20] reported a significant PEH after HIIE and CONT

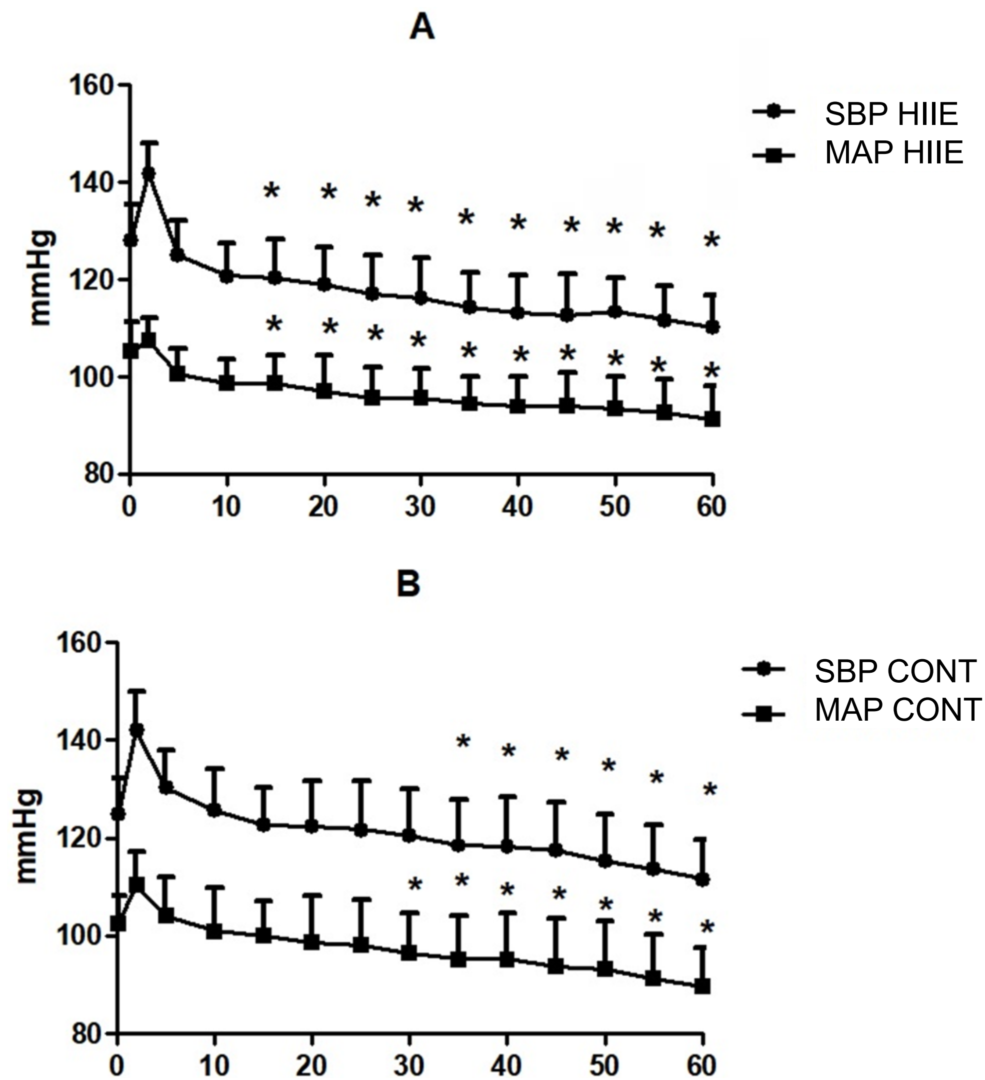

Figure 1 - Systolic blood pressure (SBP) behavior and mean arterial pressure (MAP) during the first hour following (A) high-intensity interval exercise (HIIE) and (B) continuous aerobic exercise (CONT); *$p < 0.05$ compared with pre-exercise, within- group comparisons.

in hypertensive, elderly subjects during a 24-hour period, with significantly lower BP levels in HIIE than CONT. According to the authors, these findings may be attributed to elevated BP levels in the study population, and the muscle mass involved in the exercise, since treadmill protocols seem to exert a higher effect on PEH.[20,21] It is worth pointing out that the protocols used in the studies cited above were not matched by volume.

Lacombe et al.,[22] compared the influence of equicaloric protocols of HIIE and CONT (not matched by volume) on PEH in prehypertensive subjects.[22] Reduced BP was seen one hour after the exercise sessions, with no significant differences between them.[22] These findings corroborate our results, since, as exercises sessions were equalized by volume (i.e., total distance covered) or by energy expenditure, the magnitude of PEH caused by the exercise tests was not different between the conditions. In addition, in the study by Lacombe et al.,[22] exercise duration was similar between HIIE and CONT (~20 vs. ~21 min, respectively),[22] whereas results of our study indicated a higher time/efficiency ratio, with shorter duration (~35 vs. ~44 min), for HIIE, compared with CONT.

The results of the present study showed that, compared with baseline BP values, there was an

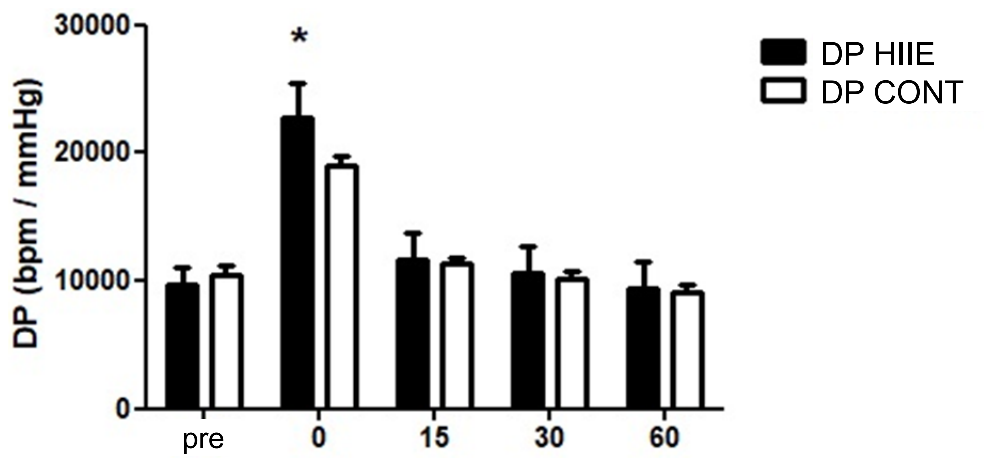

Figure 2 - Double product (DP) in response to high-intensity interval exercise (HIIE) and continuous aerobic exercise (CONT) before and during the first hour following the exercise sessions; * $p < 0.05$.

absolute reduction of 17.9 mmHg and 13.4 mmHg in SBP following HIIE and CONT, respectively. Such decrease is of clinical relevance, with a potential effect on cardiovascular risk reduction.[2] Similar effect has been reported in hypertensive individuals,[20,23,24] with increased resting BP. In this regard, PEH results from a decrease in peripheral vascular resistance by reduction in sympathetic activity.[18,25] In normotensive subjects, PEH seems to be lower than in hypertensive individuals.[7,19] However, in general the protocols of exercise of previous studies had a low volume and short duration (20 minutes) as compared with the protocol used in our study. Thus, higher volume protocols may be associated with higher sympathetic withdrawal and vasodilation after exercise.

In addition, we did not find any significant changes in DBP over time or between the exercise protocols. These findings are in accordance with those reported in the literature,[22] and was somehow expected, since the physiological response of DBP to dynamic exercise is to maintain baseline levels, which were normal in our sample.

As expected, myocardial work index, estimated by DP, was significantly higher following HIIE than CONT. This finding is related to the typical elevation in HR in high intensity exercises, with no major clinical impact in this population. In this sense, many strategies involving high intensity exercise and elevated HR have been shown to promote significant reductions in BP, not only in normotensive but also in hypertensive subjects.[1,16]

Besides, PEH at the 15th minute following HIIE and at the 30th minute following CONT may be associated with increased DP in the former, leading to increased cardiac output, shear stress and vasodilation induced by nitric oxide.[26] Based on the fact that endothelium-dependent vasodilation in response to exercise seems to be dependent on exercise intensity,[27] the high intensity of the HIIE protocol may be responsible for the earlier PEH in this condition.

Among the limitations of this study are the small sample size and the lack of a control condition.

Conclusion

Both HIIE and CONT, matched by volume, promote PEH of similar magnitude. In HIIE, PEH occurs earlier than CONT, suggesting an additional beneficial effect of this exercise modality on cardiovascular system, in addition to requiring a shorter exercise duration.

Further studies using ambulatorial BP monitoring could provide a more precise understanding of the mechanisms of BP behavior in response to HIIE and CONT equalized by volume. Also, studies to investigate the different biochemical and physiological mechanisms by which HIIE and CONT promote PEH are urgently needed.

Author contributions

Conception and design of the research: Boeno FP, Ramis TR, Farinha JB, Moritz C, Santos VP, Oliveira AR, Teixeira BC. Acquisition of data: Boeno FP, Ramis TR, Farinha JB, Moritz C, Santos VP, Oliveira AR, Teixeira BC. Analysis and interpretation of the data: Boeno FP, Ramis TR, Farinha JB, Moritz C, Santos VP, Oliveira AR, Teixeira BC. Statistical analysis: Boeno FP, Ramis TR, Farinha JB, Moritz C, Santos VP, Oliveira AR, Teixeira BC. Writing of the manuscript: Boeno FP, Ramis TR, Farinha JB, Moritz C, Santos VP, Oliveira AR, Teixeira BC. Critical revision of the manuscript for intellectual content: Boeno FP, Ramis TR, Farinha JB, Moritz C, Santos VP, Oliveira AR, Teixeira BC.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Universidade Regional Integrada do Alto Uruguai e das Missões (URI) under the protocol number 2.202.349. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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