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ASSESSMENT OF SEX DIFFERENCES IN SYSTOLIC BLOOD PRESSURE RESPONSES TO EXERCISE IN HEALTHY, NON-ATHLETIC YOUNG ADULTS

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ABSTRACT

DIMKPA U, UGWU AC, OSHI DC. **Assessment of Sex Differences in Systolic Blood Pressure Responses to Exercise in Healthy, Non-Athletic Young Adults.** ***JEPonline*** 2008;11(2):18-25. Gender-differences in systolic blood pressure (SBP) responses to maximal exercise have not been reported previously. We assessed gender-differences in SBP during and after exercise in non-athletic young adults. Three hundred and twenty five young adults 18-35 years (males n=160; 22.38 ± 3.74 yrs and females n=165; 22.28 ± 2.62 yrs) performed ergometer exercise at > 90% maximum heart rate. SBP and heart rate (HR) were measured during exercise at 2 minutes intervals, and post-exercise at 2 minutes interval until SBP recovered to baseline. SBP responses during and after maximal exercise were assessed using percentage SBP rise ($\%SBP_{RISE}$) and SBP ratio in 3 minutes of recovery relative to 1 minute ($SBPR_2$). Males experienced a significantly higher $\%SBP_{RISE}$ (39.82 ± 9.52; $p<0.001$) and lower $SBPR_2$ (0.92 ± 0.06; $p<0.001$) in comparison to females. Correlation between $\%SBP_{RISE}$ and $\%HR_{RISE}$; $SBPR_2$ and VO_{2MAX}; $SBPR_2$ and %HR decline in 1 min and $SBPR_2$ and %HR decline in 3 min were 27%, 59%, 32%, 24% in males and 4%, 34%, 25%, 23% in females. Our data showed gender differences in SBP responses while males indicated higher SBP response during and after exercise than females. The reported data may be useful in interpreting more accurately the significance of abnormal SBP responses to exercise in statistical terms stratified by gender.

Key Words: VO_{2MAX}, Ergometer; Heart Rate; SBP Ratio, Workload.

INTRODUCTION

A normal response in an apparently healthy subject is a linear increase in SBP as exercise intensity increases. This rise in SBP with increasing dynamic work is a result of increase in cardiac output (1). Cardiac output increase during exercise is a function of (heart rate) HR X (stroke volume) SV. During exercise, an increase in sympathetic activity and a decrease of vagal discharge leads to an increase of HR, SV and myocardial contractility to satisfy energy demands of working skeletal muscles (2). Systolic blood pressure reaches a plateau at peak exercise and remains at or near this value through the first minute of the recovery period following a tolerable exertion exercise (3). After maximum exercise, there is normally a decline in SBP, which generally reaches resting levels within five minutes to six minutes (1, 4).

Lack of scientific data exists regarding gender differences in normal SBP responses during and after maximal exercise. Investigations regarding SBP responses to progressive exercise have mainly been applied towards clinical application in diagnosing cardiovascular abnormalities. For example, an exercise-induced rise in SBP has been found (5, 6, 7, 8, 9) to be a predictor of labile hypertension left ventricular hypertrophy and stroke in apparently healthy people. Studies (10, 11, 12, 13) have associated a decline in SBP during recovery with increased risk of coronary artery disease, angina pectoris and future myocardial infarction.

The purpose of this study is to determine, gender differences in normal SBP responses during and after a maximal-effort cycle ergometer exercise test in healthy young adults of 18-35 years. We hypothesized that the degree of rise of SBP during exercise and the rate of decline of SBP after exercise were higher in males than females. Additionally, we hypothesized that gender differences in the degree of SBP rise may be associated with the degree of rise in HR, while that of rate of SBP decline may be associated with the percentage HR decline and maximum oxygen uptake (VO_{2MAX}).

METHODS

Subjects

Three hundred and twenty five, healthy, non-athletic, young-adult Nigerians selected from College of Health Sciences, Igbinedion University, Okada, in Edo State, Nigeria, participated in the study between 2004 and 2006. Of this population, 160 (22.38 ± 3.74 years) were males, while 165 (22.28 ± 2.62 years) were females. Subjects were selected based on the results of a structured health and life-style screening questionnaire, their ability to perform a maximum-effort exercise test, body mass index measurement (computed as weight in kilogram divided by height in meters squared), resting blood pressure and resting HR measurements, urinalysis and blood chemistry tests. Subjects were excluded if they had a history of unstable cardiovascular, peripheral vascular and respiratory disease, a malignancy, and orthopedic or musculoskeletal lesions. Subjects selected were non-athletic but physically active (since they occasionally participated in recreational activities such as soccer, table tennis, lawn tennis, and basketball), non-smokers, non-alcoholics, non-obese, non-diabetics, non-asthmatics, non-hypertensive, apparently healthy and free of cardiovascular diseases and not taking medications that could affect cardiovascular functions, such as heart rate. Subjects were informed (written and oral) of the experimental procedures and their consents were obtained before participation. The Experiments and Ethics Committee of the College of Health Sciences of the University approved the study.

Procedures

The exercise test was performed between 8.00 AM and 11.00 AM in a well-ventilated room of about 29ºc temperature, using a mechanically braked cycle ergometer. Participants were instructed not to consume beverages containing alcohol or coffee and not to eat a heavy meal or participate in any

vigorous activity 24 hours before the test. They were also properly instructed on how to perform the exercise test with demonstrations. The testing protocol consisted of an initial two-minute warm up exercise at a work rate of 180 kg-m/min (˜ 30 Watts work load). This was followed by an increase in workload of 120 kg-m/min (20W) every minute until the subject reached a tolerable exhaustion. Heart rate was measured twice before exercise after 5 minutes and 10 minutes of rest with the subject sitting on the cycle ergometer using the Omron electronic monitor. The mean of the values was used as the pre-exercise HR. During the exercise test, HR was measured at 2-minute intervals. The peak HR was the highest value achieved during the exercise test. At post exercise, HR was first measured at one minute of recovery and subsequently at every 2 minutes interval (i.e. 1, 3, 5....min) and discontinued as soon as the SBP returned to pre-exercise value. Percentage HR rise was computed as [peak HR minus pre- exercise HR divided by pre-exercise HR] x 100. Percentage HR decline after exercise was calculated as [peak HR minus post-exercise HR (at 1min and 3 min, respectively) divided by peak HR] x 100.

During the progressive exercise test, the maximal oxygen uptake (VO_{2MAX}) and the maximum carbon dioxide production (VCO_{2MAX}) were measured using a breath-by-breath Oxycon Alpha respiratory gas analyzer (Jaegar, Wuerzburg, Netherlands). Criteria for the establishment of VO_{2MAX} included a plateau in oxygen consumption despite an increase in cycling speed, a respiratory exchange ratio greater than 1.00, and an achievement of age-predicted maximum HR above 90%. The rating of perceived exertion to exercise (RPE) (14) was obtained through an oral questionnaire for the subjects immediately after the exercise. The most common reasons for stopping the exercise test were leg fatigue, exhaustion, breathlessness, and dizziness irrespective of sex. An experienced physician supervised the entire exercise test.

Blood Pressure Measurements

Resting blood pressure was measured one week earlier before the exercise test to ascertain whether a subject was normotensive or not. The measurement was done after 10 and 15 minutes of rest in a seated position in a quiet room, using the cuff stethoscope method. The mean of the two values was used as the resting blood pressure. Subject's pre-exercise blood pressure was measured twice also after 10 and 15 minutes of rest while sitting on the cycle ergometer using the electronic sphygmomanometer (Omron). There was no significant difference observed between the earlier obtained resting blood pressure and the pre-exercise blood pressure values in both males and females. The two SBPs showed variances of 86.12 (resting SBP) and 84.80 (pre-exercise SBP) in males and 122.24 (resting SBP) and 119.06 (pre-exercise SBP) in females. During maximal exercise, blood pressure was measured every two minutes using the electronic method. The peak SBP was defined as the highest value achieved during the test. SBP within the first minute after exercise and further measurements of SBP at two minute intervals until recovery to pre-exercise level were measured with the subject still sitting on the cycle without pedaling. The degree of SBP rise during maximal exercise may reflect changes in sympathetic and parasympathetic activities (13), thus percentage rise of SBP was used in the assessment of SBP response during exercise. Percentage rise of SBP during exercise was calculated as [(peak SBP - pre-exercise SBP) ÷ pre-exercise SBP] x 100. Percentage decline of SBP during recovery was calculated as [peak SBP - post-exercise SBP (at 1min and 3 min, respectively) ÷ peak SBP] x 100. SBP ratio (SBPR) is a very useful and readily obtainable parameter, often employed in the assessment of cardiovascular responses to physical stress. Ratio of SBP at 3 min of recovery to peak exercise ($SBPR_1$) was computed as post SBP at 3 min divided by peak SBP while ratio of SBP at 3 min of recovery to 1 min of recovery ($SBPR_2$) was computed as post exercise SBP at 3 min divided by post exercise SBP at 1 min. We investigated gender differences in SBP recovery using the third minute SBP ratio relative to 1 minute of recovery ($SBPR_2$). This ratio was preferred to the third minute SBP ratio relative to peak exercise because it has the advantage of the accuracy of blood pressure measurement (11]) since both SBPs can be

obtained only in the recovery state. This avoids the inaccuracy associated with exercise blood pressure measurement (15).

Statistical Analyses

Descriptive data are presented as means and standard deviations (SD) for continuous data. Data analysis between the two genders was compared using Independent-Sample T-tests. Correlations between percentage rise in SBP and percentage rise in HR, and correlations of $SBPR_2$ with VO_{2MAX}, and %HR decline (at 1min and 3 min of recovery respectively) were analyzed using Pearson's bivariate correlation test. Associations between $\%SBP_{RISE}$ and $\%HR_{RISE}$ with adjustment for VO_{2MAX}, and maximum work load $Load_{max}$; between $SBPR_2$ and VO_{2MAX} with adjustment for Age; and between $SBPR_2$ and %HR decline in 1min and 3min with adjustment in VO_{2MAX} were analyzed using Partial Correlation Coefficient test (SPSS for Windows, Version 11.0). Statistical significance was set at $p<0.05$ for independent sample t-tests and $p<0.01$ for correlation tests.

RESULTS

Baseline Characteristics of Subjects

Demographic data and measured values of baseline characteristics of subjects are as presented in Table 1. Age, body mass index (BMI) and pre- exercise systolic blood pressure (SBP_{PRE}) showed no significant differences between genders. Pre- exercise diastolic blood pressure (DBP_{PRE}) was significantly higher in males than females ($p<0.001$), while pre-exercise heart rate (HR_{PRE}) was significantly lower ($p<0.001$) in males than females.

Table 1. Baseline characteristics of the subjects for different genders.

Characteristics	Males (n=160)	Females (n=165)
Age (years)	22.38 ± 3.74 (18 -35)	22.28 ± 2.62 (18-33)
BMI (kg/m^2)	21.76 ± 2.06 (17.30-26.50)	21.59 ± 2.45 (16.49-29.0)
SBP_{PRE} (mmHg)	117.35 ± 9.20 (96-138)	116.85 ± 10.91 (94-138)
DBP_{PRE} (mmHg)	79.26 ± 6.18 * (68-90)	73.82 ± 7.57 (60-88)
HR_{PRE} (bpm)	72.59 ± 4.98 * (59-87)	75.09 ± 4.28 (62-88)

Source: Laboratory Data. Data are means ± SD and range, n= number of subjects, * = males are significantly different from females

Characteristics of Subjects during Exercise

During the exercise test, peak exercise SBP (SBP_{PEAK}), peak exercise DBP (DBP_{PEAK}), percentage rise of SBP ($\%SBP_{RISE}$), maximum oxygen uptake (VO_{2MAX}), maximum carbon dioxide production (VCO_{2MAX}), maximum workload ($Load_{max}$) and percentage rise of HR ($\%HR_{RISE}$) were significantly higher ($p<0.001$), in males than females. The peak exercise HR (HR_{PEAK}), respiratory exchange ratio (RER), rate of perceived exertion (RPE), showed no significant differences between both genders.

Post-Exercise Test Characteristics of Subjects

At post-exercise, SBP in 1 minute (SBP_{1MIN}), percentage decline of SBP after 3 minutes, percentage decline of HR after 1 minute, and percentage decline of HR after 3 minutes showed significantly higher values ($p<0.001$) in males than the females. There were no significant differences in post-exercise SBP in 3 minutes (SBP_{3MIN}) and percentage decline of SBP after 1 minute between both genders. Furthermore, males showed significantly lower values in, post-exercise HR in 1 minute (HR_{1MIN}), post-exercise HR in 3 minutes (HR_{3MIN}), ratio of SBP at 3 min of recovery to peak exercise ($SBPR_1$), and in ratio of SBP at 3 min of recovery to 1 min of recovery ($SBPR_2$), ($p<0.001$).

Table 2. Exercise test characteristics of subjects for different genders.

Characteristics	Males (n=160)	Females (n=165)
SBP_{PEAK} (mmHg)	163.41 ± 7.98 * (138-178)	156.14 ± 10.26 (132-176)
DBP_{PEAK} (mmHg)	79.88 ± 5.90 * (70-90)	74.32 ± 7.40 (60-90)
HR_{PEAK} (bpm)	198.53 ± 10.52 (175-212)	199.87 ± 9.78 (170-208)
$\%SBP_{RISE}$	39.82 ± 9.52 * (15.94-66.67)	34.01 ± 5.24 (18.84-45.83)
$\%HR_{RISE}$	174.47 ± 20.32* (133.33-220.31)	166.76 ± 16.77 (126.47-225.81)
VO_{2MAX} ($ml.kg^{-1}.min^{-1}$)	41.90 ± 6.06 * (30-51)	37.93 ± 3.07 (29-46)
VCO_{2MAX} ($ml.kg^{-1}.min^{-1}$)	46.83 ± 6.41 * (32-60)	42.93 ± 3.67 (32-52)
RER	1.12 ± 0.06 (1.00-1.30)	1.13 ± 0.06 (1.00-1.33)
$LOAD_{MAX}$ (Watts)	366.25 ± 17.55 * (325-400)	344.84 ± 17.99 (325-400)
RPE	18.43 ± 0.71 (17-20)	18.41 ± 1.02 (15-20)

Source: Laboratory Data. Data are means ± SD and range, n= number of subjects, * = males are significantly different from females.

Table 3. Post exercise characteristics of subjects for different genders.

Characteristics	Males (n=160)	Females (n=165)
SBP_{1MIN} (mmHg)	135.49 ± 10.85 * (119-172)	130.34 ± 10.14 (110-150)
SBP_{3MIN} (mmHg)	124.93 ± 8.21 (109-151)	124.00 ± 10.99 (96-146)
HR_{1MIN} (bpm)	110.86 ± 5.74 * (95-127)	120.28 ± 7.08 (92-136)
HR_{3MIN} (bpm)	70.20 ± 5.84 * (63-105)	78.49 ± 4.28 (68-90)
%SBP DECLINE IN 1MIN	17.02 ± 5.99 (1.71-28.41)	16.56 ± 2.26 (10.37-25.30)
%SBP DECLINE IN 3MIN	23.46 ± 4.91 * (8.70-32.95)	20.65 ± 3.28 (12.20-30.43)
%HR DECLINE IN 1MIN	43.94 ± 4.93 * (47.50-70.00)	39.73 ± 3.83 (30.11-47.12)
%HR DECLINE IN 3MIN	64.53 ± 3.50 * (41.67-68.50)	60.56 ± 3.79 (42.86-66.99)
$SBPR_1$	0.76 ± 0.05 * (0.67-0.91)	0.79 ± 0.03 (0.70-0.88)
$SBPR_2$	0.92 ± 0.06 * (0.76-1.01)	0.95 ± 0.02 (0.84-0.99)

Source: Laboratory Data. Data are means ± SD and range, n= number of subjects, * = males are significantly different from females.

Association of SBP Ratio with VO_{2MAX} and Percentage HR

Correlating $SBPR_2$ with VO_{2MAX}, males showed a stronger correlation (r= -0.766; r^2=0.59; p<0.001), than females (r= -0.586; r^2=0.34; p<0.001). A weaker correlation was observed after controlling for age, in males (r= -0.757; r^2=0.57; p<0.001) and females (r= -0.340; r^2=0.11; p<0.001). $SBPR_2$ also had a negative correlation with %HR decline in 1min in males (r= -0.563; r^2=0.32; p<0.001) and in females (r= -0.500; r^2=0.25; p<0.001). After controlling for VO_{2MAX}, the correlation was reduced in males (r= -0.145; r^2=0.02; p<0.05) and in females (r= -0.254; r^2=0.06; p<0.001). The correlation between $SBPR_2$ and %HR decline in 3 min was -0.482 (r^2=0.24; p<0.001) in males and -0.483 (r^2=0.23; p<0.001) in females. After adjustment with VO_{2MAX}, the correlation between the two variables was -0.297 (r^2=0.08; p<0.001) in males, and –0.150 (r^2=0.02; p<0.03) in females.

DISCUSSION

SBP Response during Exercise

In the present study, we assessed SBP response between males and females during maximal exercise using percentage SBP rise. Results indicate a significantly higher percentage rise in SBP in males than females. Studies (13, 16) have shown that a rise in SBP during exercise is mainly due to increase in cardiac output and reflects the level of sympathetic and parasympathetic drive. Increase in cardiac output is a function of increase in HR. Changes in blood pressure are usually mediated by the baroreflex mechanism via HR changes (17). This baroreflex mediated response of HR to changes in arterial blood pressure indicates the capacity of reflex cardiac autonomic modulation (18). A progressive increase in HR has been reported to be due to increase in sympathetic activity and a decrease in parasympathetic activity (19). Other studies have observed that men show greater sympathetic activity (20), and higher baroreflex responsiveness than females (18).

We did not study gender differences in autonomic nervous system modulation of the heart. However, but our study indicated gender differences in percentage rise of HR during exercise in which there was a higher percentage rise in HR in males than females. Whether changes in the degree of HR rise to exercise are responsible for sex differences in SBP response during maximal exercise is not clear and has not been reported. We therefore investigated whether percentage SBP rise was related to percentage HR rise. A regression analysis revealed a weak correlation between the two variables in both genders suggesting percentage HR rise to be a poor contributor to the changes observed in the percentage SBP rise.

Post-Exercise SBP Response

Previous studies have shown that SBP recovery ratio is a very important tool used in assessment of the rate of decline of SBP during recovery (3). Studies (10, 11, 12, 13) have associated blunted decline of SBP during recovery with increased risk of coronary artery disease, angina pectoris, and myocardial infarction. The ratio of SBP at 3 min to 1 min of recovery was used in the present study to assess gender differences in SBP response during recovery. The third minute SBP relative to 1 minute was preferred to the ratio of SBP at 3 min of recovery to peak exercise due to its advantage in accuracy of blood pressure measurement (11). The present study showed a faster decline of SBP during recovery (i.e. lower $SBPR_2$) in males than the females. To our knowledge, gender differences in the rate of decline of SBP during recovery have not been previously reported.

Our results further indicated a higher VO_{2MAX}, and higher %HR decline (at 1min and 3 min) in males than females. Studies (1, 21) have shown that aerobic capacity is higher in males than females, thus suggesting the influence of VO_{2MAX} on gender differences in SBP recovery. Gender differences in the rate of HR decline have not been previously studied. However, the rate of HR decline has been related to cardiovagal baroreflex sensitivity (2, 22). In these studies, increased sympatho-inhibition and vagal activation of the heart and arterial vasculature will enhance the decline of HR. Studies (18, 23, 24, 25) however, showed higher cardiovagal baroreflex sensitivity in men than women. Similarly, studies have shown that rate of HR decline is related to VO_{2MAX} (22, 26) which have been reported to be higher in males than females (1, 21).

We therefore investigated whether these variables were associated with the rate of SBP recovery. Results showed a substantive correlation between $SBPR_2$ and VO_{2MAX} in males (r^2=58%) and a weaker correlation in females (r^2=34%). These results suggest VO_{2MAX} as a contributor to the changes observed in rate of SBP recovery in this study. Results further revealed that %HR decline in1 min, and %HR decline in 3 min, weakly correlated with $SBPR_2$ respectively in both male and female groups. The correlations were greatly reduced when adjusted for VO_{2MAX} which has been

previously associated to rate of HR decline (22). The associations between $SBPR_2$ and percentage HR decline (in 1 min and 3 min) were however marked at 1 minute of recovery than at 3 minutes.

CONCLUSIONS

Normal systolic blood pressure response to maximal exercise shows gender differences amongst healthy, non-athletic, young adults. Young adult males of age 18-35 years showed higher responses as they presented higher percentage rise in SBP during exercise and higher rate of SBP decline during recovery. Percentage HR rise was not a strong contributor to the changes in SBP response during exercise. VO_{2MAX} on the other hand indicated stronger contribution to the changes in SBP response after exercise than percentage HR decline. The reported data could be used by clinicians in cardiac rehabilitation settings to interpret more accurately the significance of exaggerated SBP response during exercise in a subject of a specific sex and may permit investigators to define and interpret blunted SBP decline after exercise in statistical terms stratified by gender.

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