Determination of Systolic Blood Pressure Recovery Time after Exercise in Apparently Healthy, Normotensive, Nonathletic Adults and the Effects of Age, Gender and Exercise Intensity

UCHECHUKWU DIMPKA †1, ANDREW C. UGWU ‡2,
[1]Department of Physiology, Faculty of Basic Medical Sciences, Ebonyi State University, Abakiliki, Ebonyi State, Nigeria; [2]Department of Physiology, School of Medical Sciences, University of Benin, Benin City, Edo State, Nigeria

†Denotes graduate student author, ‡denotes professional author

ABSTRACT

Int J Exerc Sci 2(2): 115-130, 2009. The aim of this study was to determine in statistical terms, the systolic blood pressure recovery time (SBPRT) and the effects of age, gender and exercise intensity in a large sample of apparently healthy non-athletic adults (n=597, aged 18-68). Subjects performed mild, moderate, and severe ergometer exercise tests. Blood pressure was measured before exercise (after 10 and 15 minutes of rest), during exercise (at 2-minute intervals) and at every minute of post-exercise recovery until systolic blood pressure (SBP) returned to baseline. The present findings indicate that the average values of SBPRT were between 5 and 7 minutes regardless of age, gender or exercise intensity. Systolic blood pressure recovery time increased with each age group ($p<0.001$) in all the exercise intensities. Young and middle-aged men indicated higher SBPRT than females ($p<0.001$) in mild and moderate exercise regimens. In men, SBPRT appeared to decrease with increase in exercise intensity ($p<0.001$) but indicated no significant differences amongst the exercise intensities in women. The present study therefore indicated mean SBPRT values that were consistent with previously reported values and which indicated age and gender effects following three exercise intensities of cycle ergometer. The reported data will help clinicians to define post-exercise SBP responses in statistical terms stratified by age, gender and exercise intensity in future investigations and during clinical assessment of individuals.

KEY WORDS: Recovery time, exercise intensity, cycle ergometer, systolic blood pressure.

INTRODUCTION

Systolic blood pressure recovery after exercise represents an important index of cardiovascular and autonomic nervous system response to physical stress and has been shown to be a clinical tool applied toward diagnosing cardiovascular abnormalities (11, 14, 15, 17, 21). After exercise, systolic blood pressure (SBP) is expected to decline rapidly and uniformly from peak exercise level to baseline (23). The time it takes blood pressure to recover to resting position after physical stress has been reported to be an index of autonomic function (24). A delay in the return of SBP to normal is therefore said to represent an abnormal response (23). These literatures suggest that blood pressure recovery time may be a potential clinical tool for interpreting blood pressure responses.

Apart from two previous reports (9, 23), limited studies exists on the average time it takes SBP to decline from peak to pre-exercise levels. The above reviews reported that SBP may generally reach pre-exercise levels within an average time of five to six minutes following exercise. However, these literatures failed to provide adequate information to elucidate their reports. For example, Fletcher et al. (9) could not cite any reference to support their report on systolic blood pressure recovery time (SBPRT), while the reference (1) cited by Taylor and Beller (23), failed to indicate any data relating to the reported time of recovery of SBP. Similarly, we could not find any previously published statistical data or methodologies to back up and elucidate these facts. Furthermore, studies (3, 4) have previously reported differences of age and gender on SBP responses to exercise but not SBPRT. No previous study has also statistically stratified SBPRT by age, and gender following three exercise intensities of cycle ergometry. The novel aspect of the present study therefore would be the quantification and stratification of SBPRT by age, and gender following three exercise intensities of cycle ergometry.

In the present study therefore, we aimed to determine statistically, the time it takes SBP to recover from peak exercise level to pre-exercise level. We carried out exercise tests involving apparently healthy men and women of different age groups, who underwent ergometer exercise tests of different intensities. We further investigated whether the systolic blood pressure recovery time is influenced by age, gender and exercise intensity. We therefore hypothesized that average SBPRT values may differ from previously reported values and will show age, gender and exercise intensity effects.

METHOD

Subjects

Five hundred and ninety seven apparently healthy, normotensive subjects between the ages of 18 to 68 years, selected from students and staff of Igbinedion University, Okada and residents of Okada town in Edo state Nigeria, participated in the study between 2004 and 2007. The number of study participants according to age, gender and exercise regimen is as indicated in Figure 1. Subjects were randomly selected based on the results of a structured health and lifestyle screening questionnaire, physical examination, morphometric measurements and medical history. Criteria for inclusion in the study were as follows: (a) subjects should be non-athletic but who should occasionally participate in recreational activities such as soccer, table tennis, lawn tennis, badminton, basketball, cycling and others; physical activity history of the subjects consisted of the subjects' yes or no responses to the question "Do you participate in recreational and sports activities for at least three times in a week" (subjects were also asked to mention types of recreational activities they participate in) (b) ability of a subject to at least perform a mild exercise intensity (50% of age–predicted maximum HR) (c) no prior history of unstable cardiovascular, peripheral vascular and respiratory disease, malignancy, and orthopedic or musculoskeletal lesions (d) subjects should be non-smokers, non-alcoholics, non-obese,

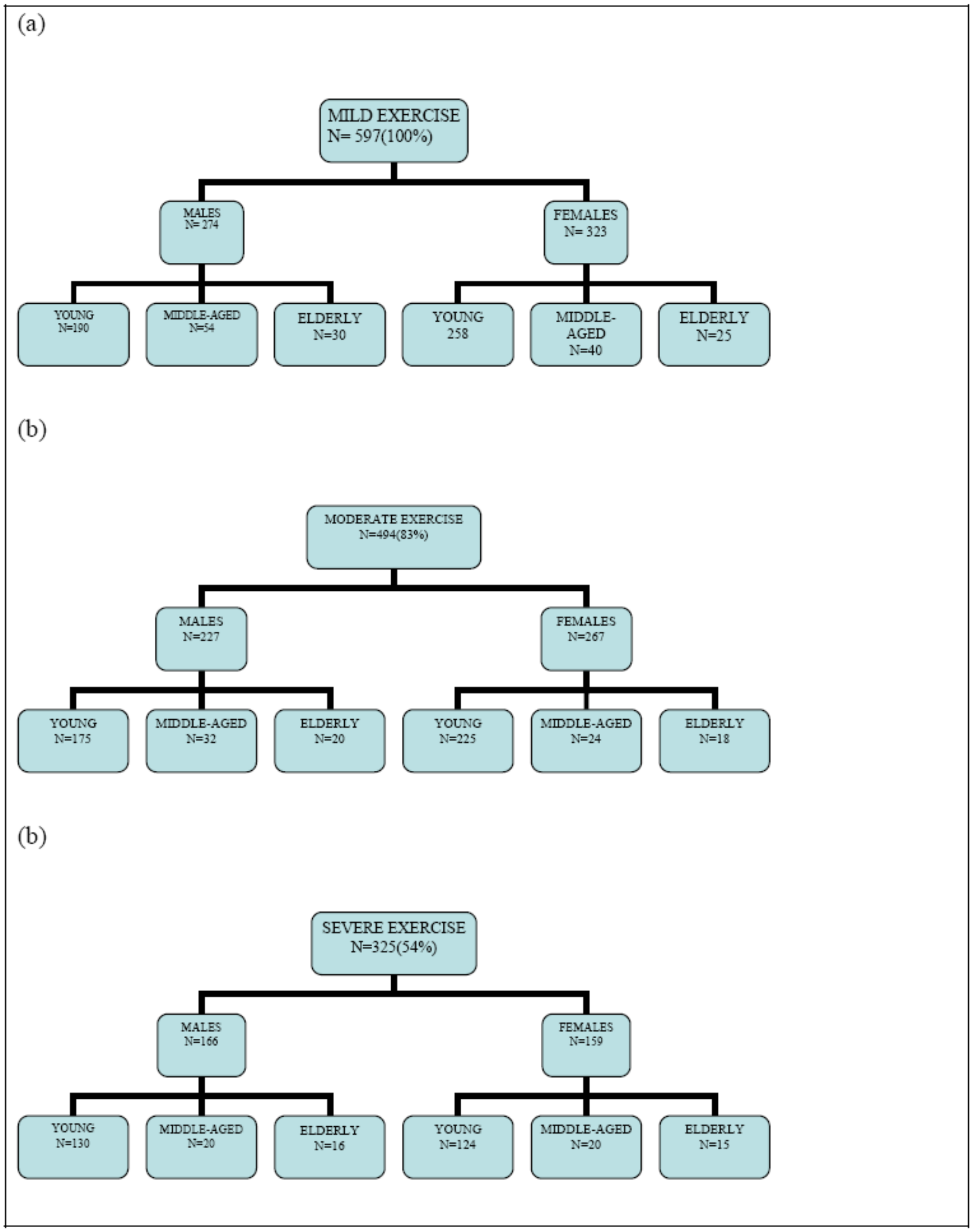

Figure 1. Flow diagram showing subjects participation by gender and age for each exercise regimen (a) mild exercise (b) moderate exercise (c) severe exercise. N=number of subjects.

and non-diabetics (e) not taking medications that could affect cardiovascular functions (f) not menstruating at the time of test if female. 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 Igbinedion University Okada, Edo state approved the study.

Table 1: Basal characteristics of the study population by age and gender. Data are means ± SD. *= significant age effect in both gender groups, ?= significant age effect among the male age groups only, ?= significant age effect among the female age groups only.

	MALES			FEMALES		
Characteristics	**Young**	**Middle-aged**	**Elderly**	**Young**	**Middle-aged**	**Elderly**
Participation	190	54	30	258	40	25
Age (yrs) *	22 ± 3.06	42 ± 5.42	63 ±2.40	20 ± 1.70	46 ± 6.34	62 ± 1.95
Height (m) ˅	1.76±0.06	1.73±0.09	1.66±0.07	1.65±0.06	1.67±0.05	1.66±0.09
Weight (kg) ^	68.3±7.69	69.5±7.51	70.7±7.36	60.3±7.80	63.5±8.44	68.8 ±7.0
Body Mass Index(kg/m2)*	22 ± 2.10	23.1±1.84	25.4±1.04	22 ± 2.27	22.5±2.18	24.8±0.80
Waist Circumference (cm) *	78.8±5.75	87.6±5.40	85.5±3.74	75.2±2.76	78 ± 2.49	75.1±2.20
Resting SBP (mmHg) *	120 ±8.29	124 ±6.31	129 ±4.22	118 ±11.8	123 ±3.22	125 ±2.50
Resting DBP (mmHg) *	76 ± 6.58	80 ± 5.86	83 ± 2.75	75 ± 7.76	77 ± 6.35	81 ± 2.45
Resting HR (bpm) ^	73 ± 5.26	73 ± 3.62	72 ± 3.00	75 ± 4.12	73 ± 2.64	72 ± 3.66

Exercise test

Each subject performed an exercise test involving three different exercise intensities, (mild, moderate, and severe). Each of the exercise intensity tests was performed on a separate day starting with mild, moderate, and then severe. The exercise tests were carried out between 8.00 AM and 11.00 AM in a well-ventilated room, using a mechanically braked cycle ergometer (Homeware Ltd, North York, Ontario, Canada). With the ergometer cycling protocol, it is easy to obtain reliable blood pressure measurements especially during recovery period. The cycle ergometer usually consists of progressive incremental workloads that may have minor effects on SBPs achieved during the exercise test (14). Participants were instructed not to consume beverages containing alcohol or coffee, not to eat a heavy meal, or participate in any vigorous physical activity 24 hours before the test. They were also properly instructed on how to perform the exercise test with demonstrations. The testing protocol was comprised of an initial two-minute warm up of exercise at a work load of 20 Watts, followed by a linear increase in workload by 20 Watts every minute until the subject reached a targeted percentage of age-predicted maximum heart rate for each exercise intensity (mild, 50%; moderate, 70%; severe, 80%). The age–predicted maximum HR (HRmax) was determined as [HRmax = 208 minus (0.7 x age)], (22). The rating of perceived exertion (RPE) to exercise (2) was obtained through an oral questionnaire for the subjects immediately after the exercise protocol. The RPE of

Table 2. Exercise test characteristics of subjects by gender and age. Data are means ± SD. *= significant age effect (in both gender groups), ? = significant age effect (among the female age groups only), †=significant gender effect.

	MALES			FEMALES		
Characteristics	**Young**	**Middle-age**	**Elderly**	**Young**	**Middle-age**	**Elderly**
Mild Exercise						
Peak exercise SBP(mmHg)*†	143±7.96	148±8.53	155±7.78	137±11.07	143±2.34	147±5.8
Peak exercise DBP(mmHg)*†	79± 6.21	82 ± 5.78	85 ± 2.66	76±7.69	79±6.24	83±2.10
Peak exercise HR (bpm) *†	96±1.07	89 ± 1.90	82 ± 0.84	97±0.59	88±2.22	82 ±0.68
Exercise duration*†	5.94 ±0.22	5.22± 0.76	4.63±0.49	5.59 ±0.49	5.02 ±0.69	4.60± 0.50
Rating of perceived exertion	11.0±0.96	11.5±0.75	11.7±0.47	10.97±0.83	11.07±0.76	11.56±0.51
Moderate Exercise						
Peak exercise SBP(mmHg)*†	166±11.42	168±9.42	173±7.33	159±13.79	166±6.0	171±6.67
Peak exercise DBP(mmHg)*†	80 ± 5.60	81 ± 5.69	84 ± 2.48	77±7.61	81±6.92	84±2.22
Peak exercise HR (bpm) *†	135± 1.51	126± 2.30	115 ± 1.06	136±0.86	120±3.34	115±1.03
Exercise duration*†	9.33± 0.75	9.06± 1.04	7.70±0.47	8.51± 1.04	8.87± 1.03	7.27± 0.75
Rating of perceived exertion	13.3±0.48	13.5±0.51	13.8±0.41	13.61±0.48	13.3±0.44	13.44±0.51
Severe Exercise						
Peak exercise SBP (mmHg)*†	182±10.5	186±10.37	189±7.32	179±13.99	183±6.83	186±6.95
Peak exercise DBP (mmHg)^†	80± 6.13	81±6.74	84± 2.36	74±7.43	79±6.59	83±2.31
Peak exercise HR (bpm) *	155±1.45	142±3.59	131±1.16	155±0.99	137± 3.64	131±1.25
Exercise duration*†	13.97±1.00	12.35±1.95	10.9±0.88	13.48±1.32	13.65±1.08	10.73±0.79
Rating of perceived exertion	18.7±0.63	18.8±0.69	19.4±0.50	18.9±0.71	18.6±0.60	19.1±0.64

subjects corresponded to the appropriate exercise intensity performed according to the Borg's scale. During the exercise tests, a total of 6 visits were made by subjects who were able to complete the three exercise tests; a total of 4 visits for those who completed the moderate exercise test, and those who could not continue due to fatigue or other contra-medical indications. All the 597 subjects (100%) by age and gender completed the mild exercise regimen (Figure 1); 494 (83%) subjects completed the moderate exercise; and 325 (54%) subjects completed the severe exercise regimen. This indicates that 103 and 272 subjects could not complete the moderate and severe exercise phases respectively and their data were not included in the data analysis of both exercise tests. All those who could not complete the moderate exercise test were excluded from participating in the severe exercise test. The most common reasons why some subjects could not complete the exercise tests (moderate or severe) were, leg fatigue, exhaustion, breathlessness and dizziness irrespective of age or gender. The average duration of each of the exercise intensity tests according to age and gender is presented in Table 2.

Heart rate (HR) was measured twice immediately before exercise (after 10 min and 15 min of rest) using the Omron electronic monitor (HEM-712C, Omron Health Case Inc., Vernon Hills, Illinois). The mean of the values was used as the pre-exercise HR. During the exercise test, HR was measured at 2-minute intervals until the subjects reached their age adjusted, predicted maximum HR for the particular exercise intensity. The peak exercise HR was the highest value achieved at the termination of each of the exercise tests, after the subject has reached his predetermined HR. An experienced physician supervised the entire exercise test.

Blood Pressure Measurements

Resting blood pressure was measured one week prior to the exercise test, and after 10 and 15 minutes of rest in a seated position in a quiet room using both cuff-stethoscope (manual) and electronic (HEM-712C, Health Care Inc., Vernon Hills, Illinois) methods. The mean values of the two methods correlated ($p<0.001$) with each other, and showed no significant differences. We however used the mean of the electronic method as the resting blood pressure. The resting blood pressure measurement was used to ascertain whether a subject was normotensive or not. Prior to each day's exercise test, subject's pre-exercise blood pressure was also measured twice (after 10 and 15 minutes of rest) when sitting on the cycle ergometer, using the electronic method. There was no significant difference observed between the pre-exercise SBP and the earlier obtained resting blood pressure values in all cases. During the exercise, blood pressure was measured at two-minute intervals (with the same electronic method), until the termination of exercise, when the subject has reached his or her predicted maximum HR for the particular exercise intensity. The peak exercise SBP was defined as the highest value achieved during the test. Systolic blood pressure after exercise was measured every minute until recovery to pre-exercise level. During the post-exercise SBP measurement, subjects were asked to be in a sitting position on the bicycle without pedaling while the research personnel were blinded to the SBP test results at baseline and during exercise. These measurements were repeated for the subjects, under the same experimental conditions, on a separate day and the mean of the values obtained from the two days' tests was used as the experimental value. This was done in order to reduce errors that may arise from the measurement of BP and HR using electronic method.

Statistical Analyses

Descriptive data are presented as means ± SD. Test of normal distribution of data was analyzed using Kolmogorov-Smirnov test. Data analysis between two study groups was compared using the independent sample t-test. One-way analysis of variance (ANOVA) was used to compare variables in three groups. Pearson's bivariate correlation test was used to test the relationship between age and SBPRT. BMI-adjusted association between SBPRT and age was analyzed using Pearson's partial correlation tests. All statistics were done using SPSS for Windows (Version 16.0). Statistical significance was set at $p<0.05$ for the independent sample t-test and ANOVA test, and $p<0.01$ for correlation tests.

RESULTS

Among the study population, 448 were young adults (190 males and 258 females aged 18-30 yrs), 94 were middle-aged (54 males and 40 females aged 36-59 yrs), and 55 were elderly adults (30 males and 25 females aged 60-68 yrs). General characteristics of subjects (by age and gender) are shown in Table 1. Young males indicated significantly higher resting DBP ($p<0.05$); lower HR ($p<0.001$) and higher waist circumference ($p<0.001$) than females. There were no significant differences in resting SBP and BMI between the young males and females. Middle aged males indicated higher waist circumference ($p<0.001$), and higher DBP ($p<0.05$). BMI, resting SBP and resting HR indicated no significant differences between the two groups. Elderly males presented higher BMI ($p<0.05$) and waist circumference ($p<0.001$), higher resting SBP ($p<0.005$), and DBP ($p<0.05$) than the elderly females. Resting HR indicated no significant differences between the two groups. ANOVA analysis revealed that BMI, waist circumference, resting SBP, and resting DBP indicated age effects ($p<0.001$) in male and female groups respectively. Resting HR showed age effect ($p<0.001$) only in females but not in males.

The number and percentage of subjects who participated in each of the exercise intensity tests is as presented in the flow chart in figure 1 and table 2 shows the exercise test characteristics of subjects by age group, gender and according to exercise intensities. The ANOVA analysis revealed that in mild exercise, peak exercise SBP, and peak exercise DBP, significantly increased with each age group ($p<0.001$) for all genders; peak exercise HR declined with each age group for all genders ($p<0.001$). During moderate exercise, males indicated significant age effects ($p<0.05$; $p<0.01$; $p<0.001$) for peak exercise SBP, and peak exercise DBP and peak exercise HR respectively. The same trend was also observed in females ($p<0.001$ for all effects). During severe exercise, there were significant age effects for peak exercise SBP ($p<0.05$), and peak exercise HR ($p<0.001$), in males and females respectively. Significant increase in peak DBP with age was also observed in females ($p<0.001$) but not in males ($p>0.05$), A t-test analysis revealed that men indicated significantly higher peak exercise DBP ($p<0.001$ for all effects) and higher peak exercise SBP ($p<0.001$; $p<0.01$; $p<0.001$) than females, during mild, moderate, and severe exercise regimens respectively. Higher peak exercise HR was also observed in males than females in mild ($p<0.001$) and moderate ($p<0.05$) exercise intensities but not in the severe exercise ($p>0.05$).

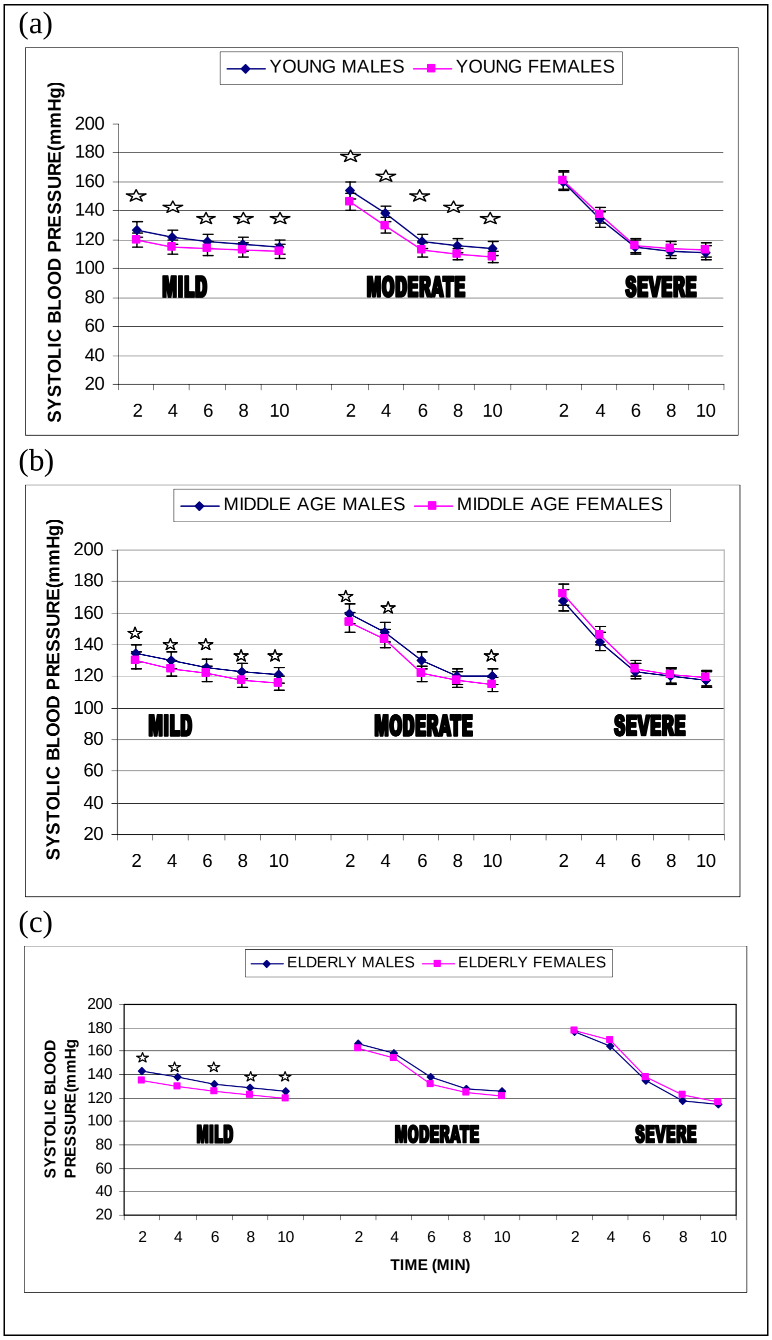

Figure 2. Systolic blood pressure during recovery by age and gender and at different exercise intensities. *= significant gender difference.

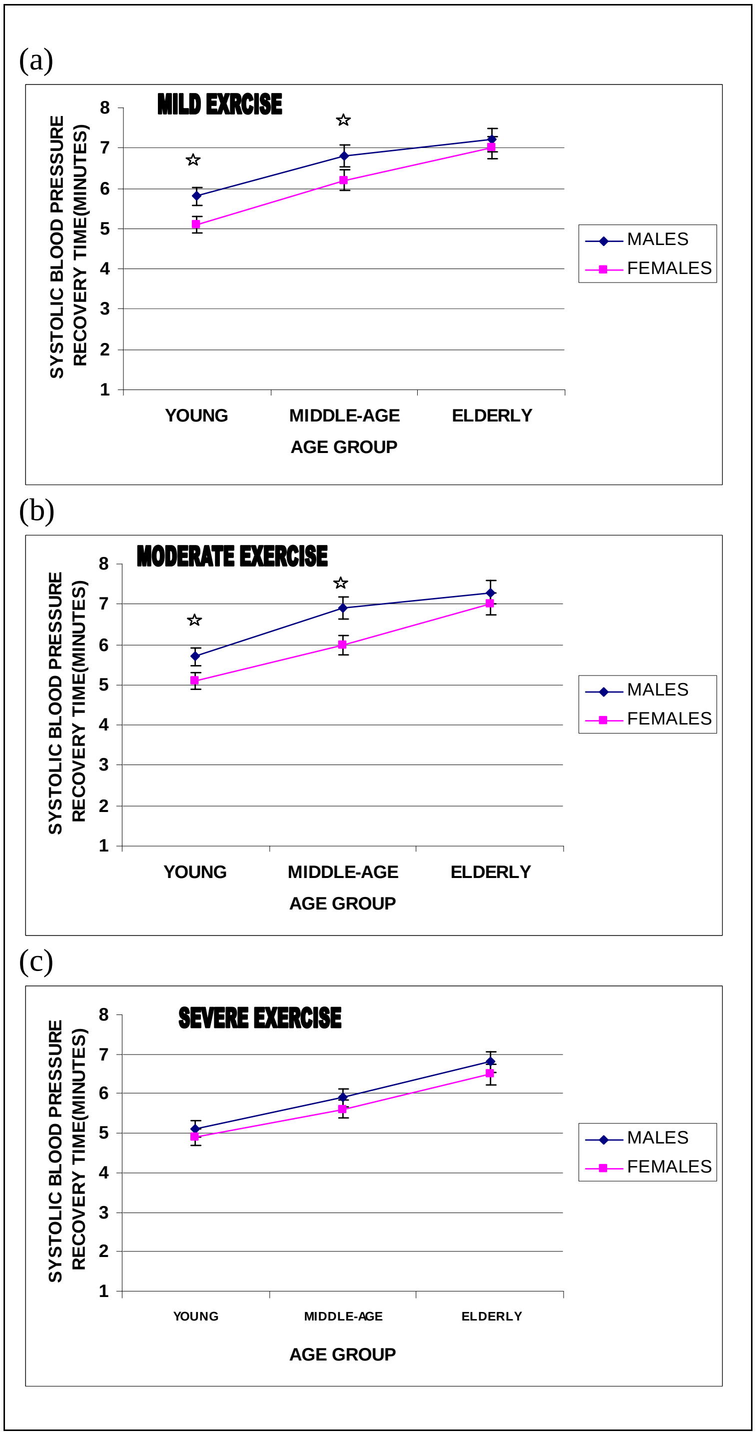

Figure 3. Systolic blood pressure recovery time by age group and gender in large referral study population for different exercise intensities (a) mild (b) moderate (c) severe.*= significant gender difference.

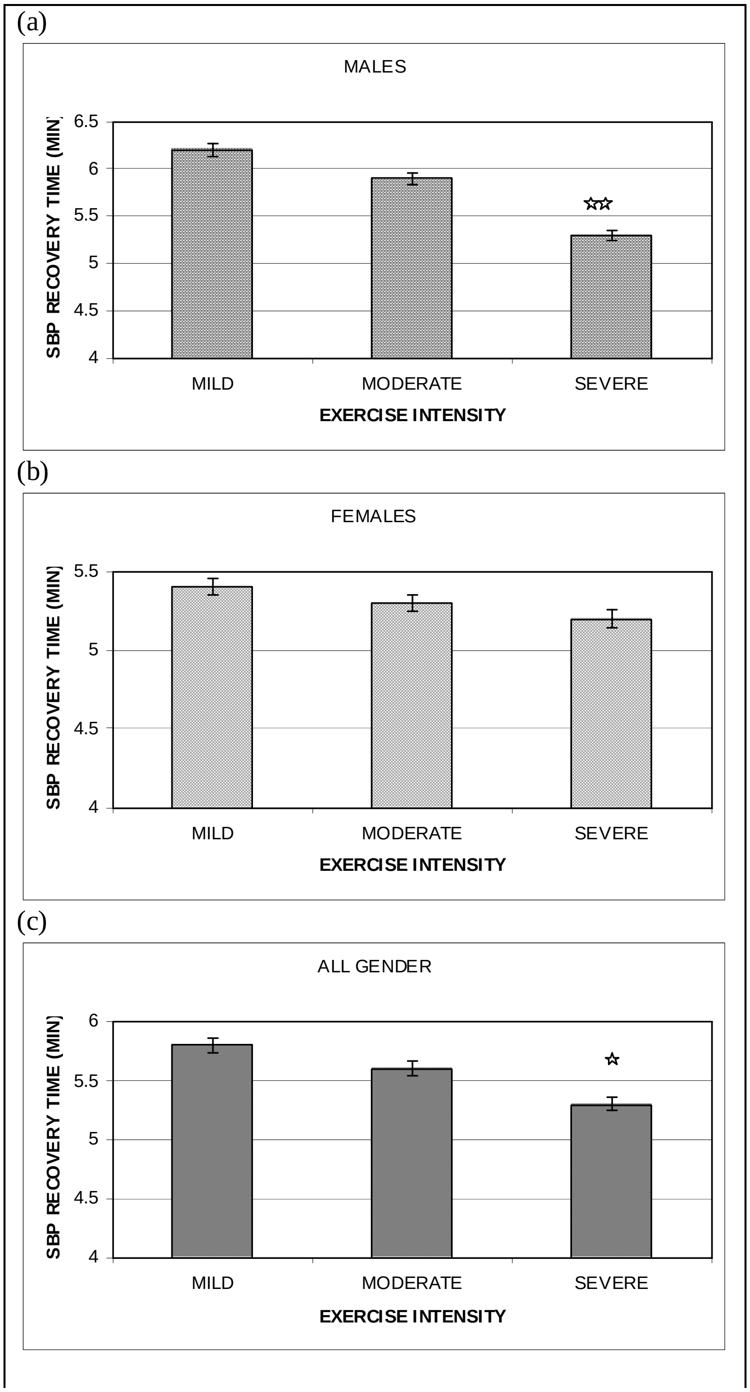

Figure 4. Systolic blood pressure time by exercise intensity in (a) all male (b) all female and (c) all gender study groups. *=p<0.005 exercise intensity effect; **=p<0.001 exercise intensity effect.

The changes of SBP as it declines from peak exercise to baseline are as presented in Figure 2. An independent t-test analysis revealed that after mild exercise, males experienced significantly higher SBPs ($p<0.001$ or $p<0.005$ or $p<0.05$) at all periods of recovery (2, 4, 6, 8, and 10 minutes) than the females in the three age groups. After the moderate exercise, young males presented higher SBPs ($p<0.001$) than young females at 2, 4, 6, 8, 10 mins respectively; middle-age males indicated higher SBPs than females ($p<0.05$; $p<0.001$; $p<0.005$) at 2min, 6 min, and 10 min respectively, but not at 4 min, and 8 min ($p>0.05$); elderly males and females indicated no significant differences in SBP at all periods of moderate exercise recovery. After severe exercise, all the three age groups did not show gender differences in SBP at all periods of recovery.

The data for mean ± standard deviation with 5th, 10th, 90th, and 95th percentiles of SBPRT stratified by age, gender, and exercise intensity are presented in Table 3.

Table 3. Systolic blood pressure recovery time and selected percentiles stratified by age and gender at different exercise intensities.

	MALES			**FEMALES**		
Age group	**Mild**	**Moderate**	**Severe**	**Mild**	**Moderate**	**Severe**
Young						
Mean ± SD	5.8± 1.08	5.6± 1.08	5.1± 0.81	5.1± 0.94	5.1± 0.84	4.9± 0.82
Percentile						
5th	4	4	4	4	3	4
10th	4	4	4	4	5	4
90th	7	7	6	6	6	6
95th	8	8	7	7	7	6
Middle-age						
Mean ± SD	6.8± 0.82	6.9± 0.71	5.9± 0.99	6.2± 1.23	6.0± 1.18	5.6± 1.19
Percentile						
5th	5	6	5	4	4	4
10th	5	6	5	5	5	4
90th	8	8	7	8	8	7
95th	8	8	8	9	8	7
Elderly						
Mean ± SD	7.2± 1.54	7.3± 1.26	6.8± 0.68	7.0± 1.73	7.0± 1.6	6.5± 1.35
Percentile						
5th	5	5	5	5	5	5
10th	5	5	6	5	5	5
90th	9	9	7	10	9	8
95th	10	9	8	10	9	9
All age group						
Mean ± SD	6.2± 1.21	6.0± 1.21	5.0± 1.03	5.4± 1.19	5.3± 1.15	5.3± 1.12
Percentile						
5th	4	4	3	4	3	4
10th	5	4	3	4	5	4
90th	8	8	6	7	7	7
95th	8	8	7	7	7	7

In summary, our data indicated values (mean ±SD) of 6.2 ± 1.21, 6.0 ± 1.21, 5.0 ± 1.03 minutes for 'All male age group', and 5.4 ± 1.19, 5.3 ± 1.15, 5.3 ± 1.12 minutes, for 'All female age group', after mild, moderate, and severe exercise regimens respectively. When all the study population data were pooled together, result indicated mean values and ranges of 5.7 ± 1.27 (4-10) minutes for mild exercise, 5.6 ±1.22 (3-10) minutes for moderate exercise, and 5.2 ± 1.09 (3-9) for severe exercise.

The ANOVA for SBPRT revealed age differences (see Figure 3). The mean SBPRT significantly increased ($p<0.001$) with each age group in all the exercise regimens. A further Pearson's bivariate correlation test (Table 4) revealed that SBPRT was significantly associated with age ($p<0.001$) in all the age and gender groups considered. Further Pearson's partial correlation analysis indicated that these associations remained significant after controlling for body mass index (Table 5). A student t-test analysis also indicated gender effects in young and middle aged males who had significantly higher SBPRT ($p<0.001$) than their female groups in the mild and moderate exercise regimens but not in severe exercise ($p>0.05$). The elderly adults indicated no significant differences in SBPRT between both genders in all the three exercise regimens. A significant age-gender interaction effect was also observed in mild ($p<0.001$), moderate ($p<0.001$), and severe ($p<0.005$) exercise regimens.

Further ANOVA analysis involving the three exercise intensities (see Figure 4) indicated that in 'all male' data, SBPRT was significantly lower in response to an increase in exercise intensity ($p<0.001$); in 'all female' data, there was no exercise intensity effect. When 'all gender' data were analyzed, our data also revealed a significantly lower SBPRT ($p<0.005$) in response to increase in exercise intensity.

DISCUSSION

In a large sample of apparently healthy, normotensive adults, we determined age- and gender-dependent normal values for systolic blood pressure recovery time following a mild, moderate and severe

Table 4. Association of age with systolic blood pressure recovery time by age-group and gender at different exercise intensities.

	MILD	MODERATE	SEVERE
Combined male age groups	r= 0.553; r^2=0.306; p<0.001	r= 0.600; r^2=0.360; p<0.001	r= 0.696; r^2=0.484; p<0.001
Combined female age groups	r= 0.510; r^2=0.260; p<0.001	r= 0.579; r^2=0.335; p<0.001	r= 0.575; r^2=0.331; p<0.001
Combined gender (young)	r= 0.604; r^2=0.365; p<0.001	r= 0.527; r^2=0.278; p<0.001	r= 0.431; r^2=0.186; p<0.001
Combined gender (middle-age)	r= 0.570; r^2=0.325; p<0.001	r= 0.375; r^2=0.141; p<0.001	r= 0.719; r^2=0.517; p<0.001
Combined gender (elderly)	r= 0.874; r^2=0.764; p<0.001	r= 0.902; r^2=0.814; p<0.001	r= 0.833; r^2=0.694; p<0.001
Combined age-groups and genders	r= 0.541; r^2=0.293; p<0.001	r= 0.593; r^2=0.352; p<0.001	r= 0.624; r^2=0.389; p<0.001

cycle ergometer exercise tests. Systolic blood pressure recovery time indicated gender differences, increased significantly with age and appeared to decrease with increase in exercise intensity especially in men.

To our knowledge limited studies (9, 23) have been found reporting on the average length of time it takes systolic blood pressure to decline from peak exercise to resting position. Similarly, no published work has been found which statistically elucidates the facts reported about SBPRT in the above studies. Previous studies (3, 4) have examined age and gender effects on SBP responses after exercise using the third minute SBP recovery ratio but no previous study has been published that has evaluated age or gender effects on SBPRT.

In the present study (Table 3) we determined the normal mean values of SBPRT and presented selected percentiles categorized by age decades, gender and exercise intensity. Our result was consistent with and close to values reported in previous studies (9, 23). These mean values and percentiles were provided to facilitate definition of high and low systolic blood pressure recovery times for a spectrum of ages for both genders and may be useful to clinicians in interpreting post-exercise SBP responses in future investigations.

The present study indicated gender differences in both exercise and post-exercise blood pressures. For example, our data indicated that peak SBP and peak DBP were higher in men than in females. Similarly, men presented higher SBPs than women at different periods of recovery after exercise in mild and moderate exercise regimens. Previous studies have also reported that peak exercise SBP and DBP were higher in men than in women (5, 8, 13, 18). Our result also revealed gender differences in SBPRT. Males indicated higher SBPRT than females in mild and moderate exercise regimens, suggesting a faster SBP recovery to baseline in females than males. A previous study (24) has shown that blood pressure recovery time is a valuable index of autonomic activity.

Table 5: Association between age and systolic blood pressure recovery time after controlling for body mass index.

	MILD	MODERATE	SEVERE
Combined male age groups	$r= 0.508$; $r^2=0.258$; $p<0.001$	$r= 0.568$; $r^2=0.322$; $p<0.001$	$r= 0.675$; $r^2=0.455$; $p<0.001$
Combined female age groups	$r= 0.488$; $r^2=0.238$; $p<0.001$	$r= 0.570$; $r^2=0.325$; $p<0.001$	$r= 0.533$; $r^2=0.284$; $p<0.001$
Combined gender (young)	$r= 0.607$; $r^2=0.368$; $p<0.001$	$r= 0.527$; $r^2=0.278$; $p<0.001$	$r= 0.767$; $r^2=0.588$; $p<0.001$
Combined gender (middle-age)	$r= 0.640$; $r^2=0.410$; $p<0.001$	$r= 0.368$; $r^2=0.135$; $p<0.01$	$r= 0.826$; $r^2=0.682$; $p<0.001$
Combined gender (elderly)	$r= 0.877$; $r^2=0.769$; $p<0.001$	$r= 0.458$; $r^2=0.210$; $p<0.005$	$r= 0.825$; $r^2=0.680$; $p<0.001$
Combined age-groups and genders	$r= 0.534$; $r^2=0.285$; $p<0.001$	$r= 0.556$; $r^2=0.309$; $p<0.001$	$r= 0.602$; $r^2=0.362$; $p<0.001$

Other studies have also reported that SBP recovery is influenced by sympathetic and parasympathetic nervous activities (14, 15). These studies suggest that SBP recovery will be delayed with increased sympathetic activity and attenuated vagal reactivation. It has been reported that at all ages women have been found to have reduced sympathetic activity and enhanced parasympathetic activity relative to men (12). This may explain why women indicated lower SBPRT than males in the present study. Our study further indicated that both genders did not show significant differences in SBPRT after severe exercise. Whether this was due to gender related changes in autonomic response to increase in exercise intensity is not known and may need further studies to elucidate the facts.

This study demonstrated that peak exercise SBP and DBP increased with age and is consistent with previous studies (7, 8, 18). Systolic blood pressure at different periods of recovery also indicated positive association with age, suggesting a faster SBP recovery in young than older adults as demonstrated previously (3). A similar age effect was observed in SBPRT which also indicated significant increase with each age group in the three exercise regimen. A further partial correlation analysis revealed an independent, significant, and positive relationship between SBPRT and age after controlling for BMI in different gender and age categories, thus confirming the earlier observed age effects. These results may be a reflection of increased systemic arteriolar resistance; increased sympathetic activity and attenuated parasympathetic activity which are associated with advancing age (6, 10, 19, 20). These factors have also been previously associated with delayed SBP recovery (14, 15, 23).

We further observed that SBPRT decreased with increase in exercise intensity in all male data and in the 'combined gender' population. The mechanism responsible for this outcome is not well understood. However, it has been previously reported that the decrement in blood pressure during recovery is more pronounced following intense exercise (16). MacDonald further reported that blood pressure decrements in seconds or minutes following exercise can be attributed to the sudden perfusion of the previously occluded muscle mass and a transient pressure undershoot caused by a pooling of blood in the dilated, previously exercising muscle bed. Significant thermoregulatory or prostaglandin effects have also been reported to occur after very high exercise intensities in normotensive sedentary individuals (16). These reports may suggest that increase in thermoregulatory and vasodilator substances, which increase blood flow to previously exercising muscles may be associated with severe exercise intensity, leading to a higher decrease in blood pressure than other lower exercise regimens. Additionally, it is interesting to note that the ability to complete the severe exercise intensity may be a function of an individual's physical fitness level. Though we did not measure the basal fitness level of subjects, it is thought that the lower SBPRT recorded in these subjects who completed the severe exercise regimen may be an indicator of their physical fitness.

Limitations of study: Our knowledge of the subjects' basic fitness level was inadequate since we relied on their ability to complete a mild exercise test and their responses to the question 'Do you participate in recreational and sports activities for at least three times in a week'. We admit that the measurement of the basal fitness level of the subjects prior to exercise test, would have strengthened our data, since physical fitness is a confounder of SBP recovery. Similarly, our study involved non-athletic adults who underwent exercise tests at sub-maximal levels and also evaluated systolic blood pressure recovery time during inactive exercise recovery mode. Our study therefore may not apply to SBP recovery in athletic individuals or recovery from maximal exercise intensity, or to other cycling exercise recovery modes. Further studies are therefore recommended in these areas.

In summary, we determined statistically, normal average values of systolic blood pressure recovery time stratified by age, gender and sub-maximal exercise intensities in a large apparently healthy, non-athletic study population. The present study indicated systolic blood pressure recovery time values that were close to, and consistent with previously reported values and which indicated age and gender effects. While we recommend further studies in SBPRT that will apply to athletes, maximal exercise intensity and active exercise recovery mode, we do hope that these data will help clinicians to define in statistical terms, the post-exercise systolic blood pressure responses stratified by age, gender and exercise intensity in future investigations and during clinical assessment of individuals.

REFERENCES

1. Amon KW, Richard KL, Crawford MH. Usefulness of the post exercise response of systolic blood pressure in the diagnosis of coronary artery disease. Circulation 70: 951-956. 1984.

2. Borg G.A. Psychophysical bases of perceived exertion. Med Sci Sports Exc 14: 377-381, 1982.

3. Dimkpa U, Ugwu AC. Age-related differences in systolic blood pressure recovery after a maximal effort exercise test in non-athletic adults. Int J Exerc Sci 1(4): 142-152, 2008.

4. Dimkpa U, Ugwu AC, Oshi DC. Assessment of sex differences in systolic blood pressure responses to exercise in healthy non-athletic young adults. Journal of Exercise Physiology online 11(2): 18-25, 2008.

5. Daida H, Allison TG, Squires RW, Miller TD, Gau GT. Peak exercise blood pressure stratified by age and gender in apparently healthy subjects. Mayo Clin Proc 71: 445-452, 1996.

6. Davy KP, DeSouza CA, Jones PP, Seals DR. Elevated heart rate variability in physically active young and older adult women. Clinical Science 94: 579-584, 1998.

7. Ellestad, M. Reliability of blood pressure recordings. Am J Cardiol 63: 983-985, 1989.

8. Erikssen J, Jervell J, Forfang K. Blood pressure responses to bicycle exercise testing in apparently healthy middle-aged men. Cardiology 66:56-63, 1980.

9. Fletcher GF, Balady GJ, Amsterdam AE, Chaitman B, Robert E, Jerome F et al. Exercise standards for testing and training. A statement for health care professionals from the American heart association. Circulation 104: 1694-1740, 2001.

10. Goldsmith RL, Bigger JT, Bloomsfield DM, Steinman RC. Physical fitness as a determinat of vagal modulation. Med.Sci Sports Exerc 29(6): 812-817, 1997.

11. Hashimoto M, Okamoto M, Yamagata T, Yamane T, Watanabe M, Tsuchioka Y, et al. Abnormal systolic blood pressure during exercise recovery in patients with angina pectoris. J Am Coll Cardiol 22: 659-664, 1993.

12. Huxley VH. Sex and the cardiovascular system: the intriguing tale of how women and men regulate cardiovascular function differently. Advan Physiol Edu 31: 17-22, 2007.

13. Irving JB, Bruce RA, DeR0uen TA. Variations in and significance of systolic blood pressure during maximal exercise (treadmill) testing. Am J cardiol 39:841-848, 1977.

14. Kurl S, Laukkanen JA, Rauramaa R, Lakka TA, Sivenius J, Salonen JJ. Systolic blood pressure response to exercise stress test and risk of stroke. Stroke 32: 2036-2041, 2001.

15. Laukkanen JA, Kurl S, Salonen R, Lakka TA, Rauramaa R, Salonen JT. Systolic blood pressure during recovery from exercise and the risk of acute myocardial infarction in middle aged men. Hypertension 44: 820-825, 2004.

16. MacDonald JR. Potential causes, mechanisms, and implications of post exercise hypotension. J Human Hypertens 16(4): 225-236, 2002.

17. McHam SA, Marwick TH, Pashkow FJ, Lauer MS. Delayed systolic blood pressure recovery after graded exercise: an independent correlate of angiographic coronary disease. J Am Coll Cardiol 34: 754-759, 1999.

18. Michelsen S, Otterstad JE. Blood pressure response during maximal exercise in apparently healthy men and women. J Intern Med 227:157-163, 1990.

19. Oxeham H, Sharpe N. Cardiovascular aging and heart failure. Eur J Heart Fail 5(4): 427-434, 2003.

20. Seals D, Esler M. Human ageing and the sympathoadrenal system. J Physiol 528:3: 407-417, 2000.

21. Singh JP, Larson MG, Manolio TA, O'Donnell CJ, Lauer M, Evans JC et al. Blood pressure response during treadmill testing as a risk factor for a new-onset hypertension. The Framingham heart study. Circulation 99:1831-1836, 1999.

22. Tanaka H, Monahan KD, Seals DR. Age-predicted maximum heart rate revisited. J Am Coll Cardiol 37(1): 153-156, 2001.

23. Taylor AJ, Beller GA. Post-exercise systolic blood pressure response; clinical application to the assessment of ischemic heart disease. American Academy of Family Physicians 58(5): 1-9, 1998.

24. Vogel ER, Sandroni P, Low PA. Blood pressure recovery from valsalva maneuver in patients with autonomic failure. Neurology 65:1533-1537, 2005.