Impaired Balance and Higher Prevalence of Falls in Subjects With Intermittent Claudication

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Background. The purpose of this study was to determine whether peripheral arterial disease (PAD) subjects have impaired balance and a higher prevalence of falls than non-PAD controls and to determine whether balance and falls are related to the severity of PAD and functional status.

Methods. A total of 367 PAD subjects (aged 68 ± 1 years; mean ± SEM) and 458 non-PAD controls (aged 67 ± 1 years) were recruited. Unipedal stance time, history of ambulatory stumbling and unsteadiness, and history of falling were recorded. Additionally, subjects were characterized on age, ankle/brachial index (ABI), anthropometry, measured and self-reported ambulatory function, and monitored daily physical activity.

Results. Unipedal stance time was 28% shorter (p < .001) in the PAD subjects than in the non-PAD controls (15.9 ± 0.9 vs 22.1 ± 1.0). History of ambulatory stumbling and unsteadiness was 86% more prevalent (p < .001) in the PAD group (150/367 = 41%) than in the controls (101/458 = 22%), and history of falling was 73% more prevalent (p < .001) in the PAD subjects (95/367 = 26%) than in the controls (69/458 = 15%). Within the PAD group, 6-minute walk distance, self-reported ambulatory function, and daily physical activity were significantly related to the balance and falling measures (p < .05), whereas ABI was unrelated (p > .05).

Conclusions. Compared with the controls, PAD subjects with intermittent claudication had impaired balance and a greater likelihood of falling, both of which were associated with ambulatory function and daily physical activity.

SYMPTOMATIC peripheral arterial disease (PAD) afflicts 6% of the American population above the age of 55 (1). PAD is a leading cause of morbidity due to ambulatory dysfunction associated with intermittent claudication (2). PAD subjects frequently experience intermittent claudication during ambulation because the peripheral circulation is inadequate to meet the energy needs of the active lower-extremity muscle.

The ambulatory dysfunction in subjects with intermittent claudication (3) may trigger a decline in other domains of physical function. For example, PAD subjects with intermittent claudication have a lower daily physical activity level (4), worse self-perceived ambulatory function (5), and lower health-related quality of life (6). The ability to maintain balance and how it relates to falls is a domain of physical function that has important health consequences (7) but has not been assessed in the PAD population. PAD subjects may be particularly susceptible to poor balance and a greater rate of falling because impaired peripheral circulation is associated with sensory and motor nerve dysfunction of the lower extremities (8).

The purposes of this study were (i) to determine whether PAD subjects have impaired balance and a higher prevalence of falls than non-PAD controls and (ii) to determine whether balance and falls are related to the severity of PAD and functional status.

Methods

Subjects

A total of 1113 subjects between the ages of 38 and 89 years (65 ± 10 years; mean ± SD) were evaluated in the Geriatric Research, Education, and Clinical Center at the Maryland Veterans Affairs Health Care System (MVAHCS) at Baltimore. The subjects were recruited from the Vascular Clinic at the site of the Baltimore MVAHCS and from local newspaper and radio advertisements. Of these subjects, 367 were included into a PAD group defined as having a positive Rose questionnaire for intermittent claudication (9) and an ABI < 0.90 (10). A total of 458 subjects were included in a non-PAD control group defined as having a negative Rose questionnaire for intermittent claudication and an ABI ≥ 1.00. Because diabetes might confound the effect of PAD on balance and falls, 163 subjects with a history of diabetes were excluded from this study. The remaining 125 subjects were excluded because they did not meet the Rose questionnaire and ABI criteria of either group.

The demographic characteristics of the PAD subjects consisted of 312 men (85%), 55 women (15%), 228 whites (62%), and 139 African Americans (38%). The non-PAD controls consisted of 271 men (59%), 187 women (41%), 352 whites (77%), and 106 African Americans (23%). All subjects lived independently at home. The procedures used in this study were approved by the Institutional Review Board at the University of Maryland, Baltimore. Written informed consent was obtained from each subject prior to the investigation.

Measurements

Balance and falls.—Subjects performed a unipedal stance test while wearing shoes by lifting the leg of their choice so
that the first metatarsophalangeal joint was above the contralateral medial malleolus (11). Subjects were permitted to touch the shoulder of the test administrator to assist them into this position. When the subjects were told to begin, they removed their hand from the shoulder of the test administrator and maintained the unipedal position for a maximum of 60 seconds with their eyes open and both arms held loosely at their sides. Movement of the arms or standing foot was not permitted during the test. Unipedal stance time was recorded with a stopwatch from the start of the test until the raised foot touched the ground when the position could no longer be maintained.

In addition to the unipedal stance time, balance was assessed by asking the subjects if they had often stumbled or felt unsteady while walking over the past year. A stumble was defined as a loss of balance that was restored before a fall occurred, and unsteadiness was defined as a routine or regular sense of difficulty with balance while walking (11). Subjects also were asked whether they had fallen over the past year. A fall was defined as unintentionally coming to rest on the ground or at some other lower level, not as a result of an overwhelming hazard that would result in a fall by most young, healthy persons (12).

Anthropometry.—Height was recorded from a stadiometer (SECA, Berlin, Germany), and body weight was recorded from a balance-beam scale (Health-O-Meter Inc., Bridgeview, IL) without shoes. From these measurements, body mass index (BMI) was calculated as weight (kg)/height (m)². Additionally, girths were obtained with a steel measuring tape at the minimal waist and maximal hip locations to assess the distribution of fat (waist/hip ratio). The median value of three trials was recorded for both girth measurements.

Ankle/brachial index.—Subjects rested supine for 10 minutes, after which ankle and brachial systolic blood pressures were obtained. Ankle systolic pressure was measured with a nondirectional Doppler flow detector (model 810-A; Parks Medical Electronics, Inc., Aloha, OR), a pencil probe (9.3 MHz), and standard-size ankle blood pressure cuffs (10 cm width). Measurements were taken from the posterior tibial and dorsalis pedis arteries in both legs. The higher of the two arterial pressures from the more severely diseased leg was recorded as the resting ankle systolic pressure. Brachial systolic blood pressure was measured from both arms with an automated blood pressure machine (model 1846-SX; Dinamap Vital Signs Monitor, Critikon, Inc., Tampa, FL) using either a standard adult-size blood pressure cuff (14 cm width) or a large adult-size cuff (17 cm width). Brachial systolic pressure was recorded from the arm yielding the higher systolic pressure. From these measures, the ankle/brachial index (ABI) was calculated as ankle systolic pressure/brachial systolic pressure.

Six-minute walk test.—Subjects performed a 6-minute walk test that was timed by trained exercise technicians with the aid of a stopwatch. Two cones were placed 100 feet apart in a marked corridor. Subjects were instructed to walk as many laps around the cones as possible and to inform the technician when the onset of claudication occurred. The technician stood at the center of the 100-foot course and provided encouragement every 2 minutes. Subjects were permitted to stop walking during the test if their claudication became intolerable and to resume walking as soon as they could. The technician recorded the time and distance to onset of claudication as well as the total distance walked during the test. The walking distances were converted from feet to meters.

Walking impairment questionnaire.—Self-reported ambulatory ability was assessed using a validated questionnaire (5). Subjects were asked to evaluate their walking ability at various speeds and distances and their ability to climb stairs. A score ranging from 0 and 100 was used to assess each aspect, with a score of 0 representing inability to perform the task and a score of 100 representing no difficulty.

Daily physical activity.—Physical activity level was monitored over two consecutive days by a Caltrac accelerometer (Muscle Dynamics, Torrance, CA) attached to the belt of each subject and worn slightly anterior to the hip (13). Subjects were instructed to wear the accelerometer during their waking hours and to remove it before going to bed. The accelerometer assessed daily physical movements by recording vertical accelerations of the body and converted these movements into caloric expenditure during the 48-hour monitoring period.

Statistical Analyses

Unpaired t tests and chi-square tests were used to assess whether differences in unipedal balance, fall history, and physiological measurements existed between the PAD and non-PAD groups. Pearson product-moment and Spearman rank correlation coefficients were calculated to assess whether balance and falls were related to the severity of PAD and to functional status within the PAD group. All analyses were performed using the SPSS-PC statistical package (SPSS, Inc, Chicago, IL). Statistical significance was set at \( p < .05 \). Measurements are presented as means ± SEM.

Results

Balance and Falls

Unipedal stance time was 28% shorter \( (p < .001) \) in the PAD subjects than in the non-PAD controls \( (15.9 ± 0.9 \text{ seconds vs } 22.1 ± 1.0 \text{ seconds}) \). History of ambulatory stumbling and unsteadiness was 86% more prevalent \( (p < .001) \) in the PAD group \( (150/367 = 41\%) \) than in the control group \( (101/458 = 22\%) \), and history of falling was 73% more prevalent \( (p < .001) \) in the PAD subjects \( (95/367 = 26\%) \) than in the controls \( (69/458 = 15\%) \) (Figure 1).

Within the PAD group, unipedal stance time was related to history of ambulatory stumbling and unsteadiness \( (r = -.58, p < .001) \) and to history of falling \( (r = -.51, p < .001) \), and history of ambulatory stumbling and unsteadiness was related to history of falling \( (r = .37, p < .001) \).

Clinical Measures

Table 1 shows that all of the clinical measures except for age were significantly different \( (p < .001) \) between the
Table 1. Clinical Characteristics of Peripheral Arterial Disease (PAD) Subjects With Intermittent Claudication and Non-PAD Controls

<table>
<thead>
<tr>
<th>Variable</th>
<th>PAD Group (n = 367)</th>
<th>Non-PAD Group (n = 458)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>68 ± 1</td>
<td>67 ± 1</td>
<td>.134</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>80.4 ± 0.8</td>
<td>86.5 ± 0.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI, weight/height²</td>
<td>27.6 ± 0.2</td>
<td>29.8 ± 0.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Waist/hip ratio</td>
<td>0.93 ± 0.01</td>
<td>0.89 ± 0.01</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ABI</td>
<td>0.61 ± 0.01</td>
<td>1.18 ± 0.01</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>6-Minute walk distance, m</td>
<td>372 ± 5</td>
<td>482 ± 5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>6-Minute walk pain-free</td>
<td>175 ± 6</td>
<td>482 ± 5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>WIQ distance, %</td>
<td>34 ± 2</td>
<td>75 ± 2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>WIQ speed, %</td>
<td>35 ± 1</td>
<td>63 ± 2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>WIQ stairs, %</td>
<td>43 ± 2</td>
<td>66 ± 2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Daily physical activity, kcal/d</td>
<td>355 ± 20</td>
<td>532 ± 14</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Notes: Values are mean ± SEM. BMI = body mass index; ABI = ankle/brachial index; WIQ = walking impairment questionnaire.

PAD and control groups. As expected, the PAD subjects had a 46% lower ABI, a 63% lower pain-free distance, and a 22% lower total distance covered during the 6-minute walk test and had 32% to 52% lower self-reported walking and stairclimbing ability. Additionally, the PAD subjects had a 25% lower daily physical activity, a 7% lower body weight, and a 4% greater WHR than the controls.

The relationships between clinical characteristics and unipedal stance time, history of ambulatory stumbling and unsteadiness, and history of falling within the PAD group are shown in Table 2. The 6-minute walk distance, WIQ speed and stairclimbing scales, and daily physical activity were significantly related to all three of the balance and falls measures (p < .05). The WIQ distance scale was significantly related to unipedal stance time and to history of ambulatory stumbling and unsteadiness (p < .05), whereas weight and BMI were related only to history of ambulatory stumbling and unsteadiness (p < .05). Age was significantly related to unipedal stance time (p < .001) but not to the self-report measures.

**DISCUSSION**

The major findings of this investigation were that (i) PAD patients had 28% shorter unipedal stance time, 86% higher prevalence of ambulatory stumbling and unsteadiness, and 73% higher prevalence of falling than non-PAD controls and (ii) the relative instability of the PAD group was exacerbated in patients with worse ambulatory function and lower physical activity levels.

**Balance and History of Falls**

Impaired balance and higher prevalence of falling in PAD subjects places them at higher risk for serious injury (7), restricted physical activity (7,14,15), higher cost and more frequent hospitalizations for fall-related injuries (16), higher nursing home admissions (17), and greater mortality (14). The additional health burden of these fall-related events is particularly alarming given that PAD subjects with intermittent claudication already have higher cardiovascular morbidity and mortality than age-matched controls (18).

Thus, impaired peripheral circulation and intermittent claudication may trigger a spiraling decline of physical function and loss of functional independence.

It is interesting to note that the PAD subjects in the present study had stability profiles that resembled, albeit to a lesser degree, the stability measures of subjects with overt peripheral neuropathy (PN) (11). The PN subjects had a 67% shorter unipedal stance time than age-matched controls (11), whereas PAD subjects in the present study had a 28% shorter unipedal stance time than controls. Furthermore, 55% of the PN subjects had reported a fall, and 77% of those who had not fallen reported that they frequently stumbled or felt unsteady (11). Although prevalence of falling and stumbling were lower in the current group of PAD sub-

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Table 2. Correlation Coefficients Between Clinical Characteristics and Unipedal Stance Time, History of Ambulatory Stumbling and Unsteadiness, and History of Falling in 367 Peripheral Arterial Disease Subjects With Intermittent Claudication

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation With Unipedal Stance Time</th>
<th>Correlation With Stumbling and Unsteadiness</th>
<th>Correlation With Falling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>−0.35***</td>
<td>0.03</td>
<td>0.00</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>−0.02</td>
<td>−0.13*</td>
<td>−0.05</td>
</tr>
<tr>
<td>BMI, weight/height²</td>
<td>−0.10</td>
<td>−0.12*</td>
<td>−0.01</td>
</tr>
<tr>
<td>Waist/hip ratio</td>
<td>−0.02</td>
<td>−0.03</td>
<td>−0.01</td>
</tr>
<tr>
<td>ABI</td>
<td>0.05</td>
<td>−0.06</td>
<td>−0.01</td>
</tr>
<tr>
<td>6-Minute walk distance, m</td>
<td>0.28***</td>
<td>−0.24***</td>
<td>−0.20***</td>
</tr>
<tr>
<td>6-Minute walk pain-free</td>
<td>0.10</td>
<td>−0.07</td>
<td>−0.05</td>
</tr>
<tr>
<td>WIQ distance, %</td>
<td>0.12*</td>
<td>−0.18***</td>
<td>−0.08</td>
</tr>
<tr>
<td>WIQ speed, %</td>
<td>0.14***</td>
<td>−0.25***</td>
<td>−0.17***</td>
</tr>
<tr>
<td>WIQ stairs, %</td>
<td>0.19**</td>
<td>−0.17***</td>
<td>−0.12*</td>
</tr>
<tr>
<td>Daily physical activity, kcal/d</td>
<td>0.26***</td>
<td>−0.26***</td>
<td>−0.16**</td>
</tr>
</tbody>
</table>

Notes: BMI = body mass index; ABI = ankle/brachial index; WIQ = walking impairment questionnaire.

*p < .05; **p < .01; ***p < .001.
jects (26% and 41%, respectively) than in the PN subjects, progression of PAD to intermittent claudication appears to lead to the development of instability. It is possible that sensory and motor nerve dysfunction of the lower extremities in PAD subjects (8), secondary to impaired peripheral circulation, is a potential mechanism for their impaired balance and greater falling prevalence.

Correlates of Balance and Falls

Ambulatory dysfunction was related to the impairment in balance and fall measures in the PAD subjects with intermittent claudication. This finding is in agreement with other studies that found that gait impairments are related to poorer balance in healthy elderly subjects (19,20). In the present study, the relationship between ambulatory dysfunction with balance and falls was particularly robust within the PAD population. Ambulatory function, measured directly during a 6-minute walk test and by self-report with the WIQ, significantly correlated with both measured and self-reported measures of balance and the self-reported measure of falling history over the past year. Consequently, PAD subjects who have the most severe intermittent claudication are the most susceptible to experience balance problems and are the most likely to fall and suffer health complications due to fall-related injuries.

Low levels of physical activity also were related to balance and fall measures in PAD subjects. This finding is in agreement with other studies that found that baseline levels of physical activity were associated with balance performance in healthy elderly men and women (21) and that a 3-month, low-intensity exercise program improves balance by 81% in elderly women (22). The results from the present study suggest that PAD patients with the lowest physical activity levels are at the greatest risk of impaired balance and falls. Because both ambulatory function and physical activity are associated with instability in PAD subjects with intermittent claudication, it is possible that a program of exercise rehabilitation can ameliorate their instability as well as improve their claudication pain (23).

It is interesting to note that within the PAD group, age was correlated with the objective measure of balance (unipedal stance time) but not with the subjective measures of self-reported stumbling and falling. The decrease in balance with age is supported by previous investigations (19,24). The lack of association between the objective measure of balance with the subjective measures of balance and falling may occur from under-reporting due to poor recall by the oldest subjects (25).

Summary and Conclusion

The primary findings of this investigation were that (i) PAD patients had 28% shorter unipedal stance time, 86% higher prevalence of ambulatory stumbling and unsteadiness, and 73% higher prevalence of falling than non-PAD controls and (ii) the relative instability of the PAD group was exacerbated in patients with worse ambulatory function and lower physical activity levels. Compared with the controls, PAD patients with intermittent claudication had impaired balance and a greater likelihood of falling, both of which were associated with ambulatory function and daily physical activity. Consequently, patients with intermittent claudication who have poor balance and a history of falls may be prime candidates to improve these outcomes through a program of exercise rehabilitation provided that they can safely ambulate on a treadmill or in the community.

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