Walking and Leisure-Time Activity and Risk of Hip Fracture in Postmenopausal Women

Diane Feskanich, ScD
Walter Willett, MD, DrPH
Graham Colditz, MD, DrPH

Despite varying populations and diversity in methods of assessing physical activity, evidence from epidemiological studies suggests that the risk of hip fracture can be reduced by 20% to 50% for active compared with sedentary adults.\(^1\)\(^2\) Most hip fractures result from a fall,\(^3\) and several clinical trials have demonstrated that regular activity can reduce fall occurrence\(^4\)\(^-\)\(^6\) through improvements in muscle strength\(^7\)\(^-\)\(^11\) and balance.\(^12\)\(^-\)\(^14\) Physical activity can also reduce fracture risk by increasing the mechanical load on bone, which promotes remodeling. Clinical trials have demonstrated that femoral bone density can be increased with weight-bearing exercise or resistance training.\(^15\)\(^-\)\(^17\)

Although physical activity has definite benefits for bone health, its relative contributions to fracture reduction by type, frequency, intensity, and duration of activity have been difficult to define. In this analysis, we examined associations between exercise and leisure-time activities and the risk of hip fracture among postmenopausal women in the Nurses’ Health Study, considering type, intensity, and duration of activity. We also assessed the concurrent influences of body mass index, postmenopausal hormone use, smoking, and diet.

METHODS

The Nurses’ Health Study is an ongoing cohort of 121,700 women who in 1976 (time of initial mail questionnaire) were registered nurses between the ages of 30 and 55 years and residing in 1 of 11 US states. Approximately 98% of the cohort is white. Follow-up questionnaires are sent every 2 years and the response rate is at least 90% in each cycle. Deaths are confirmed through the National Death Index.\(^18\) On the initial questionnaire, participants provided a medical history and information on lifestyle and other risk factors related to cancer and heart disease. Subsequent questionnaires updated these data and were expanded to include other diseases and relevant risk factors. Time spent in specific exercise or leisure-time activities was added to the questionnaire in 1986.

This analysis began in 1986 with the postmenopausal women who responded to the specific activity questions and had not reported a previous

Context Physical activity can reduce the risk of hip fractures in older women, although the required type and duration of activity have not been determined. Walking is the most common activity among older adults, and evidence suggests that it can increase femoral bone density and reduce fracture risk.

Objective To assess the relationship of walking, leisure-time activity, and risk of hip fracture among postmenopausal women.

Design, Setting, and Participants Prospective analysis begun in 1986 with 12 years of follow-up in the Nurses’ Health Study cohort of registered nurses within 11 US states. A total of 61,200 postmenopausal women (aged 40–77 years and 98% white) without diagnosis of cancer, heart disease, stroke, or osteoporosis at baseline.

Main Outcome Measures Incident hip fracture resulting from low or moderate trauma, analyzed by intensity and duration of leisure-time activity and by time spent walking, sitting, and standing, measured at baseline and updated throughout follow-up.

Results From 1986 to 1998, 415 incident hip fracture cases were identified. After controlling for age, body mass index, use of postmenopausal hormones, smoking, and dietary intakes in proportional hazards models, risk of hip fracture was lowered by 6% (95% confidence interval [CI], 4%–9%; \(P<.001\)) for each increase of 3 metabolic equivalent (MET)–hours per week of activity (equivalent to 1 h/wk of walking at an average pace). Active women with at least 24 MET-h/wk had a 55% lower risk of hip fracture (relative risk [RR], 0.45; 95% CI, 0.32–0.63) compared with sedentary women with less than 3 MET-h/wk. Even women with a lower risk of hip fracture due to higher body weight experienced a further reduction in risk with higher levels of activity. Risk of hip fracture decreased linearly with increasing level of activity among women not taking postmenopausal hormones (\(P<.001\)), but not among women taking hormones (\(P=.24\)). Among women who did no other exercise, walking for at least 4 h/wk was associated with a 41% lower risk of hip fracture (RR, 0.59; 95% CI, 0.37–0.94) compared with less than 1 h/wk. More time spent standing was also independently associated with lower risks.

Conclusion Moderate levels of activity, including walking, are associated with substantially lower risk of hip fracture in postmenopausal women.
hip fracture or a diagnosis of cancer, heart disease, stroke, or osteoporosis. Eligible women entered the analysis after menopause. A total of 61,200 women, aged 40 to 77 years, contributed to this analysis with follow-up through 1998.

**Hip Fracture Outcomes**

In 1982, participants reported all previous hip fractures with the date and circumstances leading to fracture. Incident fractures were reported on subsequent biennial questionnaires. Only fractures due to low or moderate trauma (eg, slipping on ice, falling from the height of a chair) were included as cases in this study. Those associated with high trauma (eg, skiing, falling off a ladder) were excluded from analysis (about 15% of reported hip fractures). During the 12 years of follow-up, 415 cases were identified among the women in this study. The median age at fracture was 67 years (range, 46-75 years). Although we relied on self-reports of hip fractures, we expected reliable information in a cohort of registered nurses. Specificity was demonstrated in a small validation study in which all 30 reported hip fractures were confirmed by medical records.

**Activity and Inactivity**

In 1986, participants were asked to report the average amount of time spent per week during the previous year in each of 7 activities: walking or hiking outdoors, jogging (>10 min/mile), running, bicycling (including stationary machine), racquet sports, lap swimming, and other aerobic activity (eg, aerobic dance, rowing machine). These activities were the most common ones reported by women in the University of Pennsylvania Alumni Health Study. For each activity, women chose one of 11 duration categories that ranged from zero to 11 h/wk or more. Walking pace was also reported as either easy (<2 mph), average (2.9 mph), brisk (3-3.9 mph), very brisk (4 mph), or unable to walk. Activity was reassessed in 1988, 1992, 1994, and 1996. The last 3 activity questionnaires included 2 additional items: other vigorous activities (eg, lawn mowing) and lower intensity exercise (eg, yoga, stretching).

Each activity on the questionnaire was assigned a metabolic equivalent (MET) score based on the classification by Ainsworth et al. One MET is the energy expenditure for sitting quietly. MET scores for specific activities are defined as the ratio of the metabolic rate associated with that activity divided by the resting metabolic rate. For example, walking at an average pace was assigned a MET score of 3; jogging, 7; and running, 12. MET scores for walking were assigned based on walking pace; for other activities, a leisurely to moderate intensity score was selected. The scores for MET-hours per week for each activity were calculated from the reported hours per week engaged in that activity multiplied by the assigned MET score, and the values from the individual activities were summed for a total MET-hours per week score. To obtain the best long-term measure of physical activity, total values were cumulatively averaged in analyses. That is, at the beginning of each 2-year follow-up cycle, the MET-hours per week is the mean of all MET-hours per week calculated from responses to the questionnaires up to that time.

We also assessed inactivity with hours per week spent sitting and standing (at home, at work, and other time away from home). These items were on the questionnaires in 1988, 1990, and 1992, and hours of standing were cumulatively averaged over follow-up in this analysis. For sitting, the data were collected with one general question in 1988, which was later expanded to 2 (in 1990) and 3 (in 1992) more specific questions. Predictably, the total reported hours per week of sitting in the cohort increased as the number of questions increased. Therefore, separate category cut points were created for each year of data collection and hours of sitting were updated, but not cumulatively averaged, over follow-up.

The ability of the activity questionnaire to assess total activity and inactivity over the previous year was tested in a sample of 151 white women. Compared with four 7-day activity diaries, the questionnaire underascertained total activity by approximately 20% and inactivity by 35%. However, the correlations for total MET-hours per week of activity (r = 0.62; 95% confidence interval [CI], 0.44-0.75) and total hours of inactivity (r = 0.41; 95% CI, 0.25-0.54) suggest that the questionnaire is a reasonably valid tool for categorical ranking of respondents. The activity questionnaire was also compared with 4 past-week questionnaires collected seasonally during the year. For walking, the primary activity among postmenopausal women, the correlation was 0.70 (95% CI, 0.49-0.84).

In 1980, participants were asked to report the number of hours per week spent in moderate and vigorous activity as well as the frequency in which they engaged in any regular activity long enough to work up a sweat. From the responses to these questions, we estimated the number of hours per week that participants engaged in leisure-time activities in 1980. This was used with the 1986 hours per week from the activity questionnaire to determine a 6-year change in activity level.

**Covariates**

Weight was requested on all biennial questionnaires and body mass index (BMI) was calculated using the height reported on the initial 1976 questionnaire. Postmenopausal hormone use (never, past, or current) and smoking (never, past, or current, with time since quitting for past smokers and number of cigarettes per day for current smokers) were also assessed every 2 years. Diet was measured at least every 4 years beginning in 1980 with a semiquantitative food frequency questionnaire, and intakes of calcium, vitamin D, retinol, protein, vitamin K, alcohol, and caffeine were calculated from the reported consumption of foods and use of multivitamins and specific vitamin or mineral supplements. The BMI and nutrient intakes were cumulatively averaged over follow-up in this analysis.

**Statistical Analysis**

Study participants contributed person-time from the return date of their 1986 questionnaire or the questionnaire on...
which they first became postmenopausal until the occurrence of a hip fracture, death, or the end of follow-up on June 1, 1998. A total of 576,518 person-years was accrued from the 61,200 women in this analysis. Median follow-up time per woman was 11.6 years.

Person-time was allocated to the appropriate category for each exposure and covariate variable at the beginning of every 2-year follow-up cycle. Age-adjusted incidence rates were calculated within exposure categories and relative risks (RRs) are the ratio of the rate in each upper category compared with the rate in the lowest category. Cox proportional hazards models were used to calculate multivariate RRs adjusted for other risk factors for hip fracture. P values for linear trend and for interaction in stratified analyses were determined using continuous exposure variables in the models. Statistical analysis was conducted using SAS statistical software (Version 6.12; SAS Institute Inc, Cary, NC) and P < .05 was used as the level of significance.

RESULTS

The postmenopausal women in this analysis were fairly sedentary. From the 7 activity questions in 1986, the median total activity was 7 MET-h/wk (equivalent to 2.3 h/wk of walking at an average pace), while 19% of the women reported zero or minimal leisure-time activity (ie, <15 min/wk). In the general US population, 29% of adults engage in no leisure-time activity. Walking was by far the most popular activity in this cohort, contributing 66% of the total MET-hours per week. The median duration among walkers was 1.25 h/wk. Biking (14%) and other aerobic activity (11%) were contributors toward total activity.

Table 1. Characteristics of Postmenopausal Women (N = 61,200) by Metabolic Equivalent (MET)–Hours per Week of Activity in the Nurses’ Health Study, 1986–1998

<table>
<thead>
<tr>
<th>Activity, MET-h/wk†</th>
<th>0-0.9</th>
<th>1-3.9</th>
<th>4-9.9</th>
<th>10-15.9</th>
<th>16-23.9</th>
<th>≥24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>60</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Type of activity, h/wk†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>0.2</td>
<td>0.6</td>
<td>1.0</td>
<td>1.6</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>30</td>
<td>33</td>
<td>35</td>
<td>37</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Sitting‡</td>
<td>38</td>
<td>37</td>
<td>37</td>
<td>36</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Body mass index</td>
<td>25.6</td>
<td>25.1</td>
<td>24.7</td>
<td>24.3</td>
<td>23.6</td>
<td></td>
</tr>
<tr>
<td>Current use, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hormone replacement therapy</td>
<td>29</td>
<td>36</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Cigarettes</td>
<td>23</td>
<td>17</td>
<td>14</td>
<td>13</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Thiazide diuretic</td>
<td>17</td>
<td>15</td>
<td>14</td>
<td>13</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Calcium supplement</td>
<td>37</td>
<td>43</td>
<td>36</td>
<td>48</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Multivitamin</td>
<td>38</td>
<td>43</td>
<td>36</td>
<td>47</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Daily intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium, mg</td>
<td>868</td>
<td>917</td>
<td>953</td>
<td>978</td>
<td>1007</td>
<td></td>
</tr>
<tr>
<td>Vitamin D, µg</td>
<td>7.5</td>
<td>7.9</td>
<td>8.3</td>
<td>8.5</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Retinol, µg</td>
<td>1255</td>
<td>1302</td>
<td>1369</td>
<td>1397</td>
<td>1453</td>
<td></td>
</tr>
<tr>
<td>Vitamin K, µg</td>
<td>165</td>
<td>175</td>
<td>186</td>
<td>194</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Protein, g</td>
<td>73</td>
<td>74</td>
<td>75</td>
<td>75</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Alcohol, g</td>
<td>6.1</td>
<td>5.8</td>
<td>6.1</td>
<td>6.6</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Caffeine, mg</td>
<td>336</td>
<td>320</td>
<td>310</td>
<td>308</td>
<td>299</td>
<td></td>
</tr>
<tr>
<td>Total energy, kcal</td>
<td>1663</td>
<td>1688</td>
<td>1699</td>
<td>1709</td>
<td>1729</td>
<td></td>
</tr>
<tr>
<td>Hip fracture incidence/100,000 women per year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-standardized</td>
<td>118</td>
<td>82.4</td>
<td>70.2</td>
<td>52.7</td>
<td>46.6</td>
<td></td>
</tr>
<tr>
<td>Adjusted‡</td>
<td>230</td>
<td>184</td>
<td>155</td>
<td>124</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

*Values are standardized to the age distribution of the study population over follow-up from 1986 to 1998.
†Calculated from time spent in exercise and leisure-time activities in 1986, 1988, 1992, 1994, and 1996. Values were cumulatively averaged in analyses.
‡Data are for 1992 only.
§Hip fracture incidence estimated for white women 65 years old who have never smoked, do not use postmenopausal hormones, do not drink alcohol, and are at the median level for all other covariates.

Among the postmenopausal women in this study, both activity and BMI exhibited significant inverse associations with risk of hip fracture (Table 2). These associations were independent of one another and showed little confounding by the other measured risk factors. Compared with the women in the lowest category of less than 3 MET-h/wk, those with 24 MET-h/wk or higher had a significantly lower (55%) hip fracture risk (RR, 0.45; 95% CI, 0.32–0.63) in the multivariate analysis. Risk declined in a dose-dependent manner with a 6% decrease in risk (95% CI, 4%-9%) for every 3 MET-h/wk increase in activity (equivalent to 1 h/wk of walking at an average pace). Risks of hip fracture among women with BMIs between 25.0 and 29.9 were not different from that of the reference group with BMIs between 23 and 24.9. A BMI of 30 or higher was associated with 50% the hip fracture risk of women in the reference group, and women with a BMI of less than 23 had significantly higher risk (45%-83%; Table 2). These inverse associations between activity, BMI, and risk of hip fracture were unchanged when women were excluded during follow-up because of diagnosis of cancer, heart disease, stroke, or diabetes. We also found that fracture risks were unchanged when women who reported balance problems in 1990 (5% of the study population) were excluded from analysis.

Based on our risk estimates, we calculated the percentage of hip fractures...
in the Nurses’ Health Study cohort that could have been prevented if all participants had exercised at a higher level. If all had exercised at 9 MET-h/wk or higher, 23% (95% CI, 15%-34%) of the hip fractures could have been prevented; at 15 MET-h/wk or higher, 32% (95% CI, 21%-44%) could have been prevented; and if all exercised at 24 MET-h/wk or higher, 42% (95% CI, 27%-59%) of the hip fractures could have been prevented.

Higher levels of physical activity were significantly protective against hip fractures among both the leaner (BMI <25; P for trend <.003) and heavier women (BMI ≥25; P for trend <.001). However, the heavier women had a lower fracture risk in every activity category (FIGURE 1). Even among the leanest (BMI <21) and heaviest (BMI ≥30) women, we observed significant inverse linear associations between activity and risk of hip fracture (P for trend = .04 in both BMI strata).

The association between activity and hip fractures appeared dissimilar for users and nonusers of postmenopausal hormones (FIGURE 2). However, a test for interaction was not statistically significant (P = .12). Among the nonusers, there was a steep decline in risk (P for trend <.001) with higher levels of activity. For the postmenopausal hormone users, risk was significantly lower compared with nonusers in the lowest activity category of less than 3 MET-h/wk (RR, 0.45; 95% CI, 0.26-0.78) and there was little further risk reduction with higher activity levels (P for trend = .24). In the highest activity category of 24 MET-h/wk or higher, the reduced risk of hip fracture was essentially the same for the hormone users (RR, 0.29; 95% CI, 0.16-0.51) and nonusers (RR, 0.33; 95% CI, 0.22-0.50) when both were compared with nonusers in the lowest activity category. We also examined the association between physical activity and hip fracture stratified by median years of age and by median intakes of calcium, vitamin D, and retinol, but did not find any evidence that the association differed in the upper and lower strata of these variables.

We explored the risk of hip fracture among women who increased or decreased their level of activity based on the differences in hours per week reported on the 1980 and 1986 questionnaires (TABLE 3). Consistent with our primary analyses, risk was assessed from 1986-1998 and women with a diagnosis of cancer, heart disease, stroke, or osteoporosis were excluded at baseline.
Among women who reported a low activity level of less than 1 h/wk in 1980, those who increased their activity to 4 h/wk or more by 1986 had an RR of 0.53 (95% CI, 0.27-1.04) compared with those who remained in the low-activity category. Risk appeared to decrease as the 1986 activity level increased (P for trend = .07). Among women who reported a high activity level of 4 h/wk or more in 1980, risk of hip fracture was doubled among those who decreased to less than 1 h/wk in 1986 (RR, 2.08; 95% CI, 1.20-3.61) compared with those who remained in the high-activity category. Risk increased linearly with increasing reduction of activity (P for trend = .004). Similar results were found when comparing change in activity between 1986 and 1992. For those who increased activity from less than 3 to 15 MET-h/wk or more from 1986 to 1992, the adjusted RR for hip fracture was 0.34 (95% CI, 0.13-0.88) and for those who decreased activity from 15 MET-h/wk or more to less than 3 MET-h/wk, the RR was 1.84 (95% CI, 0.86-3.92).

Since walking was the primary activity for the postmenopausal women in this cohort, we examined whether walking was associated with a lower risk of hip fracture. No other activity was reported with sufficient frequency for an individual analysis. To focus only on walking, we included women at baseline and during follow-up when they reported engaging in any other activity for 20 min/wk or more. Compared with women who reported no activity or who walked for less than 1 h/wk, those who walked 4 h/wk or more had a significantly lower risk of hip fracture (RR, 0.59; 95% CI, 0.37-0.94) and there was a significant dose-response of lower risk with longer duration of walking (P for trend = .02; Table 4). Walking pace was also a significant predictor of hip fracture. Compared with an easy pace, women reporting an average pace had 49% lower risk and women reporting a brisk to very brisk pace had 65% lower risk. When both duration and pace were analyzed in the same multivariate model, the RRs for pace did not change while those for duration were attenuated (RR, 0.72; 95% CI, 0.45-1.16 for ≥4 h/wk).

Sitting and standing were assessed as measures of inactivity in this cohort. Sitting was not significantly associated with risk of hip fracture (Table 5), although a nonsignificant increase in risk was observed among the women sitting 55 h/wk or more (RR, 1.29; 95% CI, 0.85-1.96) compared with those sitting for less than 10 h/wk after controlling for hours of standing, total MET-hours per week, BMI, and the other measured risk factors. In contrast to sitting, we observed a significant dose-response relationship between standing and risk of hip fracture (P for trend = .01). Compared with women who stood for less than 10 h/wk, women standing for 55 h/wk or more had a significantly lower (46%) risk. Standing for any duration of 10 h/wk or more was associated with a significantly lower (28%) fracture risk (RR, 0.72; 95% CI, 0.53-0.97).

**COMMENT**

In this 12-year prospective study among postmenopausal women, total physical activity from exercise and leisure-time activities was associated with a significantly lower risk of hip fracture. Our primary measure of activity was a MET-hour, which combined an assessment of duration and intensity. Risk of hip fracture declined 6% for every increase of 3 MET-h/wk (equivalent to 1 h/wk of walking at an average pace).

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**Table 3.** Relative Risks (RRs) of Hip Fracture by Change in Hours of Activity Between 1980 and 1986

<table>
<thead>
<tr>
<th>Activity in Hours per Week in 1986</th>
<th>&lt;1 h/wk</th>
<th>1-2 h/wk</th>
<th>≥3 h/wk</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>57</td>
<td>22</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Person-years (1986-1998)</td>
<td>55 268</td>
<td>23 642</td>
<td>20 357</td>
<td>18 024</td>
</tr>
<tr>
<td>RR (95% CI)</td>
<td>1.00</td>
<td>0.86 (0.52-1.43)</td>
<td>0.79 (0.45-1.38)</td>
<td>0.53 (0.27-1.04)</td>
</tr>
</tbody>
</table>

*Adjusted for age, body mass index, smoking, postmenopausal hormone use, and intakes of calcium, vitamin D, retinol, protein, vitamin K, and caffeine. CI indicates confidence interval.

**Table 4.** Relative Risks (RRs) of Hip Fracture by Hours Per Week of Walking and by Walking Pace

<table>
<thead>
<tr>
<th>Walking, h/wk†</th>
<th>&lt;1</th>
<th>1</th>
<th>2-3</th>
<th>≥4</th>
<th>P for Trend</th>
<th>Easy</th>
<th>Average</th>
<th>Brisk/Very Brisk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>115</td>
<td>41</td>
<td>36</td>
<td>22</td>
<td>.006</td>
<td>65</td>
<td>99</td>
<td>30</td>
</tr>
<tr>
<td>Person-years</td>
<td>130 807</td>
<td>55 575</td>
<td>45 044</td>
<td>36 215</td>
<td>47 887</td>
<td>142 912</td>
<td>68 683</td>
<td></td>
</tr>
<tr>
<td>RR (95% CI)</td>
<td>1.00</td>
<td>0.75 (0.53-1.08)</td>
<td>0.75 (0.51-1.09)</td>
<td>0.67 (0.42-0.96)</td>
<td>.009</td>
<td>1.00</td>
<td>0.56 (0.41-0.77)</td>
<td>0.39 (0.25-0.61)</td>
</tr>
</tbody>
</table>

*Women were excluded when they reported engaging in an exercise or leisure-time activity other than walking for 20 min/wk or more. This analysis included 34 592 women and 214 hip fractures. CI indicates confidence interval.
† Assessed in 1986, 1988, 1992, 1994, and 1996 and values were cumulatively averaged.
‡ Adjusted for age, body mass index, smoking, postmenopausal hormone use, and intakes of calcium, vitamin D, retinol, protein, vitamin K, alcohol, and caffeine.
Previous prospective studies using differing measures of activity among older men and women have reported a 25% to 39% lower risk of hip fracture in the active vs inactive participants.23-25

As observed in this and other studies,26-27 higher BMI is also associated with a reduced risk of hip fracture, likely due to its weight-bearing effect on bone, the protection supplied by padding around the hips in the event of a fall, and the conversion of androgens to estrogen in fatty tissues.28 However, we found that heavier women could further reduce their fracture risk by engaging in more physical activity. Though lean women also appeared to benefit from activity, the very elderly or those with involuntary weight loss may be at higher risk of fractures due to general frailty.29

Even during adult years, initiation of regular physical activity can reduce fracture risk, but activity must be maintained to preserve the benefits. We found that risk of hip fracture decreased among sedentary women who increased their activity to 4 h/wk or more compared with those who remained sedentary. Conversely, risk increased among those who were actively exercising but became sedentary. Although women with a major chronic disease were removed from this analysis, we cannot exclude the possibility that other medical conditions or underlying disease contributed to both the reduced activity and increased fracture risk. Similar to our finding, Hoi- drup et al23 reported that risk of hip fracture increased among moderately active men and women who were sedentary 6 years later compared with those who remained in the moderately active group.

Several studies have reported an interaction between activity and postmenopausal hormone use. In clinical research, a combination of estrogen supplementation plus exercise was more effective than exercise alone in increasing trabecular bone mineral density in older women.30 Population studies have observed a reduced risk of hip fracture with postmenopausal hormone use among sedentary women, but not among physically active women.31,32 In our cohort, we found that active women not taking supplemental estrogen had similar protection against hip fractures as that provided by hormone use. Interactions reported between the effects of calcium intake and physical activity on bone density33,34 were not supported by our data.

Based on accumulated evidence for all health outcomes, at least 30 minutes to 1 hour of moderate intensity exercise on most days of the week is recommended for adults.35,36 However, recommendations for bone health may be different from those focused on cardiovascular fitness in which intensity of activity to raise heart rate is a critical factor. A high peak load or impact may be more important than endurance.37,38 Also, vigorous exercise is associated with a higher risk of fall-related fractures;2 particularly in the elderly and those with functional limitations.39 For bone, activities that improve balance or flexibility are important to reduce the risk of falling,40 while weight-bearing activities and resistance training can increase muscle size and strength7,41 and lead to higher bone mineral density at the muscle site.37,41

Walking may increase femoral bone density,42 and it is a relatively safe and easy activity and already the most common exercise among older adults.3 In our cohort, walking for 4 h/wk or more was associated with a 41% lower risk of hip fracture. A faster pace was also associated with lower risk, perhaps because of a greater impact on the bone. Several cross-sectional studies have reported positive correlations between walking and bone density.43-45 A prospective study reported a 30% lower risk of hip fracture among women who walked for exercise.46 In relatively short-term clinical trials, brisk walking attenuated femoral bone loss, but increased the risk of falling,47 while a walking program increased spinal bone mineral density, but had no effect at the femoral site.48

Table 5. Relative Risks (RRs) of Hip Fracture by Hours of Sitting and Standing per Week*

<table>
<thead>
<tr>
<th>Hours per Week</th>
<th>Sitting†</th>
<th>Standing§</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR (95% CI)</td>
<td>RR (95% CI)</td>
</tr>
<tr>
<td>&lt;10</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>10-24</td>
<td>0.85 (0.57-1.25)</td>
<td>0.85 (0.57-1.25)</td>
</tr>
<tr>
<td>25-39</td>
<td>0.81 (0.54-1.20)</td>
<td>0.81 (0.54-1.20)</td>
</tr>
<tr>
<td>40-54</td>
<td>0.74 (0.49-1.11)</td>
<td>0.74 (0.49-1.11)</td>
</tr>
<tr>
<td>≥55</td>
<td>1.03 (0.69-1.54)</td>
<td>1.03 (0.69-1.54)</td>
</tr>
</tbody>
</table>

*CI indicates confidence interval.
†Assessed in 1988, 1990, and 1992 and values were updated in analyses. Cut points were specific for each year due to the differing number of questions used in data collection.
‡Adjusted for sex, age, body mass index, smoking, calcium, vitamin D, retinol, protein, vitamin K, alcohol, and caffeine.
§Adjusted for sex, age, body mass index, smoking, calcium, vitamin D, retinol, protein, vitamin K, alcohol, and caffeine.
Standing was also associated with a lower risk of hip fracture in our cohort, independent of body weight and time spent in leisure-time activities. As a weight-bearing activity, standing could confer benefits to balance and muscle that may translate into improved bone strength and protection against hip fracture. Although prior research is limited, the prospective Study of Osteoporotic Fractures reported a 70% increased risk of hip fracture among postmenopausal women who stood for less than 4 h/d, and a cross-sectional study found that active nurses had higher femoral bone mineral densities compared with clerks sitting at a desk.

The results of this study are applicable to white postmenopausal women and may not be generalizable to men, to women of other racial or ethnic backgrounds, or to a more elderly or frail population. Also, we lacked prospective data on frequency of falling and it is possible that women who experienced a bad fall but did not break a bone were more cautious and therefore limited their activity.

In conclusion, more leisure-time activity is associated with a lower risk of hip fractures in postmenopausal women. Walking is the most common exercise and is a suitable activity for lowering fracture risk. Both lean and heavy women can reduce their fracture risk by increasing their level of activity.

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Statistical expertise: Feskanchik, Willett. Obtained funding: Willett, Colditz. Administrative, technical, or material support: Colditz.

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REFERENCES


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