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METABOLIC SYNDROME AND ARTERIAL ELASTICITY IN YOUTH

Andrew W. Gardner, Ph.D.^a, Donald E. Parker, Ph.D.^b, Sowmya Krishnan, M.D.^a, and Laura J. Chalmers, M.D.^a

^aCMRI Diabetes and Metabolic Research Program, University of Oklahoma Health Sciences Center, Oklahoma City, OK

^bDepartment of Biostatistics and Epidemiology, University of Oklahoma Health Sciences Center, Oklahoma City, OK

Abstract

Objective—To compare arterial elasticity in children, adolescents, and young adults with and without metabolic syndrome (MetS), and to assess which MetS components, demographic measures, and body composition measures are associated with arterial elasticity.

Materials/Methods—Two-hundred six subjects (107 females and 99 males) between the ages of 10 and 20 years were recruited by local newspaper advertisements, university email advertisements, and informational flyers. Subjects were assessed on MetS components, demographic measures, body composition measures, and arterial elasticity via radial tonometry. Forty-five subjects (22%) had MetS, as defined by the International Diabetes Federation, and 161 subjects (78%) did not.

Results—The primary novel finding was that group differences were not observed for large artery elasticity index (LAEI) (MetS = 16.1 ± 4.4 (ml $\times$ mmHg⁻¹) $\times$ 10 (mean $\pm$ SD), control = 15.4 ± 4.9 , (ml $\times$ mmHg⁻¹) $\times$ 10, $p=0.349$), and small artery elasticity index (SAEI) (MetS = 9.2 ± 2.7 (ml $\times$ mmHg⁻¹) $\times$ 100, control = 8.4 ± 2.9 , (ml $\times$ mmHg⁻¹) $\times$ 100, $p=0.063$). In the MetS group, fat free mass was positively associated with arterial elasticity, and was the strongest multivariate predictor of LAEI (partial $R^2=0.41$) and SAEI (partial $R^2=0.41$).

Conclusions—Youth with MetS did not exhibit differences in LAEI and SAEI compared to controls. Furthermore, fat free mass of youth with MetS was positively associated with arterial elasticity, and was the strongest predictor of both LAEI and SAEI. The clinical implication is that exercise intervention designed to increase fat free mass might increase arterial elasticity in youth, particularly in youth with MetS.

Keywords

Arterial elasticity; body composition; fat free mass; metabolic syndrome; youth

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Address correspondence to: Andrew W. Gardner, Ph.D., O'Donoghue Research Building, 1122 N.E. 13th Street, Suite 150, University of Oklahoma Health Sciences Center, 1122 N.E. 13th Street, Suite 150, Oklahoma City, OK 73117. Telephone (405) 271-4272 ext. 42743, FAX: 405-271-4273, andrew-gardner@ouhsc.edu.

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INTRODUCTION

Metabolic syndrome is a condition linking insulin resistance, dyslipidemia, hyperglycemia, and hypertension. Metabolic syndrome increases the risk of developing diabetes, cardiovascular disease, and subsequent cardiovascular morbidity and mortality, and thus is an early marker of increased risk of atherosclerosis and its associated complications. Metabolic syndrome is a prevalent condition, which is increasing in recent years. As obesity becomes more common in youth and in young adults, metabolic syndrome is now seen in these populations, thereby increasing cardiovascular risk at very young age.

Arterial elasticity is an early, non-invasive marker predictive of cardiovascular events. In adults, arterial elasticity is impaired with modifiable cardiovascular risk factors such as smoking, hypertension, increased cholesterol, elevated low-density lipoprotein cholesterol, increased triglycerides, diabetes, elevated insulin and glucose levels, increased high-sensitive C-reactive protein, and increased levels of endothelial biomarkers P-selectin and urinary albuminuria. Although obesity worsens these risk factors, it is associated with increased arterial elasticity in youth, which may be related to growth and physical maturation. However, the influence of individual components of metabolic syndrome on arterial elasticity in youth is not clear. It is possible that metabolic syndrome components counteract the obesity-related higher arterial elasticity observed in youth.

The purposes of this study are (1) to compare arterial elasticity in children, adolescents, and young adults with and without metabolic syndrome, and (2) to assess which metabolic syndrome components, demographic measures, and body composition measures are associated with arterial elasticity. We hypothesize that arterial elasticity is lower in youth with metabolic syndrome, particularly in those with more components of metabolic syndrome.

METHODS

Subjects

Institutional Review Board Approval, Informed Consent, and Child's Assent. The procedures used in this study were approved by the Institutional Review Board at the University of Oklahoma Health Sciences Center. For subjects younger than 18 years of age, both the child and parent or legal representative agreed to participate by signing the child's assent form. Subjects 18 years of age and older signed the informed consent form.

Recruitment—Healthy subjects between 10 and 20 years of age were evaluated in the General Clinical Research Center and the Children's Medical Research Institute Diabetes and Metabolic Research Program from September, 2006 to October, 2011. The subjects were recruited by local newspaper advertisements, university email advertisements, and informational flyers distributed in Oklahoma City and surrounding areas.

Inclusion and Exclusion Criteria—Subjects were included in this study if they met the following criteria: (a) between 10 and 20 years of age, (b) a Tanner Stage of 2 or greater for boys and girls, and (c) subjects were ambulatory. Subjects were excluded for the following criteria: (a) under treatment for hypertension (n=2), (b) under treatment for dyslipidemia (n=6), (c) current smoking (n=15), (d) insulin or non-insulin dependent diabetes mellitus (n=5), (e) use of oral contraceptives (n=11), and (f) history of any form of cardiovascular disease, pulmonary disease, renal disease, liver disease, or active cancer (n=3). A total of 248 subjects were evaluated for this study, with 206 subjects deemed eligible to participate and 42 subjects were excluded.

Metabolic Syndrome Groups—According to the International Diabetes Federation, metabolic syndrome in children and adolescents is defined as having abdominal obesity plus at least two of the other four components of metabolic syndrome consisting of elevated triglycerides, reduced HDL cholesterol, elevated blood pressure, and elevated fasting glucose. Abdominal obesity in children between 10 and 15 years of age was defined as a waist circumference value 90th percentile of age, sex, and ethnicity norms, or the adult cutoff point, whichever is lower. For subjects 16 years of age and older, the adult criteria was used to define abdominal obesity, consisting of a waist circumference of 94 cm for males and 80 cm for females. Of the remaining four components of metabolic syndrome, the adult definitions of elevated triglycerides (> 150 mg/dl), elevated blood pressure (> 130/85 mm Hg), and elevated fasting glucose (> 100 mg/dl) were utilized. Reduced HDL cholesterol in children between 10 and 15 years of age was defined as a value < 40 mg/dl, whereas in those 16 years of age and older the adult criteria of < 40 mg/dl in males and < 50 mg/dl in females was utilized. Of the 206 subjects included in this study, 45 (22%) screened positive for metabolic syndrome, whereas the remaining 161 (78%) screened negative.

Measurements

Primary Outcome Measures: Large Artery Elasticity Index and Small Artery Elasticity Index

Diastolic Pulse Contour Analysis Test

Instrumentation: Arterial elasticity measurements were obtained by an HDI/PulsewaveTM CR-2000 Research Cardiovascular Profiling System (Hypertension Diagnostic, Inc., Eagan, Minnesota, USA) which analyzes the shape of arterial pressure waves produced by heart beats. This system determines large artery elasticity index and small artery elasticity index by gathering and analyzing a 30-second analog tracing of radial artery waveforms digitized at 200 samples per second using a non-invasive, direct contact acoustic transducer. A beat determination is made using a beat-marking algorithm during the 30-second period, which determines systole, peak systole, onset of diastole, and end diastole. The beat is then incorporated into a parameter estimating algorithm, and measures of arterial elasticity are calculated from the decline in diastolic blood pressure using a modified Windkessel Model. Diastolic pulse contour analysis by the modified Windkessel Model separates the diastolic waveform into a declining exponential wave and dampened sinusoidal oscillating wave. The decline in the exponential wave is a function of the elasticity of large arteries (capacitive arterial compliance), and the decline in the dampened sinusoidal oscillating wave is a function of the elasticity of the small arteries (oscillatory or reflective arterial compliance) of the most peripheral vessels. Stroke volume was estimated from a validated equation using measurements of ejection time, heart rate, body surface area, and age, thereby enabling cardiac output and systemic vascular resistance to be calculated.

Procedures: Arterial elasticity measurements were obtained in the morning following an overnight fast of at least eight hours, prior to engaging in any strenuous physical activity, and following 5 to 10 minutes of rest in the supine position. An appropriately sized blood pressure cuff was placed around the subject's left upper-arm, and a rigid plastic wrist stabilizer was placed on the subject's right wrist to minimize wrist movement and stabilize the radial artery during the measurement. An Arterial PulsewaveTM Sensor was placed on the skin directly over the radial artery at the point of the strongest pulse, while the arm rested in a supine position. The non-invasive acoustic sensor was adjusted to the highest relative signal strength, and a calibration period of several minutes was performed to obtain stable arterial waveforms. Subsequently, arterial waveforms were recorded for 30 seconds and the diastolic portion was digitized at 200 samples per second to determine large artery elasticity index and small artery elasticity index values, which assess the elasticity of the large and

small arteries throughout the arterial system. Measurements were averaged over three consecutive 30-second trials.

Outcome Measures and Procedures: The diastolic pulse contour analysis test was performed to obtain the primary outcome measures of large artery elasticity index and small artery elasticity index. The HDI/PulsewaveTM CR-2000 Research Cardiovascular Profiling System converted the large artery elasticity index value to a whole number by multiplying the units ($\text{ml} \times \text{mmHg}^{-1}$) by 10, and it converted the small artery elasticity index value to a whole number by multiplying the units ($\text{ml} \times \text{mmHg}^{-1}$) by 100. In addition to large artery elasticity index and small artery elasticity index, a battery of other cardiovascular parameters were obtained from the HDI/PulsewaveTM unit including systolic blood pressure, diastolic blood pressure, mean arterial pressure, pulse pressure, heart rate, estimated cardiac output, and systemic vascular resistance. Using the above procedures, the test-retest intraclass reliability coefficient is $R = 0.87$ for large artery elasticity index and $R = 0.83$ for small artery elasticity index.

Secondary Outcome Measures

Medical Screening through Medical History, Physical Examination, and Anthropometry—Subjects were evaluated during a medical history and physical examination. Demographic information, pubertal status by Tanner stage, height, weight, body mass index, cardiovascular risk factors, co-morbid conditions, blood samples, and a list of current medications were obtained. Waist and hip circumferences were measured and recorded to the nearest millimeter by trained technicians using a plastic measuring tape.

Body-Composition Assessment—Following an overnight fast of at least eight hours, body fat percentage, fat mass, and fat-free mass were obtained using a BC-418 eight-electrode bio-electrical impedance analysis device (Tanita Corp., Tokyo, Japan). Subjects stood barefoot on the base of the unit, which has two stainless-steel rectangular foot-pad electrodes fastened to a metal platform set on force transducers. During this measurement, subjects held hand-grip electrodes. The system has a total of eight electrodes, two for each hand and foot. All electrodes are connected to a digital circuit board. Age, height, and body type (all classified as standard and none classified as athletic) were entered for each subject for calculation of body fat percentage. The assessment of body composition through bio-electrical impedance using model BC-418 has been validated against measurements obtained from dual-energy X-ray absorptiometry in males and females ranging in age from 6 to 64 years.

Statistical Analyses

For Tables 1 and 2 independent t-test were used to examine differences between the two groups in means of measurement variables and single degree of freedom Chi Square was used for proportions of dichotomous variables. Statistical significance for group comparisons was set at a 2-tailed level of $\alpha = 0.05$. For regression purposes dichotomous variables were code 0, 1 with 1 representing Male, Caucasian, and condition present. Simple linear regression was used to obtain slopes, R-squares, and p values within each group. Multiple linear regression models which included a term for interaction were used to examine differences in slopes between the two groups. The p value for interaction term was used for significance test. An all possible regression procedure was used to obtain the multivariate models with the model having largest R^2 and for which all independent variables in model were significant at $\alpha = 0.10$ was selected for presentation. All analyses were performed using the NCSS statistical package (NCSS Inc, Kaysville, UT).

RESULTS

No significant differences were observed between the two groups for age ($p = 0.424$), height ($p = 0.051$), and race ($p = 0.573$) (Table 1). The metabolic syndrome group had higher values for weight ($p < 0.001$), body mass index ($p < 0.001$), waist/hip ratio ($p < 0.001$), body fat percentage ($p < 0.001$), fat mass ($p < 0.001$), fat free mass ($p < 0.001$), and had a lower percentage of males ($p = 0.032$). By definition, all subjects with metabolic syndrome had abdominal obesity. As expected, those with metabolic syndrome had a higher prevalence of the components of metabolic syndrome, consisting of elevated fasting glucose ($p < 0.001$), elevated blood pressure ($p = 0.008$), elevated triglycerides ($p < 0.001$), and reduced HDL cholesterol ($p < 0.001$). In the metabolic syndrome group, elevated blood pressure was the least prevalent component (16%), whereas the other components were prevalent in more than 70% of the subjects.

The metabolic syndrome group had higher hemodynamic values for systolic blood pressure ($p < 0.001$), diastolic blood pressure ($p = 0.005$), mean arterial pressure ($p = 0.002$), pulse pressure ($p < 0.001$), stroke volume ($p < 0.001$), cardiac output ($p < 0.001$), and lower systemic vascular resistance ($p < 0.001$) (Table 2). No significant differences were observed between the two groups for heart rate ($p = 0.301$), large artery elasticity index ($p = 0.349$), and small artery elasticity index ($p = 0.063$).

Large Artery Elasticity Index

In the metabolic syndrome group, large artery elasticity index was positively correlated with age ($p < 0.05$), fat free mass ($p < 0.001$), and elevated fasting glucose ($p < 0.05$), and it was higher in males ($p < 0.05$) (Table 3). In the control group, large artery elasticity index was positively correlated with age ($p < 0.001$), weight ($p < 0.001$), body mass index ($p < 0.001$), fat mass ($p < 0.001$), fat free mass ($p < 0.001$), and reduced HDL-cholesterol ($p < 0.001$). Fat free mass was the strongest univariate correlate of large artery elasticity index in the metabolic syndrome group ($R^2 = 0.25$) and in the control group ($R^2 = 0.20$). The slopes for large artery elasticity index with body mass index ($p < 0.01$), reduced HDL-cholesterol ($p < 0.01$), and weight ($p < 0.05$) were significantly different between the two groups (Table 3). In a multivariate regression model for large artery elasticity index in the metabolic syndrome group, the significant independent variables included fat free mass ($p < 0.001$), elevated triglycerides ($p = 0.026$), and body mass index ($p = 0.075$), with fat free mass being the strongest (partial $R^2 = 0.41$) (Table 4). In a multivariate regression model for large artery elasticity index in the control group, the significant independent variables included weight ($p < 0.001$), body mass index ($p < 0.001$), and fat free mass ($p = 0.089$), with weight being the strongest (partial $R^2 = 0.16$).

Small Artery Elasticity Index

In the metabolic syndrome group, small artery elasticity index was positively correlated with weight ($p < 0.01$), fat free mass ($p < 0.001$), and elevated fasting glucose ($p < 0.01$), and it was higher in males ($p < 0.01$) (Table 5). In the control group, small artery elasticity index was positively correlated with age ($p < 0.001$), weight ($p < 0.001$), body mass index ($p < 0.001$), fat mass ($p < 0.001$), fat free mass ($p < 0.001$), abdominal obesity ($p < 0.01$), and reduced HDL-cholesterol ($p < 0.01$), and it was higher in males ($p < 0.01$). Fat free mass was the strongest univariate correlate of small artery elasticity index in the metabolic syndrome group ($R^2 = 0.35$), and weight ($R^2 = 0.30$) and fat free mass ($R^2 = 0.27$) were the strongest univariate correlates in the control group. The slopes for small artery elasticity index with body mass index ($p < 0.05$), elevated fasting glucose ($p < 0.01$), and reduced HDL-cholesterol ($p < 0.01$) were significantly different between the two groups (Table 5). In a multivariate regression model for small artery elasticity index in the metabolic syndrome

group, the significant independent variables included fat free mass ($p < 0.001$), and elevated fasting glucose ($p = 0.036$), with fat free mass being the strongest ($R^2 = 0.29$) (Table 6). In a multivariate regression model for small artery elasticity index in the control group, the significant independent variables included weight ($p < 0.001$), percentage body fat ($p < 0.001$), and fat free mass ($p = 0.032$), with weight being the strongest ($R^2 = 0.14$).

DISCUSSION

Metabolic Syndrome and Arterial Elasticity

A novel finding in this study was that arterial elasticity means were not different between youth with and without metabolic syndrome. This null finding is particularly noteworthy given that those with metabolic syndrome had a higher body mass index, body weight, fat mass, and fat free mass than those without metabolic syndrome. We have previously found that obesity is positively associated with large artery elasticity index in subjects between 9 and 20 years of age, and that body mass index is associated with small artery elasticity index. These findings agree with other reports from our laboratory and with other investigators who found that body weight positively correlates with small artery compliance in children, and obese children and adolescents have slower pulse wave velocity (ie, higher arterial elasticity) than lean controls. The fact that the metabolic syndrome group did not have higher large and small artery elasticity, despite their greater body mass, suggests that the components of metabolic syndrome may have exerted a negative and counteractive influence on arterial elasticity. For example, hypertension, increased triglycerides, and elevated glucose, all components of metabolic syndrome, impair arterial elasticity in younger and older adults. It is possible that in youth the detrimental influences of metabolic syndrome components reduced arterial elasticity to values similar to those without metabolic syndrome, and that the continued chronic burden of metabolic syndrome components will reduce arterial elasticity even further throughout adulthood.

Components of Metabolic Syndrome and Arterial Elasticity

From a univariate standpoint, the only component of metabolic syndrome that was associated with large and small artery elasticity in the metabolic syndrome group was elevated fasting glucose. The positive association indicates that higher levels of fasting glucose was associated with higher large and small artery elasticity, possibly due to concomitantly increased levels of insulin in subjects with metabolic syndrome. Hyperinsulinemia exerts a vasodilatory influence and increases local blood flow. The lack of correlation between elevated fasting glucose and arterial elasticity in the control group provides further support for this notion, as the insulin levels in the controls would be expected to be lower. The group difference in slope between elevated fasting glucose and small artery elasticity index further emphasizes the potential role that hyperinsulinemia has on arterial elasticity, as the slope was significantly higher in the metabolic syndrome group. In the multivariate models, elevated fasting glucose was a significant and positive predictor of small artery elasticity index in the metabolic syndrome group, even after adjustment for fat free mass, but this was not the case in the control group. In multivariate models for large artery elasticity index, elevated triglyceride was a significant and negative predictor in the metabolic syndrome group, but not in the control group. This finding suggests that elevated triglyceride levels reduce arterial elasticity, supported by previous studies, and this effect is only evident in youth with metabolic syndrome.

Fat Free Mass and Arterial Elasticity

Of the body composition measurements, fat free mass was most highly associated with large artery elasticity index and small artery elasticity index in subjects with metabolic syndrome, and was the second highest correlate with the arterial elasticity measures in the controls,

only behind body weight. These findings were confirmed in multivariate models, as fat free mass was the strongest predictor of both large and small artery elasticity in the metabolic syndrome group, but not in the control group. These results indicate that fat free mass is associated with higher arterial elasticity in those with metabolic syndrome. Our results also support previous findings that fat free mass is a strong and positive predictor of arterial elasticity in youth. Thus, intervention strategies designed to increase muscle mass in youth with metabolic syndrome, such as the weight-bearing activity of ambulation and resistive training exercise, may lessen the vascular burden associated with metabolic syndrome.

Another key finding was that fat free mass was more strongly associated with small artery elasticity than with large artery elasticity in both groups. This suggests that muscle mass plays a key role in the microvasculature, possibly due to the development of an increased network of capillaries and arterioles with greater muscle mass. Greater vascular cross-sectional area accompanying greater fat free mass would be expected to lower systemic vascular resistance and increase arterial elasticity. A final interesting observation was that the slopes of body mass index and body weight with the arterial elasticity measures were higher in the control group than in the metabolic syndrome group. This finding suggests that physical growth and maturation have a positive influence on arterial elasticity in youth without metabolic syndrome. However, in youth with metabolic syndrome who are obese, further increases in body mass index and body weight have minimal influence on arterial elasticity, and may actually result in a decline in arterial elasticity.

Limitations

There are limitations to this study. The cross-sectional research design of this study does not allow causality to be established when examining the relationship between arterial elasticity with metabolic syndrome, the components of metabolic syndrome, demographic measures, and body composition. A self-selection bias may also exist regarding study participation. Another limitation is that diastolic pulse contour analysis is a non-invasive technique to determine elasticity of the large and small arteries. It has been suggested that a variety of other factors in the arterial system during diastole could contribute to the measurements of LAEI and SAEI. However, this technique has been validated with invasive measures of arterial compliance and provides reliable measurement of arterial elasticity. There is a limitation associated with the assessment of body fat percentage, as bio-electrical impedance analysis technique underestimates fat mass and body fat percentage compared to dual-energy X-ray absorptiometry, even though the measures from both techniques are highly correlated. A final limitation is that the present findings only apply to apparently healthy subjects with a wide range in body composition.

Summary, Conclusion, Clinical Significance

In summary, 22% of children, adolescents, and young adults in our study population have metabolic syndrome as defined by the International Diabetes Federation. The primary novel finding was that large and small artery elasticity indices were not different between youth with and without metabolic syndrome. Fat free mass was a significant predictor of both arterial elasticity measures, and was the strongest predictor in the metabolic syndrome group. In conclusion, youth with metabolic syndrome did not exhibit differences in large and small artery elasticity compared to controls. Furthermore, fat free mass of youth with metabolic syndrome was positively associated with arterial elasticity, and was the strongest predictor of both large and small artery elasticity. The clinical implication is that exercise intervention designed to increase fat free mass might increase arterial elasticity in youth, and this approach appears more clinically relevant for youth with metabolic syndrome.

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Abbreviations

HDL cholesterol	high density lipoprotein cholesterol
HDI	Hypertension Diagnostic Inc
LAEI	large artery elasticity index
SAEI	small artery elasticity index

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Table 1

Clinical characteristics of subjects with and without metabolic syndrome. Values are either means (standard deviation) or percentages.

Variables	Control Group (n = 161)	Metabolic Syndrome Group (n = 45)	P Value
Age (years)	14.2 (2.6)	14.5 (2.3)	0.424
Weight (kg)	63.0 (21.1)	100.1 (24.7)	< 0.001
Height (cm)	162.8 (12.2)	166.7 (10.6)	0.051
Body Mass Index (kg/m ²)	23.3 (6.0)	35.9 (8.1)	< 0.001
Waist/Hip Ratio	0.81 (0.08)	0.88 (0.08)	< 0.001
Body Fat Percentage (%)	25.4 (9.2)	40.4 (5.3)	< 0.001
Fat Mass (kg)	17.0 (10.9)	39.2 (11.6)	< 0.001
Fat Free Mass (kg)	45.4 (12.8)	56.9 (12.9)	< 0.001
Sex (% males)	56	38	0.032
Race (% Caucasian)	35	40	0.573
Abdominal Obesity (% yes)	25	100	-----
Elevated Fasting Glucose (% yes)	16	73	< 0.001
Elevated Blood Pressure (% yes)	4	16	0.008
Elevated triglycerides (% yes)	4	77	< 0.001
Reduced HDL Cholesterol (% yes)	28	80	< 0.001

Table 2

Hemodynamic measures of subjects with and without metabolic syndrome. Values are means (standard deviation).

Variables	Control Group (n = 161)	Metabolic Syndrome Group (n = 45)	P Value
Systolic Blood Pressure (mmHg)	113 (10)	121 (9)	< 0.001
Diastolic Blood Pressure (mmHg)	59 (7)	63 (8)	0.005
Mean Arterial Pressure (mmHg)	79 (8)	83 (9)	0.002
Pulse Pressure (mmHg)	53 (7)	58 (6)	< 0.001
Heart Rate (b/min)	67 (11)	65 (9)	0.301
Stroke Volume (ml/b)	87.3 (18.3)	107.2 (16.8)	< 0.001
Cardiac Output (ml/min)	5.8 (1.0)	6.9 (0.9)	< 0.001
Systemic Vascular Resistance ($\text{dyne} \times \text{sec}^{-1} \times \text{cm}^{-5}$)	1103 (212)	988 (174)	< 0.001
Large Artery Elasticity Index ($\text{ml} \times \text{mmHg}^{-1}$) $\times 10$	15.4 (4.9)	16.1 (4.4)	0.349
Small Artery Elasticity Index ($\text{ml} \times \text{mmHg}^{-1}$) $\times 100$	8.4 (2.9)	9.2 (2.7)	0.063

Table 3

Association between large artery elasticity with clinical characteristics.

Variables	Control Group		Metabolic Syndrome Group	
	Slope	R ²	Slope	R ²
Age	0.8065	0.180 ***	0.6813	0.123 *
Weight	0.1061 †	0.204 ***	0.0271 †	0.023
Body Mass Index	0.2226 ††	0.074 ***	−0.1131 ††	0.043
Waist/Hip Ratio	−8.7656	0.019	1.1686	0.000
Body Fat Percentage	0.0277	0.003	−0.2346	0.078
Fat Mass	0.1198	0.070 ***	0.0641	0.028
Fat Free Mass	0.1717	0.199 ***	0.1715	0.249 ***
Sex	0.7139	0.005	2.9584	0.107 *
Race	0.2877	0.001	−0.8495	0.009
Abdominal Obesity	1.2352	0.012	----	----
Elevated Fasting Glucose	0.4989	0.001	3.0122	0.094 *
Elevated Blood Pressure	−0.9515	0.001	−1.5857	0.017
Elevated triglycerides	−0.2304	0.000	−2.9871	0.081
Reduced HDL Cholesterol	3.0538 ††	0.079 ***	−1.9249 ††	0.031

* Significant linear regression $p < 0.05$,** $p < 0.01$,*** $p < 0.001$.† Significant group difference in slopes $p < 0.05$,†† $p < 0.01$.

Table 4

Regression coefficient summary for independent variables used in regression models for large artery elasticity index (LAEI) in the control group and in the metabolic syndrome group.

Dependent Variables	Predictors	Regression Coefficient	95% Confidence Interval	Partial R ²	P Value
Control Group *	Body Mass Index	-0.8391	-1.1699 to -0.5082	0.1402	< 0.001
	Fat Free Mass	-0.1033	-0.2226 to 0.0160	0.0187	0.089
	Weight	0.3778	0.2408 to 0.5147	0.1616	< 0.001
	Intercept	15.8721	11.837 to 19.9072		
Metabolic Syndrome Group **	Body Mass Index	-0.1265	-0.2665 to 0.0134	0.0771	0.075
	Fat Free Mass	0.2172	0.1340 to 0.3005	0.4101	< 0.001
	Elevated Triglycerides	-3.0653	-5.7394 to -0.3913	0.1183	0.026
	Intercept	10.8269	4.8858 to 16.7680		

* Overall model results for LAEI in control group: $R^2 = 0.3284$, $p < 0.001$.

** Overall model results for LAEI in metabolic syndrome group: $R^2 = 0.4643$, $p < 0.001$.

Table 5

Association between small artery elasticity with clinical characteristics.

Variables	Control Group		Metabolic Syndrome Group	
	Slope	R ²	Slope	R ²
Age	0.2638	0.080 ***	0.1424	0.014
Weight	0.0620	0.303 ***	0.0490	0.197 **
Body Mass Index	0.1840 †	0.216 ***	0.0671 †	0.040
Waist/Hip Ratio	2.2838	0.005	-1.8706	0.003
Body Fat Percentage	0.0309	0.014	-0.0429	0.007
Fat Mass	0.0846	0.150 ***	0.0902	0.146
Fat Free Mass	0.0963	0.267 ***	0.1250	0.351 ***
Sex	1.0954	0.052 **	2.3630	0.180 **
Race	0.2956	0.004	0.2046	0.002
Abdominal Obesity	1.1585	0.044 **	-----	-----
Elevated Fasting Glucose	0.0186 ††	0.000	2.7681 ††	0.211 **
Elevated Blood Pressure	0.0614	0.000	-0.6920	0.009
Elevated triglycerides	0.4789	0.002	0.0235	0.000
Reduced HDL Cholesterol	1.3563 ††	0.067 **	-1.6487 ††	0.061

* Significant linear regression $p < 0.05$,** $p < 0.01$,*** $p < 0.001$.† Significant group difference in slopes $p < 0.05$,†† $p < 0.01$.

Table 6

Regression coefficient summary for independent variables used in regression models for small artery elasticity index (SAEI) in the control group and in the metabolic syndrome group.

Dependent Variables	Predictors	Regression Coefficient	95% Confidence Interval	Partial R ²	P Value
Control Group *	Fat Free Mass	-0.0802	-0.1535 to -0.0069	0.0292	0.032
	Percentage Body Fat	-0.1267	-0.1921 to -0.0613	0.0862	<0.001
	Weight	0.1333	0.0805 to 0.1861	0.1383	<0.001
	Intercept	6.6709	4.8514 to 8.4904		
Metabolic Syndrome Group **	Fat Free Mass	0.1066	0.0538 to 0.1593	0.2890	<0.001
	Elevated Glucose	1.6371	0.1090 to 3.1653	0.1025	0.036
	Intercept	1.9064	-0.9586 to 4.7714		

* Overall model results for SAEI in control group: $R^2 = 0.3714$, $p < 0.001$.

** Overall model results for SAEI in metabolic syndrome group: $R^2 = 0.4392$, $p < 0.001$.