Original Article (short paper)

Sex and exercise-mode differences in post-exercise blood pressure and heart rate variability responses during a workday

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Abstract — Aims: To assess the influences of sex and exercise mode on post-exercise Blood Pressure (BP) immediately after exercise and during daily work. **Methods**: 20 healthy adults (9F/11M), randomly underwent three experimental sessions prior to their work routine: RE- Circuit resistance exercise at 40% of 1RM, AE- Aerobic exercise at 60-70% of heart rate (HR) reserve and CON- Control session. BP was assessed before and along the 1st hour of the post-intervention period (i.e. laboratory phase), and intermittently for 9h in the workplace. Results**:** RE promoted great BP reductions, but only in men, and this reduction persisted along the daily work (Men-RE: SBP= -1069±695 mmHg.540min; DBP= -612±325 mmHg.540min). On the other hand, AE produced slight DBP reduction in men during daily work (Men-AE: DBP= -241±730 mmHg.540min), and in women only in the laboratory phase (Women-AE: SBP= -108±65mmHg.60min). **Conclusion**: Resistance exercise promotes a significant positive impact on BP in men but does not seem to be effective for women. On the other hand, AE produces moderate BP reductions in men and women.

Keywords: exercise; post-exercise hypotension; sex distribution; heart rate; physiological stress.

Introduction

Exercise is an important non-pharmacological therapy for cardiovascular risk prevention and treatment. Physical training promotes improvements in several cardiovascular parameters, including reductions of blood pressure (BP) [1] and resting heart rate (HR) [2], and improvements in ventricular [3] and endothelial [4] functions. Interestingly, some recent studies have demonstrated that a single session of exercise is also able to promote several cardiovascular benefits, among them a transient reduction in BP which can persist for up to 24 hours [5,6], otherwise known as post-exercise hypotension (PEH).

PEH has been shown to occur either after aerobic (AE) [5,7,8] or resistance exercises (RE) sessions [9–12], men and women [7,8,13–16], normotensive [12,17,18] and hypertensive [5,9,11] and in young [13–15,17] and old adults [5,10,11]. Regarding its clinical relevance, PEH is an important adjuvant in BP control of hypertensive [19,20], and also a strategy for prevention of hypertension in normotensives [21]. Additionally, there are indications that the BP reduction occurring after a single session of exercise is positively associated with the chronic BP reduction achieved after a period of physical training [22]. However, despite all of these implications, PEH magnitude and duration have been shown to be highly variable, with some studies reporting magnitudes of reductions between 0-20 mmHg [9,10,17], and durations between 1-24h [5,9,10,18].

Factors such as sex and the type of exercise type help to explain the high variability in PEH. A greater PEH has been reported after AE than RE [20,23], but circumstantial variables might affect such relations and little is known about the concurrent influence of sex on post-AE and post-RE BP responses. So, the aim of the present study was to assess the influence of sex and exercise type on PEH in healthy adults. To address this issue, we compared, in men and women, the BP responses after a moderate-intensity AE, a circuit-based RE and a non-exercise control session (CON). Since recent a study had reported that RE can result in a greater cardiac autonomic stress than AE [24], we also compared the post-exercise HR variability (HRV) between sessions.

Methods

Participants

Twenty non-sedentary (assessed from International Physical Activity Questionnaire – IPAQ; Table 1) healthy subjects participated in this study (11 men and 9 women). The sample comprised the staff (professors and technicians) from the Federal University of Uberlândia. All volunteers were informed of the risks and benefits of the study and signed an informed consent form before the beginning of the study. This study was approved by the local Ethics Committee for human studies from Federal University of Uberlandia (CAAE: 28174814.9.0000.5152). All volunteers' characteristics are presented in table 1.

Experimental Protocol

The experimental protocol was carried out in four separate visits 48h apart. In the first visit, the volunteers answered questions about the presence of risk factors for cardiovascular disease, physical activity was assessed using IPAQ, anthropometric measurements were taken (i.e. body mass, height, waist-to-hip ratio), and maximal dynamic strength was assessed using a 1RM test, based on the protocol described by Nieman [25]. Briefly, the participant attempted up to five times to reach the 1RM in each exercise performed in the study. The highest workload attained was defined as the 1RM.

From the second to the fourth visits, participants randomly underwent the three experimental sessions. Prior to the experimental sessions, the volunteers were instructed to maintain their regular diet, to avoid beverages containing caffeine and alcohol and do not perform physical exercises. All volunteers were familiarized with treadmill and the RE before the experimental sessions.

The experimental session began at 07:00 am, after the subjects' usual breakfast. The session started with resting measurements in the seated position. Subjects, then, performed the exercise interventions (AE; RE; CON). After the interventions, subjects remained in seated recovery at the laboratory, for 60 min, and then returned to their occupation under intermittent monitoring for an additional 9 hours (Figure 1).

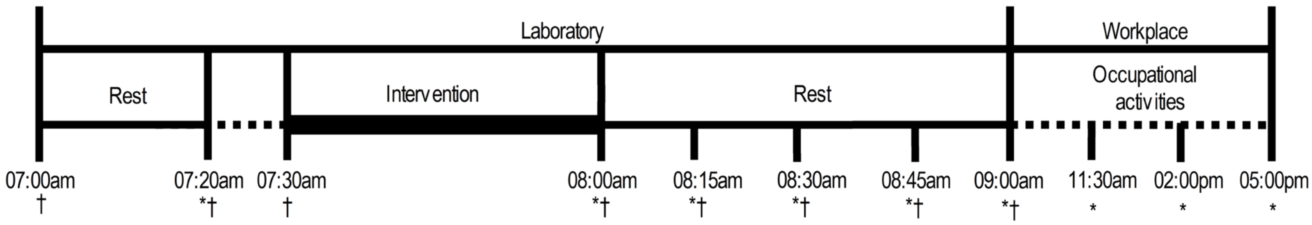

Figure 1. Experimental study design; †Beat-by-beat HR recording; *Blood pressure measurement.

Interventions

Aerobic exercise (AE) session:

AE was performed on a treadmill for 30 minutes at 60 – 70% of HR reserve (HRR). Maximal HR was estimated according to the age (i.e. maximum HR = 220 - age) [26]. During AE, the treadmill speed was fixed to 5.5 km/h and further changes in exercise intensity were provided by changes in treadmill inclination (%).

Resistance exercise (RE) session:

RE consisted on three circuits of six exercises at 40% of 1RM. During each exercise, the participant performed 20 repetitions (60 seconds) with 30 seconds of interval between exercise and two minutes between circuits. The order of exercises was: Leg press 45° (hip and knee extensions), Lat. Pull down (frontal shoulder adduction with elbow flexion), Leg curl (knee flexion), Chest press on the machine (horizontal shoulder abduction with elbow extension), Leg extension on the machine (knee extension) and Low rower (shoulder abduction and elbow flexion).

Control session (CON):

During CON, participants remained seated in a comfortable chair without talking for 30 min.

Measurements

HR was recorded using an HR monitor (POLAR® RS800cx; sampling frequency = 1000Hz) on a beat-by-beat basis. HR was registered in a seat position in bouts of fifteen minutes prior to each BP measurement, only in laboratory conditions (i.e. rest and 60 min of recovery). During all sessions and phases, systolic (SBP) and diastolic BP (DBP) were measured three times by an automatic BP analyzer (Microlife® BP 3BT0A), that was previously calibrated [27]. The average of the three measurements was used for the analyses. Resting measurements were taken after 20 min of rest. At recovery, SBP and DBP were measured every 15 minutes for 60 minutes at the laboratory environment and at 210, 360 and 540 minutes after exercise at the office where they worked. Office BP measurements were carried out by the same researchers, using the same apparatus of the laboratory. So, the BP was monitored for 9 hours after the experimental sessions.

Data Analyses

Heart rate (HR) and Heart Rate Variability (HRV)

HR data were transferred to a computer using Polar Pro trainer5® software and HRV analysis was performed in *Kubios* HRV 2.2 (University of Kuopio, Finland), that was validated for this analysis by Tarvainen and co-workers [28]. Prior to the analysis, the RR intervals (RRi) were visually inspected and filtered using a moving average filter. The HRV was analyzed in both time- and frequency-domain [29].

For time-domain analysis, the following indices were calculated: RMSSD - the square root of the mean of the sum of the squares of differences between adjacent RRi; SDNN - standard deviation of all normal RRi recorded at an interval of time expressed in ms; and pNN50 - percentage of pairs of adjacent RRi differing by more than 50 milliseconds in the whole recording. For frequency-domain analysis, firstly the

RRi series were interpolated at 4 Hz and then the signal linear trend component removal was performed using the smooth priors approach. For the power spectral density function calculation, the RRi interval signal was multiplied by a Hanning window and then the Fast Fourier Transform of the product was taken. The low- and high-frequency spectral bands (LF and HF, respectively) were calculated through the integral of the power spectral density curve in their respective bands (i.e. LF: 0.04 – 0.15 Hz; HF: 0.15 – 0.4 Hz; ms^2). LF and HF were expressed in normalized units (nu), which represent the relative contribution of each component for the total power minus the very low-frequency component [29].

Blood pressure (BP)

The BP responses over time were analyzed using the net changes (Δ) of each time points of SBP and DBP in relation to the rest BP values. We also estimated the incremental area under the curve (AUC) of these BP responses over the laboratory, office and total general measures during a working day. AUC (BP x Time) was estimated by the trapezoidal method.

Statistical analysis

Data are presented as a mean ± standard error of mean and its normality was checked by Shapiro-Wilk test. The area under the curve (AUC) was calculated using the trapezoidal method (integration), in order to evaluate the behavior of the variables in relation to time using the software Graph Pad Prism version 4. The comparison of baseline variables between sexes was performed by independent T-Test. The comparisons of AUCs BP and HRV between the sessions were, respectively, performed using One-way and Two-way ANOVAs (session vs. time). When necessary, the Newman-Kells post-hoc test was employed to identify the differences. All analyses were performed in SPSS for Windows 21.0 (Illinois, USA) and the significant level was set at p≤0.05.

Results

The general characteristics of the volunteers are shown in Table 1. Greater values of SBP, DBP, Body mass, Height, Waist-Hip Ratio and 1RM workload for all exercises were observed in men ($P<0.05$). The other descriptive variables were not statistically different between sexes. All volunteers were healthy, none of them were using medication, and there were two postmenopausal women who had hormone replacement for more than 5 years.

Men's SBP AUCs were lower in all periods in RE compared with CON. On the other hand, there were no differences for any period when comparing AE with CON, with only a tendency (p = 0.08) of low SBP in AE during the laboratory period (Figure 2a and 2b). Men's DBP AUCs were lower in RE than CON during all periods, and lower in RE than AE during laboratory period. Additionally, DBP AUCs were lower in AE than CON in office and general periods (Figures 3a and 3b).

Table 1. General characteristics of all participants

	Men (n=11)	**Women (n=9)**	**All (n=20)**
Age (years)	36.6 ± 10	40.0 ± 11.1	38.2 ± 10.4
BM (Kg)	83.7 ± 12.2*	63.4 ± 6.1	74.6 ± 14.2
Height (m)	1.76 ± 0.05*	1.59 ± 0.03	1.68 ±0.09
BMI (Kg/m²)	27 ± 3	25 ± 3	26 ± 3
WHR	0.86 ± 0.05*	0.77 ± 0.06	0.82 ± 0.07
Resting SBP (mmHg)	123 ± 8*	101 ± 7	113 ± 13
Resting DBP (mmHg)	73 ± 4*	65 ± 5	70 ± 6
Resting HR (bpm)	71 ± 8	75 ± 10	73 ± 9
HR Max. (bpm)	183 ± 10	180 ± 11	182 ± 10
1RM Leg Press (Kg)	310 ± 55*	175 ± 48	249 ± 86
1RM Lat. Pull down (Kg)	75 ± 11*	41 ± 5	59 ± 19
1RM Leg Curl (Kg)	46 ± 13*	24 ± 5	37 ± 15
1RM Chest Press (Kg)	58 ± 11*	24 ± 4	43 ± 19
1RM Leg extension (Kg)	77 ± 18*	41 ± 8	61 ± 23
1RM Low Rower (Kg)	67 ± 8*	36 ± 3	53 ± 17
IPAQ - irregularly active	5 (45%)	5 (55%)	10 (50%)
IPAQ - Active	4 (36%)	2 (22%)	6 (30%)
IPAQ – Very Active	2 (18%)	2 (22%)	4 (20%)

BM- Body Mass; BMI- Body Mass Index; DBP- Diastolic Blood Pressure; HR- Heart Rate; SBP- Systolic Blood Pressure; WHR- Waist-Hip ratio; IPAQ – International Physical Active Questionnaire; *Difference with women; P≤0.05.

Women's SBP AUC was lower during laboratory period after AE compared with both RE and CON. During the general period, SBP AUC was higher after RE compared with AE but not with CON (Figures 2c and 2d). There were no significant differences between all periods and sessions for DBP AUCs in women (Figures 3c and 3d).

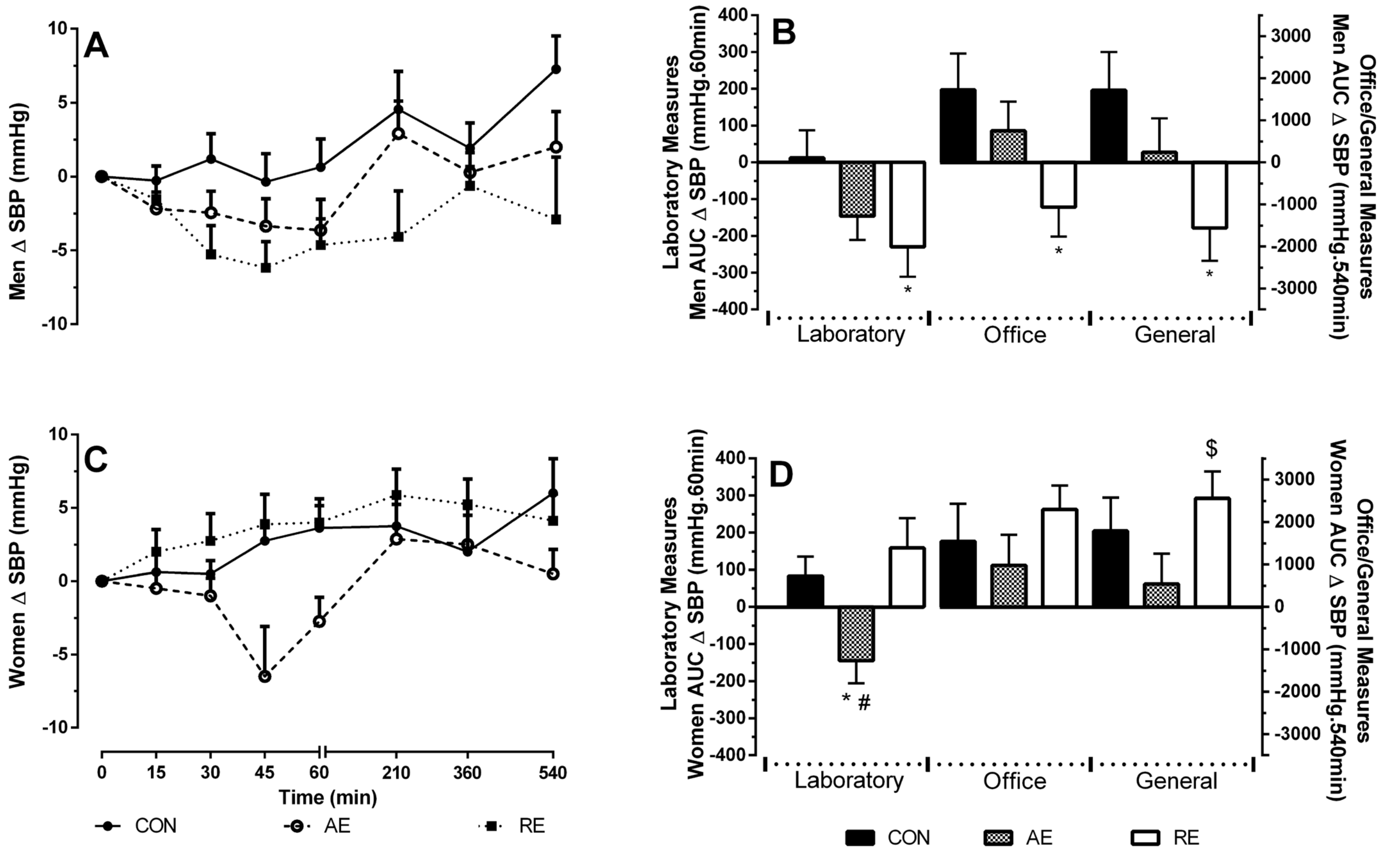

Figure 2. Delta and AUC of SBP of men and women; Time-related responses in delta SBP are present in the left side (panels A and C) and the correspondent AUC of SBP are present in the right side (panels B and D); The upper panels depict men and bottom panels depict women results; Right graph: Left Y axis: 1 hour on the laboratory; Right Y axis: 8 hours on the work place and general; AE- Aerobic session; AUC- Area Under the curve; CON- Control session; RE- Resistance session; SBP- Systolic blood pressure; * Difference with CON; $ Difference with AE. # Difference with RE.

Table 2 shows the sex differences on AUCs of SBP and DBP. There were no significant differences between sexes for all periods in AE and CON. However, on RE, men presented lower AUCs of SBP and DBP than women for all periods, except for SBP in the Laboratory.

Table 3 presents the HRV data measured prior to the exercise and in intervals of 15 min for the 60-min recovery in the laboratory. In CON, there were no time-related differences in any HRV index in men. On the other hand, both SDNN and pNN50 were greater at 60' in comparison with pre-intervention in women. In men's AE, RE and Women's RE, all vagal indices (HF, SDNN, RMSSD, and pNN50) were reduced, and the LF was increased at all time-points during recovery in comparison with pre-exercise (except for: 45' RMSSD and LF in Men RE; 15' LF and HF in Men AE; 45' and 60' SDNN, and 60' RMSSD in Women RE). In women's AE there were no differences in any HRV index between recovery and pre-exercise.

Regarding the comparison between sessions, men presented lower values of time domain indices (SDNN, RMSSD and pNN50) at all moments (except for AE 45' RMSSD) on RE and AE compared with CON. Women presented lower values of SDNN at 45' and 60', and lower values of RMSSD and pNN50 at 45' on AE in comparison with CON. Besides, women present lower values of time domain indices on all moments of recovery on RE in comparison with CON.

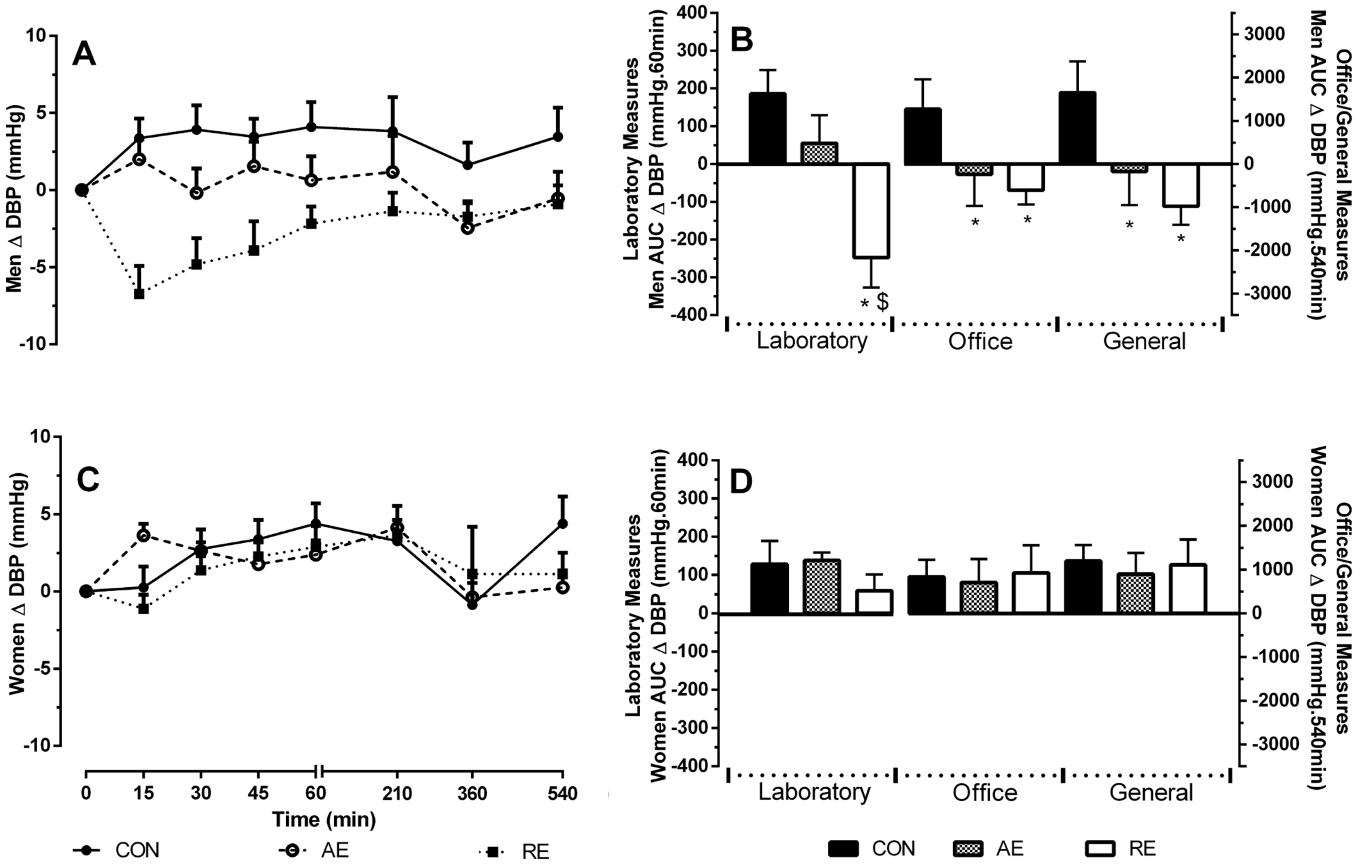

Figure 3. Delta and AUC of DBP of men and women; Time-related responses of delta DBP are present in the left side (panels A and C) and the correspondent AUC of DBP are present in the right side (panels B and D); The upper panels depict men and the bottom panels depict women results; On the right graph- Left Y axis represents 1 hour on the laboratory; Right Y axis represents 8 hours on the work place and general; AE- Aerobic session; AUC- Area Under the curve; CON- Control session; RE- Resistance session; SBP- Systolic blood pressure; * Difference with CON; $ Difference with AE.

Table 2. Sex difference on Area Under the Curve of BP

n = 20 (9F and 11M)		CON		AE		RE	
		Men	Women	Men	Women	Men	Women
Laboratory	AUC of ΔSBP (mmHg.60min)	12±75	78±47	-147±64	-108±65	-230±81	153±71
	AUC of ΔDBP (mmHg.60min)	186±63	114±56	55±74	149±22	-248±79*	78±42
Office	AUC of ΔSBP (mmHg.540min)	1725±861	1637±786	749±693	962±639	-1069±695*	2487±531
	AUC of ΔDBP (mmHg.540min)	1268±688	778±345	-241±730	680±476	-612±325*	1226±635
General	AUC of ΔSBP (mmHg.540min)	1718±908	1883±704	241±808	620±638	-1564±778*	2712±578
	AUC of ΔDBP (mmHg.540min)	1651±724	1135±330	-175±777	892±426	-983±425*	1399±589

AE- Aerobic session; CON- Control session; RE-Resistance session; *Difference with women.

Table 3. Heart rate variability measured at pre-exercise and during recovery in laboratory

			Pre	15’	30’	45’	60’
MEN	CON	SDNN (ms)	68.7 ± 26.0	72.4 ± 33.6	66.6 ± 30.8	75.2 ± 39.0	78.0 ± 34.8
		RMSSD (ms)	43.0 ± 26.6	37.2 ± 19.3	35.9 ± 17.4	37.4 ± 21.5	42.9 ± 24.1
		pNN50 (%)	14.8 ± 11.8	13.8 ± 13.1	14.6 ± 13.5	14.1 ± 14.8	17.2 ± 15.0
		LF (nu)	71.8 ± 12.8	72.7 ± 18.1	72.3 ± 12.5	81.1 ± 10.1	74.2 ± 15.1
		HF (nu)	28.2 ± 12.8	27.3 ± 18.1	27.7 ± 12.5	18.9 ± 10.1	25.8 ± 15.1
	AE	SDNN (ms)	59.5 ± 26.7	32.7 ± 13.8*†	42.6 ± 23.3†	51.8 ± 26.6†	54.3 ± 31.1†
		RMSSD (ms)	34.3 ± 13.1	13.0 ± 7.7*†	19.9 ± 12.1*†	23.7 ± 12.1	24.6 ± 13.8†
		pNN50 (%)	13.0 ± 9.9	1.2 ± 2.2*†	3.6 ± 5.2*†	6.5 ± 7.9*†	6.3 ± 7.2*†
		LF (nu)	67.2 ± 15.4	83.0 ± 9.2*	80.5 ± 9.2*	80.3 ± 10.8	84.9 ± 8.3*
		HF (nu)	32.8 ± 15.4	17.0 ± 9.2*	19.5 ± 9.2*	19.7 ± 10.8	15.1 ± 8.3*
	RE	SDNN (ms)	61.3 ± 23.1	24.3 ± 6.7*†	28.4 ± 8.2*†	40.5 ± 16.1*†	41.2 ± 13.6*†
		RMSSD (ms)	32.5 ± 11.5	10.6 ± 6.5*†	11.5 ± 5.6*†	18.9 ± 9.4*†	18.4 ± 7.8*†
		pNN50 (%)	11.2 ± 9.2	1.4 ± 2.7*†	1.2 ± 1.8*†	2.1 ± 2.2*†	2.8 ± 3.1*†
		LF (nu)	67.9 ± 14.3	77.9 ± 15.7	86.0 ± 7.6*†	87.5 ± 7.2*	84.5 ± 9.3*
		HF (nu)	32.1 ± 14.3	22.1 ± 15.7	14.0 ± 7.6*	12.5 ± 7.2*	15.5 ± 9.3*
WOMEN	CON	SDNN (ms)	57.9 ± 18.0	56.6 ± 25.6	64.1 ± 23.0	69.7 ± 20.9	74.6 ± 21.1*
		RMSSD (ms)	33.3 ± 12.8	30.3 ± 13.7	38.1 ± 18.4	41.7 ± 16.9	42.8 ± 16.9
		pNN50 (%)	12.0 ± 9.4	12.1 ± 10.0	16.7 ± 12.6	19.0 ± 17.2	23.3 ± 16.1*
		LF (nu)	68.5 ± 13.2	69.8 ± 16.0	71.5 ± 12.7	68.7 ± 21.4	65.4 ± 19.6
		HF (nu)	31.5 ± 13.2	30.2 ± 16.0	28.5 ± 12.7	31.3 ± 21.4	34.6 ± 19.6
	AE	SDNN (ms)	55.1 ± 21.2	46.6 ± 23.8	47.6 ± 27.1	48.9 ± 22.3†	54.6 ± 20.4†
		RMSSD (ms)	26.0 ± 14.6	26.2 ± 22.0	29.4 ± 15.9	25.8 ± 15.5†	34.1 ± 18.8
		pNN50 (%)	8.6 ± 12.6	3.5 ± 3.6	7.9 ± 7.4	7.2 ± 10.0†	15.4 ± 18.1
		LF (nu)	73.3 ± 10.6	73.7 ± 15.2	74.3 ± 11.2	73.1 ± 21.0	66.9 ± 27.9
		HF (nu)	26.7 ± 10.6	26.3 ± 15.2	25.7 ± 11.2	26.9 ± 21.0	33.1 ± 27.9
	RE	SDNN (ms)	56.3 ± 22.8	27.7 ± 11.8*†	32.4 ± 10.3*†	41.8 ± 10.6†	44.1 ± 15.9†
		RMSSD (ms)	35.1 ± 14.3	10.8 ± 7.2*†	13.7 ± 7.1*†	19.0 ± 7.7*†	22.2 ± 10.5†
		pNN50 (%)	16.7 ± 11.7	0.9 ± 2.3*†	1.3 ± 2.0*†	2.5 ± 2.8*†	5.2 ± 6.2*†
		LF (nu)	54.5 ± 16.7†	77.8 ± 11.5*	77.8 ± 12.9*	72.2 ± 17.3*	72.9 ± 11.8*
		HF (nu)	45.5 ± 16.7†	22.2 ± 11.5*	22.2 ± 12.9*	27.8 ± 17.3*	27.1 ± 11.8*

AE- Aerobic session; CON- Control session; HF and LF: high- and low-frequency components of heart rate variability calculated from spectral analysis (i.e. normalized units); pNN50 - percentage of pairs of adjacent RRi differing by more than 50 milliseconds; RE- Resistance session; RMSSD – the square root of the mean of the sum of the squares of differences between adjacent RR intervals; SDNN- standard deviation of RR intervals; *Difference with Pre-exercise moment; † Difference with control session.

Discussion

This study investigated the influences of sex and type of exercise (i.e. moderate-intensity AE vs. circuit-based RE) on BP and HRV responses immediately after exercise and during working hours in healthy men and women. When comparing BP responses between sessions and sexes, we found that: (1) for RE, men presented PEH of both SBP and DBP, and this effect persisted for nine hours during work journey; while women did not present PEH at any time; (2) for AE, men presented PEH of DBP, and this effect was observed only at office time; while women presented PEH of SBP only at laboratory time. These results indicate important differences in BP responses after AE and RE in men and women, with RE promoting greater benefits in men than in women, and AE presenting equivocal results. When comparing HRV responses between sessions and sexes, we found greater HRV reduction after RE, for both men and women. This result indicates RE results in a greater autonomic stress than AE.

The differences between AE and RE on post-exercise BP responses have motivated the interest from previous studies [23,30]. A recent Meta-Analysis including 65 studies with a broad range of subjects' characteristics and exercise protocols have reported greater PEH after AE than RE [31]. This result was substantiated by Teixeira, Ritti-Dias, Tinucci, Mion Júnior, Forjaz [23], who observed greater and longer (i.e. up to 120 min) BP reductions after AE than RE in healthy subjects. However, these results are not unanimous [30,32] and in a study very similar to ours, Mota, et al [30] observed similar PEH after a circuit-based RE and AE, either immediately after exercise or during work hours. In the present study, PEH has also occurred after AE and RE, but, at least in men, the greater responses (i.e. longer and greater PEH) were promoted by the RE. Differences in exercise protocols and participants' characteristics might help to explain the divergences between previous and our findings. In this sense, in Teixeira, Ritti-Dias, Tinucci, Mion Júnior, Forjaz study [23], RE was slightly more intense (i.e. 50% 1RM) than in the present study. Although controversial, it has been shown that higher intensities produce lower PEH for RE (i.e. lower PEH) [33], which could help to explain the reduced PEH after RE in Teixeira, Ritti-Dias, Tinucci, Mion Júnior, Forjaz study [23]. Furthermore, Mota, et al [30] have studied hypertensive subjects while the present study was conducted with healthy normotensive subjects, and evidence has shown greater PEH after AE in the former group [34], which could help to explain the greater PEH after AE in Mota et al.'s study [30].

Another important confounding factor in most of the studies investigating BP responses after exercise is the sex. Indeed, PEH has been performed with men [34] and the results of the present study indicate that this could be an important limitation since men and women presented different BP responses after AE and RE. Accordingly, while men presented PEH for 9 hours after RE, women did not present PEH after this type of exercise. On the other hand, after AE men presented a minor PEH that was expressed only at office time, and women presented PEH restricted to the laboratory time. These results suggest that men seem to beneficiate more from a circuit-based RE than women, while AE seems to present unclear results. One possible explanation for the greater post-RE PEH in men may reside on their slightly higher initial BP levels which has shown to be associated with greater PEH magnitude [31]. Sex-based differences in autonomic control of blood pressure may also underlie some of the differences observed [31], however, the tools of the present study do not allow further speculation. The influence of sex on post-RE and post-AE BP responses has been investigated by several studies [7,8,13–16,31]. A recent Meta-Analysis [31] has demonstrated a greater magnitude of PEH in men than women after a broad range of exercises. Specifically for RE, Queiroz, Rezk, Teixeira, Tinucci, Mion, Forjaz [13] did not observe differences between young men and women on BP responses after moderate-intensity RE. Similar results were found by Somani et al.[14] using isometric exercise, and by Ramírez et al [15] using plyometric exercises. Apart from the reported differences in RE protocols, differences in participants' characteristics might help to explain the differences between previous and our findings.

In this sense, all of the aforementioned studies have studied young subjects (≈22–25 years), while the present study has engaged middle-aged men and women (mean age = 38.2 years). Although controversial, it has been reported lower PEH in older compared with younger subjects [7,31], which could help to explain such divergences. For post-AE BP responses, Deschenes, Hillard, Wilson, Dubina, Eason [8] and Senitko, Charkoudian, Halliwill [16] did not observe differences between men and women after moderate-intensity AE. A similar result was found by Cote, Bredin, Phillips, Koehle, Warburton[35] after high-intensity interval exercise. The timeframe of the BP measurements might help to explain the differences between these and our findings. Moreover, in all of the aforementioned studies the BP was only measured in the laboratory (max 60 min post-exercise), and since sex-related differences on post-AE BP might also be present during ambulatory measurements, as demonstrated in the present study (i.e. workplace), care should be taken when interpreting previous studies.

The present study also investigated the autonomic stress imposed by AE and RE in men and women. To address such a question, we have assessed the HRV, a non-invasive measure of cardiac autonomic modulation [29], for 60 min after exercise. In this sense, after RE, both in men and women, all vagal indices of HRV (e.g. SNN, RMSSD, pNN50, and HF) were reduced, and the sympathetic index of HRV (i.e. LF) was increased for 60 min. On the other hand, after AE, only in men the HRV was significantly changed in comparison with rest and CON. This greater autonomic stress imposed by RE than AE exercise was already reported by Heffernan, Kelly, Collier, Fernhall [36] and Niemela, Kiviniemi, Hautala, Salmi, Linnamo, Tulppo [24], and suggests an increase in cardiovascular risks after RE [37]. Although the potential mechanisms behind these results are beyond of the possibilities of the present study, alterations in metaboreflex and baroreflex control of HR [38], and changes in plasma volume [39] might help to explain the increased autonomic stress imposed by RE. Next studies should assess such mechanisms.

Some limitations of this study are worth mentioning. Firstly, two women participating in the present study were already post-menopausal. Since menopause seems to influence PEH responses [40], this factor could have affected the results. However, an alternative analysis excluding these women did not affect the general conclusions and, for this reason, we decided to maintain them in the final analysis. Secondly, the menstrual cycle of non-menopausal women was controlled by self-report and experimental sessions were conducted in a similar phase of their cycle, avoiding the early-follicular phase [41]. Third, the present study engaged only normotensive, non-sedentary healthy subjects, which limits the clinical applicability of our results. Although PEH is a clinically desirable response for hypertensive subjects, previous evidence suggests that blood pressure reduction in response to exercise is also important for the prevention of cardiovascular diseases and cardiovascular events in normotensive patients [42]. The physical activity level may also have influenced the sex-differences in PEH and next studies should verify these responses along the full physical activity spectrum (i.e., sedentary to athletes). Finally, due to methodological restraints, we were unable to perform HRV recordings during daily work, which did not allow us to verify the autonomic impact of AE and RE on work routine.

Future studies should investigate the sex-related differences in post-AE and post-RE BP and HRV in hypertensive or in cardiovascular disease populations for immediate and prolonged post-exercise hours. Therefore, the present results strengthen the clinical importance of RE on BP control, particularly for men, since a reduced BP during work hours might prevent negative outcomes. However, it should be taken into account that RE causes greater autonomic stress, so it should be used with care in populations with autonomic imbalance, whether hypertensive or normotensive.

Conclusion

A circuit-based RE protocol is effective in reducing both SBP and DBP at the immediate post-exercise laboratory phase and during nine hours of daily work activities in healthy men but not in women. On the other hand, moderate-intensity AE slightly reduces DBP during work journey in men and decreases SBP only for the first-hour post-exercise in women. In both sexes, RE promoted a greater autonomic impact than AE as observed by the greater HRV reduction after the former.

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