Differences in Arterial Stiffness and Its Correlates in Tri-Ethnic Young Men and Women

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Objectives: Arterial stiffness is an important measure of pathologic changes in the arterial system and is associated with cardiovascular disease morbidity and mortality. Early identification of an increase in arterial stiffness in young persons may improve cardiovascular health outcomes. The objectives were to evaluate the sex and ethnic differences in arterial stiffness levels among young adults.

Methods: Demographic information, body size, blood pressure, and serum lipid measures were obtained cross-sectionally among tri-ethnic college students in an urban setting (N=491). Arterial pulse pressure (APP) was mathematically derived as a surrogate measure of arterial stiffness. Multiple regression models were fitted to determine the adjusted APP levels.

Results: The average (plus or minus standard error) age of participants were 21.2 (±.2) years. No differences were seen in age or body mass index (BMI) between White non-Hispanic (n=160), Hispanic (n=165), and Black non-Hispanic (n=166). Males were slightly older (21.7 ± .3 years) and heavier (24.6 ± .3 kg/m^2) than females (20.7 ± .2 years and 22.4 ± .2 kg/m^2). Adjusted APP was higher in males (41.8 ± .6 mm Hg) compared to their female counterparts (38.9 ± .6) (P<.01). However, ethnic variations in adjusted APP were not significant.

Conclusions: Variations in arterial stiffness levels by sex exist among young adults. Further exploration of important cardiovascular risk among young individuals is recommended. (*Ethn Dis*. 2006;16:837–843)

Key Words: Arterial Stiffness, Black, Ethnicity, Hispanic, Sex, White, Young Adults

Introduction

Although cardiovascular disease (CVD) is the leading cause of death in US adults,[1] screening for CVD is not common among healthy young adults. While CVD does not usually manifest until adulthood, its risk factors, such as elevated blood pressure, increased body weight, and serum cholesterol, may exist early in life.[2–3] Pathologic changes in the arterial system, such as stiffening of the arteries, may also exist early in life and can contribute to CVD morbidity and mortality.[4] Identification of arterial stiffness in young adults may predict CVD in later life.[2,4] Recognizing changes in the arterial system in young individuals has public health and clinical implications for several cardiovascular outcomes of adults.

Elevated arterial stiffness is a condition associated with pathologic changes in the arterial system and is related to the structural and functional components of the artery. The structural and functional components depend on the intrinsic properties of muscle, elastin, and collagen in the artery.[4–7] Arterial stiffness is related to the artery's ability to expand and recoil with cardiac pulsation and relaxation. The capacity of the arterial system to receive blood pumped from the heart is related to its ability to distend for a given pressure as well as its size. When such capacity of the arterial system is reduced, compliance of the artery is decreased, resulting in stiffness of the artery.[8]

Since arterial stiffness increases with age,[9–10] studies are commonly seen in older adults but are scant among young adults in the United States. To identify arterial stiffness in asymptomatic and healthy young adults, its measurement should be relatively easy, noninvasive, and cost-effective. Several ways exist of measuring arterial stiffness in population studies. These methods are either in vivo or surrogate measures.[4,11–12] In vivo measures are either indirectly measured with the pulse wave velocity or directly visualized on ultrasound. A surrogate measure of arterial stiffness is defined by arterial pulse pressure (APP), which is the difference between systolic blood pressure (SBP) and diastolic blood pressure (DBP).[13–15] Each measurement method (pulse wave velocity, ultrasound, APP) has its own limitations. While increased APP level suggests elevated arterial stiffness, APP is influenced by other factors, such as the presence of wave reflection and rapidity of the ventricular ejection.[13] Currently, no gold standard method exists to measure arterial stiffness. While pulse wave velocity is increasingly recognized as the classical index, APP is considered the most cost-effective index of arterial stiffness.[16]

Increased arterial stiffness is commonly observed in older adults, since it has been considered intrinsic to the aging process of the arteries.[11,17–18] Therefore, one correlate of increased arterial stiffness is age.[1,8,19–23] Other correlates of increased arterial stiffness are obesity[4,12] and lipid abnormalities.[19,24] In addition, hypertension,[12,25–26] diabetes,[19,23,25,27] atherosclerosis,[27–28] coronary heart dis-

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ease,[29] smoking,[30] and sodium intake[19–20] have also been linked to increased arterial stiffness among older adults. However, the causal relationship between these conditions and increased arterial stiffness has yet to be delineated.

A nonmodifiable correlate of arterial stiffness is sex. Differences in arterial stiffness between males and females have been found in some studies[23,31–33] but not in others.[19–20] Because CVD incidence and prevalence vary between men and women, sex differences in arterial stiffness among young adults need further exploration. In addition, variations in arterial stiffness among ethnic groups have not been extensively studied. Ethnic variation in arterial stiffness and other CVD risk factors are of special importance because of high levels of CVD risk and premature mortality from CVD in ethnic minority (eg, African Americans, Hispanics) populations in the United States.[3,34] The diversity of Florida's population presents a unique setting to conduct this study since arterial stiffness among Hispanics is relatively understudied. Thus, a Hispanic-serving institution in an urban city in Florida was chosen to assess arterial stiffness variations among White non-Hispanic, Hispanic, and Black non-Hispanic young adults. The aims of this study were to compare arterial stiffness, as defined by mean APP, between males and females and between White non-Hispanics, Hispanics, and Black non-Hispanics. Second, known correlates of arterial stiffness were compared between sexes and three ethnic groups. Specifically, sex and ethnic comparisons in mean levels of age, height, weight, obesity index or body mass index (BMI), blood pressure (SBP, DBP), APP, and blood lipid profiles were made. Third, sex and ethnic group differences in mean APP levels were assessed while controlling for correlates of APP such as age, BMI, and blood lipid profiles.

METHODS

A cross-sectional assessment of arterial stiffness levels between young men and women of three ethnic groups was conducted. The objective of the primary study was to assess the cardiovascular risks among college students in an urban setting.

Study Site and Sample

The study was conducted at Florida International University (FIU), which is located in metropolitan Miami, Florida. All procedures involved in the study were approved by the institutional review board at FIU. Eligibility criteria were students <40 years of age who enrolled during the academic years 1999–2001 and belonged to one of the three ethnic groups. Targeted ethnic groups were White non-Hispanic, Hispanic, and Black non-Hispanic. Eligible students were invited for a one-time laboratory visit, which lasted approximately one hour. A light breakfast and an incentive of $5.00 were provided for the participants.

Among 504 eligible and willing participants, 13 were excluded because they did not belong to one of the three targeted ethnic groups (n=491). One subject did not provide age. Height, weight, and BMI were available for 487 (99.2%) of the participants. Blood samples were obtained from 370 (75.4%) of the participants; 24.6% refused blood drawing.

The sample size estimation for the original study indicated that 300 subjects (50 in each sex-ethnic group) were sufficient to assess the differences between these groups.[35] Hence, missing data on lipid profiles or other variables were not imputed.

Measurements

For the original study, all students were required to complete three cardiovascular risk-assessment instruments, in addition to other measurements. Measurements relating to this report are discussed in this section. In addition to demographic information, anthropometric data, blood pressure, and blood lipid profiles were measured. Height was measured in inches and converted to meters, and weight was measured in pounds and converted to kilograms. Body mass index (BMI) in kg/m^2 was calculated. Supine blood pressure (mm Hg) was measured three times, and an average of three readings was taken for SBP and DBP levels. Arterial pulse pressure (APP) was derived mathematically from SBP and DBP (APP=SBP – DBP). A fasting blood sample of 15 mL was drawn to assess blood lipid levels. Serum total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and triglyceride levels were reported in milligrams per deciliter. Cholesterol and HDL values were reported as a ratio. Blood samples were analyzed and reported by Quest Diagnostics Laboratory, West Palm Beach, Florida. Detailed data collection procedure of the original study is outlined elsewhere.[35] Demographic characteristics (sex, ethnicity) and continuous variables of age, weight, height, BMI, SBP, DBP, APP, and blood lipid profiles were included in analysis.

Statistical Analysis

Data were entered and managed in SPSS (SPSS Inc., Chicago, Ill) and analyzed by using the SAS software (SAS Institute, Cary, NC). For research aims 1 and 2, descriptive statistics were reported. Percentages were computed for demographic characteristics. Sex differences were evaluated by using t

Table 1. Demographic characteristics of participants (*N*=491)

Characteristics	*n*	%
Sex		
Male	240	48.88
Female	251	51.12
Ethnicity		
White non-Hispanic (WNH)	160	32.59
Hispanic (H)	165	33.60
Black non-Hispanic (BNH)	166	33.81
Sex-ethnic groups		
Male, White non-Hispanic	80	16.29
Male, Hispanic	81	16.50
Male, Black non-Hispanic	79	16.09
Female, White non-Hispanic	80	16.29
Female, Hispanic	84	17.11
Female, Black non-Hispanic	87	17.72

tests. Ethnic variations were assessed by using the general linear model (GLM) procedure. For both sex and ethnic comparisons, means and standard errors (SE) of age, blood and pulse pressure, lipid profiles, and anthropometric measures were reported. For research aim 3, multiple regression models of APP were fitted to evaluate sex and ethnic differences adjusting for several correlates of the APP. These correlates were age, BMI, and five indicators relating to lipid profiles. In addition, sex and ethnicity were included in the model to evaluate ethnicity- and sex-specific adjusted APP levels, respectively. The results of two regression models (with and without sex-ethnicity interaction) did not differ significantly. Hence, a more parsimonious model (without interaction) was presented.

RESULTS

Current analysis was restricted to 240 males and 251 females (n=491); participants included 160 White non-Hispanic, 165 Hispanic, and 166 Black non-Hispanic (Table 1).

Average and SE of age was 21.2 (± .2) years. Other differences between male and female participants are shown in Table 2.

Differences in participants by ethnicity are shown in Table 3. Sex-ethnic variations in the adjusted APP levels are depicted in Figure 1. Arterial pulse pressure (APP) levels were consistently higher in males than in females. The mean and SE of APP (mm Hg) was the highest among the Hispanic males (42.3 ± 1.1), followed by White males (41.6 ± 1.1), Black males (41.6 ± 1.1), White females (40.7 ± 1.1), Hispanic females (38.2 ± 1.1), and Black females (38.0 ± 1.1) (Figure 1). The subgroup differences were statistically significant (P<.01) between two pairs only–White vs Black females and White females vs Black males.

Table 4 depicts the adjusted APP levels between sex and ethnic groups. When age, BMI, lipid levels, and ethnicity were adjusted, APP levels remained different between sexes. Adjusted APP level in males were higher than in females. However, when sex, age, BMI, and lipid levels were adjusted, APP levels were not significantly different between three ethnic groups. Although the difference was not statistically significant, APP level was the highest in Whites, followed by Hispanics and Blacks.

DISCUSSION

This is the first report that examines the differences in arterial stiffness levels among healthy young adults of three ethnic groups (White non-Hispanic, Hispanic, and Black non-Hispanic) in the United States. Sex differences in arterial stiffness have been reported before, although the findings were inconsistent in the literature. Participants in our study were relatively young with an average age of 21 years. Contrary to our findings, studies among Chinese populations found no differences between sexes in arterial stiffness.[19–20] However, our findings were in agreement with those of Laogun and Gosling,[23] in which arterial stiffness levels were found to diverge between girls and boys at approximately 15 years of age. Although statistically not significant, similar findings of arterial stiffness variations in 16-year-old US boys and girls were observed in a study by Riley et al.[31] Sex differences in both unadjusted and adjusted APP were significant in our study. Our study used a surrogate measure of arterial stiffness, whereas the mean ultrasound measured pressure-strain elastic modulus was used in the Riley et al[31] study. Despite the variation in arterial stiffness measurements of

Table 2. Unadjusted arterial pulse pressure (APP) plus or minus standard error (SE) and other covariates by sex

	Male (*n*=240)			Female (*n*=251)			
	n	Mean	SE	*n*	Mean	SE	*P*
Age (years)	240	21.68	.30	250	20.66	.24	*
Height (inches)	237	70.18	.21	250	64.61	.19	*
Weight (lb)	237	171.76	1.87	250	133.01	1.50	*
BMI (kg/m^2)	237	24.56	.25	250	22.42	.22	*
SBP (mm Hg)	241	118.43	.60	250	111.38	.63	*
DBP (mm Hg)	241	75.99	.48	250	71.81	.48	*
APP (mm Hg)	241	42.44	.56	250	39.57	.48	*
Total cholesterol (mg/dL)	180	168.64	2.97	190	167.68	2.70	NS
HDL (mg/dL)	180	45.51	.89	190	54.45	.97	*
LDL (mg/dL)	180	103.05	2.48	190	98.09	2.22	NS
Triglyceride (mg/dL)	180	100.68	4.58	190	78.01	2.99	*
Cholesterol/HDL ratio	180	3.91	.11	190	3.20	.06	*

* P≤.01.

BMI=body mass index; SBP=systolic blood pressure; DBP=diastolic blood pressure; HDL=high-density lipoprotein; LDL=low-density lipoprotein; NS=not significant.

Table 3. Unadjusted arterial pulse pressure (APP) plus or minus standard error (SE) and other covariates by ethnicity

	WNH (n=160)			H (n=165)			BNH (n=166)				
	n	Mean	SE	n	Mean	SE	n	Mean	SE	P	Significant Pair(s)
Age (years)	160	21.76	4.65	165	20.63	4.13	165	21.10	3.97	NS	
Height (inches)	159	67.74	4.36	162	67.12	3.93	166	67.11	4.31	NS	
Weight (lb)	159	150.58	31.93	162	151.21	34.23	166	153.74	31.80	NS	
BMI (kg/m^2)	159	22.97	3.56	162	23.49	4.20	166	23.90	3.54	NS	
SBP (mm Hg)	160	114.53	9.35	165	114.32	10.63	166	115.60	10.86	NS	
DBP (mm Hg)	160	72.84	8.05	165	73.67	7.16	165	75.01	8.05	†	WNH and BNH
APP (mm Hg)	160	41.68	7.02	165	40.65	7.89	165	40.59	9.75	NS	
Total cholesterol (mg/dL)	120	170.43	32.86	124	167.31	43.97	126	166.79	37.89	NS	
HDL (mg/dL)	120	50.21	13.76	124	47.55	11.12	126	52.49	14.72	*	BNH and H
LDL (mg/dL)	120	101.82	27.81	124	101.34	36.63	126	98.42	30.96	NS	
Triglyceride (mg/dL)	120	92.03	49.96	124	93.34	61.74	126	81.95	46.31	NS	
Cholesterol/HDL ratio	120	3.60	1.11	124	3.72	1.57	126	3.32	.83	†	BNH and H

* $P \leq .01$

† $P \leq .05$.

NS=not significant; BMI=body mass index; SBP=systolic blood pressure; DBP=diastolic blood pressure; HDL=high density lipoprotein; LDL=low density lipoprotein; WNH=White non-Hispanic; H=Hispanic; BNH=Black non-Hispanic.

these studies, Riley et al[31] found that arterial stiffness level (Ep) in boys was higher (67 ± 3 kPa) than in girls (62 ± 2 kPa). In our study, male participants also had higher levels of arterial stiffness compared with the females as in previous studies.[23,31–32] The difference in arterial stiffness may likely be due to the differences in physical characteristics between sexes; boys were taller, heavier, and had higher BMIs than girls. In addition, hormones may have played a role in arterial stiffness between sexes. Changes in arterial stiffness in women corresponded to puberty and menopause.[22] Arterial pulse pressure (APP) as a measure of arterial stiffness was different in sexes in older subjects because of small physical characteristics independent of the role of hormones (menopause).[36] Significant sex difference in APP adjusted for age, BMI, ethnicity, and sex-ethnicity interaction was also found among a slightly younger US population (age 13 to 17 years).[37]

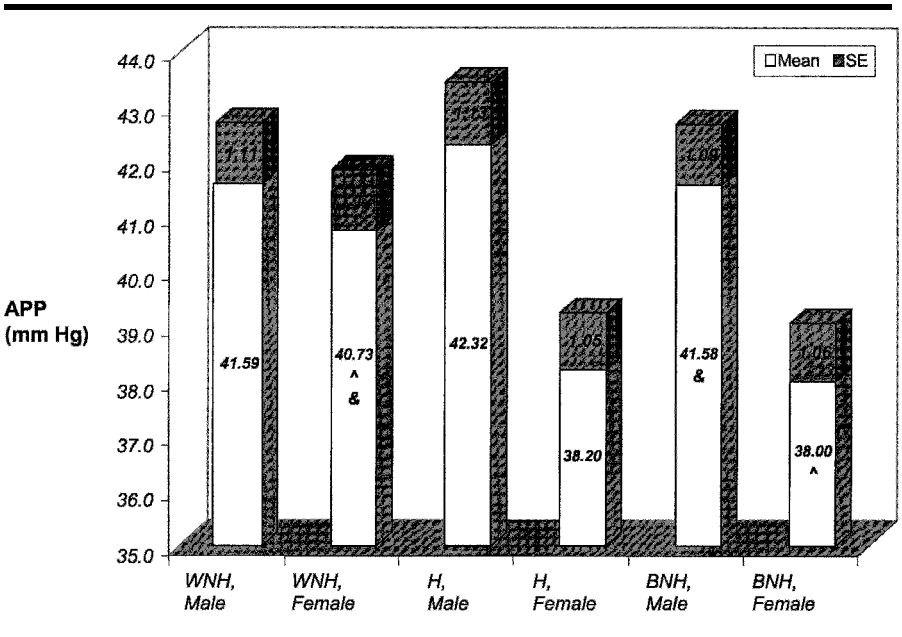

Figure 1. Sex-ethnic differences in mean arterial pulse adjusted (APP) ± standard error. Adjusted for age, BMI, and lipid profiles. WNH=White non-Hispanic; H=Hispanic; BNH=Black non-Hispanic^& Significantly (P<.01) different pairs

Since arterial stiffness differences in Hispanics and other ethnic groups have not been reported, the consistency with other studies cannot be assessed. Among adolescents, ethnic differences in APP between African Americans and Caucasians in Minnesota were not significant.[37] However, ethnic variations in other CVD risk factors in adolescents and young adults have been determined.[3,35,38–39] In our study, ethnic variations in arterial stiffness, as measured by APP, were not statistically significant. However, we found significant variations in DBP between ethnic groups; specifically DBP levels were different between White non-Hispanics and Black non-Hispanics. Although BMI variations between tri-ethnic groups did not reach significance, Black non-Hispanics were heavier (23.9 ± 3.5 kg/m^2) than the White non-Hispanics (23.0 ± 3.6 kg/m^2). This finding is consistent with that of other studies.[3,35,38–39]

Arterial pulse pressure (APP) as a surrogate measure of arterial stiffness in our study may not provide an

Table 4. Adjusted arterial pulse pressure (APP) plus or minus standard error (SE) levels by sex and ethnicity

	Adjusted* APP levels (mm Hg)		
	Mean	**SE**	***P***
Sex			
Male	41.84	.65	<.01
Female	38.91	.63	
Ethnicity			
White non-Hispanic	41.11	.77	>.05
Hispanic	40.19	.76	
Black non-Hispanic	39.73	.75	

* Adjusted for age, body mass index, lipid profiles, and sex or ethnicity.

accurate ascertainment of arterial stiffness among participants, which is a limitation of this study. Correlates of arterial stiffness assessed in this study were age, BMI, blood pressure, and lipid profiles. Sex and ethnic differences in BMI,[35,40–42] blood pressure,[25–26,43–44] and lipid profiles[19,24,42,45] have been reported. However, these comparison studies were not limited to young adults only. Nevertheless, BMI levels among Mexican American males were significantly higher than among Whites and Blacks in San Antonio, Texas. This ethnic trend was not observed among females aged 6–17 years, and the lowest BMI was observed among the Whites in the same study.[41] We also found BMI to be lowest among Whites, followed by Hispanics and Blacks. The breakdown of Hispanic race was not available, but most Hispanic college students are likely of Cuban descent in our study. The variation in composition of Hispanic group in our study and the study in San Antonio (mostly Mexican American)[41] may have contributed to different findings. Blood pressure studies that compared Black and White healthy young adults revealed that the mean SBP and DBP did not differ between them.[43] However, the results from the Hispanic Health and Nutrition Examination Survey and the second National Health and Nutrition Examination Survey found that Mexican Americans had lower mean SBP and DBP compared with non-Hispanic Whites or Blacks.[44] Although the Hispanic group is not of Mexican descent in our study, we found a similar pattern for SBP but not DBP. Diastolic blood pressure (DBP) level in our study was lowest among Whites (72.8 ± 8.1 mm Hg), followed by Hispanics (73.7 ± 7.2 mm Hg), and Blacks (75.0 ± 8.1 mm Hg). However, the difference in DBP was significant only between Blacks and Whites. Gardner et al[45] examined lipid levels among older adults and found Black men and women had lower non-HDL cholesterol levels than either White or Mexican American men and women. In our study, we found significantly different levels of HDL and cholesterol/HDL ratio between ethnic groups. Although the results of our and Gardner et al's[45] studies are not directly comparable, both lipid levels (HDL and cholesterol/HDL ratio) significantly differed between Hispanics and Black non-Hispanics in our study ($P<.01$).

… we found significant variations in DBP between ethnic groups; specifically DBP levels were different between White non-Hispanics and Black non-Hispanics.

This is the first study that compared arterial stiffness levels and correlates of arterial stiffness in tri-ethnic young adults who were presumably healthy. The strength of our study lies in the recruitment of adequate subjects in each ethnic group. However, our participants were recruited by using convenience sampling of college students. Hence, our results may not be generalizable to young adults of other populations. Another limitation of our study deals with the cross-sectional design. Because of the nature of the design, the causal relationship between arterial stiffness and other variables (BMI, blood pressure, and blood lipid levels) could not be assessed. We employed the available measurement of arterial stiffness, ie, APP in this report. Arterial pulse pressure (APP) is considered a surrogate measure, thus, ascertainment of arterial stiffness level may not be as accurate as other measurements of arterial stiffness. However, the clinical value derived from any of the noninvasive arterial stiffness measurements to date does not describe all clinically relevant arterial wall properties.[5] Our APP estimates were derived from SBP and DBP measures at the brachial artery, and brachial artery pulse pressure often overestimates the central pulse pressure in populations.[15]

In conclusion, ethnic and sex variations of cardiovascular risks exist in young adults. Our findings would contribute to the body of knowledge of cardiovascular disease, and our study should serve as a foundation for future epidemiologic studies to assess ethnic variations in arterial stiffness among young adults. Young individuals who are at high risk should be identified early as cardiovascular risks (eg, high blood pressure) tend to track from childhood and adolescence to adulthood.[46] Conceivably, early identification of high-risk young adults should

prevent future cardiovascular disease complications. Future studies should use population-based random sampling method and include ethnic minority groups. Breakdown of Hispanic ethnicity also warrants further exploration in the future, as Cuban Americans may be systematically different from Columbian Americans in terms of culture and disease risk. For example, prevalence of cardiovascular risk (hypertension) has been demonstrated to vary between Mexican Americans in the southwestern United States, Puerto Ricans in New York, and Cuban Americans in Miami-Dade County, Florida.[47] In addition, we recommend that a technically better, robust, and noninvasive measure of arterial stiffness be used in the future population studies.

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