Age-Related Differences in Systolic Blood Pressure Recovery after a Maximal-Effort Exercise Test in Non-Athletic Adults

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ABSTRACT

Int J Exerc Sci 1(4) : 142-152, 2008. The present study investigated the rate of systolic blood pressure recovery (SBPR) amongst three male age groups. Ninety-six apparently healthy, non-athletic adult males (48 young [23.91±4.58 years], 32 middle-aged [41.78±5.98 years] and 16 elderly [62.87±2.57 years]) participated in the study. Subjects performed a maximal-effort ergometer exercise test. Maximal oxygen uptake (VO_{2max}) was measured during the exercise protocol; heart rate (HR) and SBP were measured before exercise (after 10 and 15 minutes of rest), during exercise (at 2-minute intervals), and at the first minute of post-exercise recovery and subsequently at 2-minute intervals until the recovery of SBP. Results showed that third-minute SBP ratio relative to 1 minute of recovery ($SBPR_y$) was significantly lower ($p<0.01$; $p<0.001$) in the young (0.87± 0.06) when compared to middle aged (0.91 ± 0.05) and elderly adults (0.93 ± 0.04). Using bivariate correlation analysis, VO_{2max} and %HR decline at 1 minute and 3 minutes of recovery, correlated with $SBPR_y$ in all age groups but after controlling for their confounders, only %HR decline in 3 min remained significantly correlated with SBPR in all the age groups. This study therefore showed age differences in SBPR after exercise with younger adults indicating faster recovery than older adults. After controlling for factors influencing SBPR, %HR decline in 3 min of recovery appeared to be a stronger contributor to age differences in SBPR than %HR decline in 1 min and VO_{2max}. The reported data indicate the need to take age into account when interpreting SBPR after exercise during physical assessment of healthy individuals.

KEY WORDS: Maximal effort, recovery, systolic blood pressure, heart rate, maximal oxygen consumption, adult male age-groups

INTRODUCTION

After maximal exercise, systolic blood pressure (SBP) usually declines to baseline and generally reaches pre-exercise values within five to six minutes (2, 11). A delay in SBP return to pre-exercise levels represents an abnormal response (30). The rate of decline of SBP after exercise can therefore be used to assess cardiovascular responses to physical stress and provide information that is complementary to the traditional exercise test parameters. The post-exercise systolic blood pressure recovery (SBPR) is an expression of the rate of SBP decline after peak exercise. To assess SBPR, a very useful and readily obtainable parameter, the third minute SBP ratio is often employed. The third minute SBP ratio is an expression of the decline of the post-exercise blood pressure in 3 minutes relative to the peak exercise SBP value (30), or relative to 1 minute SBPR (22). The third minute SBP ratio relative to peak exercise is calculated as the SBP at 3 min divided by the peak exercise SBP value, and a value greater than 0.90 is considered abnormal (30). The SBP ratio relative to 1 min is calculated as the SBP at 3 min divided by the 1 min SBPR value, and a value greater than 1.0 is considered a delayed decline (22).

To our knowledge, no previous study has investigated in statistical terms, the age related differences in SBPR among adult male age groups and the mechanisms responsible for the age differences. Studies on post-exercise SBPR have mainly focused on its diagnostic and prognostic values in the evaluation of known or suspected ischemic heart diseases. For example, delayed decline in SBP has been associated with increased risk of coronary diseases (1, 2), stroke (17), hypertension (28), and acute myocardial infarction (20). Ageing is associated with increased risk of cardiovascular diseases such as the conditions mentioned above (18, 19, 25). Similarly, certain factors which influence SBP recovery such as systemic vascular resistance, sympathetic and parasympathetic nervous activities, aerobic capacity, and baroreflex sensitivity, have also been associated with age. For example, with increasing age, systemic vascular resistance increases (25), parasympathetic activity decreases (5, 13), sympathetic activity is elevated (27), peak aerobic capacity (VO_{2max}) declines (10, 11), and baroreflex sensitivity reduces (15, 21). These plethora of information are suggestive of the fact that SBPR may be associated with age.

The purpose of this study is to investigate whether there is an age-related difference in the rate of decline of SBP after a maximum effort ergometer exercise test in healthy, non-athletic adult males, and the factors which may be associated with this age difference. We therefore hypothesized that the rate of SBP decline is faster in younger adults than older ones. We also hypothesized that VO_{2max} and rate of HR decline after exercise may be associated with this age difference in SBPR.

METHOD

Participants

Ninety-six, apparently healthy, non-athletic, Nigerian adult males participated in the study. The study group was selected from students and staff members of Igbinedion University, Okada, and residents of Okada town in Edo State, Nigeria. The study group included 48 young adults (23.91 ± 4.58 years), 32 middle-aged (41.78 ± 5.98 years), and 16 elderly adults (62.87 ± 2.57 years). Subjects were selected based on the results of a structured health and lifestyle screening questionnaire; body mass index, Ponderal index, and waist circumference measurements; resting blood pressure and heart rate measurements; urinalysis (for determination of glucose level) and blood chemistry tests (for determination of blood lipids, glucose and insulin). Subjects were excluded if they had a history of unstable cardiovascular, peripheral vascular and respiratory disease, a malignancy, and orthopedic or musculoskeletal lesions. All subjects selected were non-athletic but physically active since they occasionally participated in recreational activities such as soccer, table tennis, lawn tennis, badminton, and basketball. Subjects were also non-smokers, non-alcoholics, non-obese, non-diabetics, non-asthmatics, non-hypertensive, apparently without cardiovascular diseases and not taking medications that could affect cardiovascular functions. 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.

Protocol

Exercise Test: The exercise test was performed between 0800 and 1100 in a well-ventilated room of about 28 ± 0.84ºC (range, 27-29ºC), using a mechanically braked cycle ergometer (Homeware Ltd, North York, Ontario, Canada). 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 ability of the subjects to perform maximum-effort exercise was used as a criterion for selection. The testing protocol was comprised of an initial three-minute warm up of exercise at a work load of 50 Watts, followed by a step-by-step increase in workload by 20W every minute until the subject reached a tolerable exhaustion. 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 peak exercise. The peak HR was the highest value achieved during the exercise test. During post exercise recovery, HR was first measured at one minute of recovery and subsequently at 2-minute intervals (i.e. 1, 3, 5 min) and discontinued as soon as the SBP returned to the pre-exercise value. We used percentage HR decline to express the rate of HR recovery after exercise in this study. Percentage HR decline after exercise was calculated as [peak HR – post-exercise HR / 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 over 15 sec intervals by the breath-by-breath method with the use of the Oxycon Alpha respiratory gas analyzer (Jaegar, Wuerzburg, Germany) (12). Maximal oxygen uptake was defined as the highest value for or plateau in oxygen uptake. 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% (4, 23). The age–predicted maximum HR (HRmax) was determined as HRmax = [208 – (0.7 x age)] (29). The rating of perceived exertion (RPE) to exercise (3) was obtained through an oral questionnaire for the subjects immediately after the exercise protocol. The most common reasons for stopping the exercise test were, leg fatigue (eighteen), exhaustion (twenty), breathlessness (two) and dizziness (three) irrespective of age. 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 and electronic methods. There were no significant differences observed between the mean values of the two methods. 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 the 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 Omron electronic sphygmomanometer (Omron Health Care Inc., Vernon Hills, Illinois). There was no significant difference observed between the pre-exercise SBP and the earlier obtained resting blood pressure values in all the age groups. During the exercise, blood pressure was measured at two-minute intervals. The peak SBP was defined as the highest value achieved during the test. SBP within the first minute after exercise and further measurements of post-exercise SBP at two-minute intervals until recovery to pre-exercise level were measured using the electronic method (i.e. measurements were done at 1, 3, 5, 7 min and so on). 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.

Percentage decline of SBP during recovery was calculated as [peak SBP – post-exercise SBP / peak SBP] x 100. Ratio of SBP at 3 min of recovery to peak exercise ($SBPR_x$) was computed as post SBP at 3 min divided by peak SBP while the ratio of SBP at 3 min of recovery to 1 min of recovery ($SBPR_y$) was computed as post exercise SBP at 3 min divided by post exercise SBP at 1 min. We investigated age difference in SBPR using the third minute SBP ratio relative to one-minute of recovery ($SBPR_y$). This ratio was preferred to the third-minute SBP ratio relative to peak exercise ($SBPR_x$) because it has the advantage of the accuracy of blood pressure measurement (22), since both SBPs can be obtained only in the recovery state. This avoids the inaccuracy associated with exercise blood pressure measurement (9).

Statistical Analyses

Descriptive data are presented as means and standard deviations (SD). Data analysis amongst the various groups was compared by One-Way ANOVA using the Bonferroni multiple comparison test. Correlations of $SBPR_y$ with VO_{2max}, and %HR decline (at 1 min and 3 min of recovery respectively) were analyzed using Pearson's bivariate correlation test. Associations between $SBPR_y$ and VO_{2max} with adjustment for Age; and between $SBPR_y$ and %HR decline in 1 min and 3 min with adjustment in VO_{2max} were analyzed using Pearson's partial correlation coefficient test. All statistics were completed using SPSS for Windows (Version 11.0). Statistical significance was set at $p<0.05$ for the ANOVA tests and $p<0.01$ for correlation tests.

RESULTS

At baseline, the mean ages of the subjects were 23.91 ± 4.58, 41.78 ± 5.98, 62.87 ± 2.57 years for the young, middle-aged, and the

Table 1. Baseline characteristics of subjects for different age groups.

CHARACTERISTICS	*YOUNG (n=48)*	*MIDDLE-AGED (n=32)*	*ELDERLY (n=16)*
AGE (Years)	23.91 ± 4.58∗^ (18-35)	41.78 ± 5.98∗ (36-58)	62.87 ± 2.57 (60-68)
HEIGHT (Meters)	1.8 ± 0.08 ∗^ (1.60-1.90)	1.75 ± 0.09 (1.60-1.90)	1.73 ± 0.07 (1.60-1.80)
WEIGHT (kg)	71.4 ± 8.24 (59.6-91.47)	70.4 ± 8.24 (52.0-84.2)	72.6 ± 6.1 (62.5-85.9)
BODY MASS INDEX (kg/m²)	21.82 ± 1.84∗^ (17.3-26.0)	22.76 ± 1.57∗ (20.3-25.7)	24.06 ± 1.32 (21.8-26.5)
PONDERAL INDEX (kg/m³)	11.98 ± 1.32∗^ (10.03-15.99)	13.15 ± 1.22 (11.32-15.90)	13.88 ± 1.08 (12.1-15.5)
WAIST CIRCUMFERENCE (cm)	81.6 ± 7.15∗^ (72-92)	87.7 ± 5.46 (73-93)	86.0 ± 4.76 (77-93)
PRE-EXERCISE SBP (mmHg)	110.04 ± 5.51∗^ (96-122)	121.09 ± 7.49∗ (100-130)	131.87 ± 4.17 (125-140)
PRE-EXERCISE DBP (mmHg)	79.35 ± 4.89^ (68-90)	78.96 ± 5.91* (70-90)	84.37 ± 4.06 (78-90)
PRE-EXERCISE HR (bpm)	71.18 ± 2.83 (63-77)	71.40 ± 3.40 (62-76)	70.87 ± 3.36 (64-77)

Source: Laboratory Data. Data are means ± SD and range, n= number of subjects, ∗ = significantly different from elderly, ^ = significantly different from middle-aged.

elderly adults respectively. Pre-exercise SBP was significantly lower ($p<0.001$) in young adults than the middle-aged and the elderly, and in the middle-aged than the elderly. Measured values of other major baseline characteristics such as height, weight, body mass index, ponderal index (PI), waist circumference, pre-exercise diastolic blood pressure (DBP) and pre-exercise HR are as presented in Table 1.

During exercise, peak exercise SBP showed no significant difference between young and middle-aged adults. Young and middle-aged adults however indicated lower values ($p<0.001$ and $p<0.05$ respectively) than the elderly. Peak exercise HR was significantly higher ($p<0.001$) in the young adults than both middle-aged and the elderly. The middle-aged group also presented a higher peak exercise HR than the elderly ($p<0.02$). Young adults indicated a significantly higher ($p<0.001$) relative VO_{2max} than the middle-aged and the elderly. Middle-aged had a higher VO_{2max} than the elderly ($p<0.001$). Similarly, young adults indicated a significantly higher absolute VO_{2max} than the middle-aged ($p<0.05$) and the elderly ($p<0.001$); the middle-aged also had a higher absolute VO_{2max} than the elderly ($p<0.001$). Rating of perceived exertion showed no significant differences amongst the three age groups. Measured values of other exercise test characteristics during the exercise such as peak exercise DBP, relative and absolute maximum carbon dioxide production (VCO_{2max}), respiratory exchange ratio, and maximum workload are as presented in Table 2.

Table 2. Exercise test characteristics of subjects for different age groups.

CHARACTERISTICS	*YOUNG (n=48)*	*MIDDLE-AGED (n=32)*	*ELDERLY (n=16)*
PEAK-EXERCISE SBP (mmHg)	181.60 ± 9.35∗ (162-200)	184.81 ± 6.14∗ (173-198)	190.81 ± 6.01 (182-202)
PEAK-EXERCISE DBP (mmHg)	80.52 ± 4.75∗ (70-90)	80.62 ± 5.74∗ (70-90)	86.18 ± 4.13 (80-92)
PEAK-EXERCISE HR (bpm)	177.41 ± 6.90∗^ (162-190)	169.06 ± 4.32∗ (160-178)	163.87 ± 5.56 (156-172)
RELATIVE VO2max ($ml.kg^{-1}.min^{-1}$)	47 ± 2.56∗^ (34-51)	43.93 ± 3.51∗ (37-50)	33.18 ± 3.81 (28-40)
RELATIVE VCO2max ($ml.kg^{-1}.min^{-1}$)	53 ± 3.84∗^ (40-60)	47.53 ± 3.91∗ (40-54)	40.50 ± 1.96 (38-45)
ABSOLUTE VO2MAX ($L.min^{-1}$)	3.36 ± 0.49∗^ (2.10-4.47)	3.09 ± 0.48∗ (1.92-4.10)	2.41 ± 0.29 (1.96-2.93)
ABSOLUTE VCO2MAX ($L.min^{-1}$)	3.78 ± 0.62∗^ (2.47-5.31)	3.35 ± 0.50∗ (2.18-4.20)	2.94 ± 0.27 (2.54-3.61)
RESPIRATORY EXCHANGE RATIO	1.12 ± 0.05∗^ (1.0-1.23)	1.08 ± 0.04∗ (1.02-1.18)	1.23 ± 0.13 (1.03-1.43)
MAXIMUM WORK-LOAD(Watts)	360 ± 14.87∗ (330-390)	350 ± 30.48∗ (270-390)	326 ± 34.42 (270-370)
RATING OF PERCEIVED EXERTION	18.72 ± 0.61 (18-20)	18.65 ± 0.86 (17-20)	19.12 ± 0.80 (18-20)

Source: Laboratory Data. Data are means ± SD and range, n= number of subjects, ∗ = significantly different from elderly, ^ = significantly different from middle-aged.

After exercise, young adults showed a significantly lower ($p<0.001$) post-exercise SBP in 1 minute, post-exercise SBP in 3 minutes, post-exercise HR in 1 minute and post-exercise HR in 3 minutes than the middle-aged and the elderly respectively. The middle-aged also presented a significantly lower post-exercise SBP in 1 minute ($p<0.005$) and post-exercise SBP in 3 minutes ($p<0.001$) than the elderly. Post-exercise HR in1 minute and post-exercise HR in 3 minutes showed no significant differences between the middle-aged and the elderly. Percentage SBP decline in 1 min and 3 min of recovery and percentage HR decline in 1 min and 3 min respectively, showed significantly higher values ($p<0.001$) in young adults than middle-aged and elderly adults. Similarly, percentage SBP decline in 3 min was higher ($p<0.002$) in middle-aged than elderly, while percentage SBP decline in 1 min and percentage HR decline in 1 min and 3 min respectively, indicated no significant differences between these two age groups. Young adults presented a significantly lower $SBPR_x$ than middle-aged and elderly ($p<0.001$). Middle-aged had a higher $SBPR_x$ than the elderly ($p<0.002$). Similarly, $SBPR_y$ was significantly lower in young adults than the middle-aged ($p<0.01$) and the elderly ($p<0.001$), while it showed no significant difference between the middle-aged and the elderly.

Table 3. Post-exercise characteristics of subjects for different age groups.

CHARACTERISTICS	*YOUNG (n=48)*	*MIDDLE-AGED (n=32)*	*ELDERLY (n=16)*
POST-EXERCISE SBP IN 1MIN (mmHg)	145.37 ± 11.19*^ (119-172)	157.15 ± 9.45* (140-172)	167.75 ± 8.01 (158-182)
POST-EXERCISE SBP IN 3MIN (mmHg)	126.0 ± 8.24*^ (109-151)	143.18 ± 13.39* (118-169)	156.62 ± 3.86 (147-162)
POST-EXERCISE HR IN 1MIN (bpm)	113.25 ± 7.52*^ (95-127)	130.56 ± 4.78 (120-138)	129.50 ± 6.84 (118-140)
POST-EXERCISE HR IN 3MIN (bpm)	70.08 ± 8.92*^ (63-105)	113.93 ± 11.75 (92-128)	109.87 ± 8.05 (96-121)
%SBP DECLINE IN 1MIN	19.89 ± 5.41*^ (8.24-32.26)	12.14 ± 0.98 (9.83-14.14)	9.37 ± 1.72 (7.37-13.13)
%SBP DECLINE IN 3MIN	30.59 ± 3.38*^ (23.21-38.38)	22.61 ± 5.57* (11.98-34.08)	17.88 ± 1.77 (15.05-20.20)
%HR DECLINE IN 1MIN	36.14 ± 3.89*^ (28.16-44.77)	22.69 ± 4.06 (13.75-29.14)	20.88 ± 5.07 (12.66-29.07)
%HR DECLINE IN 3MIN	60.36 ± 6.02*^ (35.98-66.84)	32.51 ± 7.67 (20.0-45.24)	32.87 ± 5.50 (24.38-44.19)
$SBPR_x$	0.69 ± 0.03*^ (0.62-0.77)	0.77 ± 0.05* (0.66-0.88)	0.82 ± 0.01 (0.80-0.85)
$SBPR_y$	0.87 ± 0.06*^ (0.76-0.98)	0.91 ± 0.05 (0.81-0.99)	0.93 ± 0.04 (0.88-0.99)

Source: Laboratory Data. Data are means ± SD and range, n= number of subjects, * = significantly different from elderly, ^ = significantly different from middle-aged.

Correlation of $SBPR_y$ and VO_{2max} indicated a significant negative correlation in young adults (r= -0.386; p<0.005), the middle-aged (r= -0.953; p<0.001), and the elderly (r= -0.683; p<0.003). After adjusting for age, these two variables remained significantly correlated in middle-aged (r= -0.732; p<0.001) but showed no significant correlation in the young (r= -0.338) and the elderly (r= -0.311).

$SBPR_y$ was negatively correlated with percentage HR decline in 1 min of recovery in the young (r= -0.648; p<0.001), middle-aged (p= -0.877; p<0.001) and elderly (r= -0.833; p<0.001). Both variables remained associated after adjustment with VO_{2max} in young (r= -0.631; p<0.001), and elderly (r= -0.699; p<0.003) but showed no significant correlation in middle-aged (r= -0.356; p>0.01).

A correlation of $SBPR_y$ and percentage HR decline in 3 min recovery indicated significant negative correlation in the young (r= -0.484; p<0.001), middle-aged (r= -0.962; p<0.001), and elderly (r= -0.889; p<0.001), and after adjusting for VO_{2max}; the correlations were; r= -0.440; p<002, r= -0.737; p<0.001, and r= -0.784; p<0.001 for the young, middle-aged and elderly, respectively.

DISCUSSION

The rate of SBP recovery was compared amongst the three age groups in a study including healthy, non-athletic adult males.

This study showed that there was an age-related difference in the rate of SBPR after maximal-effort exercise. Additionally, when correlated with SBPR in all age groups using bivariate correlation test, VO2max and percentage HR decline appeared to account for this age difference in SBP recovery but after controlling for their confounders, the influence of VO_{2max} either disappeared or reduced while that of percentage HR decline in 3 min remained more consistent in all age groups than percentage HR decline in 1 min.

In the present study, age difference in SBPR was investigated using the third minute SBP ratio relative to one-minute of recovery ($SBPR_y$). This ratio was preferred to the third-minute SBP ratio relative to peak exercise ($SBPR_x$) because it has the advantage of the accuracy of blood pressure measurement (22), since both SBPs can be obtained only in the recovery state. This avoids the inaccuracy associated with exercise blood pressure measurement (9). To our knowledge, age related differences in the rate of SBPR after maximal exercise have not been previously reported.

However, the rate of SBP decline from dynamic exercise has been associated with systemic vascular resistance, sympathetic and parasympathetic nervous activities (17, 20, 30), VO_{2max} (6, 20), and baroreflex sensitivity (26). These studies suggest that the rate of SBP decline will be delayed with elevated systemic vascular resistance, increased sympathetic activity, attenuated vagal reactivation, decreased VO_{2max} and decreased baroreflex sensitivity. Interestingly, ageing has been related with these factors affecting SBPR. For example, with increasing age, systemic vascular resistance increases (7, 25), parasympathetic activity decreases (5,13), sympathetic activity is elevated (27), VO_{2max} declines (10, 11), and baroreflex sensitivity reduces (15, 21). Though most of the factors mentioned in the above literatures are not within the scope of this study, it is thought that these literatures may help explain age differences in SBPR as observed in the present study in which younger adults experienced faster recovery than older adults.

Peak aerobic capacity (VO_{2max}) is considered the best measure of cardiovascular fitness and exercise capacity (11). We therefore investigated the role of VO_{2max} in the age differences in SBPR and our finding which revealed that younger adults indicated higher VO_{2max} than older adults showed consistency with previous studies (10, 11) which reported a decline of VO_{2max} with age**.** This study also indicated that as VO_{2max} increases, the rate of SBP recovery increases (indicated by lower third min SBP ratio). Younger adults who indicated higher VO_{2max} in this study, also experienced faster SBPR. We have previously demonstrated that young males who presented higher VO_{2max} than females experienced faster SBPR after maximal-effort exercise (6), thus showing that VO2max may be a very important factor contributing to SBPR after exercise. The present findings also agreed with a previous study (20) which reported that a greater decline of SBP from peak exercise to the recovery is a reflection of a good aerobic capacity and level of an individual's physical activity and fitness level.

The present study further revealed that the observed association between SBPR and VO_{2max} disappeared in the young and elderly adult groups but reduced in the middle aged group after controlling for SBPR confounder. The reason for this inconsistency in the relationship between these variables in those age groups is not understood and this may require further studies.

We also investigated the role of post-exercise HR recovery in age differences in SBPR. To our knowledge no previous study has reported age differences in the rate of HR decline after exercise as shown by this study in which younger adults presented faster rate of HR decline than the older adults. However, it has been reported that the rate of post-exercise cardiodeceleration is used as an index of cardiac vagal reactivation (14). A previous study (8) has related faster HR recovery after exercise to augmented baroreflex function. The baroreflexes are an important mechanism by which the central nervous system exerts regulatory control over arterial blood pressure by evoking changes in efferent cardiac vagal activity and sympathetic outflow to the heart and vasculature (15). Another study (20) has also linked elevated SBP after exercise with attenuated vagal reactivation. A decline of cardiovagal baroreflex sensitivity with age has been previously reported (15, 21, 24). These facts therefore tend to suggest that the faster rate of HR decline observed in younger than older adults in this study may be a contributing factor to the age differences observed in SBPR in which younger adults experienced faster recovery than the older ones.

It was further observed that after controlling for its confounder, the influence of percentage HR decline on SBPR appeared relatively more consistent than that of VO_{2max} and marked in the 3 minute of recovery than at 1 minute. It is not clear why the influence of the rate of HR decline was marked at 3 minute of recovery than at 1 minute. Further studies are recommended to elucidate the facts.

In conclusion, the rate of systolic blood pressure recovery after exercise in healthy, non-athletic adult males shows an age-related difference with young adults presenting a faster rate of recovery than the older age groups. Our study further revealed that this age differences appeared to be strongly associated with VO_{2max} and percentage HR decline when these variables were initially correlated with SBP recovery. However, after controlling for their confounders, percentage HR decline in 3 minutes appeared to be a better contributing factor to the age differences in SBP recovery than percentage HR decline in 1 minute and $VO_{2max.}$ The reported data indicate the need to take age into account when interpreting SBP recovery after exercise during physical assessment of apparently healthy individuals.

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