Published in final edited form as:

J Am Geriatr Soc. 2013 July ; 61(7): 1080–1088. doi:10.1111/jgs.12326.

Objective measures of Physical Activity, Fractures and Falls: The Osteoporotic Fractures in Men Study (MrOS)

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Abstract

Background/Objectives—Self-reported physical activity (PA) has been linked to lower hip fracture and fall rates. The objective of this study was to determine the association between objectively measured PA, fractures and falls.

Design/Setting/Participants—2731 men (mean age 79 yrs) recruited at 6 US clinical sites into a longitudinal cohort study.

Measurements—Total and active energy expenditure (EE) and minutes per day spent in sedentary and moderate intensity activities were measured using the multi-sensor SenseWear Pro Armband (SWA) for at least 5 days. Energy expended at a metabolic equivalent (MET >3) was termed active EE. Incident non-spine fractures and falls were identified every 4 months.

Results—759 (28.2%) men fell at least once over 12 months of follow-up; 186 (6.8%) men experienced 1 fracture over an average follow-up of 3.5 ± 0.9 years. The association between PA and falling varied by age (p interaction=0.02). Men <age 80yrs, with the lowest active EE had a lower risk of falling (relative risk (RR)=0.75; p trend = 0.08) while men >80 yrs, with the lowest active EE had a higher risk of falling, RR=1.43, p trend=0.09. In multivariate models including health status, men in the lowest quintile of active EE had a significantly higher risk of fracture, hazard ratio (HR)=1.82 (95% confidence interval (CI) 1.10, 3.00), p trend=0.04. Men with less than 33 minutes/day of moderate activity had a 70% increased risk of fracture, HR=1.70(95% CI, 1.03, 2.80).

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Author Contributions: JAC had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: JAC, Eric Orwoll, Dawn C. Mackey. Acquisition of data: Jane A. Cauley, SLH, Peggy M. Cawthon, Kristine E. Ensrud, Eric Orwoll. Analysis and interpretation of data: Jane A. Cauley, Stephanie L. Harrison, Peggy M. Cawthon, Michelle E. Danielson, Eric Orwoll, Dawn C. Mackey. Drafting of the manuscript: Jane A. Cauley. Critical revision of the manuscript for important intellectual content: Peggy M. Cawthon, Kristine E. Ensrud, Michelle E. Danielson, Eric Orwoll, Dawn C. Mackey. Statistical analysis: Jane A. Cauley, Stephanie L. Harrison, Dawn C. Mackey, Obtaining funding: Jane A. Cauley, Kristine E. Ensrud, Eric Orwoll. Administrative, technical or material support: Jane A. Cauley, Peggy M. Cawthon, Michelle E. Danielson, Eric Orwoll, Dawn C. Mackey.

Conflict of Interest: None of the authors have any conflicts to report.

Conclusion—Age modifies the association between PA and falling. Interventions aimed at >30 minutes of moderate PA per day may reduce fractures extending existing PA guidelines to the oldest old, the fastest growing proportion of those over age 65.

Keywords

Exercise; osteoporosis; population studies; falls; fractures; physical activity

INTRODUCTION

Falls and osteoporotic fractures are common among older adults: about 30% of community dwelling individuals fall at least once per year and 40% of these falls lead to injury¹⁻⁴. Most fractures (>95%) occur because of a fall⁵ and osteoporotic fractures, a major public health problem, results in morbidity, disability and reduced quality of life⁶. Given current demographic trends an increasing number of older men are at risk of falls and fractures.

A recent meta-analysis of the association between physical activity (PA) and hip fractures showed that moderate to vigorous activity was associated with a 45% (95% confidence interval (CI), 31-56%) lower risk of hip fracture among men and women⁷. However, women comprised 79% of the subjects in the meta-analysis suggesting that studies in men were underpowered with imprecise estimates. Few epidemiological studies have examined the association of PA and other fractures, which account for 80% of the total fracture burden and results are inconclusive⁸.

Observational studies have also generally reported equivocal results about the association between usual PA and risk of falling, but some data suggest higher risk among the most active and least active, a so called U-shaped relationship⁹⁻¹². Two recent meta-analyses^{11, 12} of randomized clinical trials of exercise programs and falls suggested that exercise may reduce falls, especially interventions that include balance exercises and a higher total dose of exercise^{13, 14}. Interventions that included a walking program were associated with higher risk of falls than interventions without a walking program.

Most of these previous studies relied on self-report of PA via questionnaires which included a limited number of select activities typically sports and leisure time activities¹². Lower intensity activities and unstructured activities, which account for the majority of total energy expenditure (EE)¹⁵, are more difficult to quantify by self-report. In addition, self-report is subject to recall bias and typically overestimates actual amounts of PA^{16, 17}. These limitations are exacerbated when assessing PA of older adults who are more likely to engage in PA on an irregular basis^{18, 19}.

The purpose of the current study was to determine the association of total and active EE and time spent in sedentary and moderate activities, all measured objectively, with incident falls and fractures in a large community based cohort of older men. We explored whether the association between activity and falls and fractures was linear or “U” shaped.

METHODS

Study Sample

In 2000-2002, 5994 men enrolled in the Osteoporotic Fractures in Men Study (MrOS), a longitudinal cohort study designed to determine risk factors for osteoporosis, fractures and falls in six US clinical centers (Birmingham, AL; Minneapolis, MN; Palo Alto, CA; Monongahela Valley near Pittsburgh, PA; Portland, OR and San Diego, CA). Men were recruited primarily through mass mailings targeted to age-eligible men. The MrOS study has

been described in more detail previously²⁰. Briefly, all men were > age 65, able to walk independently and did not report bilateral hip replacements; 35% of men were age 65-69 and 11%, age 80 or older at baseline. Eleven percent of men were minorities; most rated their health as good to excellent and the mean (range) body mass index (BMI) was 26.9 kg/m² (17-56) at the baseline visit. Men attended a baseline visit in 2000-02 and follow-up visit 4.5 years later. All active men were then invited to a third visit in 2007-2009; of 4682 active men, 3354 (72%) wore an activity monitor, (Appendix, Figure 1). For this analysis we excluded 623 men who either reported use of an osteoporosis medication (e.g., bisphosphonates) at the third visit or who wore the activity monitor <90% of the prescribed time or for less than 5 days. The final analytical sample included 2,731 men. Written informed consent was obtained from each participant and the protocol was approved by the institutional review boards at each institution.

Objective Energy Expenditure and Physical Activity Assessment

Men were instructed to wear the multi-sensor SenseWear Pro Armband (SWA) (Body Media, Inc; Pittsburgh, PA) at all times, including while sleeping, for a typical 7 day period and to remove it only for brief periods for bathing and water activities. The armband was worn over the right triceps muscle, and data were sampled in 1 minute epochs from a heat flux sensor, a galvanic skin response sensor, a skin temperature sensor, a near body temperature sensor and bi-axial accelerometer. These data served as inputs in proprietary algorithms (Innerview Professional 5.1 software, Body Media, Inc; Pittsburgh, PA) along with height, weight, handedness and smoking status to estimate total EE in kilocalories per day (kcal/d). Energy expended at a moderate or greater intensity level was termed active EE. Minutes per day spent in sedentary (MET = 1.5), moderate (METs 3-<6) and vigorous (METs >6) intensity activities were quantified. A validation study comparing the SenseWear Pro Armband with the criterion method of doubly labeled water showed acceptable levels of agreement for total EE and active EE in older adults²¹.

Other Measurements

At the third clinic visit, weight was measured in light clothing without shoes and height by a Harpenden Stadiometer; BMI was computed as a kg/m². Demographic, medical history, general health status, smoking and alcohol consumption were obtained from standardized questionnaires. History of fractures includes fractures before baseline (2000-2002) and all incident adjudicated fractures up to visit 3. Self-reported PA was assessed using the Physical Activity Scale for the Elderly (PASE)²². Gait speed was measured in meters/seconds on a standard 6 m course. Self-report of a physician diagnosed cardiovascular disease (CVD), hypertension, diabetes, chronic obstructive pulmonary disease (COPD), Alzheimer's disease, Parkinson's, kidney or liver disease and non-skin cancers were recorded. We examined the prevalence of more than 1 of these comorbidities across physical activity quintiles. Participants also completed the Teng Modified Mini-Mental State (3MS) examination²³.

Bone Density Measurements

Total hip bone mineral density (BMD) (g/cm²) was measured at visit 3 using fan-beam DXA (QDR 4500W, Hologic Inc., Waltham, MA, USA)²⁰. A central quality-control lab, certification of DXA operators, and standardized procedures for scanning phantoms and participants were used to ensure reproducibility of DXA measurements.

Follow-up and Outcome Ascertainment

Fracture and fall events were reported by participants at 4 month intervals on brief mailed questionnaires. Participants were asked if they had fallen in the past 4 months; if so, the number of times they had sustained a fall and whether any fractures occurred over the 4

months was recorded. Subsequently, study physicians centrally adjudicated reported fractures from medical records. Deaths were confirmed with death certificates, 95% of these contacts were completed. The average follow-up for fractures was 3.5 ± 0.9 years. For falls, we limited analyses to one year after the third clinic visit.

Statistical Analyses

The primary PA variables included total EE (kcal/d), active EE (kcal/d) and minutes per day spent in sedentary and moderate intensity activities. PA variables were divided into quintiles. Differences in visit 3 characteristics across quintiles of total EE were tested using ANOVA or chi-square tests. We calculated the percentage of men with at least one fall across quintiles of PA. Negative binomial regression was used in the falls models to account for interdependence of recurrent events and estimated the relative risk (RR) 95% CI of falling versus no falls. Age-adjusted incidence rates of fracture per 1000 person years were calculated across quintiles of PA. Cox proportional hazards regression models were used to calculate the hazard ratio (HR) (95% CI) across quintiles of PA. The top quintile formed the referent group for all analyses with tests for trend across quintiles.

Base models for falls and fractures included age, race, clinic and season. Multivariate (MV) models for falls included the base model plus height, weight, self-reported history of diabetes, health status (good, excellent versus fair, poor, very poor), and smoking (current versus past or never). Multivariate models for fractures also included total hip BMD and fracture history. In subsequent models, we added fall history (year before visit 3) to the models to test whether history of falls attenuates the association between PA and fractures. We hypothesized that the association between PA and falls and fractures could differ by age and we ran separate models for the young old (<80) and the oldest old (≥ 80) and tested for an interaction. To test for the so called “U” shaped relationship⁹⁻¹², we used quintile 3 as the referent and also ran a continuous model adding in a quadratic term but there was no evidence of a U-shaped relationship for either outcome (data not shown). All analyses were conducted using SAS version 9.1 (SAS Institute, Inc. Cary, North Carolina).

RESULTS

Men with the highest total EE (>2683 kcal/day) were on average 7 years younger, more likely to be White, weighed about 17kgs more, had a faster gait speed and higher BMD and lean mass than men with lowest total EE (<1975kcal/day), Table 1. The most active men were also less likely to report diabetes or a previous fracture and more likely to report excellent/very good health status. The overall prevalence of current smoking was low but was slightly higher among the men with the lowest total EE. The differences in alcohol consumption across total EE quintiles, while statistically significant, were modest. Overall the prevalence of more than 1 comorbidity was high but decreased with increasing total EE. The most active men also had the highest cognitive function. Physical activity by self-report increased across quintiles of total EE. The proportion of active EE to total EE was higher among the most active men. The most active men (quintile 5) averaged of 154 minutes per day of moderate activity compared to 35 minutes per day among the least active.

Falls

A total of 759 (28.2%) men fell at least once over 12 months of follow-up. Total EE and active EE were lower in men who fell compared to men who did not fall, during the 1 year of follow-up, Table 2. There was a linear decline in physical activity with increasing number of falls. The amount of sedentary activity increased with increasing fall risk. Nevertheless, the absolute differences in PA by fall status, while statistically significant, were small.

Significant interactions were observed between objective measures of PA and age for prediction of falls (Figure 1). Among men <80 years, the proportion of men who fell at least once was almost 3 times higher among men with the most active EE or the greatest number of minutes per day of moderate activity minutes compared with the lowest activity. In contrast, among men ≥ age 80, the proportion of men who fell was highest among men in the lowest quintile of active EE and moderate activity minutes.

In the MV models of active EE, men younger than 80 years with the lower active EE had a 25-47% lower risk of falling (p trend=0.08) compared to the most active men, Table 3. Similar results were observed for moderate activity. In contrast, among men ≥ 80 years, men with the lowest active EE had a 43% higher risk of falling, RR=1.43(0.90, 2.26), (p trend=0.09, p interaction=0.02). Men less than 80 years with the least amount of sedentary activity had a 29% (0.84, 1.99) higher risk of falling compared to men with the most sedentary activity, (p trend=0.10). In contrast, men ≥ age 80 with the least amount of sedentary activity were about 33% (0.42, 1.06) less likely to fall than men who were the most sedentary (p trend=0.09, p interaction p=0.01).

Fractures

A total of 1861 (6.8%) men experienced 1 fracture over an average follow-up of 3.5 ± 0.9 years. Men who experienced an incident fracture had lower PA and greater sedentary activity than men without a fracture, Table 2. The greatest differences were observed for active EE and moderate intensity activities where the median was 25% and 17% lower, respectively among the men who experienced an incident fracture compared to men without a fracture.

Higher levels of total EE, active EE and moderate intensity activity were associated with lower rates of fracture while men with higher sedentary activity had a higher rate of fracture, Table 4. There was no evidence of an interaction of physical activity with age for fracture (data not shown). The hazard ratio for fractures was higher among men with the least amount of total EE. Similar results were observed for active EE where men with less than 190.6 kcal/day of active EE had an 82% increased risk of fracture compared to the men with the greatest active EE (>775kcal/d), HR=1.82 (1.10, 3.00), p trend=0.04. Men with the least sedentary activity had a lower fracture risk but this association was slightly attenuated in the MV models, p trend=0.09. Participating in less than 33 minutes of moderate activity (quintile 1) was associated with a 70% increased risk of fracture compared to most active men. Individuals who have a history of falls may adjust their physical activity because of a fear of falling but adding fall history to our fracture models had no effect (data not shown).

DISCUSSION

Our prospective results demonstrated important interactions between age and PA for fall risk whereby the oldest old men (≥ age 80) were at a greater risk of falling at lower activity levels and higher sedentary activity. The opposite was true for the men < age of 80 yrs. These associations were consistent across all of the activity variables and were independent of important confounding variables. The higher risk of falling among the younger men at greater levels of activity may reflect greater exposure to higher fall risk circumstances. Physical activities may displace the body's center of gravity and balance predisposing one to a fall. This acute risk of a fall during physical activity appears to be greatest in the young old. On the other hand, the greater risk of falling among oldest men at lower physical activity levels may reflect a combination of poor muscle strength and balance, functional impairment and poor health status which place them at a higher risk of falls. To our knowledge, no previous study identified this important interaction with age and fall risk. However, our results are consistent with a previous randomized clinical trial which showed

that among individuals with poor baseline physical function (e.g., perhaps older individuals), the risk of falls decreased for exercise participants. But, among those with better baseline physical function (e.g., perhaps younger individuals), the exercise intervention led to an increased risk of falling ²⁴.

Our results suggest that fall prevention strategies aimed at reducing the incidence of falls need to take into consideration the age of the patient. Among the young-old, care must be taken to select physical activities that do not expose individuals to a higher risk of falls. For the oldest old, interventions aimed at increasing active EE or time spent in moderate activities >30 minutes a day may reduce fall risk.

For fractures, we found no evidence of an interaction with age suggesting that although more active younger men fall more, there was no increase in fractures. Among the total population, men with the lowest levels of total EE, active EE and moderate activity were at a 70-80% increased risk of fracture, independent of age, BMD, fall history, health status, body weight and other important variables. The observation that total EE was important suggests that any EE may help to lower fracture risks. Most previous studies typically quantified leisure time or recreational activities which ignore large components of total EE. For approximately every 400 kcal/d increase inactive EE there was about a 20% lower risk of fracture. These results are novel and important since our population of men was considerably older than men from other prospective studies

Our results suggest that active EE of approximately 200 kcal/day or 30 minutes of moderate activity may reduce the risk of fracture. These results lend further support to federal exercise guidelines that endorse moderate intensity activities for at least 30 minutes on most days or preferably all days of the week ²⁶. Evidence of the applicability of these guidelines to the oldest old is sparse but important given their high prevalence of sedentary lifestyles. These activity levels are attainable in most older people. Activities such as walking 3 mph, bowling, golfing with a cart, vacuuming or car washing are all activities that meet this criteria and could be incorporated into older people's lifestyle.

Prospective studies have also examined physical “inactivity” defined as time spent reading, watching television or sitting and found that greater amounts of sedentary activity were associated with an increased risk of hip fracture ^{27, 28}. Consistent with these observations, men with the least sedentary activity had about a 30% lower risk of fracture. Approximately each 90 minute increase in sedentary activity was associated with about a 20% increase in fracture.

Our study is limited by its observational design. Randomized clinical trials provide the strongest evidence about the causal relationship between an exposure e.g., PA and fracture risk. The Lifestyle Intervention and Independence for Elders (LIFE) Study is a phase 3 randomized trial of 1600 sedentary older persons followed for an average of 3.7 years ²⁹. This study will test whether a supervised moderate intensity PA program reduces mobility disability and fall injuries but the study is not powered to show a decrease in fractures. A fracture trial would be cost-prohibitive, requiring a very large sample size and many years of follow-up. For example, to observe a 20% decrease in hip fracture risk, a 5 year trial would need to enroll about 35,000 men in each group ⁷. A. Bradford Hill summarized several criteria that guide the consideration of causality ³⁰. The observation that increased PA reduces fracture risk meets several of these criteria: strength and dose response of the association (70-80% reduced risk); consistency across many different activity variables; temporal sequence of events (prospective design of our study) and biological plausibility (improved BMD, muscle strength, physical performance and balance).

The primary limitation of observational studies is the inability to balance confounding variables across activity groups. Health status is the most important confounder of the association between PA and fractures. “Healthier” individuals are more active because they chose to and because they are capable of participating. Indeed, a greater proportion of men who had the highest EE reported excellent/very good health status. Nevertheless, 80% of the least active men also reported very good to excellent health status. We adjusted for health status, age and other important confounding variables in our multivariate model and our results remained statistically significant.

There are a number of strengths to our study. We objectively measure PA using state of the art monitors in almost 3000 men with an average age of 79 years and followed these men for 3.5 years with 95% complete follow-up. We collected detailed information about potential confounders. There are, however, additional limitations. We studied a cohort of generally healthy men who were able to return for clinic visits and wear a activity monitor for a mean of 5 days. Therefore, our results may not be generalizable to sicker, older men or women. Hip fractures are the most devastating type of fracture and we were unable to examine hip fractures alone. However, non-spine fractures account for 80% of all osteoporotic fractures. A recent report from Norway showed stronger associations between leisure time and fractures at weight bearing sites⁸ but we had too few fractures to stratify by weight bearing status. Because of our observational design, there could still be residual confounding by unmeasured factors. We assessed falls every 4 months and may have, therefore, underreported the true incidence of falls. Finally, more accurate recall of falls may vary by activity level. This could lead to misclassification of fall status and would tend to bias our results to the null.

In conclusion, age modifies the association between PA and falls. Higher activity places men <80 yrs at greater risk of falling but oldest old (≥ 80 yrs) men, at a lower risk of falling. Interventions to reduce falls need to be tailored for specific age groups. Men who maintained active EE >200 kcal/day or 30 min/day of moderate activity had a reduced risk of fracture. Our results extend existing PA guidelines to the oldest-old, the fastest growing proportion of those over age 65.

Acknowledgments

Jane A. Cauley: Grants/Funds, NIH (NIAMS/NIA)

Stephanie L. Harrison: Employed by CPMC

Kristine E. Ensrud: Grants/Funds, NIH; Consultant, DMSB for Merck Sharpe & Dohme

Funding: 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 (NIAMS), the National Institute on Aging (NIA), the National Center for Research Resources (NCRR), and NIH Roadmap for Medical Research under the following grant numbers: U01 AR45580, U01 AR45614, U01 AR45632, U01 AR45647, U01 AR45654, U01 AR45583, U01 AG18197, U01-AG027810, and UL1 RR024140.

Sponsor's Role: None

Appendix

* Ineligible for activity monitor: 32, cognitive impairment; 36, physical, medical problem; 9, no device/scheduling problem; 10, right arm disability/amputation; 45, oxygen use; 26, oxygen use by spouse, household member; 30, pacemaker; 54, other.

Appendix, Figure 1.

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Figure 1.

Proportion of men who fell at least once over 12 months of follow-up stratified by age, < 80 years and men ≥ 80 years.

Table 1

Characteristics of men in the total population and across quintiles of total energy expenditure (EE) with tests for linear trend.

	All Subjects N=2731	Total EE Expenditure (kcal/d)					p-trend
		Q1 (<1944.4)	Q2 (1944.4 - 2162.0)	Q3 (2162.0 - <2377.2)	Q4 (2377.2 - 2661.2)	Q5 (>2661.2)	
Age (years), mean (+/- SD)	78.9 (5.1)	82.8 (5.4)	80.1 (5.0)	78.4 (4.4)	77.0 (4.0)	76.2 (3.6)	<0.001
White, n (%)	2468 (90.4)	468 (85.7)	489 (89.7)	497 (90.9)	509 (93.2)	505 (92.3)	<0.001
BMI (kg/m ²), mean (+/- SD)	27.2 (3.7)	25.4 (3.1)	26.8 (3.4)	27.3 (3.5)	27.9 (3.9)	28.4 (3.9)	<0.001
Weight (kg), mean (+/- SD)	82.0 (13.1)	71.9 (9.5)	79.6 (10.3)	82.5 (11.5)	85.5 (13.2)	89.3 (13.4)	<0.001
Height (cm), mean (+/- SD)	173.6 (6.8)	168.3 (5.3)	172.2 (5.7)	173.8 (5.9)	176.2 (6.4)	177.3 (6.7)	<0.001
Total hip BMD, mean (+/- SD)	0.95 (0.14)	0.88 (0.14)	0.94 (0.13)	0.96 (0.14)	0.97 (0.13)	1.00 (0.14)	<0.001
Alcohol (drinks/wk)	2.9 (1.3)	2.8 (1.3)	2.8 (1.2)	3.0 (1.2)	3.0 (1.2)	3.0 (1.3)	<0.01
Gait speed (m/s)	1.14 (0.23)	1.1 (0.2)	1.1 (0.2)	1.2 (0.2)	1.2 (0.2)	1.2 (0.2)	<0.001
Total body lean mass (kg)	55.9 (7.1)	49.2 (4.9)	54.0 (5.3)	56.0 (5.7)	58.7 (6.4)	61.1 (6.8)	<0.001
Appendicular lean mass (kg)	23.6 (3.4)	20.4 (2.3)	22.6 (2.5)	23.6 (2.7)	25.0 (3.1)	26.1 (3.3)	<0.001
Diabetes, n (%)	416 (15.2)	91 (16.7)	105 (19.3)	81 (14.8)	74 (13.6)	65 (11.9)	<0.01
Fracture history, n (%)	718 (26.4)	153 (28.0)	156 (28.6)	149 (27.4)	128 (23.6)	132 (24.2)	0.03
Comorbidities* (1+), n (%)	2173 (79.6)	469 (85.9)	445 (81.7)	419 (76.6)	439 (80.4)	401 (73.3)	<0.001
Teng 3MS (0-100), mean (+/- SD)	97.2 (6.0)	90.1 (8.0)	92.1 (6.2)	93.5 (5.1)	94.0 (4.3)	93.9 (5.0)	<0.001
Smoke, n (%)	51 (1.9)	13 (2.4)	12 (2.2)	9 (1.7)	8 (1.5)	9 (1.7)	0.23
Health status, n (%)							
Excellent/Very good	2394 (87.8)	434 (79.6)	464 (85.3)	488 (89.4)	497 (91.0)	511 (93.4)	<0.001
PASE score, mean (+/-SD)	135.9 (67.2)	99.7 (60.0)	123.8 (61.5)	142.6 (61.7)	147.6 (66.8)	165.7 (67.0)	<0.001
Active EE (kcal/d), mean (+/-SD)	500.8 (380.5)	171.0 (116.9)	286.3 (144.2)	436.5 (193.7)	581.4 (229.2)	1027.5 (395.5)	<0.001
Minutes (m/d), mean (+/-SD)							
Sedentary activity	1235.4 (92.6)	1305.4 (58.6)	1278.2 (60.7)	1244.5 (68.3)	1214.7 (74.1)	1134.2 (90.3)	<0.001
Moderate activity	82.6 (59.8)	35.3 (25.5)	53.0 (31.0)	75.9 (39.2)	94.5 (44.5)	154.2 (66.1)	<0.001
Vigorous activity	10.8 (12.7)	4.2 (5.0)	6.3 (6.3)	9.4 (8.6)	12.5 (11.5)	21.6 (18.6)	<0.001

* Self-report of a physician diagnosed cardiovascular disease, hypertension, diabetes, chronic obstructive pulmonary disease, Alzheimer's disease, Parkinson's disease, kidney or liver disease and non-skin cancers.

Table 2

Objective energy expenditure and physical activity by falls and non-spine fracture status.

	No Falls (n=1937)	1 Fall (n=379)	2 or more Falls (n=380)	p-value	p-trend
Total EE (Kcal/d)					
Mean (SD)	2365.7 (427.0)	2346.3 (434.8)	2304.0 (445.5)	< 0.01	0.01
Median	2323.2	2286.2	2228.3		
Active EE (Kcal/d)					
Mean (SD)	513.2 (380.4)	504.8 (390.6)	453.9 (371.4)	< 0.01	0.01
Median	419.4	392.4	360.2		
Sedentary (min/day)					
Mean (SD)	1231.7 (91.9)	1236.3 (93.5)	1246.9 (94.3)	< 0.05	0.01
Median	1245.6	1246	1259.8		
Moderate (min/day)					
Mean (SD)	84.4 (59.8)	83.9 (61.5)	75.0 (58.3)	< 0.01	0.05
Median	71.6	69.2	62.5		
Fracture					
	NO (n=2545)	YES (n=186)	p-value		
Total EE (Kcal/d)					
Mean (SD)	2356.6 (433.6)	2270.8 (400.3)	0.01		
Median	2310.8	2170.3			
Active EE (Kcal/d)					
Mean (SD)	506.3 (383.4)	425.7 (330.4)	0.002		
Median	411.4	328.3			
Sedentary (min/day)					
Mean (SD)	1234.2 (92.8)	1250.9 (88.5)	0.02		
Median	1246.8	1264.4			
Moderate (min/day)					
Mean (SD)	83.3 (60.1)	72.5 (55.0)	0.02		
Median	70	59.8			

Table 3
Relative Risk (RR) of falling across quintiles of objective physical activity stratified by age.

	Age <80					Age 80				
	N (%)	RR ¹ (95% CI)	RR ² (95% CI)	N (%)	RR ¹ (95% CI)	RR ² (95% CI)	N (%)	RR ¹ (95% CI)	RR ² (95% CI)	p-interaction
Total EE (kcal/d)										
Q1 (<1975.0)	40 (10.0)	1.04 (0.66, 1.64)	0.78 (0.44, 1.37)	134 (37.3)	1.07 (0.63, 1.83)	1.24 (0.70, 2.21)				0.50
Q2 (1975.0 - <2201.6)	64 (16.0)	0.87 (0.59, 1.26)	0.71 (0.47, 1.09)	100 (27.9)	1.17 (0.69, 1.99)	1.30 (0.75, 2.25)				
Q3 (2201.6 - <2407.4)	77 (19.3)	0.66 (0.47, 0.94)	0.57 (0.40, 0.80)	60 (16.7)	0.81 (0.47, 1.40)	0.92 (0.52, 1.61)				
Q4 (2407.4 - <2683.2)	93 (23.3)	0.69 (0.50, 0.95)	0.65 (0.47, 0.90)	41 (11.4)	1.11 (0.61, 2.00)	1.07 (0.60, 1.91)				
Q5 (>2683.2)	126 (31.5)	Ref	Ref	24 (6.7)	Ref	Ref				
P trend		0.93	0.27			0.63			0.27	
Active EE (kcal/d)										
Q1 (<190.6)	58 (14.5)	0.94 (0.62, 1.41)	0.75 (0.48, 1.19)	131 (36.5)	1.67 (1.05, 2.65)	1.43 (0.90, 2.26)				0.02
Q2 (190.6 - <323.8)	55 (13.8)	0.63 (0.41, 0.96)	0.53 (0.36, 0.79)	80 (22.3)	1.13 (0.69, 1.85)	1.11 (0.68, 1.79)				
Q3 (323.8 - <507.8)	73 (18.3)	0.70 (0.49, 1.01)	0.63 (0.44, 0.90)	75 (20.9)	1.10 (0.68, 1.79)	1.12 (0.69, 1.82)				
Q4 (507.8 - <775.0)	100 (25.0)	0.70 (0.51, 0.97)	0.66 (0.48, 0.92)	41 (11.4)	0.97 (0.56, 1.69)	1.00 (0.58, 1.70)				
Q5 (>775.0)	114 (28.5)	Ref	Ref	32 (8.9)	Ref	Ref				
P trend		0.42	0.08			0.01			0.09	
Sedentary activity (mins/day)										
Q1 (>1159.8)	107 (26.7)	1.09 (0.73, 1.63)	1.29 (0.84, 1.99)	36 (10.0)	0.56 (0.35, 0.88)	0.67 (0.42, 1.06)				0.01
Q2 (1159.8 - <1224.8)	94 (23.5)	0.95 (0.63, 1.43)	1.08 (0.69, 1.68)	44 (12.3)	0.62 (0.41, 0.95)	0.78 (0.51, 1.18)				
Q3 (1224.8 - <1269.8)	72 (18.0)	0.95 (0.62, 1.44)	0.98 (0.63, 1.52)	84 (23.4)	0.70 (0.49, 1.01)	0.85 (0.59, 1.22)				
Q4 (1269.8 - <1314.0)	62 (15.2)	0.75 (0.49, 1.17)	0.81 (0.52, 1.28)	82 (22.8)	0.78 (0.55, 1.13)	0.87 (0.60, 1.24)				
Q5 (>1314.0)	65 (16.3)	Ref	Ref	113 (31.5)	Ref	Ref				
P trend		0.36	0.10			0.005			0.08	
Moderate activity (mins/day)										
Q1 (<32.6)	57 (14.3)	0.93 (0.62, 1.40)	0.76 (0.48, 1.20)	122 (34.0)	1.83 (1.21, 2.79)	1.54 (0.99, 2.39)				0.01
Q2 (32.6 - <55.8)	59 (14.8)	0.68 (0.46, 1.01)	0.59 (0.40, 0.87)	86 (24.0)	1.23 (0.80, 1.91)	1.18 (0.77, 1.83)				
Q3 (55.8 - <84.6)	77 (19.3)	0.77 (0.54, 1.11)	0.68 (0.48, 0.98)	67 (18.7)	1.17 (0.74, 1.84)	1.15 (0.73, 1.82)				
Q4 (84.6 - <125.0)	95 (23.8)	0.81 (0.58, 1.14)	0.79 (0.56, 1.10)	44 (12.3)	1.08 (0.64, 1.82)	1.13 (0.69, 1.86)				
Q5 (>125.0)	112 (28.0)	Ref	Ref	40 (11.4)	Ref	Ref				

	Age <80		Age 80		p-interaction
	N (%)	RR ¹ (95% CI)	RR ² (95% CI)	RR ¹ (95% CI)	
P trend		0.42	0.10	0.003	0.06

RR¹= Base model=Adjusted for age, race, clinic, season.
RR²= Multivariate model=Base model + health status, height, weight, smoking, diabetes.

Table 4

Incidence rate(per 1000 person yrs). (95% confidence interval) and hazard ratio (95% confidence interval (CI)) of non-spine fractures across quintiles of objective physical activity.

	Incidence Rate (95% CI)	Base Model HR (95% CI)	MV Model HR (95% CI)
Total EE (kcal/d) per 1SD increase HR=0.86 (0.72, 1.02) p=0.08			
Q1 (<1975.0)	20.2 (12.9, 27.6)	1.59 (0.96, 2.62)	1.71 (0.94, 3.11)
Q2 (1975.0 - <2201.6)	24.8 (17.5, 32.3)	1.56 (0.97, 2.52)	1.70 (1.01, 2.85)
Q3 (2201.6 - <2407.4)	12.7 (7.8, 17.6)	0.84 (0.49, 1.42)	0.90 (0.52, 1.56)
Q4 (2407.4 - <2683.2)	15.9 (9.1, 22.7)	0.99 (0.60, 1.65)	1.00 (0.59, 1.68)
Q5 (2683.2)	16.1 (8.7, 23.4)	Ref	Ref
P trend	---	0.02	0.02
Active EE (kcal/d) per 1SD increase HR=0.80 (0.67, 0.96) p=0.02			
Q1 (<190.6)	29.1 (20.1, 38.0)	2.11 (1.31, 3.40)	1.82 (1.10, 3.00)
Q2 (190.6 - <323.8)	16.2 (10.5, 22.0)	1.16 (0.69, 1.93)	1.02 (0.60, 1.72)
Q3 (323.8 - <507.8)	16.6 (10.8, 22.4)	1.10 (0.66, 1.85)	1.04 (0.62, 1.76)
Q4 (507.8 - <775.0)	16.1 (10.6, 21.5)	1.25 (0.76, 2.06)	1.20 (0.72, 2.00)
Q5 (775.0)	18.0 (8.6, 27.5)	Ref	Ref
P trend	---	0.004	0.04
Sedentary activity (min/d) per 1SD increase HR=1.20 (1.02, 1.42) p=0.03			
Q1 (<1159.8)	15.7 (9.5, 21.8)	0.64 (0.40, 1.04)	0.72 (0.43, 1.20)
Q2 (1159.8 - <1224.8)	14.1 (8.7, 19.4)	0.58 (0.36, 0.94)	0.65 (0.39, 1.08)
Q3 (1224.8 - <1269.8)	20.4 (13.7, 27.4)	0.76 (0.49, 1.17)	0.83 (0.53, 1.30)
Q4 (1269.8 - <1314.0)	20.9 (14.0, 27.7)	0.82 (0.54, 1.26)	0.93 (0.60, 1.42)
Q5 (1314.0)	23.2 (16.0, 30.4)	Ref	Ref
P trend	---	0.02	0.09
Moderate activity (min/d) per 1SD increase HR=0.83 (0.70, 0.98) p=0.03			
Q1 (<32.6)	27.3 (19.2, 35.4)	1.84 (1.15, 2.92)	1.70(1.03, 2.80)
Q2 (32.6 - <55.8)	14.9 (9.6, 20.3)	1.05 (0.63, 1.75)	0.96 (0.56, 1.62)
Q3 (55.8 - <84.6)	21.0 (14.4, 27.6)	1.29 (0.80, 2.09)	1.25 (0.76, 2.04)
Q4 (84.6 - <125.0)	14.7 (9.3, 20.1)	1.02 (0.61, 1.69)	1.01 (0.60, 1.70)
Q5 (125.0)	18.3 (9.2, 27.4)	Ref	Ref
P trend	---	0.01	0.07

Base model=Adjusted for age, race, clinic, season. Ref=referent.

Multivariate model=Base model + health status, height, weight, smoking, diabetes, fracture history, BMD total hip.