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Original Article

Aortic Pulse Wave Velocity is Associated with Functional Capacity in Young Healthy Individuals

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Abstract

Introduction: Impaired functional capacity and aortic pulse wave velocity (PWV) are predictors of cardiovascular (CV) adverse outcomes in healthy individuals as well as in those with CV disease. However, interrelation between arterial PWV and functional capacity remain to be established. Hence, the aim of the present study was to assess the relationship between arterial PWV and functional capacity in young healthy individuals.

Materials and methods: A cross-sectional study was conducted on young healthy subjects (n=58) with age ranging between 17-24 years. The PWV from four regions was included for the study: brachial-ankle PWV, carotid-PWV/aortic PWV, heart-brachial PWV and heart-ankle PWV. Functional capacity was evaluated using a six-minute walk test (6MWT). Relationship between variables were assessed using bivariate correlations and multiple linear regression analysis.

Results: Walking-distance was significantly correlated with age (r=0.334; p=0.010**)** and aortic-PWV (r=-0.259; p=0.049). Aortic PWV was robustly associated with 6MWD even after multiple adjustments with potential confounders using several models.

Conclusions: Our findings suggest that aortic-PWV is an independent predictor of functional capacity in young healthy individuals. There was an inverse association of aortic-PWV with walking-distance, suggesting that higher the aortic PWV, lower is the functional capacity.

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Introduction

Functional capacity of an individual is the ability to perform daily activities and occupation that require sustained aerobic metabolism. Individual's functional capacity depends on a complex integrated efforts and health of the pulmonary, cardiovascular, and skeletal muscle systems. Among the several existing tools, six-minute walk test (6MWT) is a simple, reliable and well-established tool to quantify the functional exercise capacity (FEC) of an individual (1, 2). Functional capacity is a better predictor of cardiovascular (CV) adverse outcomes in healthy individuals (3-5) as well as in those with CV disease (6). Advancing age, sedentary lifestyle, obesity, psychological factors, diabetes and hypertension are the contributing factors for impaired functional capacity (2, 7, 8). However, the mechanism of the association of impaired functional capacity with CV disease and mortality remains to be elucidated. Aortic stiffness is also an independent and strong predictor of cardiovascular (CV) morbidity and all-cause mortality (9-11). The pressure wave generated in the aorta during ventricular systole travels along the arterial tree up to a particular point (forward wave) and reflects back as wave reflection (12). Pulse wave velocity (PWV) is a measure of the speed of the travel of arterial (forward) pressure wave along the arterial wall and is a marker of arterial stiffness. It increases with a decrease in arterial elasticity (13). Most of the factors those contributing to impairment in functional capacity are also involved in the stiffening of arteries (14, 15). However, interrelation between arterial PWV and functional capacity remain to be established. Hence, the aim of the present study was to assess the relationship between arterial PWV and functional capacity in young healthy individuals.

Methodology

Participants and study design:

A cross-sectional study was conducted on young healthy subjects (n=58) with age ranging between 17-24 years during 15th June to 14th August 2017. Young healthy subjects aged between 17-24 years with BMI: 18.5-24.9 were included in the study. Subjects with history of acute or chronic diseases, CVS disorders, renal disorders and pulmonary disorders; the habit of smoking, chewing tobacco and consumption of beverages; subjects taking any medications, herbal drugs and vitamin supplements were excluded. Prior approval of the study was taken from the institutional ethical committee of Sri B. M. Patil Medical College, Hospital and Research Centre, BLDE University, India as per the guidelines (2006) of Indian Council of Medical Research. Written informed consent was obtained from the participants prior to their enrollment for the study. All the recordings were made in the morning between 8 am to 11 am at room temperature following supine rest for 10 minutes.

Measurement of blood pressure and heart rate:

Blood pressure and heart-rate was measured using digital blood pressure monitor (Omron HEM 7111) in a sitting posture: first at rest (following rest for 10 minutes) and second after six-minute walk test. The difference between systolic and diastolic blood pressure was estimated as pulse pressure. Mean arterial Pressure (mmHg) was calculated by adding diastolic blood pressure and 1/3rd pulse pressure.

Assessment of arterial pulse wave velocity:

Arterial PWV was measured using a validated non-invasive automatic device (Periscope, Genesis Medical Systems, India) (16). This device uses four BP cuffs and two-channel ECG leads to record arterial pressure waveforms and ECG simultaneously. The data obtained in 10 seconds was stored in the computer for further analysis. The detailed method of analysis of PWV by periscope is given in our earlier study (17). The PWV from four regions was included in the study.

a. Brachial-ankle PWV (baPWV): It reflects stiffness of aorta and peripheral artery.

b. Carotid-femoral PWV (cf-PWV)/Aortic PWV: It is a gold standard marker of aortic stiffness.

c. Heart-brachial PWV (hbPWV): It reflects stiffness of part of central elastic artery (part of the aorta) and peripheral artery of upper limb.

d. Heart-ankle PWV (haPWV): It reflects stiffness of central elastic artery and peripheral artery of lower limb.

Assessment of Functional capacity:

Functional capacity was evaluated using a six-minute walk test (6MWT). In this test, the subject walked as far as possible in six minutes and the maximum distance walked (in meters) was recorded (2).

Statistical analysis:

Data was analyzed for normality using Shapiro-Wilk test. Data with normal distribution are expressed as mean with standard deviation (SD) while non-normal distributed data as median with interquartile range (IQR). Based on data distribution, parametric or non-parametric tests were applied for further analysis of data. The gender difference in baseline characteristics was determined by Unpaired-t-test or Mann-Whitney U test. The correlation between arterial PWV and functional exercise capacity was determined by using Pearson or Spearman correlation coefficient. The association between arterial PWV and functional capacity by controlling the confounders was determined by using multiple linear regression analysis.

Results

With an aim to assess the relationship between arterial PWV and functional capacity, a total of 58 participants (Male=29; Female=29) were included in the study. Median age of the participants was 19.0 (2.0) years. Blood pressure and BMI were within normal range. Arterial stiffness indices were significantly higher in males than females. There was no significant difference in walking distance between two genders (Table I).

Six minute walking-distance was significantly correlated with age (p=0.010**)** and aortic-PWV (p=0.049). Among the PWV measured at several regions, only aortic-PWV, a marker of aortic stiffness was significantly correlated, while there was no significant correlation of baPWV, hbPWV and haPWV with 6MWD. No significant correlation was noticed between 6MWD and other co-variables (BMI and BP) (Table II).

Further analysis shows that aortic-PWV was robustly associated with 6MWD even after multiple adjustments with potential confounders using several models. Age was adjusted (β=-0.281; p=0.028; adjusted R^2=0.15) in model-1; age and BMI (β=-0.3; p=0.02; adjusted R^2=0.155) was adjusted in model-

TABLE I: Characteristics of study participants.

Variables	*Total (n=58)* *Mean±SD* *Median (IQR)#*	*Males (n=29)* *Mean±SD* *Median (IQR)#*	*Females (n=29)* *Mean±SD* *Median (IQR)#*	*p-value*
Age (years)	19 (2.0)#	19 (2.0)#	19 (2.0)#	0.669[b]
BMI (Kg/m^2)	20.59 (4.52)#	19.49 (5.09)#	21.46 (4.31)#	0.549[b]
SBP (mmHg)	117.38 (11.83)	125.14 (9.06)	109.6 (8.84)	<0.001[a]***
DBP (mmHg)	74.76 (8.04)	76.62 (8.08)	74.89 (8.14)	0.897[a]
PP (mmHg)	42.97 (11.6)	50.51 (9.47)	35.41 (7.51)	<0.001[a]***
MAP (mmHg)	87.17 (8.02)#	91.33 (12.83) #	85.67 (10.33)#	0.002[b]**
HR (bpm)	78.98 (14.13)	73.45 (14.13)	84.52 (11.97)	0.002[a]**
baPWV (cm/s)	1001.81 (125.12)	1069.84 (113.03)	933.77 (97.48)	0.001[a]***
cfPWV (cm/s)	587.75 (118.41)	638.99 (122.81)	536.5 (89.56)	0.001[a]***
hbPWV (cm/s)	299.0 (57.25)#	297.0 (53.0)#	300.0 (60.00)#	0.619[b]
haPWV (cm/s)	434.34 (44.26)	449.69 (37.29)	419 (45.94)	0.007[a]**
6MWD (meters)	479.98 (60.19)	481.93 (59.9)	478.03 (61.48)	0.808[a]

Data with normal distribution are expressed as mean with standard deviation (SD) while non-normal distributed data as median with interquartile range (IQR), **#** - Values are in median (IQR); (SBP- systolic BP; DBP- Diastolic BP; PP- Pulse pressure; MAP- Mean arterial pressure; HR-Heart rate; baPWV- brachial ankle PWV; cfPWV- Carotid-femoral PWV; hbPWV – heart brachial PWV; haPWV – heart ankle PWV; 6MWD- six minute walking distance. *p<0.05, **p<0.01, ***p<0.001: indicates the difference between males and females; a- Unpaired-t-test; b- Mann-Whitney U test.

TABLE II : Bivariate correlations between 6-minute walking-distance and co-variables (n=58).

Co-Variables	*6 Minute Walking Distance (meters)*	
	r-value	*p-value*
Age (years)	0.272	0.010[b]**
BMI (kg/m^2)	0.079	0.300[b]
SBP (mmHg)	–0.051	0.703[a]
DBP (mmHg)	–0.146	0.275[a]
PP (mmHg)	0.016	0.905[a]
MAP (mmHg)	–0.013	0.966[b]
HR (bpm)	0.059	0.662[a]
baPWV (cm/s)	–0.206	0.121[a]
cfPWV (cm/s)	–0.259	0.049[a]*
hbPWV (cm/s)	–0.139	0.297[b]
haPWV (cm/s)	–0.204	0.124[a]

*p<0.05, **p<0.01, ***p<0.001; a- Pearson correlation; b- Spearman correlation.

2; age, BMI, MAP and SBP (β=-0.333; p=0.013; adjusted R^2=0.171) was adjusted in model-3; and age, BMI, MAP, SBP, HR (β=-0.382; p=0.013; adjusted R^2=0.151) was adjusted in model-4 (Table III).

Discussion

Our findings suggest that aortic-PWV is an independent predictor of functional capacity in young healthy individuals. There was an inverse association of aortic-PWV with walking-distance, suggesting that higher the aortic PWV, lower is the functional capacity.

Kawamoto R et al studied the effect of 12 week exercise training program on older community dwelling subjects, where they found that participants with higher brachial-ankle PWV at baseline have shown less improvement in walking-distance than those with lower PWV (18). Few other studies have shown a link between the stiffness of artery and walking-distance in elderly patients with CV risk factors (19) and peripheral arterial disease (20, 21). As per our knowledge there are no studies showing a physiological relationship between pulse wave velocity and functional capacity in healthy individuals.

Impaired functional capacity and aortic pulse wave velocity (PWV) are independent predictors of cardiovascular (CV) adverse outcomes in healthy individuals as well as in those with CV disease (3-6). Artery performs two important functions: conduit and cushioning. Cushioning function of the artery decreases with an increase in arterial stiffness. So, progressive loss of cushioning has a devastating effect on the heart and the microcirculation of several organs, including skeletal muscles, which may be the probable explanation for the inverse relation of aortic PWV with functional performance of an individual (12). We presume that aortic stiffness is the common factor contributing for the impairment in functional capacity and its associated CV adverse outcomes.

In conclusion, an inverse association of aortic PWV with functional capacity suggests that functional capacity of an individual depends on the arterial health (stiffness) which reinforced the concept of Sir William Osler that “Man is as old as his arteries”. Aortic stiffness may be the linking mechanism of association between impaired functional capacity and CV disease. However, further prospective longitudinal cohorts are necessary to confirm the role of arterial stiffness in modulating the functional capacity in healthy and individuals with CV diseases.

TABLE III : Multiple linear regression analysis on dependent variable 6-minute walking-distance and independent variable carotid-femoral PWV.

Dependent variable	*Independent variable*	*B-value (std error)*	*β-value*	*t-value*	*p-value*	*Adjusted R^2*
6MWD	Model-1	–0.143 (0.063)	–0.281	–2.26	0.028*	0.15
	Model-2	–0.163 (0.064)	–0.300	–2.402	0.02*	0.155
	Model-3	–0.172 (0.067)	–0.338	–2.571	0.013*	0.171
	Model-4	–0.194 (0.076)	–0.382	–2.573	0.013*	0.151

Dependent variable- 6MWD; Independent variable- carotid-femoral PWV; Model-1 after adjusting for age; model-2=after adjusting for age and BMI; model-3=after adjusting for age, BMI, MAP and SBP; model-4=after adjusting for age, BMI, MAP, SBP and heart rate; *p<0.05, **p<0.01, ***p<0.001

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