Older Women With Osteoporosis Have Increased Postural Sway and Weaker Quadriceps Strength Than Counterparts With Normal Bone Mass: Overlooked Determinants of Fracture Risk?

Teresa Liu-Ambrose, Janice J. Eng, Karim M. Khan, Nick D. Carter, and Heather A. McKay

School of Human Kinetics, School of Rehabilitation Sciences, Department of Family Practice, and Department of Orthopaedics, University of British Columbia, Vancouver, Canada. Rehabilitation Research Laboratory, G. F. Strong Rehabilitation Center, Vancouver, British Columbia, Canada.

Background. Fracture risk is determined by both bone health and fall risk. Evidence suggests that older women with osteoporosis may have a greater risk of falling compared with their age-matched counterparts without osteoporosis (1). To determine whether fall risk screening should be a routine part of medical assessment in older women with osteoporosis, a comparison of fall risk between those with osteoporosis and healthy age-matched counterparts is needed. The purpose of this study was to compare 3 established fall risk factors between these 2 groups of women.

Methods. 42 women between the ages of 64 and 75 years old participated in this study. 21 women with osteoporosis were matched by age and current physical activity level to 21 women without osteoporosis. The performance on 3 fall risk factors (quadriceps strength, balance, and functional mobility) was compared between the 2 groups using multivariate analysis of variance. The level of significance was set at $p \leq 0.05$.

Results. There was an overall difference between the 2 groups on the fall risk factors (Wilk’s lambda = 0.769, $p = 0.018$). Dominant quadriceps strength and composite balance score were, respectively, 18% significantly less and 11% worse in women with osteoporosis than those without. Functional mobility was not significantly different between the 2 groups.

Conclusions. This study highlights older women with osteoporosis as a high fracture risk group due to having both lower bone density, and possibly, higher fall risk compared with their age-matched counterparts without osteoporosis. Both fall risk screening and fall risk reduction may be prudent to prevent fractures in women with osteoporosis.
All participants of the study were identified from a computerized database of women who had been referred for bone densitometry at the British Columbia Women’s Hospital and Health Centre’s Osteoporosis Program between 1996 and 2000. All potential participants were screened to ensure the study’s entry criteria were met. These were that the participant: (a) was at least 5 years postmenopausal; (b) weighed less than 130% of ideal body mass; (c) had no neurological conditions affecting balance, such as stroke or Parkinson’s disease; (d) had no lower limb joint replacement; (e) was community dwelling; and (f) ambulated independently.

In the 21 women who formed the experimental group, osteoporosis was confirmed by dual-energy X-ray absorptiometry (DXA) (Lunar Corp, Madison, WI) at the total hip and/or lumbar spine using the World Health Organization definition (bone mineral density [BMD] t score was at least 2.5 SD below young normal sex-matched BMD of the Lunar reference database) (12). These 21 older women were selected, based on their age and physical activity level equivalency to the control group, for this cross-sectional study from a cohort of 97 women with osteoporosis that were screened. Of the 97 women screened, 4 were excluded from being selected for this cross-sectional analysis due to the presence of a neurological condition (e.g., stroke, Parkinson’s disease). Twenty-one age-matched and physical activity level-matched women without osteoporosis were recruited separately to form the control group. The absence of osteoporosis at the total hip and lumbar spine was again confirmed by DXA (BMD t score was greater than 1.0 SD below young normal sex-matched BMD of the lunar reference database).

Descriptive Variables
We measured age in years, height (both standing and sitting) in centimeters, and mass in kilograms in all participants and calculated body mass index (BMI, kg/m²). Trained interviewers also ascertained the number of currently prescribed medications and the number of falls in the past 4 weeks. As well, the presence of osteoarthritis was confirmed by health history (interviewer-based questionnaire) and physician examination (coauthors K.M.K. and N.D.C.). The current physical activity level of each participant, in hours per week, was ascertained with a 7-day physical activity recall questionnaire (13) that categorizes intensity of activity as either moderate, hard, or very hard. The majority of participants reported physical activity only at the moderate intensity. Thus, the experimental and the control groups were matched at this intensity of physical activity. Examples of moderate intensity of physical activity include household activities such as raking the lawn, sweeping and mopping, cleaning windows, and sport activities such as brisk walking and golf (13).

Fall Risk Factors
Quadriceps strength of the dominant leg was assessed using a strap assembly incorporating a strain gauge according to the method of Lord and colleagues (14). Dominance was assessed based on asking participants with which leg they would kick a ball. In 3 experimental trials, the participants pulled against the strap assembly with maximal force and the greatest force was recorded to 0.5 kilograms. To account for size of an individual, the result was then normalized by height (m). The test-retest reliability (Pearson r) of this strength measurement is reported as 0.92 (15) and was also determined as 0.92 (Pearson r) in our laboratory for an age-matched population of 8 subjects.

Balance was assessed using the Equitest computerized dynamic posturography platform (Neurocom International, Clackamas, OR). The sensory organization test (SOT) consisted of 3 consecutive, 20-second trials of 6 combinations of visual and support surface conditions. Each participant underwent 2 sequence trials within 1 test session to overcome learning effects. The composite balance score (average of all 6 conditions) of the second trial was used as an indicator of postural balance. The composite balance score has been shown to differentiate between older nonfallers and fallers (16). In our pilot study of 10 older women between the ages of 65–75 years old, the test-retest reliability (between days) of the composite score was superior to the test-retest reliability of the individual test conditions. The intraclass correlation coefficient of the composite balance score was 0.91 (confidence interval [CI] 0.64–0.98).

Functional mobility was tested by a figure-of-eight test that involved 2 cones placed 10 meters apart (17). A handheld stopwatch measured the time it took to transverse 2 laps of the course as fast as possible. The best attempt of 2 trials was recorded. To account for the size of an individual, the result was converted to speed (m/s) and then normalized to leg length (m). This test has been shown to correlate with stair-climbing capacity and gait speed (18).

Statistical Analysis
Data were analyzed using SPSS (Windows Version 10.0; SPSS, Inc., Chicago, IL). Descriptive data are reported for variables of interest (mean, SD, and 95% CI). To minimize the overall probability of type I error, the overall significance level between groups in descriptive characteristics (age, height, mass, BMI, number of medications used, and level of current physical activity) of the participants and fall risk factors (dominant quadriceps strength, composite balance score, and functional mobility) was established using 2 separate multivariate analyses of variance (MANOVA). Between-group differences on individual variables of interest were then analyzed by analysis of variance (ANOVA). The level of significance was set at p ≤ 0.05.

RESULTS
Characteristics of the Participants
Table 1 provides descriptive data and the results of the ANOVA comparing the characteristics of the 2 groups of women. All participants ambulated independently and were community dwellers. The majority of the women were Caucasian (88%). There were 4 Asian women in the experimental group and 1 Asian woman in the control group.

Although the groups were not different overall (MANOVA, Wilk’s lambda = 0.852, p = .433), the control group had a trend toward greater body mass (p = .057). There were no differences between groups in age, height, BMI, the
The number of current medications used, and the level of current physical activity. Nine women in each group (43%) had osteoarthritis. One participant in the control group had fallen once in the previous 4 weeks.

**Fall Risk Factors**

Table 2 provides descriptive data and the results of the ANOVA comparing the 3 fall risk factors. There was an overall difference between the 2 groups on the fall risk factors (MANOVA, Wilk’s lambda = 0.769, p = .018). Dominant quadriceps strength and composite balance score were, respectively, 18% significantly less and 11% worse in women with osteoporosis than those without. However, functional mobility was not significantly different between the 2 groups.

**DISCUSSION**

Effective fracture risk reduction in older people requires augmenting bone health and reducing fall risk. We found that both quadriceps strength and balance, both established fall risk factors, were both significantly less and worse in women with osteoporosis than in women without. These differences were present despite both groups being matched by age and level of current physical activity. Our findings provide novel evidence that women with osteoporosis may be at increased fracture risk compared with age-matched counterparts not just because of lower BMD but because of increased fall risk as well. In their large prospective study of fracture incidence in 1789 men and women, Nguyen and colleagues (11) found that, next to femoral neck BMD, quadriceps strength and postural balance were the best independent predictors of fracture.

Possible reasons for the observed differences in strength and balance between these 2 groups of older women are:

- Individuals with spinal osteoporosis tend to develop kyphosis over time (19). A kyphotic posture may displace the center of gravity (COG) closer to the limits of stability (1). A displacement of the COG closer to the limits of stability will require greater efforts to maintain balance even with small perturbations, such as using a hip strategy instead of an ankle strategy. Compared to an ankle strategy, a hip strategy creates greater amplitudes of sway (20) and thus lower composite balance scores.

- Individuals with osteoporosis, with or without kyphosis, may generally prefer using a hip strategy to maintain balance even when an ankle strategy would be more appropriate (1). The reasons for this require further investigation. It has been suggested by Lynn and colleagues (1) that the fall risk of an individual may increase if a hip strategy is used in lieu of an appropriate ankle strategy.

- Fear of falling and fracture are common among those with osteoporosis (7) and this may result in a self-imposed reduction in physical activities. Decreased muscle strength and impaired balance are common consequences of chronic physical inactivity (21,22). This appears to be a less likely explanation for our findings, however, as both groups were matched by current physical activity level. Nevertheless, existing physical activity measures are imperfect (23,24) and our instrument may have been insensitive to detect current differences or significant biological differences secondary to past physical activity levels.

- One of the risk factors associated with osteoporosis is general frailty (25). Thus, the experimental group (women with osteoporosis) may have been frailler than the control group (women without osteoporosis) despite that there were no differences in the number of participants with arthritis, fall history, and the number of medications being taken. It must be noted that a standardized definition has yet to be established for frailty and we did not attempt to assess it in a comprehensive manner. Frailty appears to be a multidimensional construct that includes genetics, lifestyle, and socioeconomic influences on function, as well as the influence of medical conditions (8,26). The concept of fraility is different from the concept of “fear of falling,” as the former suggests that individuals are unable to partake in regular physical activity while the latter implies a choice not to, for fear of consequences. Future studies extending this work should attempt to measure fraility in detail.

- Low body mass is correlated with poorer balance in older women (9). There was a 7.2-kilogram difference in mean body mass between the 2 groups. Thus, the control group may have better balance secondary to their greater body mass. As low body mass is also a risk factor for osteoporosis (19), it is plausible that the association between low body mass and fracture risk (27) could be related to both increased fall risk and low bone mass.

Our finding of decreased balance in women with osteoporosis extends the findings of Lyles and colleagues (28) who found that older women with osteoporotic vertebral
compression fractures had reduced functional reach, an indirect measure of balance, compared with age- and race-matched controls who had no vertebral compression fractures. They also found that physical activity levels were comparable between the 2 groups.

The lack of difference observed in functional mobility may be secondary to the relative insensitivity of the figure-of-eight test in detecting true differences between the 2 groups. Compared to the SOT task protocol, which progressively challenged an individual in a systematic manner, the figure-of-eight test protocol was less standardized, as participants were allowed to either walk or run the course. Thus, true differences in functional mobility may have existed between the 2 groups, but was not detected due to the lack of test protocol standardization.

Conclusion

The results of this cross-sectional study highlight that older women with osteoporosis may constitute a particularly high fracture-risk group as they have both lower bone density and, possibly, higher fall risk compared with their age-matched healthy counterparts. Thus, both fall risk screening and fall risk reduction may be prudent to prevent fractures in women with osteoporosis. Exercise, in contrast to traditional pharmaceutical and nutrition interventions to optimize bone in older people, confers the benefit of influencing multiple fall risk factors at once. Exercise has been shown to improve muscle strength and balance in healthy older people (29) and in women with osteoporosis (17).

Limitations

A key limitation of this study is that participants were matched on self-reported level of retrospective physical activity. Although self-report measures of retrospective physical activity are commonly used in research studies, they are unlikely to be as accurate as direct, objective, and prospective measures of physical activity. As differences in current physical activity level may be the key basis for the observed differences in strength and balance between the 2 groups, it is important that future studies determine physical activity in an objective and prospective manner. Also, future studies investigating fall risk in individuals with osteoporosis could use more-detailed outcome measures. For example, we recommend determining and comparing overall fall risk scores (Physiological Profile Assessment [PPA]; Prince of Wales Medical Research Institute, Randwick, Sydney, NSW, Australia) (30) instead of individual physiological fall risk factors. This approach would provide stronger evidence that women with osteoporosis have a higher risk of falling compared with those without osteoporosis, as the PPA risk score predicts those at risk of falling with 75% accuracy in both community and institutional settings (14,15,31). This study did not ascertain variables, such as the degree of kyphosis, balance confidence, and fear of falling, that would have helped to explain our findings. It should be noted, however, that the primary purpose of this study was hypothesis generating, and we have shown that there are differences in the performance of fall risk factors between sample populations of women with osteoporosis and those without. Thus, we recommend that future studies further delineate the mechanisms underpinning increased fall risk in those with osteoporosis. A clinical corollary of our study is that physicians treating women with osteoporosis should consider fall risk screening and, if appropriate, referrals to fall risk reduction programs.

Acknowledgments

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UBC Bone Health Research Group: BC Women’s Hospital and Health Centre Osteoporosis Program and Faculty of Medicine, University of British Columbia, Vancouver, Canada.

Address correspondence to Dr. Janice J. Eng, School of Rehabilitation Sciences, University of British Columbia, T325-2211 Wesbrook Mall, Vancouver, BC V6T 2B5. E-mail: janiee@interchange.ubc.ca

References


Table 2. Descriptive Statistics and ANOVA Results for Physiological Fall Risk Factors (n = 42)

<table>
<thead>
<tr>
<th></th>
<th>Osteoporosis Group (n = 21)</th>
<th>Normal Group (n = 21)</th>
<th>Difference Between Osteoporosis and Normal Group (n = 21)</th>
<th>ANOVA p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoporosis Group</td>
<td>14.6 (4.4); 7.0–23.0</td>
<td>17.8 (4.5); 7.7–26.5</td>
<td>3.2 (7.6); −0.3–6.6</td>
<td>.027</td>
</tr>
<tr>
<td>Normal Group</td>
<td>70.9 (13.6); 29–87</td>
<td>79.4 (4.3); 69–88</td>
<td>8.5 (14.2); 2.0–15.0</td>
<td>.009</td>
</tr>
<tr>
<td>Functional mobility</td>
<td>2.34 (0.47); 1.56–3.21</td>
<td>2.41 (0.41); 1.80–3.46</td>
<td>0.06 (0.56); −0.19–0.32</td>
<td>.648</td>
</tr>
</tbody>
</table>

Note: Adjusted dominant quadriceps strength (kg/m²); balance (composite score out of 100 points), functional mobility (normalized figure-of-eight speed in m/s). SD = standard deviation; CI = confidence interval; ANOVA = analysis of variance.

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