Acute blood pressure and heart rate variability responses to high-intensity interval training in untrained postmenopausal women

Abstract

Background: Women after menopause have higher cardiovascular risks than pre menopause. Exercise is one of the ways to prevent and treat cardiovascular diseases in this population. **Aims:** To analyze the blood pressure (BP) and heart rate variability (HRV) responses in untrained postmenopausal women submitted to acute single session of high-intensity interval training (HIT). **Methods:** Sixteen postmenopausal women (59.9±5.6 years, 26.7±3.0 kg/m²) participated in a random order of two acute sessions in a balanced crossover format: control without exercise in sitting position or HIT session. BP and heart rate (HR) were recorder before and during 60 minutes following the sessions. **Results:** Diastolic (DBP), mean BP (MBP) and double product (DPO) showed interaction ($p<0.01$). DBP, mean BP, and DPO increased ($p<0.01$) after HIT but not after the control session. The AUC of DBP ($p= 0.02$) and DPO ($p<0.01$) were different between conditions. Time and frequency indices of HRV presented interaction ($p<0.05$) with impaired of these indices post HIT, but not post control. The AUC of time and frequency HRV indices were different between conditions. **Conclusion:** A single session of HIT may increase BP, cardiac stress and cause perturbation of the autonomic function in untrained postmenopausal women.

Key Words: Hear Rate, Autonomic Function, Aerobic Exercise, Double product, Menopause.

Introduction

The regular practice of physical activity is related to good levels of physical fitness, health benefits and lower risk of mortality in apparently healthy adults, older adults and postmenopausal women [1–3]. Aerobic exercise is largely recommended to promote cardiorespiratory fitness and to reduce cardiometabolic disease risk factors[2], and both moderate and vigorous aerobic exercises may promote these benefits [2]. Vigorous exercises are usually performed as high-intensity interval training (HIT), which is defined as repeated bouts of high-intensity exercise (i.e., ≥ the intensity of maximal oxygen consumption – VO_2max) interspersed with recovery periods [4]. Some studies showed that HIT can promote similar or superior physiological and health improvements than continuous training in both healthy and diseased patients[5,6].

Among the health-benefit effects expected with exercises it may be mentioned the post-exercise hypotension (PEH) which is defined as the reduction of systolic (SBP) and/or diastolic (DBP) blood pressure (BP), below rest values, immediately after a single session of exercise performance and may last up to 24h[7–10]. The PEH has a clinical importance in the prevention and treatment of cardiovascular diseases [7], and also may help in the regulation of BP in normotensive people, reducing the risk of developing hypertension [8]. A previous study showed that HIT session promoted longer [11] and more pronounced [12] reduction in BP than moderate-intensity continuous exercise in adults[12] and middle-aged/older hypertensive women[11]. However, in postmenopausal normotensive women, the effect of HIT on post-exercise BP responses is not yet well known. In this population, the lower circulating estrogen is related to impaired vascular function [13], that could reflect in altered cardiovascular response to exercise.

In spite of the innumerous benefits of HIT on cardiovascular fitness and health [5,6], it is known that isolated sessions of vigorous exercises may be associated with elevated risk of post-exercise sudden death [14]. In this context, understanding the post-exercise cardiac autonomic modulation by measuring heart rate variability (HRV) is important, since there is a relationship between increased sympathetic activity and reduced vagal activity with cardiac events and with risk of cardiovascular mortality including sudden death [14,15]. A previous study showed lower parasympathetic and higher sympathetic indices of HRV 1h post severe intensity exercise in experienced running [16]. In postmenopausal women, the impaired HRV post-exercise may be a

problem, since the resting cardiac modulation by the autonomic nervous system is already reduced in this population [17]. Therefore, studies investigating the acute effect of HIT on post-exercise HRV are necessary to gauge the possible risks associated with prescription of this high-intensity activity among postmenopausal women. Hence, the purpose of this study was to analyze the BP and HRV responses in untrained postmenopausal women submitted to acute single session of HIT. We hypothesized that a single HIT session would reduce BP within 60 minutes after exercise but impair cardiac autonomic modulation in postmenopausal women.

Methods

Participants

Postmenopausal women were recruited through advertisement in traditional (newspapers, radio, and TV) and electronic media (social media), with provision of a telephone contact for those who showed interest to participate. Thereafter, interviews were scheduled to verify compliance with the following inclusion criteria: amenorrhea for at least 12 months; apparently healthy; non-smokers; did not present diabetes, hypertension and coronary artery disease; did not present condition that may prevent their participation in physical activity; did not use hormones therapy or medicines that may interfere on the research results. Twenty-four participants were in accordance with inclusion criteria and signed an informed consent term, accepting to voluntarily participate in the study. One participant was excluded because she was not able to engage in treadmill exercise. Other two participants were excluded because they felt join pain during the familiarization or incremental treadmill test. Two participants gave up before and two others after performing the incremental treadmill test. One other participant was excluded due to error on rest heart rate (HR) signal. Therefore, 16 participants performed all procedures of the present study (figure 1).

Design

This is a randomized-controlled clinical trial with cross-over design, that was registered on the Brazilian Clinical Trials Registry (ReBEC: XXXX) and was approved by the Human Research Ethics Committee of the XX (CAAE: XXXX). The study

followed the CONSORT statement and the principles established in the World Medical Association Declaration of Helsinki.

Initially, the volunteers signed the informed consent, accepting their free and voluntary participation in the study. Immediately after, they filled out an anamnesis to characterize them and answered a questionnaire to analyze the need for clinical assessment before the beginning of physical activity (Physical Activity Readiness Questionnaire - PAR Q). At least 24h later, the anthropometric assessment and the familiarization to the exercise were performed. The standardized familiarization on the treadmill was performing for 15 minutes with the speeds between 3.0 and 5.0 km/h and incline between 0 and 5%. Respecting at least 48 hours of rest, an incremental treadmill test was performed [18] to determine the intensity of the HIT. HIT or control was performed in a cross-over design 14 days after the treadmill test and the order of intervention was determined randomly in a balanced way with 7 days between sessions. HR was measured during incremental test and HIT session. HR and BP were measured at rest of 15 min (pre) before the exercise (HIT session) or sitting position (control session), and every 15 min for 1 hour after both sessions (figure 2).

High-intensity training and control sessions

Participants performed 5 min of warm-up before starting HIT exercise on treadmill with fixed speed of 5.5 km/h and no incline (0%). After warming up, the volunteers performed 8 cycles of 1 min at a speed of 5.5 km/h and incline corresponding to 90% of the maximum incline reached in the incremental test [18], interspersed with 1 min of active recovery at 5.5 km/h and 0% incline. Control were performed with participants resting at seating position with same duration of HIT exercise.

Heart rate

The RR intervals (RRi) were measured during the incremental test and HIT/control sessions. Maximal heart rate (HRmax) was calculated considering the mean of 20s at the end of the test. The HR during the HIT sessions was calculated using the final 30s (HR30s) of HR recorded. The HR30s in percentage of HRmax was calculated (%HRmax). Pre-exercise or control RRi in the seated position was recorded for 15

minutes. Post-exercise or control RRi was recorded for 60 min. Data was recorded with participants breathing spontaneously, in a well-lit room. RRi was measured using a HR monitor (Polar® RS800cx; Polar Electro Oy, Finland; sampling frequency = 1000Hz). HR data were transferred to a computer using Polar Pro trainer5® software (Polar Electro, Kempele, Finland), after which the RRi were visually inspected and artefacts were replaced by the mean of the adjacent values. Samples were selected from the final 5 minutes range in each 15 min at pre- and post-exercise or control with fewest artifacts signal of 2% [15]. HRV analyses were performed in the time and frequency domains [15] through validated [19] Software (Kubios® HRV 3.0.0, University of Kuopio, Kuopio, Finland).

For analysis, time series were interpolated at 4 Hz and the linear trend component signal was removed using the smooth prior technique. The time-domain indices analyzed included the mean heart rate (meanHR), the square root of the mean squared difference of successive R-R intervals(RMSSD) and the standard deviation of all normal R-R intervals recorded at an interval of time (SDNN). For frequency-domain analysis, the signal was multiplied by a Hanning window and the Fast Fourier Transform of the product was calculated. Thus, spectral bands were calculated through the integral of the power spectral density curve and specified in low (LF: 0.04 – 0.15 Hz) and high frequencies (HF: 0.15 – 0.4 Hz). The sympatho vagal balance was obtained through the ratio of the LF to HF (LF/HF) bands.

Blood Pressure

SBP, DBP and mean blood pressure (MBP) was measured by an automatic monitor OMRON HEM–7113, in a resting seated position. At each point of analysis (at the end of each 15 min), BP was checked three times with one minute interspersing each measurement. The average of these measurements was retained for analysis. The double product (DPO) was calculated by the product of SBP and mean HR at each point.

Statistics

Data are presented as means± standard deviations. Normality of data was tested using the Shapiro Wilk test. The two-factor (time and condition) generalized estimating

equation technique (GEE) adjusted by Bonferroni test was performed for between, within, and interaction (condition × moment) comparisons of PA and HRV indices. SDNN, RMSSD, HF, LF and LF/HF did not present normal distribution and were analyzed using the gamma with log link model. Other variables were analyzed using a linear model. The area under the curve (AUC) was calculated using the Prism (GraphPad Prism® 6) and the comparisons between conditions were performed by paired t-test (PAS, PAD, PAM, DPO, mean HR, SDNN and RMSSD) or Wilcoxon test (HF, LF and LF/HF). All analyzes were performed using SPSS (IBM® SPSS® Statistics 21). The significance level adopted was $p<0.05$.

Results

The general characteristics of the participants are: 59.9 ± 5.6 years, 70.2 ± 11.4 kg, 1.62 ± 0.07 m, 26.7 ± 3.0 kg/m² and 38.5 ± 5.8% fat. The HRmax was 155±21 bpm, the HR30s was 133 ± 19 bpm and the %HRmax was 86 ± 4 %.

Blood pressure

BP and DPO data are presented in Figure 3. SBP presented time ($p<0.01$) but no interaction ($p=0.07$) or condition effects ($p=0.99$). The pairwise comparisons showed that SBP was higher at 15' post-exercise compared to pre-exercise ($p<0.01$) and returned to pre values at 30'. For DBP and MBP the comparisons showed interaction ($p<0.01$) and time effects ($p<0.01$), but no condition effect (DBP $p=0.45$; MBP $p=0.64$). The pairwise comparisons showed that after HIT, DBP and MBP were always higher compared to pre exercise ($p<0.01$). No pairwise differences were found after control. DPO showed interaction ($p<0.01$), time ($p<0.01$) and condition effects ($p=0.03$). The pairwise comparisons showed that after HIT, DPO was always higher compared to pre-exercise ($p<0.01$) and was higher at 15' compared to all subsequent points ($p<0.01$). After control, DPO was always lower compared to pre-session ($p\leq0.03$). Besides that, DPO showed significant differences between conditions at all points after the control and HIT sessions ($p\leq0.03$). The AUC of DBP ($p= 0.02$) and DPO ($p<0.01$) were different between conditions, without differences in SBP ($p= 0.91$) or MBP ($p= 0.18$).

Heart Rate Variability

The time domain of HRV results are shown in figure 4. meanHR showed interaction, time and condition effects ($p<0.01$). The pairwise comparisons showed that after HIT, meanHR was always higher compared to pre-exercise ($p<0.01$). Besides that, it was higher at 15' compared to all subsequence time points ($p<0.01$) and at 30' and 45' compared to 60' ($p\leq0.03$). After control, it was always lower compared to pre-session ($p<0.01$). Moreover, meanHR showed difference between conditions at all points after sessions ($p<0.01$).

In its turn, SDNN showed interaction and time effects ($p<0.01$) but no condition effect ($p=0.07$). The pairwise comparisons showed that after HIT, SDNN was lower at 15' and 30' compared to pre-exercise and 60' ($p<0.01$). After control, SDNN was higher at 15', 30' and 60' ($p\leq0.03$) compared to pre-session. Moreover, SDNN showed difference between conditions at 15', 30' and 60' ($p\leq0.04$).

Lastly, RMSSD showed interaction ($p<0.01$), time ($p<0.01$) and condition effects ($p=0.02$). The pairwise comparisons showed that after HIT, RMSSD was lower at 15', 30' and 45' compared to pre-exercise ($p\leq0.03$). Besides that, it was lower at 15' compared to all subsequent points ($p<0.01$) and at 30' compared to 60' ($p<0.01$). After control, RMSSD was higher at 60' compared to pre-session, 15' and 45' ($p\leq0.04$). RMSSD showed difference between groups at all points after exercise ($p\leq0.04$). The AUC of meanHR, SDNN and RMSSD were different between conditions ($p<0.01$).

The frequency-domain of HRV results are shown in figure 5. LF presented interaction and time effects ($p<0.01$), without condition effects ($p=0.17$). The pairwise comparisons showed that after HIT, LF was lower at 15' compared to pre-exercise ($p=0.04$). After control, LF was higher at 60' compared to pre-session ($p=0.01$). Furthermore, LF was different between conditions at 15' ($p=0.03$).

HF presented time ($p<0.01$), condition ($p=0.02$) and interaction ($p<0.01$) effects. The pairwise comparisons showed that in HIT, HF was higher at pre-exercise compared to 15' and 30' ($p\leq0.03$) and was lower at 15' compared to all subsequent points ($p\leq0.04$). HF did not change after control ($p>0.05$). Furthermore, HF was different between conditions at 15', 30' and 60' ($p\leq0.02$).

LF/HF presented interaction ($p=0.02$) and condition effects ($p<0.05$) but no time effect ($p=0.44$). The pairwise comparisons showed that LF/HF in HIT was lower at pre-exercise compared to 15' and 30' ($p<0.01$). Furthermore, LF/HF was different between conditions at 15' and 30' ($p\leq0.01$). The AUC of HF ($p<0.01$), LF ($p=0.02$) and LF/HF ($p=0.01$) were different between conditions.

Discussion

The main results found were that DBP and DPO increased and HRV indexes were impaired up to 60 minutes after one HIT session, contradicting our hypothesis that HIT could reduce BP responses and accepting that HIT session acutely impaired cardiac autonomic modulation in untrained postmenopausal women.

Previous meta-analytic investigation showed that PEH is reported regardless of the characteristics of the sample and exercise [9]. However, an inverse association between age and PEH was reported, suggesting that increasing age reduce the magnitude of PEH [9]. Furthermore, the reduced estrogen circulating levels in postmenopausal women may change cardiovascular response to exercise [13], which in turn could impact the fall in BP post-exercise. In addition, in the present study the basal values of SBP (107 mmHg) and DBP (64 mmHg) were normal to low, and this could also influence PEH, since greater BP falls occurs when basal levels are higher [10,20]. These factors (age, estrogen loss and pre value of BP) could justify the absence of PEH in the present study. However, a previous study reported reduction in BP in sedentary normotensive postmenopausal women after moderate continuous exercise that presented pre-exercise values similar to the present study (108/64 mmHg) [21]. It suggests that maybe the characteristic of exercise (HIT) for this population (untrained postmenopausal women) is the principal factor influencing the result found in the present study. Futures studies are necessary comparing PEH after submaximal continuous and HIT exercise sessions in untrained postmenopausal women to confirm this suggestion.

Although the mechanisms responsible for PEH are not completely understood, decreases sympathetic activity, vasoconstriction responsiveness to sympathetic activation and local vasodilators mechanisms has been reported [10,22]. In our study peripheral sympathetic activity and responsiveness was not assessed in the present study,

but the HRV indices, principally LF/HF, suggest an imbalance in autonomic activation which is maintained at least for 60 min post-exercise. It is known that the clearance of muscle metabolic products (lactate and H^+), circulating catecholamine and body temperature reduction is lower post high-intensity exercise, contributing for persistent sympathetic activation post-HIT [23–25]. Since aging and estrogen loss are linked to impaired vascular function [13], it is possible that lower peripheral vascular vasodilatation responses allied to increased sympathetic activity [22] contributed not only for the absence of PEH but also for the reported increased post-exercise DBP.

Besides no PEH effect, HIT promoted impairment in time and frequency domain indices of HRV, suggesting a decreased global (SNDD, LF) and parasympathetic branch (RMSSD, HF) modulation of the cardiac autonomic system. Added to LF/HF indices, these results suggest that HIT promoted slow vagal reactivation and persistent sympathetic overactivation after exercise. The elevated mean HR up to 60 min post-exercise reinforces the suggestion of slow recovery of autonomic system. Since poor cardiac autonomic modulation is associated with cardiac events and with risk of cardiovascular mortality [14,15], HIT session in postmenopausal women may not be as safe in this population as in others. This elevated risk is corroborated with elevated DPO values post-HIT, that correlate with myocardium oxygen consumption [26] and increases the risk of cardiovascular problems [27]. A previous study partly corroborates these results, since high-intensity exercise bouts failed to reduce DPO during the recovery period [27]. However, it is not known reference values of HRV and DPO indices correlated to cardiac events and the suggestion made in the present study is only speculative. Therefore, the results found put forth the question about the safeness of prescribing HIT exercise for untrained postmenopausal women.

As a limitation, we realize that although the present study monitored BP at the recommended time range for identifying PEH (20 – 120min) [28], it is possible that in untrained postmenopausal women the PEH post-HIT occurs later in time (post 60 min), and we do not measure these points. Futures studies are recommended to analyze PEH up to 120 min to investigate this possibility, as well as in an ambulatory condition, investigating the response of HIT on BP up to 24h after exercise. One important observation was that the intensity of HIT session was manipulated by incline of the treadmill, maintaining speed constant across participants. This choice was made while taking into account the motor skills limitations of the sample (untrained women) and to

increase the safeness of the protocol. Therefore, futures studies should investigate if the responses to other intensities or exercise modes (e.g., aquatic activities) are similar.

From our findings, we can conclude that one session of HIT may not reduce BP and can cause acute cardiac stress and impaired autonomic modulation in untrained postmenopausal women, for a period of 60 min post-exercise. Regarding the clinical applicability of the present study, although there is no consensus in the literature, we emphasize that the application of the HIT protocol in untrained post-menopause women may not be beneficial. Taking into account the chronic benefit of HIT on promote reduction of BP and healthy improvements [29] we suggests futures studies with progressive increment in intensity of exercise to try reduce the acute cardiac stress reported.