Incident Fall Risk and Physical Activity and Physical Performance among Older Men

The Osteoporotic Fractures in Men Study

Benjamin K. S. Chan1, Lynn M. Marshall1, Kerri M. Winters2, Kimberly A. Faulkner3, Ann V. Schwartz4, and Eric S. Orwoll1

1 Department of Endocrinology, School of Medicine, Oregon Health and Science University, Portland, OR.
2 School of Nursing, Oregon Health and Science University, Portland, OR.
3 Department of Epidemiology, University of Pittsburgh, Pittsburgh, PA.
4 Department of Epidemiology and Biostatistics, University of California, San Francisco, San Francisco, CA.

Received for publication October 20, 2005; accepted for publication August 8, 2006.

Physical activity and physical performance have been linked to fall risk in the elderly. The authors examined the relation between physical activity and physical performance with incident falls in the Osteoporotic Fractures in Men Study, a large prospective cohort study of 5,995 community-dwelling men in the United States at least 65 years of age. The authors also examined what types of activities are associated with falling. Incident falls between 2000 and 2005 were captured from up to 17 triannual follow-up questionnaires per participant and analyzed with generalized estimating equations. Follow-up averaged 4.5 years. The average risk of falling in the first 4 months of follow-up was 6.6%. The most active quartile had a significantly greater fall risk than did the least active quartile (relative risk = 1.18, 95% confidence interval (CI): 1.07, 1.29). Men with greater leg power and grip strength had significantly reduced fall risk (for highest leg power quartile vs. lowest: relative risk = 0.82, 95% CI: 0.73, 0.92; for highest grip strength quartile vs. lowest: relative risk = 0.76, 95% CI: 0.69, 0.85). Partitioning components of activity showed no association between fall risk and leisure activities but a positive association with household activities (for highest quartile vs. lowest: relative risk = 1.17, 95% CI: 1.07, 1.28).

Accidental falls; aged; aged, 80 and over; follow-up studies; men; risk factors

Abbreviations: CI, confidence interval; GEE, generalized estimating equation; MrOS, Osteoporotic Fractures in Men; PASE, Physical Activity Scale for the Elderly.

Falls are a major public health concern among the elderly. One third of community-dwelling adults aged 75 years or more fall each year, and falls are a major source of injury and disability (1–4). Among the elderly, fractures occurred in 3 percent of falls, minor soft tissue injury occurred in 56 percent of falls, fall-related injuries account for 5.3 percent of all hospitalizations, and 90 percent of hip fractures can be attributed to a fall (1, 5, 6). Falling is common even among healthy older adults. For example, as many as 18 percent of well-functioning older men have fallen over the course of 1 year (1). Even if a fall does not result in an injury, subsequent fear of falling may result in restricted activity (5, 7). Poor physical performance, such as leg extension strength, walking speed, lower extremity performance, and balance,
increases the likelihood of falling (1, 5, 8–10). In addition, low physical activity has been identified as a risk factor for falling among older adults, and trials of exercise interventions have shown that exercise is beneficial, potentially because physical activity helps to maintain mobility, physical functioning, muscle strength, and balance, all of which may be protective against falls (11–13). On the other hand, certain types of physical activity may increase the likelihood of falling through the displacement of an individual’s center of gravity (11, 14). Indeed, a review of the epidemiologic evidence from observational studies and clinical trials concluded that there was no consistent evidence that increased leisure time physical activity reduced fall risk and that no exercise modality was consistently effective in reducing risk (11). Although the effects on fall risk of both physical performance and physical activity individually have been investigated extensively in the literature, the interrelation between the two has not been adequately explored in prospective studies.

This study prospectively examined the relation among physical activity, physical performance, and incident falls in a large population of older adult men. It also examined if fall risk was differentially associated with certain types of activities and whether activity and performance modified the effect on fall risk on each other.

MATERIALS AND METHODS

Study participants

The Osteoporotic Fractures in Men (MrOS) Study is a prospective cohort study designed to examine the extent to which fracture risk is related to skeletal characteristics, lifestyle factors, anthropometric and physical performance measures, fall propensity, and several other factors, as well as to determine how fractures affect the quality of life in older men (15). Beginning in March 2000 through April 2002, 5,995 community-dwelling men at least 65 years of age or older were recruited from six geographically and ethnically diverse sites in the United States (Birmingham, Alabama; Minneapolis, Minnesota; Palo Alto, California; Pittsburgh, Pennsylvania; Portland, Oregon; and San Diego, California). Men who had had a bilateral hip replacement or were unable to walk without the assistance of another person were not eligible for participation. Details on recruitment of participants have been described in another publication (16). The institutional review board at each site approved the study protocol, and written, informed consent was obtained from all subjects.

Physical activity

 Observational studies have rarely assessed physical activity by use of instruments designed for and validated on an older adult population or used instruments that distinguished between leisure and nonleisure activities (11). In the MrOS Study, physical activity was quantified with the Physical Activity Scale for the Elderly (PASE) (17). The PASE is a 12-item questionnaire designed to assess the leisure, household, and occupational activities commonly engaged in by older adults. Leisure activities included light, moderate, and heavy sport and recreational activity; exercise to improve or maintain muscle strength; and walking outside the home. Household activities included light and heavy housework, home repair, lawn work, outdoor gardening, and caring for another person. Occupational activities included paid and unpaid work. Each item weighted the time spent in each activity reported during the previous 7 days, where the weights have been empirically derived from 3-day motion sensor counts, 3-day physical activity diary, and a global self-reported activity assessment (17). The weighted items yielded subscores for activities in the leisure, household, and occupational categories. A total physical activity score was computed as the sum of these subscores.

Physical performance

Physical performance was measured with five tests: leg extension power, walking speed, narrow-walk pace, time to complete five chair stands, and grip strength. Leg extension power was measured with the Nottingham power rig (18, 19). Leg extension power measured with this device correlates well with functional measures, such as chair-rising speed, stair-climbing speed and power, and walking speed in elderly subjects (19). In the MrOS Study cohort, leg extension power was measured on the rig with nine trials for each leg. The maximum value (watts) from either leg was analyzed. In total, 9.2 percent had missing data for leg power. Among these, those who had recent hip replacement surgery, orthosis, prostheses, or other physical limitation were coded as “unable due to physical limitation” (1.9 percent). The remaining 7.3 percent were coded as “missing leg power data,” because they could not attempt the assessment because of equipment malfunction or other unknown reason. Walking speed was assessed on a standard 6-m walking course. Participants were instructed to walk at their normal pace for this examination. The fastest speed (meters/second) was analyzed. A small number of participants refused to complete the gait speed measure (0.2 percent). The narrow walk was used as an indirect measure of dynamic balance. Participants were asked to walk a 6-m course while keeping each foot within a 20-cm-wide lane. A trial was considered successful if the participant had no more than two deviations from the lane. Participants were asked to do two trials. If one or both trials were unsuccessful, they were asked to do a third trial. The fastest pace (meters/second) from any successfully completed trial was analyzed. Some participants had missing narrow-walk pace data, because they were unable to successfully complete at least one trial (9.2 percent). The time to complete five chair stands (seconds) without using arms to rise was recorded to assess the muscle endurance of several large muscle groups. Some participants had missing chair stands time data because they did not complete five chair stands (2.7 percent). Grip strength was measured on a JAMAR dynamometer (Sammons Preston, Bolingbrook, Illinois). The maximum value (kilograms) from two trials from both hands was analyzed. Some participants had missing grip strength data because they were unable to successfully complete the assessment (1.9 percent).
Covariates

Other baseline information, including age, race, educational level, anthropometric measures (body mass index and height), and health status (fair or worse general health), was gathered from self-administered questionnaires and interviews by trained and certified clinical staff. The Cut-ting down, Annoyance by criticism, Guilty feeling, and Eye-openers (referred to as “CAGE”) score for alcohol abuse was used to assess alcohol abuse, with scores greater than one indicating abuse (20). The Modified Mini-Mental State Examination described by Teng and Chui (21) was used to assess cognitive function. Corrected visual acuity was also assessed, and participants with 20/40 vision or worse were considered to have poor acuity. Participants were asked if a physician or other health-care provider had ever told them that they had certain medical conditions, including the following: diabetes; hyperthyroidism; hypothyroidism; osteoporosis; stroke, blood clot in the brain, or bleeding in the brain; Parkinson’s disease; hypertension; heart attack, cor-ony, or myocardial infarction; angina; congestive heart failure or enlarged heart; chronic obstructive lung disease, chronic bronchitis, asthma, emphysema, or chronic obstruc-tive pulmonary disease; prostatitis; glaucoma; cataracts; total or partial surgical removal of stomach or intestines; arthritis or gout; kidney stones; and cancer. Participants were also asked if they had trouble with dizziness and whether they had fallen in the 12 months prior to baseline. Indicator vari-ables for each medical condition were created for use in the models. Participants were instructed to bring all prescription and nonprescription medications to the baseline clinic visit for verification. An indicator variable for psychotropic medic-ation use was created for whether the participant was currently using benzodiazepine, narcotic analgesics, nonben-zodiazepine anticonvulsants, selective serotonin reuptake inhib-itors, trazodone, or tricyclics. Current use was defined as daily or almost daily use for at least 30 days prior to baseline.

Falls ascertainment

Information on falls was collected from triannual follow-up questionnaires that were mailed to study participants in March, July, and November. The questionnaire asks if the participant has fallen in the previous 4 months. Follow-up for this study began with the participant’s date of enroll-ment. The first triannual follow-up questionnaire was mailed to enrolled participants on July 1, 2000. The present study included fall reports from up to 17 triannual questionnaire cycles up through the November 2005 mailing. A total of 5,977 men (99.7 percent) returned at least one questionnaire, of which 92 percent returned 10 or more questionnaires; 5,870 men (97.9 percent) had at least 1 full year of follow-up after baseline. Participants are followed until death or termination from the study. As of February 2006, the MrOS Study cohort had 9.8 percent mortality and 1.4 percent termination.

Statistical analysis

Because of the repeated assessments of falls during the follow-up period, the unit of analysis for statistical modeling was the response from the triannual follow-up question-naire. Generalized estimating equations (GEEs) were used to model this outcome. GEE models are an extension of generalized linear models (of which, the logistic regression model is an example) to model longitudinal data while con-structing valid standard error estimates (22, 23). By use of GEE models, arbitrary definitions (such as two or more falls within 1 year) to classify recurrent fallers are avoided and, instead, the probability of falling a 4-month triannual cycle is modeled. Fall risks, relative risks, and 95 percent confidence intervals were estimated from the models. We used the method described by Spiegelman and Hertzmark (24) for analyzing common dichotomous events to more appropriately estimate relative risks for falling. A first-order autoregressive correlation structure was assumed for the working correlation matrix for the correlated responses from the same participant.

Two types of covariates were examined in the analysis: those related to the baseline characteristics of the partici-pants and those related to the triannual follow-up question-naire. The baseline covariates examined in this analysis were described above. Site and age at baseline were included in all multivariate models. Other baseline covariates significantly associated with fall risk at \( \alpha < 0.05 \) were included in the final models. Two variables related to the triannual questionnaire were included in the models. The first was the calendar period of the questionnaire nested within study site (e.g., the questionnaire covering November through February for the Minneapolis site) to adjust for seasonal variability by geographic site, which could poten-tially be important because activity levels and fall propen-sity may be affected by climate conditions. The second was a temporal index for the questionnaire (e.g., the third ques-tionnaire returned) to adjust for participants aging through-out follow-up and, thus, having increased likelihood of experiencing a fall.

The models simultaneously included physical activity variables and physical performance variables to estimate their independent associations. Physical activity variables and physical performance measures were coded into quartiles, and indicator variables were used to estimate the relative risks compared with the lowest quartile. To incorporate the presence of missing data from the physical performance assessments, we included in the models six indicator vari-ables for the missing data scenarios (unable to do leg power assessment because of physical limitation, missing leg power data because of equipment malfunction or other un-known reason, refusal to do walking speed assessment, un-able to successfully complete at least one narrow-walk trial, unable to complete five chair stands, and did not complete grip strength assessment), and the corresponding quartile indicator variables were set to zero. This allowed the models to utilize other data from participants without physical perfor-mance data, while estimating separate fall risks from participants with physical performance data (25). Including two indicator variables for men having missing leg power data separates those who were physically unable to perform the assessment from those who could not because of ma-chine malfunction but may have otherwise been able to do so.
To examine possible effect modification, we tested interactions between the PASE total score and physical performance measures whose main effect was significantly associated with fall risk. p values were not adjusted for multiple comparisons.

RESULTS

The 5,995 men enrolled in the MrOS Study returned a total of 80,353 questionnaires (an average of 13.4 questionnaires) during an average of 4.5 years (standard deviation: 0.9) of follow-up, and 10,768 (13.4 percent) of the questionnaires indicated a fall in the previous 4 months. The average age of the men at baseline was 73.7 years (standard deviation: 5.9), and 17.9 percent were aged 80 years or more. Among the 5,867 men (97.9 percent) with at least 1 full year of follow-up after baseline, 1,489 (25.4 percent) had fallen within the first year, 3,535 (60.3 percent) had fallen over the entire course of follow-up, and 2,260 (38.5 percent) reported falling on two or more triannual questionnaires.

Table 1 shows descriptive statistics of the PASE total score and subscores, as well as the physical performance measures. On average, household activities accounted for 66 percent of the value of the PASE total score, leisure activities accounted for 26 percent, and occupational activities accounted for only 8 percent. The PASE total score and the physical performance measures were not strongly correlated (Spearman’s correlation = 0.17–0.20).

Men in the third and fourth most active quartiles had an increased risk of falling compared with the least active quartile, with relative risks of 1.10 (95 percent confidence interval (CI): 1.01, 1.20) and 1.18 (95 percent CI: 1.07, 1.29), respectively, after adjustment for baseline characteristics (table 2). Men in leg extension power quartiles 2–4 had decreased risk compared with those in the lowest quartile, with relative risks of 0.88 (95 percent CI: 0.81, 0.97), 0.86 (95 percent CI: 0.77, 0.95), and 0.82 (95 percent CI: 0.73, 0.92), respectively. Men in grip strength quartiles 2–4 had decreased risk compared with those in the weakest quartile, with relative risks of 0.88 (95 percent CI: 0.81, 0.96), 0.83 (95 percent CI: 0.75, 0.91), and 0.76 (95 percent CI: 0.69, 0.85), respectively. Men in the two fastest narrow-walk quartiles had decreased risk compared with those in the slowest quartile, with relative risks of 0.86 (95 percent CI: 0.77, 0.95) and 0.89 (95 percent CI: 0.79, 1.00), respectively. Walking speed and chair stand time were not associated with fall risk.

When partitioning PASE into leisure and household subscores and whether occupational activity was reported, we found that the association of activity with fall risk was related to household activities but not to leisure activity or occupational activity. The adjusted relative risks for the household activity subscore quartiles were nearly identical to the corresponding relative risks for the total activity score quartiles with the exception of the third quartile (figure 1). As with the total activity score, the most active quartile in terms of household activities was significantly more likely to fall compared with the least active quartile (relative risk = 1.17, 95 percent CI: 1.07, 1.28). However, the relative risks for the leisure activity subscore quartiles, ranging between 0.99 and 1.03, and 95 percent confidence intervals
included unity. Lack of occupational activity was not associated with fall risk (relative risk = 0.95, 95 percent CI: 0.88, 1.02).

Physical activity exhibited effect modification by leg extension power. Among men with leg extension power below the median value, the fall risks across PASE total score quartiles were not statistically different (figure 2). Relative risks comparing the second, third, and fourth quartiles with the first among these men were 0.97, 1.03, and 1.04, respectively, and 95 percent confidence intervals included

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age adjusted†</th>
<th>Multivariate adjusted‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative risk</td>
<td>95% confidence interval</td>
</tr>
<tr>
<td>Physical Activity Scale for the Elderly, total score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 1 Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>1.01</td>
<td>0.93, 1.11</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>1.07</td>
<td>0.98, 1.18</td>
</tr>
<tr>
<td>Quartile 4</td>
<td>1.14</td>
<td>1.03, 1.25</td>
</tr>
<tr>
<td>Physical performance measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg extension power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 1 Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>0.88</td>
<td>0.80, 0.97</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>0.88</td>
<td>0.79, 0.98</td>
</tr>
<tr>
<td>Quartile 4</td>
<td>0.86</td>
<td>0.76, 0.97</td>
</tr>
<tr>
<td>Walking speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 1 Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>0.99</td>
<td>0.90, 1.09</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>0.90</td>
<td>0.81, 1.01</td>
</tr>
<tr>
<td>Quartile 4</td>
<td>0.99</td>
<td>0.88, 1.12</td>
</tr>
<tr>
<td>Narrow walk pace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 1 Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>0.89</td>
<td>0.80, 0.99</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>0.80</td>
<td>0.72, 0.89</td>
</tr>
<tr>
<td>Quartile 4</td>
<td>0.83</td>
<td>0.73, 0.94</td>
</tr>
<tr>
<td>Chair stands time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 1 Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>0.96</td>
<td>0.86, 1.07</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>1.05</td>
<td>0.94, 1.16</td>
</tr>
<tr>
<td>Quartile 4</td>
<td>1.25</td>
<td>1.12, 1.39</td>
</tr>
<tr>
<td>Grip strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 1 Referent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>0.84</td>
<td>0.76, 0.91</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>0.78</td>
<td>0.70, 0.86</td>
</tr>
<tr>
<td>Quartile 4</td>
<td>0.74</td>
<td>0.66, 0.82</td>
</tr>
</tbody>
</table>

* Both models adjusted for triannual follow-up questionnaire variables (calendar period nested within study site and temporal index) and participant variables (did not attempt leg extension power assessment, unable to complete leg extension power assessment, did not complete walking speed assessment, did not complete at least one narrow walk trial, did not complete five chair stands, did not complete grip strength assessment, and study site).
† Additionally adjusted for age at baseline.
‡ Additionally adjusted for age at baseline, non-White race, college education or higher, body mass index, height, alcohol abuse, use of psychotropic medications, fair to very poor general health, Parkinson’s disease, arthritis or gout, cancer, trouble with dizziness, and fallen in the 12 months prior to baseline.
unity. However, among the men with leg extension power above the median value, the fall risks across PASE total score quartiles exhibited a linear trend. Relative risks comparing the second, third, and fourth quartiles with the first among these men were 1.16 (95 percent CI: 1.02, 1.32), 1.23 (95 percent CI: 1.09, 1.39), and 1.39 (95 percent CI: 1.22, 1.57), respectively. Differences between fall risk in men with leg extension power above the median versus below the median within PASE total score quartiles were significant with $p < 0.01$.

**DISCUSSION**

In this large, prospective cohort study of older men, we made three observations regarding the relation among fall risk, physical activity, and physical performance. First, we observed a relation of increased risk of falling with higher levels of self-reported physical activity and with lower levels of leg power, grip strength, and narrow-walk pace. Second, the relation between fall risk and physical activity can be attributed to household activities and not to leisure activities. Third, men with low leg power had consistent fall risk across levels of physical activity, while men with high leg power had increasing fall risk with increasing physical activity levels.

The association of physical activity with fall risk was attributable to household activities including housework, gardening, and home repair. Household activities accounted for most of the physical activity in this cohort, two thirds of total activity on average, while leisure activities accounted for only one quarter. None of the association of physical activity appeared to be due to leisure activity, which included sports and recreation, weight training, and walking.

Moreover, a $U$-shaped relation was not evident between activity (including total and both household and leisure activities) and fall risk as observed in another study (26). The household activity subscore had a standard deviation that was 43 percent of its median and was fairly symmetrically distributed. On the other hand, the leisure activity subscore had a standard deviation that was 132 percent of its median, and the distribution was skewed toward low values. Thus, household activity levels were less variable than leisure activity levels. This could have clinical and public health implications, since it indicates that the type of activities associated with increased fall risk may also be the least susceptible to behavior modification. A possible reason for this is that, at some level, household activities include mandatory tasks. For example, rain gutters must be cleared of debris, trees need pruning, or snow or ice on walkways needs to be shoveled. If community-dwelling older adults lack alternative resources for assistance, be it financial (to pay someone to do such tasks) or social (a nearby able-bodied relative or friend), they may put themselves at risk of falling by attempting to complete such tasks themselves. Indeed, the Study of Osteoporotic Fractures, a large observational study of community-dwelling older women, found that decreased family contacts were associated with an increased risk of falls independent of traditional risk factors (including physical activity) and suggested that maintaining or increasing contacts with family may reduce fall risk, possibly because of increased support with everyday activities, decreased risk taking, and specific education about risks (27). Our data corroborate this finding and suggest intervention strategies for future studies.

Somewhat surprisingly, high levels of physical activity were associated with high fall risk, even in men with preserved leg power. Indeed, that stronger individuals may be
likely to take more risks or be more active beyond their abilities has been hypothesized in the literature (1, 28). The findings from this study lend credence to this hypothesis. However, future studies on fall risk should be designed to specifically examine this interaction between activity and physical performance for confirmation of this observation. Because increased activity appears to have health benefits (e.g., in the reduction of cardiovascular events, obesity, and so on), it appears important to identify particularly active men who, despite preserved leg power, may be at increased risk and to develop means to prevent falls and fall-related injuries in these more active individuals.

One of the limitations of this study was the inability to determine the events leading up to each fall experienced by the MrOS Study participants and, thus, to attribute the cause for each fall. In addition, we were unable to assess and control for the impact of environmental hazards present among our study participants. Other limitations include the reliance on self-reported fall events, which may have resulted in recall bias since it has been suggested that individuals are more likely to recall a fall that resulted in injury (29). We did not have the ability to explore this bias with our data. Another limitation was our use of a questionnaire-based, rather than a direct, assessment of physical activity (29, 30). However, this study had a number of strengths, including the utilization of a very large cohort from ethnically and geographically diverse populations and a substantial follow-up period to accrue a large number of fall events to identify frequent fallers and distinguish them from one-time fallers. Other strengths were the measurement instruments, the use of a physical activity assessment designed specifically for older adults that was able to partition components of activity, and the use of a variety of physical performance measures to identify aspects of performance that were associated with falling. The ability to statistically adjust for a large number of fall-related covariates to limit confounding was also a strength.

In summary, a large prospective observational study of older men found that leg extension power, grip strength, and activity level were significant determinants of fall risk. Men with low leg power and low grip strength were at higher risk of falls. High activity was associated with higher fall risk. In addition, household activities were associated with fall risk, while leisure activities were not. However, men with both high leg power and low activity had lower risk. These data provide new and useful insights into the causation of falls in older men, suggest approaches for identifying men at risk for falling, and direct attention to possible clinical and public health interventions designed to prevent falls.

ACKNOWLEDGMENTS

The Osteoporotic Fractures in Men (MrOS) Study is supported by National Institutes of Health funding. The following institutes provide support: the National Institute of Arthritis and Musculoskeletal and Skin Diseases, the National Institute on Aging, and the National Cancer Institute, under the following grant numbers: U01 AR45580, U01 AR45614, U01 AR45632, U01 AR45647, U01 AR45654, U01 AR45583, U01 AG18197, and M01 RR000334.

Investigators in the MrOS Study Research Group: Coordinating Center (University of California, San Francisco, and California Pacific Medical Center Research Institute): S. R. Cummings (Principal Investigator), M. C. Nevitt (co-Principal Investigator), D. C. Bauer (co-Principal Investigator), K. L. Stone (co-Principal Investigator), D. M. Black (co-Principal Investigator), P. M. Caughon (Project Director), R. Fullman (Research Associate), and R. Benard, T. Blackwell, J. Diehl, S. Ewing, C. Fox, M. Jaime-Chavez, E. Kwan, S. Litwack, L. Y. Lui, A. Mills, L. Palermo, J. Schneider, R. Scott, D. Tanaka, and C. Yeung; Administrative Center (Oregon Health and Science University): E. Orwell (Principal Investigator), K. Phipps (co-Principal Investigator), L. Marshall (co-Principal Investigator), J. Babich Blank (Project Director), and L. Lambert, B. Chan, D. Neveel, J. Mougey, and L. Press; University of Alabama, Birmingham: C. E. Lewis (Principal Investigator), J. Shikany (co-Principal Investigator), P. Johnson (Project Director), and E. Clavino, C. Oden, N. Webb, K. Hardy, S. Felder, P. Grayson, J. Wilkoff, J. King, T. Johnsey, and J. Thompson; University of Minnesota: K. Ensrud (Principal Investigator), H. Fink (co-Principal Investigator), D. King (Program Manager), N. Michaels (Assistant Program Manager), N. Nelson (Clinic Coordinator), and C. Bird, D. Blanks, F. Imker-Witte, K. Moen, M. Paudel, and M. Slindée; Stanford University: M. Stefanick (Principal Investigator), A. Hoffman (co-Principal Investigator), E. Moore (Project Director), and K. Kent, B. Malig, and S. Wong; University of Pittsburgh: J. Cauley (Principal Investigator), J. Zmuda (co-Principal Investigator), L. Harper (Project Director), L. Buck (Clinic Coordinator), and M. Danielson, M. Nasim, D. Cusick, D. Moore, M. Gorecki, D. Lee, N. Watson, C. Bashada, C. Newman, and G. Engleka; University of California, San Diego: E. Barrett-Connor (Principal Investigator), T. Dam (co-Principal Investigator), M. L. Carroll-Petersen (Project Director), and P. Miller, N. Kamantigue, S. Szeredi, and G. Reno.

Conflict of interest: none declared.

REFERENCES