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Determinants of Brachial-Ankle Pulse Wave Velocity and Carotid-Femoral Pulse Wave Velocity in Healthy Koreans

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The aim of this study was to determine the normal value of brachial-ankle pulse wave velocity (baPWV) and carotid-femoral pulse wave velocity (cfPWV) according to age group, gender, and the presence of cardiovascular risk factors in healthy Koreans, and to investigate the association between PWV and risk factors such as prehypertension, dyslipidemia, smoking, and obesity. We measured an arterial stiffness in 110 normal subjects who were 20 to 69 yr-old with no evidence of cardiovascular disease, cerebrovascular accident or diabetes mellitus. The mean values of baPWV and cfPWV were 12.6 (± 2.27) m/sec (13.1 ± 1.85 in men, 12.1 ± 2.51 in women; $P = 0.019$) and 8.70 (± 1.99) m/sec (9.34 ± 2.13 in men, 8.15 ± 1.69 in women; $P = 0.001$), respectively. The distribution of baPWV ($P < 0.001$) and cfPWV ($P = 0.006$) by age group and gender showed an increase in the mean value with age. Men had higher baPWV and cfPWV than women ($P < 0.001$). There was a difference in baPWV and cfPWV by age group on prehypertension, dyslipidemia, current smoking, or obesity ($P < 0.001$). In multiple linear regression, age and prehypertension were highly associated with baPWV and cfPWV after adjustment for confounding factors ($P < 0.001$). The present study showed that baPWV and cfPWV are associated with age, gender, and prehypertension in healthy Koreans.

Keywords: Prehypertension; Gender Identity; Age Groups; Ankle Brachial Index; Carotid-Femoral; Pulse Wave Analysis

INTRODUCTION

Arterial stiffness is an important and independent predictor of cardiovascular risk. It is a dynamic parameter that can be modulated by changes in smooth muscle tone. The vascular endothelium plays an important role in the functional regulation of arterial stiffness (1). Pulse wave velocity (PWV) is the speed at which a pulse is transmitted from the heart to the end artery when blood is expelled during a contraction. PWV is mainly used to evaluate the hardness of artery walls and is increasingly recognized as an important predictor of cardiovascular disease (2). Mean PWV can vary depending on the study population and the method of PWV measurement. Brachial-ankle PWV (baPWV) has been widely used in East Asian countries (3, 4), while carotid-femoral PWV (cfPWV) has been used in landmark studies of arterial stiffness conducted in Europe (5, 6), Australia (7), and the USA (8).

PWV is affected by several well-known risk factors, especially, age and blood pressure. Hypertension is a major risk factor for cardiovascular disease (CVD) and cerebrovascular accident (CVA). Prehypertension is associated with an increased risk of CVD, coronary artery disease (CAD), and stroke (9). It has also been shown that prehypertension is associated with impaired coronary flow reverse (10). Cigarette smoking is an important modifiable cardiovascular risk factor (11) and obesity is a well-known risk factor for CVD (12).

However, few studies have evaluated baPWV and cfPWV in normal subjects who are free from CVD or with CVD risk factors such as male gender, and the presence of prehypertension, dyslipidemia, smoking and obesity. Therefore, in this study, we estimated normal values of baPWV and cfPWV according to age group, gender, prehypertension, dyslipidemia, smoking and obesity in healthy Korean. In addition, we investigated the association between PWV and the CVD risk factors.

MATERIALS AND METHODS

Study population and design

Our study was a substudy of an Arterial Stiffness Clinical Trial (13) performed at the Samsung Cardiac and Vascular Center from February 2010 to May 2011. Due to the screening failure and/or exclusion criteria, 137 subjects were enrolled and 27 subjects were excluded. Exclusion criteria included having acute or chronic renal dysfunction, being pregnant, having diabetes mellitus or concurrent therapy with medications that might affect blood pressure, having connective tissue disorders, proven heart

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failure, valvular heart disease, coronary artery disease, or any aortic disease (including Marfan syndrome, coarctation of the aorta, aortic aneurysm, or aortic dissection) as determined by cardiac magnetic resonance image or echocardiography. Self-reported information regarding dyslipidemia and smoking behavior was obtained from interviews.

We divided subjects into five age levels: 20-29, 30-39, 40-49, 50-59, and 60-69 yr old. According to the Joint National Committee's 7th report (14), prehypertension was defined as a systolic blood pressure (SBP) of 120-139 mmHg and/or diastolic blood pressure (DBP) of 80-89 mmHg, and normotension was defined as SBP < 120 mmHg and DBP < 80 mmHg without use of antihypertensive medication. Subjects were required to have normotension or prehypertension. Mean blood pressure (MBP) was calculated as: MBP = DBP+1/3 (SBP-DBP). Therefore, we analyzed the association between each of two PWVs, baPWV and cfPWV, and cardiovascular risk factors after adjusting for age and MBP.

We defined dyslipidemia as a diagnosis of dyslipidemia, having a history of taking medication for dyslipidemia, or having cholesterol > 200 mg/dL, LDL > 160 mg/dL or HDL < 40 mg/dL. Subjects were identified as current smokers if they had smoked within one year of the survey date. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. We defined the BMI for obesity at BMI ≥ 25 kg/m^2.

Pulse wave velocity measurement

All measurements were conducted in a quiet room with a constant temperature. After a 5-min rest, brachial BP was measured twice using an automatic cuff oscillometric device with a 3-min interval between measurements. Arterial stiffness was evaluated using baPWV and cfPWV (VP-2000; Colin Medical Technology, Komaki, Japan). A volume-rendering method was used to determine PWV. Right and left-side baPWV were measured and the average of these values was used in the analysis. BP was obtained at four limbs simultaneously by the oscillometric method. The validity and the reproducibility of this method have been reported previously (15). The carotid and femoral arterial pulse waves were digitized at 1,200 Hz, and the pulse transit time between the carotid and femoral sites (ΔTcf) was also calculated based on phase velocity theory. The path length from the suprasternal notch to the femur (ΔDsf) was calculated as ΔDsf = 0.5643-Height (cm) × 18.381. The path length from the suprasternal notch to the carotid site (ΔDsc) was calculated as ΔDsc = 0.2437-Height (cm) × 19.0. The cfPWV was calculated by the following formula: (ΔDsf-ΔDsc)/ΔTcf (16). baPWV and cfPWV were taken by well-trained examiners on the same day.

Statistical analyses

Differences in general characteristics and arterial stiffness data by age group and gender were analyzed using two-way Analysis of variance (ANOVA) for continuous variables and the chi-square-test for categorical variables. Differences in general characteristics and arterial stiffness by age group were analyzed using one way ANOVA for continuous variables. Differences between baPWV and cfPWV were analyzed by age group and gender, age group and prehypertension, age group and dyslipidemia, age group and smoking, and age group and obesity using two-way ANOVA. Correlations were assessed using regression analyses. Multiple linear regression analysis was used to determine the association between baPWV or cfPWV as a dependent variable and age, gender, heart rate, prehypertension, dyslipidemia, smoking, and obesity as independent variables.

Ethics statement

This study was approved by the institutional review board of Samsung Medical Center (IRB File No. 2010-05-004). All of the subjects submitted written informed consent.

RESULTS

The mean age of participants was 42.3 (± 13.2) yr old (42.4 ± 13.0 in male, 42.2 ± 13.4 in female; *P* = non-significant [NS]). Male subjects included a significantly higher proportion of prehypertensive subjects and current smoker than female subjects (*P* < 0.001). The mean values of SBP (*P* = 0.003), DBP (*P* < 0.001), mean BP (MBP) (*P* < 0.001), and BMI (*P* = 0.011) in males were higher than those in females. The proportion of males and females in each age group between 20 and 60 was evenly distributed. The mean values of baPWV and cfPWV were 12.6 (± 2.27) m/sec (13.1 ± 1.85 in males, 12.1 ± 2.51 in females; *P* = 0.019) and 8.70 (± 1.99) m/sec (9.34 ± 2.13 in males, 8.15 ± 1.69 in females; *P* = 0.001), respectively. And baPWV (*P* < 0.001) and cfPWV (*P* = 0.006) increased as age increased in both genders (Tables 1, 2).

We found significant differences between baPWV and cfPWV by age group (*P* < 0.001) were significantly higher in the presence of other risk factors. baPWV and cfPWV increased with aging regardless risk factors (Table 2).

Dyslipidemia (*P* = 0.002) and obesity (*P* < 0.001) had an effect on baPWV after adjustment for age and MBP, as shown in Table 3. In multiple linear regression, prehypertension was highly associated with baPWV and cfPWV after adjustment for age, gender and confounding factors (*P* < 0.001) (Table 4).

DISCUSSION

Overall, baPWV and cfPWV increased with age. baPWV and cfPWV were higher in males than in females. baPWV and cfPWV were also higher in the prehypertensive group than in the normotensive group.

Our study showed that baPWV and cfPWV increased with

Table 1. Distribution of clinical characteristics and arterial stiffness of participants by age group and gender (n=110)

Variables		Age (yr) group					*P* value*
		20-29	30-39	40-49	50-59	60-69	
	M	n = 11	n = 14	n = 9	n = 8	n = 9	
	F	n = 14	n = 12	n = 12	n = 11	n = 10	
Number (percentage)							
Prehypertension	M	8 (72.7)	7 (50.0)	8 (88.9)	6 (42.9)	4 (36.4)	0.002
	F	1 (7.1)	2 (16.7)	4 (33.3)	8 (72.7)	7 (63.6)	
Dyslipidemia	M	0 (0.0)	1 (7.1)	3 (33.3)	0 (0.0)	2 (22.2)	0.180
	F	0 (0.0)	0 (0.0)	0 (0.0)	2 (18.2)	1 (10.0)	
Current smoking	M	3 (27.3)	2 (14.3)	3 (33.3)	2 (25.0)	4 (44.4)	< 0.001
	F	0 (0.0)	0 (0.0)	1 (8.3)	1 (9.1)	0 (0.0)	
Obesity, BMI ≥ 25 kg/m^2	M	1 (9.1)	5 (35.7)	3 (33.3)	2 (25.2)	2 (22.2)	0.070
	F	0 (0.0)	0 (0.0)	1 (8.3)	2 (18.2)	4 (40.0)	
Mean (SD)							Age, Gender
SBP (mmHg)	M	122.3 ± 8.4	116.9 ± 9.7	124.8 ± 7.9	120.8 ± 7.3	117.0 ± 12.4	0.008, 0.003
	F	108.9 ± 7.0	108.9 ± 9.0	122.6 ± 13.2	120.0 ± 10.0	123.0 ± 9.9	
DBP (mmHg)	M	69.6 ± 6.6	69.1 ± 6.2	79.0 ± 6.2	74.8 ± 4.5	71.0 ± 4.1	0.003, < 0.001
	F	65.1 ± 5.4	63.9 ± 7.0	66.3 ± 9.6	72.6 ± 7.9	71.7 ± 6.2	
MBP (mmHg)	M	90.0 ± 6.0	88.6 ± 8.0	92.6 ± 7.9	92.8 ± 7.4	90.7 ± 8.1	0.013, < 0.001
	F	80.5 ± 7.0	78.7 ± 8.3	83.6 ± 12.0	90.0 ± 8.0	89.9 ± 6.5	
Pulse (beats/min)	M	68.8 ± 13.9	66.6 ± 7.6	69.3 ± 11.6	70.3 ± 11.7	70.2 ± 11.1	0.566, 0.381
	F	74.2 ± 6.7	73.5 ± 7.9	66.5 ± 6.8	69.6 ± 3.6	66.3 ± 6.7	
Height (cm)	M	179.2 ± 4.3	173.4 ± 4.5	173.3 ± 5.6	168.6 ± 5.0	166.6 ± 7.0	< 0.001, < 0.001
	F	164.0 ± 4.4	160.3 ± 5.2	162.5 ± 4.5	158.2 ± 7.6	154.6 ± 2.3	
Weight (kg)	M	74.3 ± 6.8	72.2 ± 7.7	70.2 ± 7.2	66.4 ± 11.7	62.9 ± 9.9	0.869, < 0.001
	F	53.7 ± 4.4	51.7 ± 4.4	58.3 ± 9.7	60.3 ± 5.9	58.8 ± 5.0	
BMI	M	23.1 ± 1.8	24.1 ± 2.9	23.4 ± 2.5	23.3 ± 3.8	22.5 ± 2.4	0.022, 0.011
	F	20.0 ± 1.4	20.1 ± 1.8	22.1 ± 3.5	24.2 ± 2.9	24.6 ± 1.7	
Length of Suprasternal notch to femur (cm)	M	82.7 ± 2.42	79.4 ± 2.53	79.4 ± 3.18	76.8 ± 2.83	75.6 ± 3.95	< 0.001, < 0.001
	F	74.2 ± 2.45	72.1 ± 2.92	73.2 ± 2.52	70.9 ± 4.37	68.8 ± 1.31	
Length of Suprasternal notch to carotid site (cm)	M	24.6 ± 1.04	23.3 ± 1.09	23.2 ± 1.37	22.1 ± 1.22	21.6 ± 1.71	< 0.001, < 0.001
	F	20.9 ± 1.06	20.1 ± 1.26	20.6 ± 1.09	19.6 ± 1.89	18.6 ± 0.56	
Time of heart to carotid (sec)	M	4.44 ± 0.50	3.76 ± 0.34	3.53 ± 0.47	2.56 ± 0.47	2.33 ± 0.37	< 0.001, 0.047
	F	4.27 ± 0.36	3.55 ± 0.33	3.46 ± 0.58	2.38 ± 0.29	2.28 ± 0.42	
Time of heart to femur (sec)	M	11.4 ± 1.42	10.3 ± 1.32	9.70 ± 1.01	8.66 ± 1.44	7.62 ± 1.42	< 0.001, 0.440
	F	11.9 ± 1.20	10.4 ± 1.20	10.1 ± 1.53	8.03 ± 1.05	8.13 ± 1.05	
hcPWV (m/sec)	M	5.61 ± 0.60	6.12 ± 0.48	6.69 ± 0.97	8.96 ± 0.21	9.58 ± 2.31	< 0.001, 0.016
	F	4.92 ± 0.33	5.68 ± 0.61	6.24 ± 1.27	8.37 ± 1.57	8.45 ± 1.47	
hfPWV (m/sec)	M	7.37 ± 0.90	7.74 ± 0.97	8.27 ± 0.96	9.08 ± 2.14	10.2 ± 2.07	< 0.001, < 0.001
	F	6.27 ± 0.54	6.95 ± 0.69	7.50 ± 1.30	8.98 ± 1.49	8.61 ± 1.14	
baPWV (m/sec)	12.6 ± 2.27†	10.7 ± 1.31	11.8 ± 1.54	12.4 ± 1.75	13.9 ± 1.92	14.9 ± 2.10	< 0.001
cfPWV (m/sec)	8.70 ± 1.99†	7.72 ± 1.36	8.32 ± 1.58	8.85 ± 2.39	9.40 ± 2.01	9.67 ± 2.17	0.006

*Two-way ANOVA for continuous variables or chi-square-test for categorical variables by age group; †Mean ± SD for baPWV and cfPWV. M, male; F, female; BMI, body mass index; hcPWV hfPWV baPWV cfPWV.

age and that baPWV and cfPWV were higher in males than in females. It is already known that baPWV and cfPWV are highly correlated with high blood pressure and age (17). Figueroa et al. (18) showed that the distribution of cfPWV and baPWV in 12 healthy young male adults was similar to our result in 11 healthy young male adults. Distribution of baPWV in Japanese healthy adults was similar to our baPWV by age and gender (19). Distribution of baPWV in Korean adults with normal coronary artery calcium score was also similar to our baPWV (20). Song et al. (21) showed that cfPWV was higher in males than in females. That study included participants with hypertension or diabetes, but participants with CAD were excluded. The study including participants with hypertension (22) showed higher baPWV than our results. Tanaka et al. (17) showed baPWV was strongly associated with cfPWV. Their study included CVD patients. The Rotterdam cohort study consisted of subjects ≥ 55 yr old and showed that cfPWV was higher in males than in females (23). Interestingly, in the present study, we found that the value of cfPWV by gender, blood pressure classification, obesity, and smoking was lower than that of the Rotterdam cohort study. We think this discrepancy might be due to differences in body sizes of the participants in the Rotterdam cohort study and ours. For instance, in the present study, mean BMI was 21.8 in the normotensive group and 23.7 in the prehypertensive group. Rotterdam cohort study participants' mean BMI was ranged from 26.6 to 27.7. Another reason for the difference might be due to the

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Table 2. Distribution of brachial-ankle pulse wave velocity and carotid-femoral pulse wave velocity by gender, prehypertension, obesity, smoking and age group (unit: m/sec)

Variables	Age group						*P* value*
	All	20-29	30-39	40-49	50-59	60-69	
baPWV							
Gender							Age, Gender
Male	12.1 ± 2.51	11.7 ± 1.18	12.6 ± 1.40	13.2 ± 1.46	13.9 ± 2.16	14.9 ± 2.02	< 0.001, 0.002
Female	13.1 ± 1.85	9.98 ± 8.55	10.9 ± 1.25	11.7 ± 2.14	13.9 ± 1.65	14.8 ± 2.26	
BP classification							Age, BP classification
Normotensive	11.5 ± 1.74	10.2 ± 1.13	11.6 ± 1.14	11.4 ± 1.43	12.6 ± 1.65	11.4 ± 1.91	< 0.001, < 0.001
Prehypertensive	13.7 ± 2.22	13.1 ± 1.74	12.8 ± 1.42	14.3 ± 1.93	13.4 ± 1.28	16.0 ± 1.87	
Dyslipidemia							Age, Dyslipidemia
No	12.4 ± 2.17	10.7 ± 1.31	11.7 ± 1.51	12.1 ± 1.97	14.1 ± 1.93	14.0 ± 1.76	< 0.001, < 0.001
Yes	14.8 ± 2.40	-	13.9 ± .	14.1 ± 0.92	13.1 ± 2.11	16.9 ± 3.05	
Smoking							Age, Smoking
Non	12.4 ± 2.25	10.6 ± 1.29	11.8 ± 1.55	12.2 ± 2.07	14.1 ± 2.00	14.6 ± 1.95	< 0.001, 0.036
Current	13.4 ± 2.29	11.6 ± 1.30	12.1 ± 2.00	13.0 ± 1.50	13.3 ± 1.48	15.9 ± 2.57	
Obese							Age, Obese
Non	12.2 ± 2.20	10.7 ± 1.28	11.5 ± 1.49	12.1 ± 2.00	13.5 ± 1.50	14.8 ± 2.46	< 0.001, < 0.001
Obesity	14.3 ± 1.81	12.5 ± .	13.3 ± 0.77	13.3 ± 1.81	15.6 ± 2.65	15.2 ± 1.05	
cfPWV							
Gender							Age, Gender
Male	8.15 ± 1.69	8.60 ± 1.47	8.86 ± 1.75	8.31 ± 2.19	9.42 ± 2.13	10.7 ± 2.58	0.003, < 0.001
Female	9.34 ± 2.13	7.04 ± 0.78	7.69 ± 1.10	9.56 ± 2.57	9.38 ± 2.02	8.71 ± 1.17	
BP classification							Age, BP classification
Normotensive	7.80 ± 1.19	7.35 ± 1.09	7.85 ± 1.22	7.25 ± 0.78	8.71 ± 1.02	8.63 ± 1.25	0.001, < 0.001
Prehypertensive	9.61 ± 2.22	8.39 ± 1.60	9.21 ± 1.85	10.0 ± 2.50	9.65 ± 2.24	10.4 ± 2.43	
Dyslipidemia							Age, Dyslipidemia
No	8.67 ± 2.03	7.72 ± 1.36	8.24 ± 1.56	8.92 ± 2.55	9.56 ± 2.06	9.59 ± 2.23	0.006, 0.552
Yes	9.09 ± 1.63	-	10.3 ± .	8.40 ± 1.17	8.03 ± 0.90	10.1 ± 2.18	
Smoking							Age, Smoking
Non	8.55 ± 1.91	7.68 ± 1.43	8.32 ± 1.64	8.91 ± 2.65	9.20 ± 1.76	9.10 ± 1.78	0.005, 0.038
Current	9.61 ± 2.29	8.04 ± 0.86	8.33 ± 0.71	8.59 ± 0.70	10.5 ± 3.31	11.8 ± 2.41	
Obese							Age, Obese
Non	8.66 ± 2.07	7.62 ± 1.29	8.05 ± 1.15	8.97 ± 2.62	9.62 ± 0.08	10.0 ± 2.43	0.006, 0.587
Obesity	8.91 ± 1.66	10.2 ± .	9.45 ± 2.62	8.32 ± 0.97	8.56 ± 1.70	8.88 ± 1.29	

*Two-way ANOVA.

Table 3. Influence of gender, dyslipidemia, smoking, and obesity on brachial-ankle pulse wave velocity (baPWV) and carotid-femoral pulse wave velocity (cfPWV) before and after adjustment for age and mean blood pressure (MBP)

Variables	No	Mean age (yr)	baPWV (m/sec)				cfPWV (m/sec)			
			Before adjustment		After adjustment		Before adjustment		After adjustment	
			Mean (m/s)	*P* value	Mean (m/s)	*P* value	Mean (m/s)	*P* value	Mean (m/s)	*P* value
Gender										
Female	59	42.2	12.1	0.020	12.4	0.323	8.15	0.002	8.43	0.074
Male	51	42.4	13.1		12.7		9.34		9.02	
Dyslipidemia										
No	101	41.6	12.4	0.002	12.5	0.022	8.67	0.542	8.73	0.515
Yes	9	50.9	14.8		13.6		9.09		8.36	
Current smoking										
No	94	41.5	12.4	0.106	12.6	0.516	8.55	0.048	8.67	0.607
Yes	16	46.9	13.4		12.4		9.61		8.90	
Obesity										
No	90	41.2	12.2	< 0.001	12.4	0.019	8.66	0.605	8.82	0.103
Yes	20	47.5	14.3		13.2		8.91		8.14	

different age groups used in the two studies. All the subjects in the Rotterdam cohort study were older than 55, while age of our subjects ranged from 20 to 69 yr. Interestingly, we found that cfPWV was higher among prehypertensive subjects in their twenties than among normotensive subjects in their fifties.

Our study showed that baPWV and cfPWV are associated with prehypertension. These findings are consistent with previous studies that reported an association between PWV and prehypertension (24). Blacher et al. showed an association between PWV and the development of cardiovascular disease or cardio-

Table 4. Association between brachial-ankle pulse wave velocity (baPWV) and carotid-femoral pulse wave velocity (cfPWV) and prehypertension, dyslipidemia, smoking, and obesity by gender

Variables	baPWV (m/sec)				cfPWV (m/sec)			
	Univariate*		Multiple†		Univariate*		Multiple†	
	β	*P* value	β	*P* value	β	*P* value	β	*P* value
All								
Age	0.12	< 0.001	0.10	< 0.001	0.05	< 0.001	0.05	< 0.001
Gender, male vs female	1.00	0.019	0.58	0.054	1.19	0.002	0.97	0.007
Heart rate	0.03	0.160	0.03	0.065	0.03	0.119	0.02	0.261
Prehypertension	2.20	< 0.001	1.27	< 0.001	1.81	< 0.001	1.26	< 0.001
Dyslipidemia	2.41	0.002	0.61	0.255	0.42	0.542	-0.29	0.646
Current smoking	1.00	0.105	0.53	0.209	1.06	0.048	-0.30	0.549
Obesity	2.05	< 0.001	0.93	0.018	0.25	0.605	-0.41	0.365
Male								
Age	0.08	< 0.001	0.08	< 0.001	0.05	< 0.001	0.04	0.037
Heart rate	0.04	0.056	0.02	0.297	0.05	0.052	0.03	0.237
Prehypertension	0.72	0.187	0.99	0.033	1.82	< 0.001	1.04	0.043
Dyslipidemia	1.76	0.027	0.68	0.340	0.98	0.333	0.25	0.774
Current smoking	0.50	0.396	-0.38	0.415	3.45	0.003	2.56	0.023
Obesity	0.86	0.149	0.73	0.646	0.74	0.281	-0.36	0.565
Female								
Age	0.14	< 0.001	0.11	< 0.001	0.06	0.015	0.06	0.003
Heart rate	0.01	0.860	0.05	0.045	-0.01	0.769	0.02	0.500
Prehypertension	3.23	< 0.001	1.12	0.040	1.36	0.028	1.56	0.016
Dyslipidemia	3.07	0.037	0.79	0.385	-0.27	0.768	-0.75	0.443
Current smoking	0.99	0.587	-0.05	0.960	0.01	0.998	-1.02	0.121
Obesity	3.49	< 0.001	1.01	0.133	-0.49	0.472	-0.04	0.959

*Estimated by simple linear regression analysis; †Estimated by multiple linear regression models using the variables in the table.

vascular death (5, 25). Although prehypertensive subjects with arterial stiffness do not need prehypertension medical treatment to prevent the progression of hypertension, we consider arterial stiffness evaluation in prehypertensive subjects to be helpful for controlling blood pressure using diet and physical activity while in the prehypertensive stage (26).

Dyslipidemia was insignificantly associated with baPWV and cfPWV after adjusting for confounding variables. This result was consistent with that of a study of an elderly Japanese population in which no difference was found between people with dyslipidemia and arterial stiffness (27).

Smoking was insignificantly associated with baPWV after adjusting for confounding variables. This result contrasts with that from a study of Japanese male smokers, wherein a relationship between smoking and arterial stiffness as measured by baPWV was found (28). Jatoi et al. (11) showed that current and ex-smokers had significantly higher PWV, and that the duration of smoking cessation had a significant linear relationship with improvement in PWV. However, in our study, smoking in males was significantly associated with cfPWV after adjusting for confounding variables. Edvinsson et al. (29) showed that cigarette smoking results in reduced relaxant responses of the peripheral microcirculation; that is, they observed reduced peripheral microvascular responses to both endothelial and smooth muscle cell stimulation in healthy subjects, suggesting that there is a generalized microvascular vasomotor function.

Obesity was insignificantly associated with baPWV and cfPWV after adjusting for confounding variables in this study. These findings are in contrast with results that showed a greater independent effect of adiposity on PWV in women of African ancestry (30). Obesity is associated with a markedly higher prevalence of hypertension as age increases.

There are several limitations to our study. First, our study had a small sample size. Few studies have evaluated PWV in normal subjects who are free from CVD or with CVD risk factors, which made it difficult to calculate sample size without proper reference. Therefore, we made a study design including 10 subjects by age and gender group, respectively. Second, the information regarding the dyslipidemia status of our subjects could be inaccurate. This is because we did not perform a blood test to determine subjects' cardiovascular risk factors, but rather depended on participants' self-reporting. Therefore, we recommend further studies that address the dyslipidemia problem of this study. Third, due to the limited information from our dataset, we could not investigate the relationship between PWV vs job stress, physical activity, or diet. This is an additional area in which future research is necessary.

The strength of this study is that we estimated normal baPWV and cfPWV values for healthy Korean people. Therefore, our results are useful as a normal reference.

In conclusion, baPWV and cfPWV are associated with age, gender, and prehypertension in healthy Koreans. We establish normal values for baPWV and cfPWV according to age group and gender in healthy Koreans.

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DISCLOSURE

The authors have no conflicts of interest to disclose.

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