

Absence of sex differences in systolic blood pressure and heart rate responses to exercise in healthy young adults

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Summary: The influence of sex on systolic blood pressure (SBP) and heart rate (HR) responses associated with cardiovascular morbidity, in healthy young adults was determined in ninety healthy young adults (47 females and 43 males) exercised using Bruce protocol. SBP and HR were measured pre- and post-exercise, and during recovery. SBP_{response} (peak minus pre-exercise SBP), $\%SBP_{\text{response}}$ [(peak minus pre-exercise SBP)÷pre-exercise SBP]x100, SBP_3 (SBP 3 minutes into recovery), SBP_4 (SBP 4 minutes into recovery), $SBP_{3:\text{peak}}$ (SBP_3 ÷peak SBP), $\%SBP_{d3}$ [(peak SBP minus SBP_3 minutes into recovery)x peak SBP]x100, $\%SBP_{d4}$ [(peak SBP minus SBP_4 minutes into recovery)x peak SBP]x100, HR_{response} (Peak HR minus pre-exercise HR), $\%HR_{\text{response}}$ [(peak HR minus pre-exercise HR)÷pre-exercise HR]x 100, HR_3 (HR 3 minutes into recovery), HR_4 (HR 4 minutes into recovery), $\%HR_{d3}$ [(peak HR minus HR 3 minutes into recovery)÷peak HR]x100, $\%HR_{d4}$ [(peak HR minus HR 4 minutes into recovery)÷peak HR]x100, and HR_{50-70} (HR between 50th and 70th seconds into recovery) were derived from SBP and HR measurements. SBP_{peak} , HR_{response} and $\%HR_{\text{response}}$ were higher ($p<0.05$) in males than in females whereas, SBP_{response} , $\%SBP_{\text{response}}$ and HR_{peak} were not different ($p>0.05$). There were no significant differences ($p<0.05$) in the post-exercise SBP and HR responses of males and females except for SBP_3 , SBP_4 , HR_3 and HR_4 . After adjusting for exercise duration, body mass index (BMI), and resting SBP and HR, these variables became similar ($p>0.05$). Sex differences in some SBP and HR responses to exercise, become nonexistent after adjusting for BMI, exercise duration, and resting SBP and HR.

Keywords: Diastolic blood pressure, Systolic blood pressure, Dynamic exercise, Sex difference.

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INTRODUCTION

Systolic blood pressure (SBP) and heart rate (HR) reach a plateau during exercise and remain at or near this value through the first minute of the recovery period. In normal individuals, this plateau is followed by a rapid and uniform decline of the SBP, to the resting value within five minutes (Taylor and Bellar, 1998). The HR, however, returns to resting rate over several minutes to hours, with the most marked reductions in the first few minutes after exercise (Deschenes et al, 2006; Laurer, 2008). A number of studies have established an association between delayed recoveries of SBP (Papazoglow et al, 1991; Hashimotor et al, 1993; Taylor and Bellar, 1998) and HR (Watanabe et al, 2001; Shetler et al, 2001; Curfman and Hillis, 2003; Mora et al, 2003) to the resting levels and the presence and extent of heart diseases.

The ratio of SBP at 3 minutes of recovery to peak exercise SBP ($SBP_{3:\text{peak}}$) is an important indicator of significant coronary artery disease with a diagnostic

accuracy of approximately 75%, and a ratio greater than 0.9 is considered abnormal, (Filiposvsky et al, 1999). Furthermore, several studies (Amon et al, 1984; Tsuda et al, 1993; Taylor and Bellar, 1998) indicated that using $SBP_{3:\text{peak}}$ provided the best discrimination between normal and abnormal patients (Taylor and Bellar, 1998). In addition, percentage SBP decline ($\%SBP_{\text{decline}}$) is often employed in the assessment of cardiovascular responses to physical stress (Dimkpa et al, 2008). Miyai et al, (2002) asserted that the magnitude of an exercise-induced SBP response (SBP_{response}) may present a risk factor for death from cardiovascular and non-cardiovascular causes, independent of resting blood pressure (BP).

Studies have shown that percentage of HR response ($\%HR_{\text{response}}$) provides accurate estimates of exercise intensity in both athletes and nonathletes (Karvonen and Vuorimaa, 1988; American College of Sport Medicine, 1991). Sanoven et al (2006) reported that a blunted HR increase during exercise testing at 40-100% of maximal workload indicated an autonomic nervous system impairment frequently

found in cardiac patients. The mechanism by which an impaired HR response could be associated with increased cardiovascular disease mortality includes exercise-induced myocardial ischemia (Savonen et al, 2006) and a decreased cardio-respiratory fitness (Laurer et al, 1999). In addition, impaired HR recovery predicts all-cause mortality and cardiovascular events, including sudden death in healthy population and in patients with coronary artery disease (Lauer, 2008). The link between HR recovery and mortality may be mediated through vagal tone and physical fitness (Cole et al, 1999). Even among apparently healthy subjects, HR recovery is an indicator of aerobic fitness and cardiovascular health (Fei et al, 2005). Heart rate recovery over the first 50-70 seconds (HR₅₀₋₇₀) has been reported to be a predictor of cardiovascular mortality (Hadley et al, 2008).

The factors that affect arterial pressure response to physical exertion in apparently healthy men and women include resting arterial pressure, smoking status, body surface area, exercise duration (O'Toole, 1992; Daida et al, 1996), obesity (Becker et al, 2007), genetics (Van Den Bree et al, 1990), and a family history of hypertension (Guyton et al, 2006). Certain other factors that may modify the cardiovascular response to exercise include phase of the menstrual cycle, pregnancy, age, exercise mode and environmental conditions (O'Toole, 1992). A number of studies have investigated the influence of sex on SBP responses (Gleim et al, 1991; Daida et al, 1996; Dimkpa et al, 2008; Dimkpa et al, 2009). Report on the influence of gender on HR responses to dynamic exercise, however, is not readily available (Pels et al, 1981). None of these studies on SBP and HR responses has examined sex differences in post-exercise SBP and HR values predictive of cardiovascular morbidity except Dimkpa et al (2008). The present study extends that of Dimkpa et al (2008) in that in analysing for sex differences in the SBP and HR variables, adjustments were made for some factors that may confound the influence of sex on SBP and HR responses. This study therefore investigated the influence of sex on SBP and HR responses predictive of cardiovascular morbidity among healthy young adults.

MATERIALS AND METHODS

Participants

Ninety healthy nonathletic young adults (43 males and 47 females), recruited using a non-probability sampling technique, participated in this study. The participants were undergraduate students, not older than 30 years, of Faculty of Health Sciences and Technology, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nnewi, Nigeria. They had neither physical deformity nor neurological

deficit that might preclude performance of exercise on a treadmill. They did not engage in exercise training or competitive sports, at least, two weeks prior to the exercise testing and did not consume caffeine or alcohol within 48 hours prior to the exercise test. The participants were non-smokers and had no history of cardiovascular and respiratory diseases. None of the female participants was pregnant nor in her period of menstruation. We informed them of the procedures of the study and their consents were obtained before participating. The Ethics Committee of Nnamdi Azikiwe University Teaching Hospital approved the procedures for this study.

Procedures

We included participants in this study based on their responses to a General Health and Lifestyle Questionnaire. On obtaining the consents to participate in this study, and on ascertaining that all inclusion criteria were met and that no exclusion criterion was present, the participants were given a date for the exercise testing which was not more than two weeks away. We pleaded with the participants not to participate in any competitive sport or strenuous exercise, other than normal daily activities, for the whole of the intervening period, and also not to engage in alcohol or caffeine consumption in the 48 hours prior to the given exercise date.

The venue of the data collection was the laboratory of the Department of Medical Rehabilitation, College of Health Sciences, Nnamdi Azikiwe University, Nnewi. Upon arrival at the venue, each participant rested for at least 30 minutes to allow their BP and HR to fall to the resting levels. Then, resting BP (SBP and diastolic BP) and HR were measured with an automatic BP monitor (Omron-HEM-712). Measurements included height, weight and body mass index (BMI). Bruce protocol was employed in carrying out the exercise performance (Bruce and Hornstein, 1976). The exercise was performed to the participants' comfortable exhaustion and SBP, diastolic BP and HR were taken at exhaustion. At the end of exercise session, the measurements were repeated between 50th and 70th seconds as well as at the third and fourth minute into recovery. From the measured SBP and HR measurements, the following variables were derived: SBP_{response} (peak minus pre-exercise SBP), %SBP_{response} [(peak SBP minus pre-exercise SBP)÷pre-exercise]x 100, SBP₃ (SBP at 3 minutes into recovery), SBP₄ (SBP at 4 minutes into recovery), SBP_{3:peak} (SBP₃÷peak SBP), %SBP_{d3} (percent of peak SBP minus SBP at 3 minutes into recovery), %SBP_{d4} (percent of peak SBP minus SBP at 4 minutes into recovery), HR_{response} (Peak HR minus pre-exercise HR), %HR_{response} [(peak HR minus pre-exercise HR)÷pre-exercise]x 100, HR₃ (HR at 3

minutes into recovery), HR₄ (HR at 4 minutes into recovery), %HR_{d3} (percent of peak HR minus HR at 3 minutes into recovery), %HR_{d4} (percent of peak HR minus HR at 4 minutes into recovery), and HR₅₀₋₇₀ (HR between 50th and 70th seconds into recovery).

Blood Pressure and Heart Rate Measurements

After the initial 30 or more minutes rest, BP and HR were measured in the sitting position using an automated BP device (Omron, HEM-712) following the recommended standards (Wilson et al, 2000). Three measurements, separated by 2 minutes, were taken for pre-exercise BP and HR, and the mean calculated and recorded in mmHg and beats/minute respectively. For the measurement at the end of the exercise test and in the post-exercise period, however, one measurement was feasible.

Statistical Analysis

The data obtained were analysed using Statistical Package for Social Science (SPSS) version 16. Independent t-test was used to compare descriptive characteristics of male and female groups, and their unadjusted SBP and HR responses to exercise. A one-way analysis of co-variance (ANCOVA) was used to compare SBP and HR responses to exercise between male and female groups with adjustment made for the baseline SBP, HR, duration of exercise, and body mass index (BMI).

RESULTS

The mean values of physical characteristics of participants are as shown in Table 1. The mean weight, height, and pre-exercise SBP were higher ($p < 0.05$) in males than in females. The mean pre-exercise HR, however, were higher ($p < 0.05$) for females than for males.

Table 2 shows that SBP_{peak} ($p = 0.011$), %HR_{response} ($p = 0.039$) and HR_{response} ($p = 0.014$) were higher in males than in females whereas, BP responses [SBP_{response} ($p = 0.136$) and % SBP_{response} ($p = 0.087$)] and HR_{peak} ($p = 0.347$) were not significantly different

between the two sexes. After adjusting for resting SBP, resting HR, exercise duration and BMI, the SBP_{response} ($p = 0.834$), %SBP_{response} ($p = 0.558$), and HR_{peak} ($p = 0.815$) remained similar between the two sexes while the SBP_{peak} ($p = 0.484$), HR_{response} ($p = 0.987$) and %HR_{response} ($p = 0.997$) became similar.

Table 1. Physical characteristics of participants

	Male	Female
Age (yr)	22.0±2.2	21.2±1.2
Weigh (kg)*	67.5±7.9	61.5±8.7
Height (m)*	1.8±0.1	1.7±0.1
Body mass index (kg/m ²)	21.9±2.1	22.3±2.5
Pre-exercise SBP (mmHg)*	115.7±8.6	106.3±7.2
Pre-exercise DBP (mmHg)	68.4±7.1	65.6±7.6
Pre-exercise HR (mmHg)*	72.2±10.1	78.5±9.9

*significant difference; DBP= Diastolic BP

Table 2. Exercise performance characteristics of the participants

	Male	Female
Exercise Duration (minutes)*	16.5±4.1	11.1±2.5
SBP _{peak} (mmHg)*	148.3±13.1	141.2±13.1
SBP _{response} (mmHg)	31.7±10.8	35.7±14.6
%SBP _{response} (mmHg)	28.6±11.8	33.2±13.5
DBP _{response} (mmHg)	1.2±11.1	1.5±8.7
HR _{peak} (beats/minute)	132.3±15.2	128.9±18.3
HR _{response} (beats/minute)*	59.1±19.9	50.3±20.2
%HR _{response} (beats/minute)*	85.0±37.2	66.5±32.0

*significant difference; Diastolic BP

There were no significant differences in the post-exercise SBP and HR responses of males and females except for SBP₃ ($p = 0.027$), SBP₄ ($p = 0.003$), HR₃ ($p = 0.005$) and HR₄ ($p = 0.004$) (Table 3). After

Table 3: Comparison of Post-Exercise Responses between Males and Females

	Unadjusted		Adjusted	
	Male ($\bar{X} \pm SD$)	Female ($\bar{X} \pm SD$)	Male ($\bar{X} \pm SE$)	Female ($\bar{X} \pm SE$)
SBP _{3:peak}	0.9± 0.1	0.9± 0.1	0.9± 0.0	0.9± 0.0
SBP ₃ (mmHg)*	127.7±11.9	122.2±11.0	123.3±1.9	126.2±1.8
SBP ₄ (mmHg)*	119.7±10.6	113.5± 8.3	115.0±1.3	117.8±1.3
%SBP _{d3} (mmHg)	13.7± 6.9	13.2± 6.2	15.3±1.2	11.8±1.1
%SBP _{d4} (mmHg)	19.4±7.0	19.5± 6.7	21.0±1.2	18.1±1.2
HR ₃ (beats/minute)*	112.2±14.7	103.8±12.4	108.8±2.4	107.0± 2.3
HR ₄ (beats/minute)*	109.7±13.0	102.3±10.4	106.3± 2.0	105.3± 1.9
%HR _{d3} (beats/minute)	15.6± 8.7	18.3± 8.1	16.0± 1.6	17.9±1.5
%HR _{d4} (beats/minute)	16.8±8.6	18.3± 8.1	17.2±1.6	19.4±1.5
HR ₅₀₋₇₀ (beats/minute)	132.3±15.2	128.9±18.3	130.0±3.1	131.0± 3.0

*unadjusted significant difference

adjusting for resting SBP, resting HR, BMI and exercise duration, however, the four variables became similar between males and females: SBP₃ ($p=0.329$), SBP₄ ($p=0.180$), HR₃ ($p=0.639$) and HR₄ ($p=0.751$) (Table 3).

DISCUSSION

The main objective of this study was to examine the possible influence of sex on the SBP and HR responses, predictive of cardiovascular morbidity, to dynamic exercise in healthy young adults. This study showed that there were no significant differences in SBP_{response}, SBP_{3:peak}, %SBP_{response}, %SBP_{d3}, and %SBP₄ between male and female participants except for SBP_{peak}, SBP₃, and SBP₄ which were significantly higher in males than in females. When the significantly different variables were adjusted for resting SBP, resting HR, exercise duration, and BMI, however, they became similar between males and females. Similarly, unadjusted significant differences were found for only HR_{response}, %HR_{response}, HR₃ and HR₄. When adjustment was made for resting SBP, resting HR, exercise duration, and BMI, these HR variables no longer showed significant difference between males and females. These findings therefore suggest that sex does not influence SBP and HR responses to dynamic exercise in healthy young adults. The findings may also indicate the possible roles of resting SBP, resting HR, exercise duration, and BMI in the SBP and HR responses to dynamic exercise. Arterial response to physical exertion had been earlier reported to be affected by resting arterial pressure, exercise duration (Daida et al, 1996) and obesity (Becker et al, 2007). These findings, therefore, may suggest that sex does not play a role in exercise testing that involves observation for any of these SBP and HR indices for cardiovascular morbidity.

In a recent similar study on sex differences in SBP and HR responses during and after exercise in nonathletic young adults (Dimkpa et al, 2008), differences were reported, between males and females, for SBP₃, HR₃, %SBP_{d3}, %HR_{d3}, and SBP_{3:peak}. In Dimkpa's et al (2008) study, participants exercised to exhaustion, as in the present study, and thus might have differential exercise duration. Participants might also have differential body weights. Exercise duration (O'Toole, 1992; Daida et al, 1996) and obesity (Becker et al, 2007) are factors that can affect arterial pressure responses to physical exertion. Furthermore, the sex difference in maximal cardiac output and stroke volume, of which arterial blood pressure is a function, can be accounted for by the greater percentage of body fat in women than in men (Ogawa et al, 1992). These differential factors in

males and females were not adjusted for, and this may be responsible for the findings of sex differences in those variables. In another previous study on physiological responses of men and women to an exercise bout at the same relative intensity (Deschenes et al, 2006), HR, either expressed in beat per minute or as a percentage of the peak values, and mean arterial pressure responded similarly among men and women both during and following the exercise bout. They, however, reported that men exhibited significantly higher SBP values than women at both 15 and 30 minutes of cycling which somehow conforms to the unadjusted finding in the present study. While the duration of exercise performance was the same for all the participants in their study, they reported significant differences in body mass and percent body fat of men and women, and these were not adjusted for. These discrepancies in the data treatment of the previous studies and our study may account for the difference in findings. Although, there are some physiologic differences that may affect the mechanism of cardiovascular changes, the overall response of the cardiovascular system to exercise is similar in men and women (O'Toole, 1989).

Studies (McHam et al, 1999; Laukkanen et al, 2004) have associated blunted decline of SBP during recovery (that is, SBP_{3:peak} > 0.9) with increased risk of coronary artery disease, angina pectoris and myocardial infarction. In this study, mean SBP_{3:peak} of 0.862 ± 0.07 and 0.867 ± 0.07 were found for males and females respectively. These findings show that the participants in this study had sound cardiovascular health and were indeed healthy.

In interpreting the data in this study, certain limitations may have to be considered. The findings in this study may not be generalized to individuals with cardiovascular diseases. Also, findings from a similar study in older people may be different. In view of these limitations, more studies of this nature in individuals with cardiovascular disease and healthy older people are recommended. Furthermore, more studies of this nature are encouraged to determine the validity of these findings.

In conclusion, sex differences in some SBP and HR responses, predictive of cardiovascular morbidity, of male and female healthy young adults disappear after adjustment for some covariates.

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