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Effects of a Single Bout of Exercise on Arterial Compliance in Older Adults

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Abstract

The effects of acute exercise on arterial compliance in older adults are unknown. Large and small arterial compliance were assessed during and 24 h following a 30 min bicycle ergometer test, and on a non-exercise, control condition. The change in large artery compliance was similar between the exercise and non-exercise conditions ($p = 0.876$). Small artery compliance during the exercise day was higher than the non-exercise day at 45, 60, and 75 min following exercise ($p < 0.001$), was 17% higher 30 min post-exercise than at rest ($p < 0.001$), and decreased by 20% between 30 min (4.5 ± 0.4 ml/mmHg $\times$ 100) and 120 min (3.6 ± 0.3 ml/mmHg $\times$ 100) after exercise ($p = 0.027$). The current study shows 30 min of moderate-intensity exercise transiently increases small arterial compliance 30 min after exercise, but does not elicit more sustained increases in either large or small arterial compliance.

Keywords

Arterial Compliance; Aging; Exercise

INTRODUCTION

Physically active older men and women have a lower incidence of cardiovascular disease compared to their sedentary peers.^{1–4} In addition to the beneficial effect exercise has on traditional risk factors,^{5,6} habitual exercise is capable of slowing, and in some cases reversing, the age-related declines in arterial compliance in older adults.^{7,8} In addition, arterial compliance can be increased through intervention in both younger⁹ and older adults.⁸ Furthermore, improvements in arterial compliance occur after only 1 week of exercise intervention,⁹ which suggests arterial compliance may be influenced by acute bouts of exercise. The improvement in arterial compliance following such a brief intervention is unlikely to be from chronic adaptations in structural characteristics of the arterial system. Rather, it is more likely the residual effect from the preceding bout of acute exercise.

While significant acute improvements in arterial compliance after exercise have been seen in young adults,¹⁰ it is unknown if the same affect will occur in older populations. Because arterial changes (i.e. structure and function) occur with advancing age,¹¹ the acute effects of

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exercise in young adults cannot be extrapolated to older adults. Therefore, the primary purpose of the current investigation was to examine the changes in arterial compliance occurring immediately and 24 h following a single, moderately intense bout of exercise in older adults.

METHODS

Subjects

A total of 32 men and women were recruited from the greater Oklahoma City metropolitan area to participate in this study. A physician's referral was required to determine study eligibility. The criteria for participation in this study included: 1) an age of 60 years or older, 2) free of known cardiovascular disease, 3) free of any symptoms of cardiovascular disease, 5) current non-smoking history for the previous 3 years, 6) BMI less than 30.0 kg.m², and 7) non-active lifestyle as shown by participating in an average of no more than 3 moderately intense activities per week during the past year. This study was conducted upon approval from the University of Oklahoma Institutional Review Board.

All subjects who qualified in the initial screening were subject to an orientation visit, where an informed consent form and the Physical Activity Readiness Questionnaire (PAR-Q) were completed upon arrival. A physical activity history was obtained using the Minnesota Leisure Time Physical Activity Questionnaire. Lastly, height and weight were measured and used to calculate body mass index (BMI): BMI = weight (kg)/height (m)².

Testing Protocol

The protocol for this study included two randomized conditions; one in which exercise occurred on the first day of testing and another in which no exercise was done on the first day (as shown in Figure 1). On the exercise day, subjects had a cardiovascular profile performed during supine rest prior to exercise. Subjects were then asked to complete a 30 min bout of cycle exercise as outlined in the exercise procedures. Immediately following exercise an additional cardiovascular profile was performed with subjects in the supine position. Subjects then remained in the supine position as serial measures were taken every 15 min for the next 2 h. Following the exercise day, all subjects returned for a 24-h post-exercise cardiovascular profile at rest. Following this measurement, percent body fat was assessed using air-displacement plethysmography.

On the non-exercise day, a resting cardiovascular profile was performed. The subjects then remained in the supine position for 30 min during which time no measurements were taken. Following the 30-min rest, serial profiles were performed every 15 min for the next 2 h. Total time required for the exercise and non-exercise visits was approximately 3 h each.

Diastolic Pulse Contour Analysis (DPCA)

All cardiovascular profiles were performed by the HDI/Pulsewave^{TM} CR-2000 machine (Hypertension Diagnostics, Eagan, MN). This machine uses a noninvasive technique to determine large artery (capacitance) and small artery (oscillatory) compliance. A personal computer system gathers 30-sec-long analog tracings of the radial artery using a tonometer sensor. The diastolic portion of the arterial waveform was digitized at 200 samples per second. An average beat determination is made using a beat-marking algorithm which determines systole, peak systole, onset of diastole, and end diastole during the 30 sec. The average beat is then incorporated into a parameter estimating algorithm, and a modified Windkessel model is used to determine the 2 arterial indices. This method has been validated with invasive testing,¹² and performed in our laboratory.¹³

To begin the procedure the participant was placed in a supine position and asked to lie quietly on the table without movement for 10 min. A blood pressure cuff was then attached to the upper left arm. A rigid plastic wrist stabilizer was placed on the participant's right wrist to minimize wrist movement, and stabilize the radial artery during the collection so that the maximal radial pulsation could be found by the sensor. The sensor was adjusted to the highest relative signal strength before initiating the test. All profiles were performed in triplicate to obtain an average value.

Exercise Procedures

Subjects were asked to perform a 30-min submaximal cycle ergometer exercise at 50% of their Heart Rate Reserve (HRR). This was calculated using the Karvonen formula with age predicted maximum heart rate ($220 - \text{age}$).¹⁴ A mechanically braked Monarch cycle ergometer (Ergomedic 828 E) was used for the exercise intervention, and was calibrated prior to each test. Also, prior to testing, seat height was adjusted so that there was a slight bend in the knees when the legs were at the vertical position with the subject seated.

The subject was instructed to cycle at approximately 50 revolutions per minute (rpm) as the lab technician adjusted the workload to acquire the desired heart rate. At all times during exercise an investigator acted as a spotter by standing within arms length of the participant. Blood pressure and heart rate were assessed and recorded every 3 min during the exercise bout. Blood pressure was recorded from a standing mercury sphygmomanometer. A Polar BEAT Heart Rate Monitor recorded heart rate.

Data Analysis

Descriptive statistics were performed on all subject characteristics. A two-factor (exercise condition by time), repeated measures analysis of variance (ANOVA) test was performed on the cardiovascular profile data from the exercise and non-exercise days. A one-way ANOVA was performed on the first resting measurement obtained on each of the 3 days to determine if there was an exercise effect at the 24-h post-exercise visit. Bonferroni post-hoc analyses were conducted to examine pair-wise mean differences. A comparison of means between corresponding time points from the exercise and non-exercise days was performed using a paired-samples t-test. All tests were defined as two tailed and significance was set at $p < 0.05$. Data was presented as means $\pm$ the standard deviation (SD) unless otherwise noted. All tests were performed using the Statistical Package for the Social Sciences (SPSS, v. 11.5, Chicago, IL) software.

RESULTS

The physical characteristics of the subjects are provided in Table 1. The resting cardiovascular measures of all three visits are shown in Table 2, and the large artery compliance measurements obtained during the exercise and non-exercise days are shown in Figure 2. There was no significant difference in large artery compliance between the exercise and non-exercise conditions ($p = 0.876$), between the multiple time points ($p = 0.177$), and for the change in compliance between the exercise and non-exercise conditions (condition by time interaction, $p = 0.085$).

Small artery compliance obtained during the exercise and non-exercise days are shown in Figure 3. Averaging across all time points, the small arterial compliance was significantly higher ($p = 0.012$) on the exercise day (4.4 ± 0.4 ml/mmHg $\times$ 100) compared to non-exercise (3.8 ± 0.4 ml/mmHg $\times$ 100). Furthermore, small artery compliance during the exercise day was higher than the non-exercise day at 45, 60, and 75 min following exercise ($p < 0.001$). Small artery compliance was also significantly different among time points ($p < 0.001$), as

there was a 17% increase 30 min post-exercise from the resting value ($p < 0.001$), and a 20% decrease between 30 min (4.5 ± 0.4 ml/mmHg x 100) and 120 min (3.6 ± 0.3 ml/mmHg x 100) after exercise ($p = 0.027$) (Figure 3).

Post-exercise changes were also found for systolic blood pressure, as a decrease was noted 15 min after exercise than compared to the non-exercise condition (121 ± 12 vs 131 ± 16 ; $p < 0.05$). Systolic blood pressure remained lower throughout the post-exercise period than the non-exercise condition ($p < 0.05$), until gradually increasing to a value similar to the non-exercise condition by the 120th min after exercise (136 ± 14 vs. 139 ± 16 ; $p > 0.05$). Similar post-exercise changes ($p < 0.05$) were found for diastolic blood pressure, mean arterial pressure, and pulse pressure.

The resting measures of large and small arterial compliance obtained on each of the 3 days are shown in Figure 4. No significant difference among days was present for either large ($p = 0.100$) or small arterial compliance ($p = 0.520$), suggesting that the exercise bout had minimal influence 24 h later.

DISCUSSION

Thirty minutes of moderately intense exercise on a bicycle ergometer increased small artery compliance 30 min after exercise compared with baseline in older adults, but did not alter large artery compliance. Furthermore, small artery compliance was higher 45 to 75 min following exercise than compared to the non-exercise condition.

To our knowledge this is the first study to quantify the changes in arterial compliance from acute exercise in subjects 60 years of age and older. Although previous studies have included measures of arterial compliance after acute exercise, the earliest measures were taken 30 min afterwards, and therefore may have missed the greatest exercise-mediated changes in arterial compliance.¹⁵ To overcome this limitation, the current study included measurements within the third min following exercise, as well as serial measures recorded every 15 min over the next 2 h to better track the change in large and small artery compliance over time following exercise.

Kingwell et al. observed a 66% increase in whole body arterial compliance in young males 30 min following a 30 min bout of vigorous cycling at 65% $\text{VO}_{2\text{max}}$.¹⁴ In the current study, we investigated whether a similar bout of exercise performed at a more realistic, lower intensity for older, untrained adults would alter large and small artery compliance afterwards. We found a 17% increase in small arterial compliance from rest to the peak value obtained at 30 min post-exercise, suggesting that even a modest amount of continuous exercise done at 45% HRR can transiently alter small artery compliance in older adults. The target heart of 50% HRR averaged over the entire exercise test was not reached primarily due to the first several minutes of exercise in which the desired workload had not yet been reached.

Our data suggests that the transient change in compliance following a single bout of exercise has limited affects on large and small artery compliance 1 day later. In contrast, exercise interventions have produced significant increases in artery compliance after only one week of training,⁹ which may indicate that a true exercise training effect may occur relatively quickly which is not due to the residual effects from the preceding acute exercise bout. The current study, along with others,¹⁵ have failed to find an effect of a single bout of exercise on arterial compliance lasting for greater than 30 min post-exercise for either young or old populations, thus providing support to the idea that repeated bouts of exercise are needed to elicit changes in arterial compliance. Alternatively, it is possible that an acute exercise bout does indeed change arterial compliance, but the exercise performed in the current study was

not of great enough intensity to produce lingering effects on large and small compliance following exercise. In the long term, however, moderately intense exercise, performed several times per week, may lead to improvements in arterial compliance, thereby attenuating the age-related decline in arterial compliance.^{8,9}

Other cardiovascular variables measured in the current study produced expected results from an acute bout of exercise. Post-exercise hypotension was shown through a significant and sustained decrease in systolic blood pressure for 105 min following the exercise, and is in agreement with previous results.^{16,17} A similar hypotensive response following exercise was also found for diastolic blood pressure and mean arterial pressure. Furthermore, diastolic blood pressure was significantly reduced 24 h following exercise, supporting the notion that repeated bouts of exercise may act favorably on resting blood pressure.¹⁷

There were several limitations associated with this study. First, the sample was not a random sample, as the volunteers were recruited from the surrounding area and consisted primarily of Caucasians. Therefore, the results cannot be generalized to older adult minorities. Second, physical activity could not be controlled before and during the testing process. The population selected was, however, untrained and it was assumed the exercise undertaken in the laboratory was more strenuous than normal daily activity. Lastly, the intensity of the exercise bout in this study was based on a prediction of the maximal exercise heart rate rather than from measurement obtained at maximal exercise. However, the primary objective was to perform a moderate intensity aerobic exercise, which was likely above normal for this population, and achieved with measured intensity of 45% HRR.

In summary, 30 min of moderate-intensity exercise transiently increases small arterial compliance 30 min after exercise, but does not elicit more sustained increases in either large or small arterial compliance. Greater exercise volume (i.e. greater duration and/or intensity) may be necessary to elicit more pronounced changes in either large or small arterial compliance in healthy older men and women.

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Figure 1.
Flowchart of testing order.

Figure 2.
Time course of large arterial compliance for both exercise and non-exercise conditions.
Values are mean $\pm$ SD.

Figure 3. Time course of small arterial compliance for both exercise and non-exercise conditions. Values are means $\pm$ SD. * Significant difference between the exercise and non-exercise conditions ($p < 0.05$), † Significant change from 30 min ($p < 0.05$), ‡ Significant change from rest ($p < 0.05$).

Figure 4. Resting measures of large and small arterial compliance across the 3 days of testing. Values are means $\pm$ SD.

Table 1

Characteristics of the 32 subjects.

Measure (n = 32)	Mean	SD	Minimum	Maximum
Age (Yrs)	71	7	60	87
Height (cm)	168.8	9.8	149.9	189.6
Weight (Kg)	70.8	12.2	52.1	97.4
BMI (Kg/m ²)	24.7	2.8	19.6	29.9
Body Fat (%)	34.9	7.3	20.7	48.6
BSA (m ²)	1.79	0.19	1.51	2.23
Gender (% Male)	44			
Race (% Caucasian)	97			

BMI = Body Mass Index, BSA = Body Surface Area.

Table 2

Cardiovascular measures obtained at rest on each of the three days of testing. Values are means $\pm$ SD.

Measure	Condition		
	Non-Exercise n = 32	Exercise n = 32	24-Hr Post Exercise n = 32
SBP (mmHg)	127 $\pm$ 13	126 $\pm$ 12	124 $\pm$ 12
DBP (mmHg)	72 $\pm$ 8	71 $\pm$ 6	69 $\pm$ 7*
MAP (mmHg)	93 $\pm$ 9	91 $\pm$ 9	90 $\pm$ 8
PP (mmHg)	55 $\pm$ 8	55 $\pm$ 9	55 $\pm$ 9
PR (beats/min)	62 $\pm$ 8	62 $\pm$ 9	60 $\pm$ 9
CET (msec)	339 $\pm$ 28	347 $\pm$ 28*	348 $\pm$ 27*
SV (ml/beat)	77 $\pm$ 15	76 $\pm$ 15	77 $\pm$ 15
SVI (ml/beat/m ²)	42 $\pm$ 7	42 $\pm$ 7	42 $\pm$ 6
CO (L/min)	4.6 $\pm$ 0.7	4.7 $\pm$ 0.6	4.6 $\pm$ 0.6
CI (L/min/m ²)	2.6 $\pm$ 0.2	2.6 $\pm$ 0.2	2.6 $\pm$ 0.2
LAEI (ml/mmHg x 10)	14.2 $\pm$ 4.0	14.6 $\pm$ 4.0	15.8 $\pm$ 6.3
SAEI (ml/mmHg x 100)	4.0 $\pm$ 2.4	4.2 $\pm$ 2.6	4.4 $\pm$ 2.4
SVR (dyne [*] sec [*] cm ⁻⁵)	1644 $\pm$ 299	1621 $\pm$ 278	1580 $\pm$ 265*
TVI (dyne [*] sec [*] cm ⁻⁵)	160 $\pm$ 43	153 $\pm$ 41	151 $\pm$ 45

* Significant difference from non-exercise visit,

† Significance difference from exercise visit ($p < 0.05$). SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure, MAP = Mean Arterial Blood Pressure, PP = Pulse Pressure, PR = Pulse Rate, CET = Cardiac Ejection Time, SV = Stroke Volume, SVI = Stroke Volume Index, CO = Cardiac Output, CI = Cardiac Index, LAC = Large Artery Compliance, SAC = Small Artery Compliance, SVR = Systemic vascular Resistance, TVI = Total Vascular Impedance.