Correlation of self-reported physical activity with pulse wave velocity in male adolescents

Hajime Miura*, Saori Maruoka and Megumi Sugino

Laboratory for Applied Physiology, Institute of Socio-Arts and Sciences, University of Tokushima, 1-1 Minamijyosanjima, Tokushima 770-8502, Japan

Received: December 13, 2011 / Accepted: April 10, 2012

Abstract  Habitual exercise is important for improving or maintaining arterial function with age. However, the role of physical activity on arterial stiffness in adolescents is unclear. This study evaluated the influence of physical activity on the brachial-ankle pulse wave velocity (baPWV) in high school students. The baPWV, brachial systolic blood pressure (SBP), diastolic blood pressure (DBP), and body composition were assessed in 221 healthy male high school students (16.4 ± 1.5 yrs). Self-reported physical activity (PA) was evaluated by the short form of the International Physical Activity Questionnaire (IPAQ-SF). Measurement variables were calculated for four age stages (15, 16, 17, and 18 yrs). The values for baPWV, SBP and DBP increased from 15 to 18 yrs. Stepwise regression analysis showed that SBP (β = 0.496), PA (β = -0.170), age (β = 0.186), and weight (β = -0.133) were independent contributors to baPWV, accounting for 36.6% of the variability. These results support the concept that physical activity lowers baPWV, which indicates an improvement in the arterial function of adolescents as well as middle-aged to elderly people.

Keywords: pulse wave velocity, physical activity, adolescent

Introduction  Cardiovascular disease is the main cause of mortality in developed countries, and the pathological process associated with the development of this disease begins early in life1,2). Several risk factors such as aging, obesity, diabetes, dyslipidemia, or lack of physical activity have been identified as determinants of arterial stiffness3). Arterial stiffness in adults is affected by multiple variables including age4), race5), gender6), arterial pressure6), and the presence of metabolic syndrome7). In childhood, arterial function is associated with blood pressure8), obesity9), age10), gender11), and race12). Previous studies have reported the characteristics of arterial stiffness in children (9 to 17 yrs)13), and in young to elderly (25 to 87 yrs)14), and the influence of habitual exercise on arterial stiffness in children (5 to 12 yrs)15,16) and middle-aged to older men17,18). However, little is known about the relationship between arterial function and physical activity in adolescents. Adolescents usually have a similar lifestyle at school. Therefore, different physical activities such as commuting to school or participating in sports/athletic clubs may influence arterial stiffness in adolescents. We hypothesized that the physical activity level would have a preventive effect on arterial stiffness in adolescents as well as middle-aged to older men.

The aim of this study was to investigate arterial stiffness on the basis of age and explore the effect of the current physical activity level on arterial stiffness estimated by pulse wave velocity in male Japanese high school students.

Methods  Subjects. The subjects in this study comprised 246 male high school students aged 15 to 18. Twenty-five subjects who had a medical history requiring medical treatment, or who had smoked, were excluded. All subjects (n=221, age: 16.7 ± 1.2 yrs, height: 170.1 ± 6.3 cm, weight: 63.1 ± 10.6 kg) participated in a normal school physical education class and were free from overt disease as assessed by a questionnaire, completed by each of the subject’s parents. According to age and measurement data, the subjects were divided into four groups based on current age: 15 yrs (15.0 to 15.8), 16 yrs (16.1 to 16.9), 17 yrs (17.0 to 17.9), and 18 yrs (18.0 to 18.7). The ethics committee for the Institute of Socio-Arts and Sciences of the University of Tokushima gave ethical approval for the study. The parents of all subjects provided written informed consent and all subjects gave verbal consent.

Pulse wave analysis. Brachial-ankle pulse wave velocity (baPWV), brachial systolic (SBP) and diastolic blood pressure (DBP) were measured using an automatic form
International Physical Activity Questionnaire (IPAQ).

Physical activity was assessed using the IPAQ translated into Japanese. The IPAQ version was the short form of the ‘last 7 days’ recall questionnaire20). This version contains seven questions assessing the frequency and duration of subject participation in a vigorous, moderate-intensity, and/or low-intensity activity (walking), as well as time spent sitting during a typical weekday. Scores for vigorous, moderate, and walking activity, as well as time spent sitting, were calculated in minutes per week. The sum of the three activity scores gives an indicator of total physical activity. The number of hours per week of each type of activity was multiplied by the average metabolic cost (MET), and an energy expenditure indicator was also obtained, and was expressed in MET-minutes per week. The MET is the ratio of the working metabolic rate of an activity divided by the resting metabolic rate. One MET represents the metabolic rate of an individual at rest and is set at 3.5ml of oxygen consumption per kg of body weight per minute, or approximately 1kcal·kg⁻¹·h⁻¹. The minutes per week for vigorous activity, moderate activity, or walking were multiplied by a factor of 8, 4, or 2.5, respectively. Next, the sum of energy expenditure per day for vigorous, moderate and walking was calculated as the total energy expenditure for physical activity (PA).

Statistical Analysis. The results were expressed as the means ± standard deviation. All of the analyses were conducted using the SPSS software package for Windows, Version 17.0 (SPSS, Chicago, IL). The data in each group were assessed by a one-way analysis of variance (ANOVA). A post-hoc test (Scheffe’s multiple comparison test) identified significant differences among the significant mean values. The data were also evaluated by linear regression analysis and stepwise multivariable linear regression analysis in order to assess significant determinants of baPWV in adolescents. Statistical significance was defined as p<0.05.

Results

Description of the Sample. Table 1 shows the characteristics of the subjects, while Table 2 shows the results divided into four groups. There were significant differences in height, weight, SBP, DBP, baPWV, and PA.

Factors Associated With baPWV. Linear regression analysis showed that the age, %fat, SBP, DBP, HR, and PA correlated with the baPWV (Table 3). The results of stepwise multiple linear regression analysis are shown in Table 4. SBP, PA, age, and weight accounted for 36.6% of the variation in baPWV. The standardized beta estimates were β = 0.496 (p<0.01) for SBP, β = -0.170 (p<0.01) for PA, β = 0.186 (p<0.01) for age, and β = -0.133 (p<0.05) for weight.

Discussion

This study demonstrated that SBP, DBP, and baPWV gradually increase with age, which is accordance with previous studies on children13), adults and the elderly14). However, the subjects in this study were adolescents from 15 to 18 years old. Artery function changes gradually even in adolescents. PWV is usually associated with the amount of calcium or collagen in media, and increased

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean±SD (n=221)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>16.7 ± 1.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.1 ± 6.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.1 ± 10.6</td>
</tr>
<tr>
<td>%fat (%)</td>
<td>14.4 ± 5.8</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>128.2 ± 13.8</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>66.8 ± 8.4</td>
</tr>
<tr>
<td>HR (beats·min⁻¹)</td>
<td>69.2 ± 11.0</td>
</tr>
<tr>
<td>baPWV (m·sec⁻¹)</td>
<td>10.9 ± 1.7</td>
</tr>
<tr>
<td>PA (kcal·kg⁻¹·day⁻¹)</td>
<td>16.7 ± 14.7</td>
</tr>
</tbody>
</table>

Data are shown as the means ± standard deviation. %fat, percentage of body fat; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; baPWV, brachial to ankle pulse wave velocity; PA, energy expenditure for physical activity.
arterial stiffness may be an exercise-induced increase in blood flow, leading to augmented shear stress and cyclic stretch, causing enhanced nitric oxide (NO) production

Exercise induces the promotion of circulating atrial natriuretic peptides, catecholamines, adenosine, and ATP

The seemingly favorable response of arterial stiffness in male adolescents to physical activity is probably related to increased NO bioavailability. This is thought to result from the upregulation of eNOS gene expression in response to vascular wall shear stress caused by exercise-related increases in systemic blood flow. This may also partially explain the positive effect of physical activity on baPWV. Although the mechanism underlying the age-associated increase in arterial wall stiffness in adolescents is unclear, it is often assumed to be associated with changes in elastin and collagen levels in the media. It has been suggested that the degeneration of the arterial wall begins in childhood, causing decreases in elastin, increases in collagen, and ultimately the beginning of the atherosclerotic process. This proposition appears to be plausible when considering risk factors such as physical inactivity.

Maeda et al. reported that regular exercise increased the production of NO and decreased endothelin-1. The present results imply that these suggested effects are induced by greater physical activity. Physical activity influenced arterial function in male adolescents, which was consistent with previous results in children and middle-aged to older men.

PWV with age is due to a decrease in the elastic properties caused by the degeneration of the arterial wall. The current results might be explained by structural and functional changes such as arterial wall hypertrophy and degeneration or disorganization of the medial layer with age in adolescents.

The main findings of this study were that SBP, PA, age, and weight were all found to be important factors associated with baPWV in male adolescents. The correlation of PA with baPWV, in adolescents, supports the hypothesis that physical activity has a preventive effect against arterial stiffening. Physical education lectures, extracurricular activities, or commuting to school influence the level of physical activities of this age group. Therefore, a concerted effort at the federal and/or local policy levels should be required to reinforce the availability of physical activity in adolescents. However, the observed contribution of PA to baPWV was relatively small. In adults, different work styles including sedentary or moderate to heavy physical labor in the daytime lead to large variations in the physical activity level, which greatly influence arterial function. Regarding high school students, most tend to have a similar life style at school, except for differences in commuting to school or regarding participation in sports or club activities. Such behavioral differences in the daytime may influence the contribution of PA to baPWV.

The mechanism mediating the beneficial effect of PA on arterial stiffness may be an exercise-induced increase in blood flow, leading to augmented shear stress and cyclic stretch, causing enhanced nitric oxide (NO) production. Exercise induces the promotion of circulating atrial natriuretic peptides, catecholamines, adenosine, and ATP. The seemingly favorable response of arterial stiffness in male adolescents to physical activity is probably related to increased NO bioavailability. This is thought to result from the upregulation of eNOS gene expression in response to vascular wall shear stress caused by exercise-related increases in systemic blood flow. This may also partially explain the positive effect of physical activity on baPWV. Although the mechanism underlying the age-associated increase in arterial wall stiffness in adolescents is unclear, it is often assumed to be associated with changes in elastin and collagen levels in the media. It has been suggested that the degeneration of the arterial wall begins in childhood, causing decreases in elastin, increases in collagen, and ultimately the beginning of the atherosclerotic process. This proposition appears to be plausible when considering risk factors such as physical inactivity.

Maeda et al. reported that regular exercise increased the production of NO and decreased endothelin-1. The present results imply that these suggested effects are induced by greater physical activity. Physical activity influenced arterial function in male adolescents, which was consistent with previous results in children and middle-aged to older men.

PWV is an accepted and useful index of arterial stiffness that can be measured accurately, is reproducible, and is found to correlate with intra-arterial measurements. However, one weakness of this method is that the long-term consequences of increased arterial stiffness in adolescents are still unknown. Self-reported PA was a negative influential factor on baPWV in the current study (Table 4). This result suggests that spending more time engaged in physical activities has a favorable effect on arterial stiffness in male adolescents as well as middle-aged
students. So it cannot be concluded whether these find-
could not check the menstrual cycle of female high school
were examined in the present study because we
endothelium-dependent vasodilation in adults
stiffening
thelial cells - atherogenic effects that also promote arterial
muscle cell proliferation and monocyte adhesion to endo-
crease in androgen associated with puberty would there -
changes. Male sex steroids therefore appear to promote
arterial stiffening in both the central and peripheral arter-
WV is based on the facts that blood pressure affects pulse
waves, and that stiffness of the arterial wall affects blood
pressure. The significant contribution of weight and age
to baPWV might be due to age- and development-related
stiffness, including the central and peripheral arteries
Androgen deprivation has been shown to enhance endothelium-dependent vasodilation in adults. An
increase in androgen associated with puberty would therefore increase the arterial tone, and it may contribute to stiffening of the arteries. Androgen also increases smooth
muscle cell proliferation and monocyte adhesion to endothelial cells - atherogenic effects that also promote arterial stiffening. Therefore, in our subjects, who averaged 16.7 years of age, the level of physical growth and development also influenced baPWV values.

The close correlation between blood pressure and baPWV is based on the facts that blood pressure affects pulse waves, and that stiffness of the arterial wall affects blood pressure.

### Table 4. Multiple stepwise analysis of baPWV

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \beta )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP</td>
<td>0.496</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>PA</td>
<td>-0.170</td>
<td>0.002</td>
</tr>
<tr>
<td>Age</td>
<td>0.186</td>
<td>0.001</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.133</td>
<td>0.022</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.366</td>
<td></td>
</tr>
<tr>
<td>adjusted ( R^2 )</td>
<td>0.355</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations are the same as those in Table 1.

to older men.
The close correlation between blood pressure and baPWV is based on the facts that blood pressure affects pulse waves, and that stiffness of the arterial wall affects blood pressure. The significant contribution of weight and age to baPWV might be due to age- and development-related changes. Male sex steroids therefore appear to promote arterial stiffening in both the central and peripheral arteries. Androgen deprivation has been shown to enhance endothelium-dependent vasodilation in adults. An increase in androgen associated with puberty would therefore increase the arterial tone, and it may contribute to stiffening of the arteries. Androgen also increases smooth muscle cell proliferation and monocyte adhesion to endothelial cells - atherogenic effects that also promote arterial stiffening.

### Conclusion

The current results emphasize that physical activity, as well as blood pressure or other anthropometric variables, need to be addressed to lower the pulse wave velocity, which indicates an improvement in the arterial functions in male adolescents.

### Acknowledgements

The authors wish to thank Yoshinori Takahashi, Nao Okamura, Arisa Hirahara, and Ryoko Hara for their technical assistance in this study. This study was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science, Sports and Culture of Japan (20500596).

### References


