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The relationship between arterial stiffness and maximal oxygen consumption in healthy young adults

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Objective: Arterial stiffness is associated with an increased risk of cardiovascular diseases in various populations. There was little research on the relationship between arterial stiffness and maximal aerobic capacity (VO_{2max}) in healthy young adults. The aim of this study was to investigate the relationship between VO_{2max} and arterial stiffness in young adults.
Methods: The subjects were 13 men and 10 women with mean age of 22.9 ± 0.7, 23.6 ± 0.4 years, respectively. Height, weight, body mass index, body fat (%), waist to hip ratio, total/high density lipoprotein (HDL)/low density lipoprotein (LDL) cholesterol, triglycerides, fasting glucose, blood pressure, heart rate, glycated hemoglobin and blood lactate were measured. In addition, peripheral arterial stiffness was assessed by measuring brachial-ankle pulse wave velocity (baPWV) and VO_{2max} was determined using graded exercise test.
Results: VO_{2max} had no significant correlation with baPWV ($r = 0.2$, $p = 0.2$). Total cholesterol correlated significantly to variables such as HDL ($r = 0.6$, $p = 0.0015$) and LDL cholesterol ($r = -0.6$, $p = 0.0018$). VO_{2max} had a significant association with triglyceride ($r = -0.5$, $p = 0.0033$).
Conclusions: This study suggests that there is no relationship between arterial stiffness and aerobic capacity in healthy young adults.

Introduction

Most cardiovascular risk factors such as hypertension, diabetes and endothelial dysfunction may contribute to alteration in the structure and function of arterial blood vessels.[1] Arterial stiffness represents deleterious vascular phenotypes in some pathophysiological condition such as diabetes, atherosclerosis and kidney disease, in this reason it is considered as an important surrogate marker to predict future cardiovascular outcomes.[2,3] Previous evidence has shown that arterial walls stiffen with age because aging process induced alterations in arterial wall tissue.[4,5] It has also been established that arterial stiffness increases with age in healthy individuals without overt cardiovascular disease (CVD), suggesting increasing age may be an independent risk factor for arterial stiffening.[5] To measure arterial stiffness, brachial-ankle pulse wave velocity (baPWV) has become a popular method because of an advantage of convenience to use.[6] Previous studies have shown that baPWV is highly related to risk factors for CVD and aerobic capacity.[7,8]

Both acute and chronic aerobic exercise has been suggested to reduce arterial stiffness by enhancing vascular endothelial function as well as by effectively acting on structural and functional changes in blood vessels.[5,9–11] Of these studies, Vaitkevicius et al. showed that a progressive increase in arterial stiffness with advancing age (96 men 21–91 years old and 50 women 26–96 years old) and the age-associated arterial stiffness is inversely related to exercise capacity measured by maximal aerobic capacity (VO_{2max}), suggesting arterial stiffness may be delayed by regular aerobic exercise.[5] The maximum oxygen uptake indicates the oxygen transport capacity of cardiovascular system and the ability of the tissue to utilize

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oxygen. The parameter is highly correlated with the cardiopulmonary endurance and is generally improved by endurance training and decreased with advancing age.[12] Previous evidence has shown an inverse relationship between cardiorespiratory fitness and CVD mortality, suggesting improving aerobic fitness is a key factor in cardiovascular health.[13,14] Graded Exercise Test (GXT) is a typical method to measure maximal oxygen uptake and is often used to examine the subject's risk of heart disease and cardiopulmonary endurance.[15,16] Augustine et al. have suggested that aortic stiffness is inversely associated with maximal oxygen consumption in the middle aged women with central obesity.[17] In this study, the authors suggested CVD risk factors such as insulin resistance, systemic inflammation and hemodynamic mechanical stress may be associated with aortic stiffness.[17] In addition, Tomoto et al. indicated that both baPWV and heart-ankle PWV are inversely correlated to aerobic capacity in wide range of age in the healthy men (18–64 years) and Arena et al. showed a relationship between VO_{2max} and aortic wave velocity in healthy middle aged subjects.[6,18] Taken together, aerobic capacity and arterial stiffness may be negatively correlated in disease condition such as obesity and advancing age. However, there is very limited research on the relationship between arterial stiffness and aerobic capacity in healthy young adults. Specifically, since Tomoto group showed various aerobic capacity levels and wide range of arterial stiffness in their various range of age group in 82 healthy men (18–64 years),[6] it is needed to investigate the relationship between arterial stiffness and aerobic capacity in healthy young men. In this regard, we investigated whether arterial stiffness is correlated with maximal oxygen consumption in young adults. Further, we also investigated the relationship between arterial stiffness and CVD risk factors (blood biomarkers including glycated hemoglobin (HbA1c), glucose and lipid profiles).

Methods

Participants

We calculated the sample size of this pilot study using G power program based on the results of a previously published study.[6] The total sample size was calculated to be at least 14 subjects. A healthy, young group comprising 23 subjects: 13 men (22.9 ± 0.7 years) and 10 women (23.6 ± 0.4 years) were participated in this study. We excluded subjects with a previous history of diagnosis or medication for hypertension and clinical CVD including ischemic heart disease. All subjects underwent both GXT by treadmill and evaluation of arterial stiffness by baPWV. All subjects were informed about the benefits and possible risks of the study and were participated in the study after signing a written consent form. This experimental protocol was reviewed and approved by the Institutional Review Board of Incheon National University.

Anthropometric and blood pressure measurement

All participants were arrived at the laboratory at the same time (around 10:00 a.m.) in the morning after at least 10 h overnight fasting. Body weight (kg), body mass index (BMI, kg/m^2), and body fat (%) were measured using a bioelectrical impedance method analyzer (Inbody 720, Biomedical, South Korea). The resting systolic blood pressure (SBP), diastolic blood pressure (DBP) from both arms and heart rate were measured in the seated position using an automated oscillometric blood pressure cuff (Ex-Plus 1300, Jawon Medical, South Korea).

Graded exercise test (GXT)

Maximum exercise testing was performed according to a Bruce protocol on a motor driven treadmill and maximal oxygen consumption was assessed in a controlled environment. Open circuit spirometry was used to assess cardiorespiratory fitness. The Bruce protocol is designed for healthy adults and this is a standard procedure of increasing speed and inclination on the treadmill. The initial load started at the speed of 1.7 miles per hour (mph) and an inclination of 10°. The speed was increased by approximately 0.8–0.9 mph and the slope was increased by 2° every 3 min whenever each step was done. Before each exercise session was initiated, we calibrated pneumotachometer and gas analysis according to manufacturer's instruction. A tightly sealed breathing mask connected to the airflow sensor was used. During the GXT, the oxygen uptake (VO_2), carbon dioxide production (VCO_2), pulmonary ventilation (VE) and respiratory exchange ratio (RER) were measured breath-to-breath through a stationary gas analyzer (Quark b2, COSMED, Germany). The maximal exercise test was continued until the subject voluntarily stopped. Blood lactate concentration was measured for VO_{2max} determination using an Accutrend Plus (Mannheim, Germany) before and after the GXT.

Blood analysis

Whole blood (35 μl) were collected from the fingertips after lancing the palm-side surface of a finger with lancet. Fasting blood glucose, triglycerides, high density lipoprotein (HDL), low density lipoprotein (LDL) and total cholesterol were immediately measured using a Cholestech LDX (Alere, Norway) according to manufacturer's protocol. In addition, 1.5 μl of whole blood was obtained from the fingertip and HbA1c was measured using an Afinion AS100 (Ballybrit Galway, Ireland).

Measurement of arterial stiffness

Pulse wave velocity (PWV) is a clinical method to measure arterial stiffness. PWV is usually assessed by measuring the time taken for a pulse wave to move a specified distance and is increased as arterial stiffness augments. baPWV, a validated arterial stiffness measurement, was assessed the supine position using a non-invasive device after 10 min of quiet rest according to manufacturer's protocol using a VP-1000 plus (Omron, Japan) by bilaterally collecting the brachial and the posterior tibialis (ankle) artery blood pressure.[19] Occlusion and cuffs were wrapped around both sides of the brachia and ankles and volume waveforms for the extremity were stored and analyzed automatically.

Statistical analyses

All data were presented as mean ± SD. Pearson's correlations were used to determine the relationships between measurement variables. We used paired *t*-test to determine the differences in circulating lactate concentration before and after the GXT. In addition, we used independent *t*-test to determine the differences in parameters between men and women. Statistical analyses were conducted using the GraphPad Prism version 6.05 (La Jolla, CA, USA). Statistical difference was considered significant at the $P < 0.05$ level.

Results

Basic clinical characteristics

Table 1 illustrates the basic characteristics of the study