

## Original Article

**Relationship Between the Change in Daily Step Count and Brachial-Ankle Wave Velocity During a Pedometer-Based Physical Activity Program for Older Adults**Ryo Miyazaki<sup>1,2,3)</sup>, Yoshikazu Yonei<sup>1)</sup>, Yoriko Azuma<sup>3)</sup>, Hitoshi Chiba<sup>4)</sup>, Koichiro Hayashi<sup>5)</sup>, Koji Yamatsu<sup>6)</sup>, Kojiro Ishii<sup>2,3,7)</sup>

1) Anti-Aging Medical Research Center, Graduate School of Life and Medical Sciences, Doshisha University

2) Health and Human Performance Research Center, Doshisha University

3) formerly of Laboratory of Human Performance and Fitness, Hokkaido University

4) Department of Health Science, Hokkaido University School of Medicine

5) Faculty of Human Development, Kokugakuin University

6) Faculty of Culture and Education, Saga University

7) Faculty of Health &amp; Sports Science, Doshisha University

**Abstract**

**Objective:** To study the relationship between the change in the number of steps taken and brachial-ankle pulse wave velocity (baPWV) during a long-term pedometer-based physical activity program in healthy older adults.

**Methods:** Sixty older adults participated in this 17-week program. Each subject was provided with a pedometer and was given a goal to walk a set number of steps/day. After five subjects were excluded because of insufficient step data, data from 55 subjects (19 men and 36 women; age range: 65–79 years, mean age: 71.3±3.7 years; mean body mass index [BMI]: 24.1±8.8 kg/m<sup>2</sup>) were analyzed. Subjects were checked before and after the study. Each subject was informed of his or her vascular age, calculated from baPWV, at the start of the study.

**Results:** Subjects were divided into four groups based on the results of baPWV. The group in which baPWV improved above a selected cut-off value (1,700 cm/s) revealed the largest increase in steps/day among groups. This increase (4837.7±1868.7 steps) was larger than in groups in which baPWV remained low (1406.7±2402.1 steps,  $p=0.036$ ) and high (1678.2±2871.4 steps,  $p=0.059$ ). In any group, age or initial steps/day did not influence the change in steps. Subjects classified as having an older vascular age than the actual age on the basis of initial baPWV walked further.

**Conclusion:** An increase in steps/day might improve baPWV. Although walking is a low intensity physical activity, it can have an anti-atherosclerosis effect.

**KEY WORDS:** walking, atherosclerosis, arterial stiffness, baPWV, aging**Introduction**

Pulse wave velocity has been used as an indicator of atherosclerosis and arterial stiffness<sup>1)</sup>. Recent studies have focused on the use of brachial-ankle pulse wave velocity (baPWV) as a clinical tool for screening atherosclerosis<sup>2)</sup>; this variable was recognized in 2009 as a tool for the measurement of arterial stiffness in guidelines for the diagnosis of hypertension by the Japanese Society of Hypertension (JSH2009)<sup>3)</sup>. Habitual Physical activity has been reported to effectively prevent atherosclerosis<sup>4)</sup> even when begun at an older age<sup>5,6)</sup>. This emphasizes the importance of appropriate physical activity programs for older people. Such physical activity programs should be effective, safe and easy, and walking is one activity suitable for older people<sup>7)</sup>. A quantitative increase of physical activity has been reported to prevent atherosclerosis<sup>8)</sup>. Accordingly, an increase in the number of steps taken may improve baPWV. However, most

previous studies assessed the effectiveness of physical activity programs on baPWV either using resistance training<sup>9)</sup> or exercise at special facilities<sup>10-14)</sup>. Such exercise programs are difficult for older people to complete at home without supervision. We are not aware of any investigation the relationship between the number of steps taken and baPWV among older adults.

In the present study, we established a long-term pedometer-based physical activity program for healthy older adults and analyzed the relationships between change in steps/day and change in baPWV. We hypothesized that the change in steps/day would lead to an improvement in baPWV.

## Methods

### 1. Subjects

A total of 60 healthy older adults (65 years old or older), living in the central district of S City, Hokkaido participated in this study. Subjects were recruited either from the city news of S City or bulletin boards in the city center (the Central Health Center or the M Community Development Center). During analysis, four subjects were excluded because of insufficient step data during the study period and one subject missed the final checkup for personal reasons and was excluded from the study. Therefore, data from a total of 55 subjects (19 men and 36 women; age range: 65–79 years, mean age: 71.3±3.7 years; mean body mass index [BMI]: 24.1±8.8 kg/m<sup>2</sup>) were included in the analyses. All subjects provided written informed consent. The present study was approved by the Ethics Committee of the Graduate School of Education at Hokkaido University.

### 2. Pedometer-based physical activity program

The procedures of the physical activity program are described elsewhere<sup>15</sup>. Briefly, the program consisted of pedometers and newsletters. Each subject was provided a pedometer (Walking Style HJ-720IT, Omron Healthcare Co. Ltd., Ukyo-ku, Kyoto) and instructed to walk everyday during the study. Each subject was given a goal to walk a set number of steps/day. At least once a month, subjects were instructed to bring their pedometers to the assigned center. Step data were entered by health nurses or staff into a personal computer using BI-Link Professional Edition 2.0 software (Omron Healthcare Co. Ltd., Ukyo-ku, Kyoto). Newsletters were delivered to each subject's house every four weeks. Newsletters for each subject showed the average steps/day achieved for the current month as well as the goal number of steps/day for the upcoming months, determined based on the individual's average steps/day in the current month using the following criteria. Step goals for each month were decided as follows: increase of 1,000 steps/day for subjects below 5,000<sup>16</sup>, increase to 7,500 steps/day for 5,000–7,500<sup>17</sup>, increase to 10,000 steps/day for 7,500–10,000<sup>17</sup>, and maintenance steps/day over 10,000<sup>16</sup>. In step data analysis, the average steps/day for the first week (Week 0) of the study were treated as baseline data for “start of the study”. Only data obtained during a wearing period of >12 hours per day was included in analysis. This excluded low steps/day data if a subject forgot to wear his or her pedometer.

### 3. Measurements of anthropometrics, blood pressure and baPWV

Each subject was given a medical checkup before and after the study, after an overnight fast. Anthropometrics, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured before the program was started; baPWV was measured separately on a different day during 0900–1500 h at rest using an automatic oscillometric device (form PWV/ABI; Omron Colin Co. Ltd., Bunkyo-ku, Tokyo). The validity and reproducibility of baPWV measurements have been described elsewhere<sup>18</sup>.

### 4. Estimation of vascular age from baPWV

The instrument used in the study is calibrated so that vascular age can be calculated from baPWV<sup>19</sup>. At the beginning of the study, each subject was informed of his or her vascular age via mail. When a subject's calculated baPWV was

within the range average to average + ½ standard deviation (SD) of the standard baPWV<sup>19</sup> for their actual age, their vascular age was set as equal to their actual age. If baPWV differed by more than average + ½ SD from the standard, his or her vascular age was calculated from the value average +½ SD. The subjects were divided into two groups to analyze the effect of differences between estimated vascular age and actual age; subjects were allocated to a vascular age-older group if vascular age was estimated as ≥2 years older than actual age; otherwise, the subject was enrolled into the vascular age-younger group.

### 5. Statistical analysis

All data were expressed as mean±SD, and  $p < 0.05$  was considered statistically significant. Statistical tests were performed using SPSS for Windows Ver. 15.0 (SPSS Inc., Chicago, IL, USA). Differences within groups were estimated by paired *t*-test or Wilcoxon's signed rank test. The differences between groups were estimated using one-way ANOVA, ANCOVA and the  $\chi^2$ -test. Dunnett's test was used to compare weekly average steps/day (Week 1–16) with baseline steps/day (Week 0). To estimate the effect of increasing steps/day during the study,  $\Delta$ steps/day was calculated using the following formula<sup>20</sup>:

$$\Delta \text{steps/day} = \sum_{X=1-16} \{(\text{steps/day at Week X}) - (\text{steps/day at Week 0})\}$$

To evaluate change in baPWV, we set a cut-off baPWV = 1,700 cm/s. Although there is no clear cut-off value of baPWV that defines organ disorders<sup>21</sup>, this value is a predictor of several health disorders such as all mortality<sup>22</sup>, type 2 diabetes mellitus<sup>23</sup>, cerebral ischemic small vessel disease<sup>24</sup> and acute coronary syndrome<sup>25</sup>. Each subject was categorized as either ‘high’ or ‘low’ according to his or her starting baPWV above or below the cut-off value.

At the end of the study, subjects were divided into four groups: the high-high (HH) group remained above the cut-off value baPWV throughout the study; the low-low (LL) group remained below the cut-off value; and the low-high (LH) and high-low (HL) groups showed a change in baPWV across the cut-off value.

## Results

### Characteristics of the subjects

Fifty-five subjects completed the study. At the start of the study (baseline), actual age, SBP, DBP and baPWV of the HH group was higher than other groups ( $p < 0.05$ ). The average steps/day in the first week (Week 0) and the sex ratio was similar in all groups (Table 1).

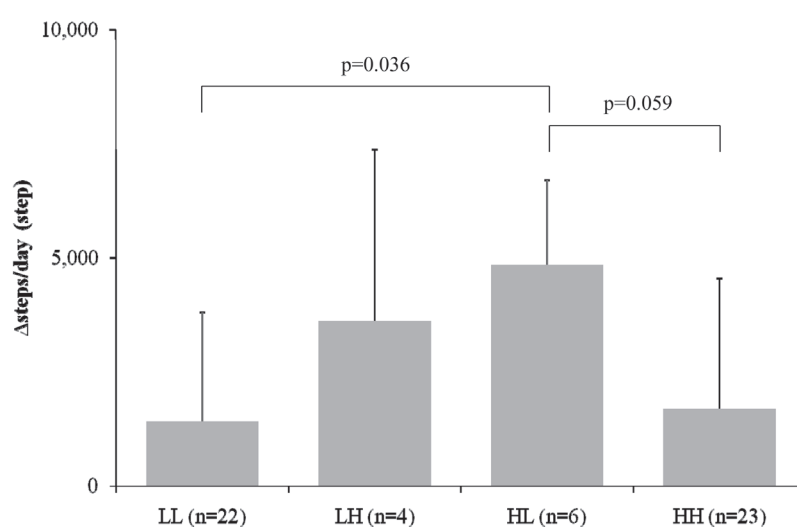
### Change in steps/day ( $\Delta$ steps/day)

The change in number of steps/day ( $\Delta$ steps/day) in each group is shown in Fig. 1. The HL group (4837.7±1868.7 steps) changed more than the LL group (1406.7±2402.1 steps,  $p = 0.036$ ) and tended to be larger than HH group (1678.2±2871.4 steps,  $p = 0.059$ ). The difference between groups in  $\Delta$ steps/day was unchanged after age and steps/day at baseline were adjusted using ANCOVA. This indicates that neither age nor steps/day at baseline affected  $\Delta$ steps/day among groups.

**Table 1** Characteristics of the subjects at baseline

	LL (n=22)	LH (n=4)	HL (n=6)	HH (n=23)	p-value	post-hoc
Male sex (No.)	5	3	3	8		
Weight (kg)	56.2 ± 7.0	61.1 ± 11.5	60.1 ± 9.4	60.8 ± 9.6	0.323	
BMI (kg/m <sup>2</sup> )	23.2 ± 2.1	24.1 ± 2.9	23.7 ± 1.8	24.7 ± 2.5	0.203	
Waist circumference (cm)	86.0 ± 6.3	82.8 ± 10.0	88.9 ± 2.5	90.4 ± 7.9	0.097	
Hip circumference (cm)	95.9 ± 5.2	96.1 ± 2.6	97.6 ± 4.2	98.4 ± 4.7	0.371	
SBP (mmHg)	132.7 ± 14.2	135.8 ± 14.6	141.7 ± 18.0	154.6 ± 19.0	0.001	LL<HH
DBP (mmHg)	76.3 ± 7.4	76.2 ± 3.4	79.2 ± 8.6	82.9 ± 12.1	0.019	LL<HH
baPWV (cm/s)	1,520.9 ± 121.9	1,666.8 ± 14.3	1,793.8 ± 94.0	2,068.7 ± 284.7	0.000	LL<HL<HH
Steps/day at week 0 (step)	10,114.2 ± 3,062.9	9,509.2 ± 3,882.3	8,506.1 ± 2,303.6	8,801.0 ± 3,940.4	0.573	

Values are Means ± SD.



**Fig. 1.** Comparison of the change in steps/day among four groups based on the cut-off value of baPWV. Error bars show SD.

### Change in anthropometrics and resting blood pressure

The changes in weight, waist circumference, hip circumference, SBP and DBP are shown in [Table 2](#). Weight, waist circumference and hip circumference decreased in all groups except the LH group ( $p < 0.05$ , [Table 2](#)).

### Change in baPWV

The baPWV of the two groups above or below the baseline cut-off value are compared in [Fig. 2](#). The change in baPWV tended to be larger in the LH group than the LL group ( $p = 0.083$ ) but there was no significant difference in change in baPWV between the HH and HL groups.

### Difference in steps/day between vascular age-older and age-younger groups.

The average steps/day in the age-older group increased every week except week 1 and 2 ( $p < 0.05$ , [Fig. 3a](#)); in the vascular age-younger group, the average steps/day only increased in week 5–9 and 13–14 ( $p < 0.05$ , [Fig. 3b](#)).

### Discussion

The present study examined whether change in baPWV was related to the number and change in number of steps/day. We found the HL group (indicating baPWV changed from high level at the start of the study to low level at the end of the study) exhibited greatest increase in steps/day. This implies that subjects with a higher initial baPWV who increased steps/day tended to decrease baPWV by the end of the program.

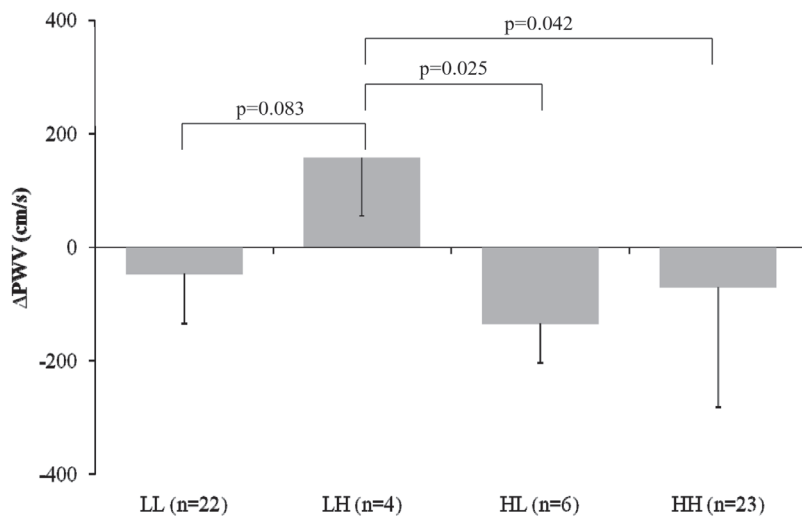
It is important to note that this program consisted of daily walking and all subjects were older adults. As far as we know, the effect of walking alone and quantitative investigation of physical activity on baPWV have not been previously reported. Most previous studies<sup>10-14</sup> measured the effect of supervised physical activity sessions using exercise facilities. For older people, visiting exercise facilities appears more difficult than walking. Given that walking is easily included in everyday routine, the results in the present study are clinically meaningful.

BaPWV is strongly influenced by SBP<sup>26</sup>. However, when the baPWV was adjusted for baseline SBP the change of baPWV in the HL group was greater than that in the LH group. As  $\Delta$ steps/day in HL group was the largest of the four groups, the result suggests the improvement in baPWV was related to the increase in steps.

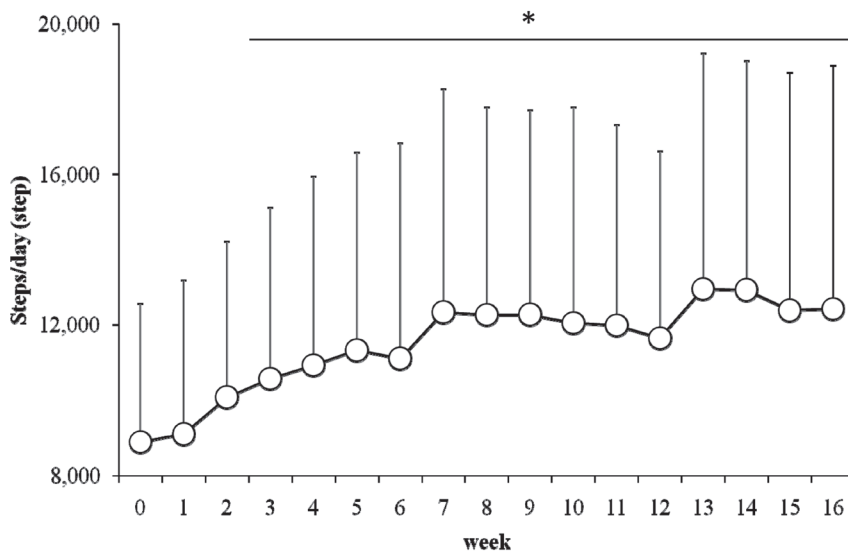
**Table 2** The change in anthropometrics, blood pressure and baPWV in each group

	LL (n=22)	p-value	LH (n=4)	p-value	HL (n=6)	p-value	HH (n=23)	p-value
Weight (kg)	-1.6 ± 2.1	0.002 **	-0.6 ± 2.1	0.583 **	-2.3 ± 1.8	0.026 *	-1.8 ± 1.6	0.000 ***
BMI (kg/m <sup>2</sup> )	-0.7 ± 0.9	0.002 **	-0.3 ± 0.8	0.553 **	-0.9 ± 0.6	0.023 *	-0.7 ± 0.6	0.000 ***
Waist circumference (cm)	-2.4 ± 3.6	0.005 **	-2.2 ± 2.1	0.126 **	-3.4 ± 4.0	0.090	-1.7 ± 3.9	0.043 *
Hip circumference (cm)	-3.6 ± 5.1	0.003 **	-0.5 ± 5.3	0.854 **	-5.3 ± 3.5	0.014 *	-3.0 ± 3.5	0.001 **
SBP (mmHg)	-11.4 ± 13.3	0.001 ***	8.8 ± 17.6	0.394 ***	-11.7 ± 13.6	0.090	-2.7 ± 16.8	0.450
DBP (mmHg)	-4.4 ± 7.6	0.014 *	8.0 ± 6.9	0.104 *	-6.0 ± 4.1	0.016 *	-2.9 ± 12.0	0.258
baPWV (cm/s)	-46.2 ± 87.6	0.022 *	157.5 ± 103.6	0.056 *	-134.0 ± 70.1	0.005 **	-69.5 ± 211.9	0.130

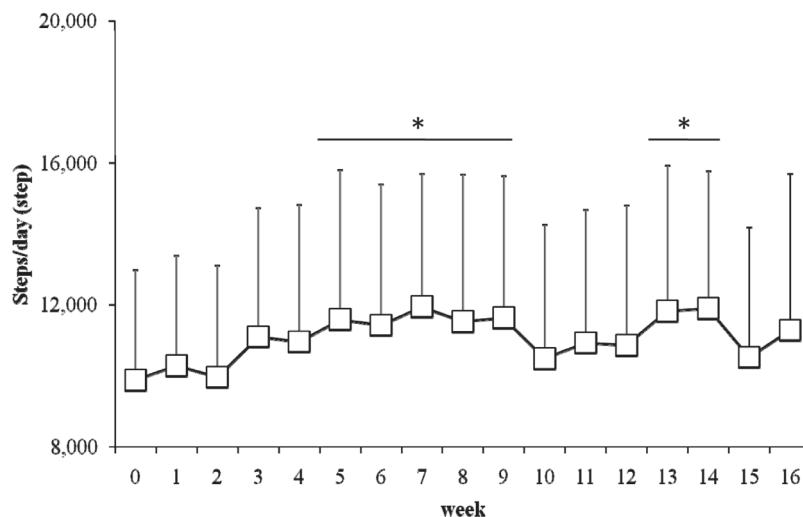
Values are Means ± SD. \* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001 vs. baseline.



**Fig. 2.** Comparison of the change in baPWV among four groups based on the cut-off value of baPWV. Error bars show SD.



**Fig. 3a.** The average steps/day of vascular age-older group during the study. \* p < 0.05 compared with week 0. Error bars show SD.



**Fig. 3b.** The average steps/day of vascular age-younger group during the study

\* $p < 0.05$  compared with week 0. Error bars show SD.

There is a dramatic, exponential<sup>27)</sup> increase in baPWV with increasing age<sup>28,29)</sup>. In the present study, the average baPWV of the subjects at baseline (men,  $1,820.1 \pm 321.5$  cm/s; women,  $1,774.7 \pm 323.7$  cm/s) was slightly higher than previously reported<sup>28)</sup>. Previous studies found PWV increased 7.5–11.8 cm/s per year<sup>29)</sup> and the decrease of 46.0 cm/s found in the present study (data not shown) is equivalent to an Anti-Aging effect of approximately 4–6 years. This demonstrates the potential of programs that encourage older people to increase daily steps to prevent atherosclerosis.

However, the physical activity level of the subjects at baseline may also affect the results. Subjects in the present study were highly active; the average steps/day at baseline was  $9,389.1 \pm 3,412.1$ , markedly higher than that reported in other studies of men and women in their 60s (7,961 for men and 6,666 steps for women)<sup>30)</sup>. Further study needs to explore the effects of physical activity in more sedentary people.

Further, the steps/day of subjects in the two groups based on vascular age assessed by baPWV differed. The vascular age-older group (indicating vascular age > actual age at start of the study) exhibited greatest increase in steps/day, although there was no difference between the two groups at the start of the study (Fig. 3a,b). That is, subjects whose vascular age was diagnosed >2 years older than actual age, walked more during the study. This result suggests that informing subjects of their vascular age encouraged the age-older group to increase physical activity. Previous studies have also suggested that telling subjects their cardiovascular age<sup>31)</sup> or lung age<sup>32)</sup> yielded better results than traditional therapies. Similarly, it was reported that interventions that used a pedometer and provided a goal induced an increase in steps/day<sup>33)</sup>. Taken together, showing older people simple indexes such as “goal steps/day” or “vascular age” may be an effective tool for increasing physical activity among the elderly.

The limitation of the present study was that we could not show any relationship between baPWV and other indicators except steps/day. This may be a result of small sample size or individual differences. However, previous studies reported that higher baPWV is related to slower walking speed among older people<sup>34)</sup> and an increase of 100 cm/s baPWV increases sarcopenia risk among older people by 1.14 times<sup>35)</sup>. Higher PWV may affect other physical measures other than

atherosclerosis. These facts imply the decrease of PWV in this study may improve health and physical functions of older people.

## Conclusions

The present study examined the effects of a 17-week pedometer-based physical activity program for healthy older adults and the relationship between change in steps/day and change in baPWV. The findings are:

1. Even low intensity physical activity such as walking may decrease baPWV.
2. A group, in whom baPWV was above 1,700 cm/s at baseline and decreased baPWV during the study, showed the largest increase in steps/day during the study
3. A group, in whom vascular age at baseline was diagnosed older than his/her actual ages, increased steps/day during the study.

These findings suggest that high individual baPWV may be decreased by increasing number of steps/day although no dose-response relationship was found between number of steps/day and baPWV. Providing simple indicators such as vascular age and target number of steps can encourage older people to increase physical activity.

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