Journal of the American Society of Hypertension ■(■) (2016) 1–9

Research Article

A cross-sectional study of physical activity and arterial compliance: the effects of age and artery size

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Manuscript received July 25, 2016 and accepted December 12, 2016

Abstract

Our study examined the relationship between habitual high levels of vigorous physical activity on large and small artery compliance via radial artery pulse wave analysis. Eighty-three healthy men (n = 44) and women (n = 39), aged 18–78 years, were recruited as habitually less active (light-to-moderate exercise ≤3 times/wk) or habitually highly active (vigorous exercise ≥5 times/wk). A multivariate analysis of variance revealed a significant interaction of age and activity level; habitual vigorous activity was associated with greater compliance in large and small arteries in older adults (40–78 years) and younger adults (18–22 years). In the large and small arteries, we observed an age-associated decrease in arterial compliance (aged ≥ 40 years), though it appears to be less pronounced in the large artery among habitually highly active subjects. This study suggests that aging may be associated with declines in large and small artery compliance that can be attenuated by habitual vigorous activity. J Am Soc Hypertens 2016;■(■):1–9. Copyright © 2016 Published by Elsevier Inc. on behalf of American Society of Hypertension.

Keywords: Cardiovascular; exercise; pulse wave analysis; stiffness.

Introduction

Incidence rates of various forms of cardiovascular disease such as hypertension, left ventricular hypertrophy, congestive heart failure, and coronary artery atherosclerosis increase with age.[1] One characteristic associated with, and predictive of, the age-related increases in cardiovascular morbidity and mortality is a gradual stiffening of the large and small arteries.[2,3] Stiffening of the arteries is reflective of detrimental changes to both the structure and function of the vessel, resulting in less vessel elasticity and reduced control of intermittent blood flow at greater, potentially damaging, velocities.[4]

Arterial compliance, the inverse of stiffness, describes the ability of the artery to expand and recoil with cardiac systole and diastole.[5] Although age-related arterial stiffness in most large arteries is intrinsic to the aging process, Tanaka et al[6] demonstrated attenuated stiffness in middle-aged males (aged 38–57 years) that performed habitual, vigorous endurance exercise. Indeed, regular physical activity has been shown to reduce age-related stiffness of the large arteries in both middle-aged and older men.[7] However, stiffness of the large arteries has been reported to be similar in young men (18–37 years old), regardless of their recent activity profile, suggesting perhaps the interaction between arterial stiffness and activity levels only becomes evident later in life.[6]

Previous research regarding age-related arterial stiffness and the effects of exercise has focused primarily on the large arteries. However, the respective stiffness values for the large and small arteries are both regarded as independent predictors of various forms of cardiovascular disease.[3]

Conflict of interest: None.

This work was supported by a research grant awarded by the United States Masters Swimming Foundation and an Indiana University, Faculty Research Support Grant to P.R.F. and J.M.S.

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http://dx.doi.org/10.1016/j.jash.2016.12.005

A recent cross-sectional study determined stiffness of the small artery to be a better predictor of hypertension, cardiovascular diseases, and stroke compared to stiffness of the large artery and aortic distensibility.[3] Moreover, McVeigh et al[8] demonstrated a strong negative correlation between compliance of the small arteries and increasing age from 20 to 80 years. Still, to our knowledge, the association between habitual physical activity and compliance of the small arteries across the lifespan has yet to be fully described.

A recent report has suggested that highly active individuals, specifically swimmers, have lower mortality rates than those that are sedentary, or walkers, and or runners.[9] As yet there is no explanation as why this may be the case other than perhaps the consistent and or persistent aspects of the physical activity that swimmers participate in. Although our focus is primarily upon habitual activity and aging, it was thought that swimmers may be the cohort of interest due to this recent observation. Therefore, the aim of the present study was to investigate the association between habitually high levels of physical activity and the compliance of the large and small arteries in men and women throughout the life span with specific interest in those who have maintained a daily routine of intense swimming. We hypothesized that (1) the habitually highly active men and women would demonstrate greater preservation of arterial compliance in both the large and small arteries with increasing age as compared to their less active age-matched peers and (2) there would be a difference in arterial compliance between the men and women, independent of activity profile and age.

Methods

Subjects

Eighty-three healthy men (n = 44) and women (n = 39) between the ages of 18 and 78 years were recruited for this study. Potential participants were recruited via flyers designed to elicit responses from either very highly active (participate in regular, vigorous exercise $\geq$ 5 times/wk) or less active/sedentary individuals (participate in light to moderate exercise $\leq$3 times/wk or none at all). Both groups subjectively reported maintaining the specified activity level for at least the past 5 years, and the highly active subjects performed regular vigorous swimming as their primary mode of exercise training as most were members of a collegiate varsity or masters swim team. All subjects were free of overt chronic diseases, nonsmokers, and none were taking vasoactive medications as assessed by a medical history questionnaire. All subjects provided their written informed consent to participate. All procedures were reviewed and approved by the Institutional Review Board at Indiana University.

Study Protocol

All subjects fasted and abstained from exercise, caffeine, and alcohol for at least 4 hours prior to testing which occurred in the morning (6 AM–10 AM hours).

Anthropometric Measurements

Prior to the arterial compliance measurements, height was recorded using standard techniques (ie, stadiometer). Body mass was measured using a digital scale (Tanita, BC-418 Segmental Body Composition Analyzer, Arlington Heights, IL) with subjects standing in the upright position.

Cardiovascular Measurements

Compliance of the small and large arteries (inverse of stiffness), blood pressure (BP), heart rate (HR), and estimated stroke volume and cardiac output were measured and recorded in one laboratory visit with a commercial pulse wave analyzer (Model CR-2000, Hypertension Diagnostics Inc, Eagen, MN). Subjects rested in the supine position on a table in a quiet, temperature-controlled room. Radial arterial waveforms were detected noninvasively by a pressure transducer amplifier system that was connected to the Model CR-2000. According to Hypertension Diagnostics Inc, Model CR-2000 followed the modified Windkessel model allowing determination of "proximal capacitive compliance (C1) and distal oscillatory compliance (C2)."[10] C1 is an estimate of large arterial compliance and C2 of small arterial compliance. A BP cuff was attached to the upper left arm, and an oscillometric BP calibration measurement was obtained. A wrist stabilizer was attached to the right wrist, and an arterial pulse pressure sensor was strapped around the stabilizer to contact the skin directly above the radial artery. The appropriate hold down force of the sensor was obtained with an external screw attachment under visual inspection of the waveform and signal of $\geq$10. The pulse was obtained without the aid of the operator.[8,10,11] The Model CR-2000 instrument has been validated invasively.[10] Correlates from noninvasively obtained measurements of C1 and C2 using Model CR-2000 with invasive waveform measurements were r = .82, $P < .001$, and r = .62, $P < .001$, respectively.[10] The instrument is also highly repeatable in both the same visit and consecutive visits 1–4 weeks apart.[12]

After resting quietly in the supine position for 15 minutes, radial arterial waveforms were recorded for 30 seconds. Representative pulse wave analysis waveforms have been illustrated by Cohn el al.[10] The obtained waveforms (mean of 30-second recording) were calibrated to the systolic and diastolic BPs. Measurements were repeated serially (within 3 minutes of one another) at least 3 times and until the resulting arterial compliance values were within 10% of each other.[13] BP, C1, C2, resting HR, and other cardiovascular measurements were recorded through