Associations of Body Composition and Physical Activity with Balance and Walking Ability in the Elderly

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Background: The epidemic of sedentary lifestyle and obesity increases the risk of disability with aging. We studied the relationships of body composition, physical activity, and muscular fitness with balance and walking ability. Methods: Men and women, age 70 to 74 y (n = 146), were randomly selected from the Finnish population register. Body composition [body weight, body-mass index (BMI), waist circumference], physical activity (questionnaire), muscular fitness (hand-grip strength), balance (commonly used field tests), and walking ability (20 m walking test) were assessed. Results: BMI (r = –0.287, P < 0.001), waist circumference (r = –0.260, P = 0.002), physical activity (r = 0.206, P = 0.013), and hand-grip strength (r = 0.244, P = 0.003) correlated with balance. BMI (r = 0.330, P < 0.001), waist circumference (r = 0.237, P = 0.004), physical activity (r = –0.252, P = 0.002), and hand-grip strength (r = –0.307, P < 0.001) also correlated with walking time. Conclusions: Overweight and central obesity as well as low muscular fitness associate with impaired balance and walking ability in the elderly.

Key Words: aging, disability, fitness, physical functional capacity

The increasing number of elderly men and women with impaired functional capacity is becoming a major challenge for health care systems in Western societies. Functional status is an important indicator of health in old age and a powerful predictor of mortality.1,2 Muscle strength, balance, and walking ability are key components of functional ability in the elderly.

The declines in muscle mass (sarcopenia) and muscle strength significantly impair functional capacity and gradually restrict the ability to carry out daily tasks. Poor hand-grip strength, an indicator of overall muscle strength, predicts future disability independent of chronic disease development.3,4 Weakness in the muscle strength of lower extremities5,6 and impaired balance6 predict falls, and walking speed, a good indicator of mobility, predicts future dependence.7 In the elderly, the
Risk of losing balance increases during walking, especially in situations demanding a sudden and unexpected reaction.\(^8,\)\(^9\) Among those with impaired balance, good muscle strength decreases the risk of future walking limitations.\(^10\)

The epidemic of sedentary lifestyle, overweight, and obesity is increasing the risk of chronic diseases and disability with aging in developed countries.\(^11\) Significant changes in body composition are known to occur with aging: fat replaces fat-free mass and redistribution of fat causes an increase in the proportion of abdominal fat.\(^12\) Physical inactivity has been shown to be associated with visceral adipose tissue accumulation.\(^13\) Optimally focused physical activity in the elderly produces many health benefits, e.g., greater muscle strength, improved balance and walking ability,\(^14\)\(^-\)\(^17\) and prevention of falls.\(^18\)\(^,\)\(^19\) The limits of stability vary according to the individual’s biomechanics, e.g., body morphology and configuration.\(^20\)\(^-\)\(^22\) Decline in balance and gait were more likely among old men and women with higher body-mass index (BMI) in a 3-y follow-up study.\(^23\) Individuals who are overweight and obese, particularly those with abdominal obesity, might be at a higher risk of falling than individuals with normal body weight, whose body mass is more centralized.\(^24\)\(^,\)\(^25\)

Although there are many reports of gerontological research on healthy aging and independence, few data are available on the associations of body composition, physical activity, and fitness with balance and walking ability in the elderly. The connection between body composition and balance has been studied in young boys\(^26\) and in premenopausal women.\(^24\) The topic, however, is especially important in the elderly, as they continue to represent one of the fastest growing segments of the population. More than one-third of persons over age 65 y fall each year, resulting in serious injury in approximately 10%.\(^27\) We studied the hypothesis that body composition, especially central obesity, and physical activity associates with balance and walking ability in elderly men and women.

Subjects

The subjects were men and women age 70 to 74 y who were randomly selected from the Finnish population register, living in the city of Kuopio. Of the 360 randomly selected individuals, 247 were invited from four out of five randomized residential areas, and 79 men and 67 women were willing to participate. The inclusion criteria were individuals who lived at home and were able to cooperate and move independently. To investigate the associations of interest in a general elderly population, we did not exclude individuals with diseases. Exclusionary criteria included severe disease, disability, unwillingness to participate, inability to contact, and participation in another study. Level of education varied from 3 to 28 y in men and from 2 to 18 y in women. All examinations were performed in the Kuopio Research Institute of Exercise Medicine. Each subject gave written informed consent to participate in the study. The study protocol was approved by the Ethics Committee of the University of Kuopio.

Methods

Using a questionnaire, subjects were asked to report diagnosed diseases, medication, marital status, education, and smoking habits. Physical functional capacity
(balance, walking ability, hand-grip strength) and anthropometric variables were measured indoors by 2 examiners using the same protocol for all subjects. The same examiner always performed the same part of the test battery.

**Balance**

Common\(^{16,28,29}\) and reliable\(^{30}\) field tests of functional capacity were used. The balance tests were performed with the subjects standing barefoot with hands on waist in the following 4 positions: 1) standing feet side-by-side; 2) in a tandem position (heel of 1 foot directly in front of the other); 3) on the right foot; and 4) on the left foot. These tests in each of the positions were repeated with eyes open and eyes closed. One practice was allowed for each test. The times achieved in each of the 8 tasks (maximum of 60 s) were recorded using a stopwatch and were summed to calculate a balance score (maximum of 480 s). The balance score (in seconds) was used in the statistical analyses. These tests were selected to represent static balance reflecting increasing challenges to the excursion of the center of mass over different base of support configurations.

**Walking Ability**

Walking speed has been found to be a good indicator of mobility in older people.\(^{31}\) The subjects were asked to walk as fast as they could 10 m in 1 direction, and after crossing a tape line on the floor, to turn and walk back the same distance to the starting point. The time (in seconds) was recorded using a stopwatch, and the recorded time was used in the statistical analyses. The number of steps were also calculated and used in the statistical analyses.

**Hand-Grip Strength**

Hand-grip strength measurement is a valid, practical clinical method describing overall muscle strength.\(^4\) Maximal isometric hand-grip strength (in kilograms) was measured 3 times for dominant and nondominant hands with a Jamar hand dynamometer (Medfit, Helsinki, Finland). The mean of the two best values of the dominant hand-grip strength was used in the analyses to indicate overall muscle strength. The subject sat in a straight-backed chair beside a table with the elbow in 90° flexion position, the forearm in neutral position holding the hand-held dynamometer on the table. The handle width of the dynamometer ranged from one to five and a width of three was used for men and two for women. The intraclass correlation coefficient between repeated hand-grip measurements from 20 subjects was 0.994 (95% CI 0.984 to 0.998), and coefficient of variation 4.7%.

**Physical Activity**

Assessment of physical activity using a 7-d recall interview has been explained previously in detail.\(^{32}\) Subjects were asked to estimate the average time they had slept (1 metabolic equivalent, MET) and the number of hours they participated in very mild (1.5 MET), light (4 MET), moderate (6 MET), and heavy (10 MET) physical activity during the previous 7 d. One MET is defined as the energy expenditure at rest, corresponding to an oxygen uptake of 3.5 mL/kg. An average daily
activity index was determined by multiplying MET values by the hours spent on each activity category. Basal metabolic rate (MJ/d) was calculated using the equation \((0.0565 \times \text{weight in kg}) + 2.04\) in men and \((0.0439 \times \text{weight in kg}) + 2.49\) in women. Daily energy expenditure was estimated by multiplying basal metabolic rate by the daily physical activity index.

**Anthropometric Measurements**

Body height was measured using a metal-scaled height meter (accuracy: 0.1 cm). Body weight was measured with a digital scale in light indoor clothing without shoes (accuracy: 0.1 kg). BMI was computed by dividing body weight (kg) by body height squared \((\text{m}^2)\). Waist circumference was measured from the bare skin mid-distance between the bottom of the rib cage and the top of the iliac crest. Hip circumference was measured at the level of the trochanter majors. The mean values of the 3 measurements of waist and hip circumferences were used in the analyses. Waist-to-hip ratio was calculated as the ratio of the circumferences of the waist to the hip. The intraclass correlation coefficient between repeated waist and hip circumference measurements from 20 subjects was 0.999 (95% CI 0.998 to 1.000) and 0.996 (95% CI 0.989 to 0.998); coefficients of variation were 0.6% and 0.8%, respectively.

**Statistical Methods**

The results are expressed as means, standard deviations, and percentages. Associations among balance, walking ability, hand-grip strength, physical activity, and body composition were analyzed by using Pearson’s correlation coefficients. Spearman’s correlation coefficients were used for skewed variables (exercise energy expenditure, walking time, and number of steps in the entire group, exercise energy expenditure in men and women and number of steps in women). Comparison of correlations between men and women was performed with \(z\)-transformed correlation coefficient.\(^{33}\) Comparison of means between men and women was performed with Student’s \(t\)-test and the Mann-Whitney test. Because of multicollinearity of body composition variables, they were included univariately in linear regression analyses to explain functional capacity adjusted for physical activity, hand-grip strength, and age. The level for statistical significance was \(P < 0.05\). All statistical analyses were performed using SPSS for Windows, Release 10.0 (SPSS, Inc., Chicago, IL).

**Results**

The characteristics of the subjects are presented in Table 1. Body-mass index was \(\geq 25\) kg/m\(^2\) in 71% of the men and in 73% of the women, and \(\geq 30\) kg/m\(^2\) in 23% of the men and in 36% of the women. The measures of physical functional capacity are shown in Table 2. Men had better balance and hand-grip strength and they walked 20 m more quickly and took fewer steps when doing so than women.

Correlations of body composition and physical activity with measures of functional capacity are shown in Table 3. There was an inverse correlation of BMI and waist circumference with balance whereas hand-grip strength and physical activity correlated directly with balance. BMI and waist circumference correlated directly with 20 m walking time whereas hand-grip strength and physical activity...
Table 1  Characteristics of the Subjects and Differences Between Men and Women

<table>
<thead>
<tr>
<th>Variable</th>
<th>All  $(n = 146)$</th>
<th>Men  $(n = 79)$</th>
<th>Women $(n = 67)$</th>
<th>$P$-value for difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>72.1 ± 1.3</td>
<td>72.0 ± 1.2</td>
<td>72.3 ± 1.3</td>
<td>ns</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.6 ± 9.5</td>
<td>171.5 ± 6.1</td>
<td>156.3 ± 5.3</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.8 ± 13.8</td>
<td>79.7 ± 11.2</td>
<td>71.2 ± 15.2</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Body-mass index (kg/m$^2$)</td>
<td>28.0 ± 4.7</td>
<td>27.0 ± 3.2</td>
<td>29.1 ± 5.8</td>
<td>0.012</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>95.0 ± 11.6</td>
<td>97.5 ± 9.5</td>
<td>91.9 ± 13.2</td>
<td>0.003</td>
</tr>
<tr>
<td>Hip circumference (cm)</td>
<td>101.9 ± 9.8</td>
<td>99.4 ± 6.0</td>
<td>104.8 ± 12.4</td>
<td>0.002</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.93 ± 0.08</td>
<td>0.98 ± 0.06</td>
<td>0.88 ± 0.06</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Diabetes (%)</td>
<td>5.5</td>
<td>6.3</td>
<td>4.5</td>
<td>ns</td>
</tr>
<tr>
<td>Cardiovascular diseases (%)</td>
<td>30.1</td>
<td>34.2</td>
<td>25.4</td>
<td>ns</td>
</tr>
<tr>
<td>Musculoskeletal diseases (%)</td>
<td>53.4</td>
<td>44.3</td>
<td>64.2</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Note. Values are means ± standard deviation. The level for statistical significance was $P < 0.05$.

Table 2  Parameters of Functional Capacity and Differences Between Men and Women

<table>
<thead>
<tr>
<th>Variable</th>
<th>All  $(n = 146)$</th>
<th>Men  $(n = 79)$</th>
<th>Women $(n = 67)$</th>
<th>$P$-value for difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance score (s)</td>
<td>219.5 ± 66.4</td>
<td>230.6 ± 69.0</td>
<td>206.5 ± 61.3</td>
<td>0.029</td>
</tr>
<tr>
<td>Hand-grip strength (kg)</td>
<td>33.1 ± 11.3</td>
<td>41.3 ± 8.0</td>
<td>23.5 ± 5.5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Walking 20 m (s)</td>
<td>17.0 ± 5.0</td>
<td>15.8 ± 3.5</td>
<td>18.4 ± 6.1</td>
<td>0.003</td>
</tr>
<tr>
<td>Number of steps</td>
<td>30.9 ± 5.7</td>
<td>28.0 ± 3.9</td>
<td>34.4 ± 5.6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Exercise energy expenditure (MJ/wk)</td>
<td>3.3 ± 3.2</td>
<td>3.7 ± 3.3</td>
<td>2.9 ± 3.1</td>
<td>ns</td>
</tr>
</tbody>
</table>

Note. Values are means ± standard deviation. The level for statistical significance was $P < 0.05$.

Table 3  Correlations of Selected Study Variables in All Subjects

<table>
<thead>
<tr>
<th></th>
<th>Walking</th>
<th>Steps</th>
<th>Grip</th>
<th>BMI</th>
<th>Waist</th>
<th>Exerc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance</td>
<td>-0.437c</td>
<td>-0.371c</td>
<td>0.244b</td>
<td>-0.287c</td>
<td>-0.260b</td>
<td>0.206c</td>
</tr>
<tr>
<td>Walking</td>
<td>0.783c</td>
<td>-0.307c</td>
<td>0.330c</td>
<td>0.237b</td>
<td>-0.252b</td>
<td></td>
</tr>
<tr>
<td>Steps</td>
<td>-0.609c</td>
<td>0.313c</td>
<td>0.062</td>
<td>-0.137</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grip</td>
<td>-0.081</td>
<td>0.277b</td>
<td>0.793c</td>
<td>-0.204a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.171a</td>
</tr>
</tbody>
</table>

Note. Balance, summed balance score; Walking, 20 m walking time; Steps, number of steps on 20 m walk; Grip, dominant hand-grip strength; BMI, body-mass index; Waist, waist circumference; Exerc, exercise (MET h/wk). *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. 
correlated inversely with 20 m walking time and number of steps taken. The correlations between men and women did not differ significantly (data not shown). In women with BMI > 27 kg/m$^2$, balance was significantly worse in those with hand-grip strength < 24 kg compared to those with hand-grip strength > 24 kg ($P = 0.010$).

In the univariate linear regression analyses in men, waist circumference explained 15% ($P = 0.001$), body weight 15% ($P = 0.001$), and BMI 8% ($P = 0.018$) of the variance in balance. Waist circumference explained 21% ($P = 0.001$), body weight 18% ($P = 0.003$), and BMI 23% ($P < 0.001$) of the variance in 20 m walking time. In women, waist circumference explained 19% ($P = 0.052$), body weight 19% ($P = 0.040$), and BMI 19% ($P = 0.045$) of the variance in balance. Waist circumference explained 25% ($P < 0.001$), body weight 26% ($P < 0.001$), and BMI 26% ($P < 0.001$) of the variance in 20 m walking time.

**Discussion**

The main findings of the present study are that overweight and central obesity as well as muscular fitness are associated with impaired balance and walking ability in the elderly. In the women, muscle strength was a stronger determinant of balance than overweight. Consistent with previous studies,$^4$ our results emphasize the importance of maintenance of muscle strength to prevent disability and chronic conditions in old age.

There are few data on the association between body composition and balance.$^{24, 26}$ In the present study, the balance score included static balance tasks, whereas walking represents a dynamic task. Measures of body fatness were inversely associated with balance and walking ability in both genders, which is consistent with previous findings.$^{24, 26}$ It has been reported that overweight and obese individuals, whose body mass is more centralized, might be at a higher risk of falling.$^{24, 25}$ We could not find that abdominal obesity, measured as waist circumference, was a stronger determinant of balance or walking ability than body weight or BMI. During loss of balance, the greater mass of obese individuals demands more muscle force to re-balance the posture. In the present study, women had a greater amount of adipose tissue and poorer balance and walking ability compared with men, indicating that women could be at a higher risk of future functional limitations and disability, as observed previously.$^{28}$ Good muscle strength is necessary for balance and is a predictor of functional limitations and disability in older adults.$^{3, 4, 34}$ In the present study, those with greater hand-grip strength performed better in the balance and walking tests.

One strength of the present study is the use of a randomly selected population-based sample of men and women age 70 to 74 y. Physically active and fit individuals are most likely to participate in scientific studies, however, and only individuals who could move independently were included in the present study. These sources of selection limit generalizability of the findings to elderly populations. Another strength of the study was the use of eight commonly used balance tasks to obtain a wide-ranging estimate of static balance.$^{16, 28-30}$ The major advantage of this approach is that these balance tasks can be measured easily and safely in both clinical and research settings. Furthermore, the tests can be performed without expensive equipment, although some inaccuracy might result from manual timekeeping. Because
of the cross-sectional study design, it was not possible to investigate the temporal order and causal relationships of body composition, physical activity, and fitness with a decline in functional capacity.

Our findings emphasize the importance of muscular fitness and weight management in prevention of aging-related reduction in functional capacity. Randomized controlled trials are needed, however, to test the efficacy of exercise training and weight reduction in improving physical functional capacity in the elderly.

Acknowledgments

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References


