Trochanteric Soft Tissue Thickness and Hip Fracture in Older Men

Carrie M. Nielson, Mary L. Bouxsein, Sinara S. Freitas, Kristine E. Ensrud, and Eric S. Orwoll, for the Osteoporotic Fractures in Men (MrOS) Research Group

Bone and Mineral Unit (C.M.N., E.S.O.), Department of Medicine, Oregon Health and Science University, Portland, Oregon 97239-3098; Orthopedic Biomechanics Laboratory (M.L.B.), Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, Massachusetts 02215; Department of Medicine (S.S.F.), Federal University of Parana, Curitiba, Parana, Brazil 80060-000; and Department of Medicine (K.E.E.), Veterans Affairs Medical Center, Minneapolis, Minnesota 55417

Background: Greater thickness of the tissue extending laterally from the greater trochanter has been associated with a lower risk of hip fracture in women. The effect of trochanteric soft tissue thickness on the risk of incident hip fracture has not been evaluated in men.

Methods: We measured trochanteric soft tissue thickness by dual-energy x-ray absorptiometry for all incident hip fracture cases (n = 70) and 222 randomly selected noncases in older men (≥65 yr) enrolled in the Osteoporotic Fractures in Men (MrOS) Study. Differences in tissue thickness between cases and controls were examined. Changes in fall force and factor-of-risk (the ratio of force from a sideways fall to femoral bone strength) associated with tissue thickness were determined. The relative risk for incident hip fracture per SD decrease in tissue thickness was calculated.

Results: Mean trochanteric soft tissue thickness did not differ significantly between cases and noncases (29.1 ± 11.9 vs 31.0 ± 11.5 mm; $P = 0.2$). Although increased tissue thickness reduced both the estimates of fall force and the factor-of-risk, tissue thickness was not associated with the risk of hip fracture (age- and bone mineral density-adjusted relative risk per SD decrease in tissue thickness = 0.90; 95% confidence interval, 0.70–1.16).

Conclusions: In this study of elderly community-dwelling men, we found no significant association between trochanteric soft tissue thickness and incident hip fracture. Trochanteric soft tissue thickness in these men was less than previously reported in older women and may explain the difference between these results and those reported in women. **(*J Clin Endocrinol Metab* 94: 491–496, 2009)**

Hip fracture is a significant cause of disability and mortality among elderly men and women (1) and results in substantial direct and indirect health care costs (2). Risk factors for hip fracture in women have been extensively reported, but less is known about the factors leading to hip fracture in men. Low body mass index (BMI) has been associated with a higher risk of hip fracture in both men and women (3). The apparent risk of low BMI might be explained by factors such as lower muscle mass, nutritional deficiencies, and lower endogenous estrogen levels, which can affect bone mineral density (BMD) or falls (3). It has also been postulated that a greater thickness of soft tissue surrounding the hip might act as a buffer for fall forces that can lead to fracture (4).

Trochanteric soft tissue thickness is a measure of the lean and fat tissue that extends laterally from the greater trochanter. A recent case-control study in postmenopausal women demonstrated that lower trochanteric soft tissue thickness was associated with greater risk of hip fracture and that lower trochanteric soft tissue thickness increased the estimated force applied to the proximal femur in a sideways fall and consequently increased the factor-of-risk as well (5). The factor-of-risk is the ratio of the force applied to the proximal femur during a sideways fall to

ISSN Print 0021-972X ISSN Online 1945-7197
Printed in U.S.A.

doi: 10.1210/jc.2008-1640 Received July 28, 2008. Accepted November 6, 2008.
First Published Online November 18, 2009

Abbreviations: aBMD, Areal BMD; BMD, bone mineral density; BMI, body mass index; CI, confidence interval; CV, coefficients of variation; DXA, dual energy x-ray absorptiometry; N, Newtons; QCT, quantitative computed tomography; RR, relative risk.

femoral bone strength (6). The force exerted on the proximal femur during a fall depends on an individual's height and weight, such that those with a higher center of gravity (*i.e.* height) and greater weight would be expected to apply a greater force to the proximal femurs during a sideways fall onto the hip (7). However, the force applied to the proximal femur will also depend on the extent of force attenuation afforded by trochanteric soft tissues (8). Therefore, thickness of trochanteric soft tissue might influence the factor of risk for hip fracture.

To determine the association between tissue thickness and hip fracture in men, we measured trochanteric soft tissue thickness by dual energy x-ray absorptiometry (DXA) among a subset of men in the Osteoporotic Fractures in Men (MrOS) Study. We evaluated the change in fall force and factor-of-risk estimates after adjustment for trochanteric soft tissue thickness and examined the association of trochanteric soft tissue thickness with incident hip fracture. We also evaluated the precision of trochanteric soft tissue thickness measures using DXA and the relationship of DXA tissue thickness to that determined from quantitative computed tomography (QCT).

Subjects and Methods

Study population

The MrOS Study enrolled 5995 men at six U.S. clinical centers (Birmingham, AL; Minneapolis, MN; Palo Alto, CA; Pittsburgh, PA; Portland, OR; and San Diego, CA) from March 2000 through April 2002. Eligible participants were at least 65 yr of age, were able to walk without assistance from another person, and had not had bilateral hip replacement surgery. All MrOS participants completed the baseline self-administered questionnaire and attended the baseline visit during which skeletal, anthropometric, and other measures were obtained. Details of the MrOS recruitment and study design have been published (9, 10). The institutional review board at each site approved the study protocol, and written informed consent was obtained from all participants.

This study of tissue thickness and hip fracture included all men who suffered a hip fracture in the follow-up period (from March 2000 through August 2006) and a sample of randomly selected participants without fracture.

Ascertainment of hip fractures

A triannual mail or phone questionnaire was used to obtain information concerning the occurrence of fractures. Ninety-nine percent of surviving men were successfully contacted. All reported hip fractures were verified centrally by physician adjudicators through medical records and radiographic report or examination of x-rays. The degree of trauma associated with the fracture was categorized into six levels, from least (fall from a standing height or less) to most traumatic (severe trauma other than a fall).

Assessment of body composition and BMD

Height (in centimeters) was measured using a Harpenden stadiometer. Participants were weighed (in kilograms) on balance beam or digital scales while wearing indoor clothing except shoes. BMI was calculated as kilograms per meter^2. BMD was measured in the proximal femur using DXA measured by Hologic QDR 4500 densitometers (Hologic Inc., Bedford, MA). Total body lean and total body fat were also assessed by DXA. Quality assurance procedures for DXA scans conducted at MrOS study sites have been reported (10). QCT scans were obtained as previously reported (11) using a standardized protocol for scanning the pelvic region from the femoral head to 3.5 cm below the lesser trochanter at settings of 80 kVp, 280 mA, 3-mm slice thickness, and 512 × 512 matrix in spiral reconstruction mode. Calibration standards with known hydroxyapatite concentrations (150, 75, and 0 mg/cm^3; Image Analysis, Inc, Columbia, KY) were included with the participant in each scan. All scans were transferred to the University of California, San Francisco for central quality review.

Trochanteric soft tissue thickness measurements

One clinician (S.S.F.) completed all trochanteric soft tissue thickness measurements and was blinded to fracture status. The thickness of soft tissue overlying the greater trochanter was assessed manually from whole body DXA scans, as previously reported (5). Briefly, in the whole-body analysis algorithm, the image brightness and contrast were adjusted as necessary to fully visualize the air background, soft tissue, and bone in the femoral region. The "trochanteric level" was determined by selecting the upper line that defines the pelvic triangle in the Hologic analysis algorithm and moving it down until it bisects the lateral most aspects of the greater trochanter on both sides of the image. At this level, bilateral trochanteric soft tissue thickness was assessed by using the Hologic scale to measure the distance (in millimeters) between the most lateral aspect of the greater trochanter and the lateral aspect of the skin-air boundary. The measures on the right and left sides differed little, if at all, within participant, and the average soft tissue thickness was used for subsequent analysis.

To assess the precision of the DXA measurement, 10 non-MrOS subjects (of a variety of body types) had whole body DXA scans performed three times. Scans were randomized, and trochanteric soft tissue thickness was blindly measured. Each scan was also blindly analyzed on three different occasions to test the reproducibility of the analyzer. Mean coefficients of variation (CV) were calculated for both interscan and intraanalyzer repeated measurements. One person performed all measurements.

Trochanteric soft tissue thickness was also measured from baseline QCT images among a subset of 30 MrOS participants. From the CT images, the most lateral point of the greater trochanter was determined, and the distance from it to the skin surface was determined. Soft tissue thickness was also measured in these men using baseline DXA images as described above. The Pearson correlation between QCT and DXA measurements for these 30 participants was calculated.

Calculation of femoral strength, fall force, and factor-of-risk

Femoral strength in a sideways fall, peak force, and factor-of-risk for hip fracture, as well as their estimates after adjustment for trochanteric soft tissue thickness, were calculated as previously described (5). Briefly, femoral strength in a sideways fall configuration was estimated from the linear regression between trochanteric areal BMD (aBMD) and femoral failure load, as determined from mechanical testing in cadaveric specimens (5).

The peak force applied to the hip during a sideways fall was estimated using information from previously published studies describing the kinematics of sideways falls and femoral impact forces during these falls (7, 12, 13). Accordingly, the peak force applied to the hip was calculated knowing each subject's height and weight and assuming a sideways fall from standing height. The force applied to the femur is actually less than the peak force because it is attenuated by trochanteric soft tissues. Thus, we also computed an "attenuated force" using the observation that the peak force applied to the hip is reduced linearly with increasing trochanteric soft tissue (8).

We computed the factor-of-risk for hip fracture (Φ) as the ratio of the applied force to estimated femoral strength in a sideways fall. The factor of risk was calculated using both the peak force (Φ_{peak}) and the attenuated force (Φ_{atten}) estimates.

Statistical analysis

Distributions of baseline characteristics among men with and without incident hip fractures were compared using χ^2 tests for categorical

TABLE 1. Baseline characteristics of men with incident hip fracture and randomly selected noncase cohort members

	Hip fracture cases (n = 70)	Non-cases (n = 222)	*P*
Age (yr)	79.7 ± 6.0	74.2 ± 6.1	<0.0001
White, non-Hispanic (%)	94.3	89.6%	0.2
Height (cm)	172.1 ± 6.2	174.0 ± 6.9	0.03
Weight (kg)	79.0 ± 12.8	83.6 ± 13.1	0.009
BMI (kg/m^2)	26.6 ± 3.9	27.6 ± 3.6	0.07
Total body fat (kg)	20.7 ± 7.3	21.9 ± 6.9	0.2
Total body lean (kg)	54.2 ± 6.6	57.2 ± 7.3	0.001
Total % fat	26.2 ± 5.9	26.3 ± 5.1	0.9
Leg fat mass (kg)	3.02 ± 1.32	3.02 ± 1.15	1.0
Leg lean mass (kg)	8.43 ± 1.17	8.93 ± 1.26	0.004
Leg % fat	24.6 ± 7.1	23.6 ± 5.8	0.3
History of fracture at baseline (%)	44.3	18.5	<0.0001
History of falls within past 12 months at baseline (%)	28.6	21.6	0.2
Femoral neck aBMD (g/cm^2)	0.64 ± 0.12	0.79 ± 0.13	<0.0001
Total hip aBMD (g/cm^2)	0.78 ± 0.14	0.96 ± 0.14	<0.0001
Trochanteric soft tissue thickness (mm)	29.1 ± 11.9	31.0 ± 11.5	0.2
Estimated femoral strength (N)	4235 ± 925	5332 ± 921	<0.001
Peak fall force (N)	7821 ± 697	8096 ± 728	0.005
Attenuated fall force (N)	5752 ± 725	5893 ± 712	0.2
Factor-of-risk, peak	1.99 ± 0.88	1.56 ± 0.27	0.0001
Factor-of-risk, attenuated	1.47 ± 0.73	1.13 ± 0.22	0.0003

Values are mean ± SD for continuous variables and percentages for categorical variables. *P* value is for unpaired *t* test of difference in means for continuous variables and difference of proportions for categorical variables.

variables and *t* tests for continuous variables. Relationships between trochanteric soft tissue thickness and other variables were determined using Pearson correlations. The log-binomial model was used to estimate the relative risk (RR) of a 1 SD decrease in trochanteric soft tissue thickness and the related biomechanical measures, adjusted for age. RRs for total hip BMD and femoral neck BMD were also calculated for comparison to these hypothesized risk factors. RRs were examined after additional adjustment for potential confounders, including clinical site, femoral neck and total hip BMD, height, weight, history of falls at baseline and calculated fall forces to determine whether these covariates altered the RR estimates for trochanteric soft tissue thickness or the related biomechanical measures by at least 10%.

Secondary analyses were performed to evaluate differences in trochanteric soft tissue thickness when hip fractures were 1) subdivided into femoral neck fractures and intertrochanteric fractures, and 2) limited to those associated with a fall from standing height or less. All analyses were conducted with SAS statistical software (SAS Institute, Inc. Cary, NC).

Results

Of the 5995 men enrolled in MrOS, 76 subjects had an incident hip fracture during an average of 4.6 yr of follow-up. Six hip fracture cases were excluded from this analysis because they had not undergone whole body DXA scans at baseline. Most (77.1%) hip fractures occurred with a fall from standing height or less. Baseline characteristics of the MrOS participants with hip fracture (n = 70) and the randomly selected comparison group (n = 222) are presented in Table 1. Men who sustained a hip fracture, compared with those who did not, were older, shorter, and weighed less. However, BMI was only slightly lower in cases than in noncases (26.6 *vs.* 27.6 kg/m^2; $P = 0.07$). Cases were more likely than noncases to have had a history of fracture at baseline (44.3 *vs.* 18.5%; $P < 0.0001$), but history of falls within the previous 12 months was not significantly different. Cases had lower total hip BMD and femoral neck BMD (both $P < 0.0001$).

There was considerable variation in tissue thickness in these men (range, 13.3–78.0 mm). As expected, trochanteric soft tissue thickness was strongly positively correlated with weight, BMI, and total body fat (Table 2). It was also moderately positively correlated with total body lean mass ($r = 0.43$; $P < 0.0001$) but was not correlated with height. Correlations with leg fat and lean mass were similar to those with total body fat and lean mass. The reproducibility of trochanteric soft tissue thickness measures was high (intraanalyzer CV, 2.6%; and interscan CV, 6.4%). Tissue thickness measures by DXA were highly correlated to those by QCT ($r = 0.80$; $P < 0.0001$; Fig. 1).

TABLE 2. Correlations between trochanteric soft tissue thickness and related variables

	Trochanteric soft tissue thickness (mm)	
	Pearson	*P* value
Age (yr)	−0.16	0.006
Average height (cm)	0.06	0.3
Weight (kg)	0.66	<0.0001
BMI (kg/m^2)	0.75	<0.0001
Total body fat (kg)	0.75	<0.0001
Total body lean (kg)	0.43	<0.0001
Total % fat	0.65	<0.0001
Leg fat mass (kg)	0.81	<0.0001
Leg lean mass (kg)	0.43	<0.0001
Leg % fat	0.69	<0.0001
Total hip aBMD (g/cm^2)	0.23	<0.0001
Femoral neck aBMD (g/cm^2)	0.22	0.0002
Trochanteric aBMD (g/cm^2)	0.14	0.02
Estimated femoral strength (N)	0.13	0.02
Peak fall force (N)	0.58	<0.0001
Attenuated fall force (N)	−0.56	<0.0001
Factor-of-risk, peak	0.04	0.48
Factor-of-risk, attenuated	−0.30	<0.0001

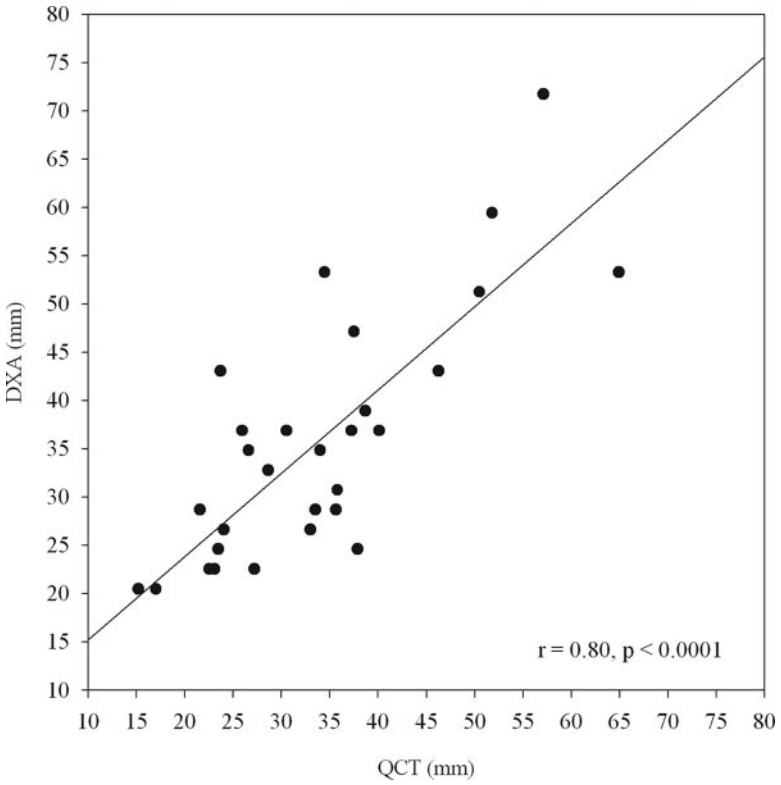

FIG. 1. Correlation between trochanteric soft tissue thickness assessed by whole-body DXA and QCT.

Trochanteric soft tissue thickness was not significantly lower in the men who had an incident hip fracture *vs.* those who did not (29.1 *vs.* 31.0 mm; $P = 0.2$; Table 1). The age-adjusted RR of any hip fracture per 1 SD decrease in trochanteric soft tissue thickness was 1.01 [95% confidence interval (CI), 0.78–1.30] (Table 3). In the 38 men with femoral neck fractures, the average tissue thickness (31.5 ± 14.0 mm) was also not different from that in the nonfractured men (31.0 mm), and the RR for femoral neck fracture was 0.82 (95% CI, 0.61–1.12). However, men with intertrochanteric fractures (n = 26) had significantly lower trochanteric soft tissue thickness than controls (26.3 ± 7.8 *vs.* 31.0 ± 11.5 mm, respectively; $P = 0.009$). Nevertheless, the RR per SD decrease in trochanteric soft tissue thickness for intertrochanteric fracture was not statistically significant (1.42; 95% CI, 0.80–2.50). After adjustment for femoral neck BMD, the RR associated with an increase in trochanteric soft tissue thickness was 0.90 (95% CI, 0.70–1.16) for all hip fractures, 1.20 (95% CI, 0.66–2.16) for intertrochanteric fractures, and 0.80 (95% CI, 0.59–1.08) for femoral neck fractures. The age-adjusted RR for hip fractures associated with a fall from a standing height or less was 0.95 (95% CI, 0.71–1.26). With age and BMD adjustment, the RR was 0.86 (95% CI, 0.65–1.14). Additional adjustment for potential confounders, including height, weight, BMI, history of falls, and body composition measures, did not appreciably alter the associations between trochanteric soft tissue thickness and hip fracture.

Before adjustment for trochanteric soft tissue thickness, the predicted fall force was lower in cases than controls, although the factor-of-risk (the ratio of fall force to femoral strength) was significantly higher in cases (Table 1). After adjusting for soft tissue thickness, attenuated fall force was reduced in both groups and was no longer different between cases and controls, but the factor-of-risk remained significantly higher in cases than controls. The difference between peak fall force and attenuated fall force (fall force adjusted for tissue thickness) was 2069 Newtons (N) (−26.5%) in cases and 2203 N (−27.2%) in controls.

Neither the fall force nor the attenuated fall force was associated with hip fracture risk. RRs for a 1 SD increase in peak and attenuated factor-of-risk were also similar to each other (1.10 and 1.09, respectively; $P < 0.001$), and their association with hip fracture risk was not statistically significant after adjustment for femoral neck BMD or additional potential confounders (Table 3).

Discussion

In this study of community-dwelling older men, there was no association between trochanteric soft tissue thickness and all incident hip fractures. Interestingly, however, trochanteric soft tissue thickness was significantly lower among men with inter-

TABLE 3. RRs and 95% CI for hip fracture

	RR (95% CI) adjusted for age	RR (95% CI) adjusted for age and femoral neck BMD
Femoral neck aBMD[a]	2.00 (1.59–2.53); $P < 0.0001$	
Total hip aBMD[a]	1.82 (1.49–2.21); $P < 0.0001$	
Trochanteric soft tissue thickness[a]	1.01 (0.78–1.30); $P = 1.0$	0.90 (0.70–1.16); $P = 0.4$
Weight (kg)[a]	1.07 (0.81–1.41); $P = 0.6$	0.85 (0.65–1.13); $P = 0.3$
BMI (kg/m^2)[a]	1.03 (0.79–1.33); $P = 0.8$	0.83 (0.64–1.08); $P = 0.2$
Estimated femoral strength[b]	0.57 (0.47–0.69); $P < 0.0001$	0.83 (0.57–1.22); $P = 0.3$
Peak force[b]	0.92 (0.70–1.21); $P = 0.6$	1.14 (0.86–1.50); $P = 0.4$
Attenuated force[b]	0.94 (0.74–1.20); $P = 0.6$	0.99 (0.77–1.28); $P = 1.0$
Factor-of-risk, peak[b]	1.10 (1.05–1.15); $P < 0.0001$	0.97 (0.89–1.05); $P = 0.4$
Factor-of-risk, attenuated[b]	1.09 (1.04–1.14); $P = 0.0002$	0.96 (0.89–1.04); $P = 0.4$

[a] RR for a 1 SD decrease.

[b] RR for a 1 SD increase.

trochanteric hip fractures compared with nonfractured controls, but the age-adjusted RR associated with soft tissue thickness was not statistically significant. Thus, in men trochanteric soft tissue thickness appears to have little influence on the risk of hip fracture.

These results contrast with those from a recent study of postmenopausal women (5) in which greater trochanteric soft tissue thickness attenuated hip fracture risk. As expected, the mean thickness observed in this study was far lower than that found in women. Among older women, trochanteric tissue thickness measured using the same DXA-based technique used in the present study averaged 40.4 mm for cases and 49.8 mm for controls (5), whereas in our study of men the mean tissue thickness was approximately 30 mm. Accordingly, adjustment for trochanteric soft tissue thickness in men resulted in much smaller decrements in fall force than those reported in women. Reductions in fall force of 50% in female cases and 61% in controls (5) exceeded the 26 and 27% reductions for male fracture and nonfracture cases, respectively, that we observed. Hence, in contrast to women in the previous study, the thickness of trochanteric soft tissue observed in this sample of men may not be great enough to reduce the forces applied to the hip during a fall meaningfully. In addition, the relative proportion of fat and lean tissue over the trochanter may differ in men and women, and as a result the attenuation of force may be affected. These results may have important implications for the understanding of hip fracture causation in men and women.

The calculations of femoral strength, peak force, and factor-of-risk were made with the assumption of a sideways fall. This type of fall is associated with the greatest risk for hip fracture in the elderly (14, 15). Few hip fractures in the current study occurred due to trauma more severe than a fall from standing height or less, and excluding these cases did not alter our conclusions.

We found that men with intertrochanteric fractures had lower trochanteric soft tissue thickness than controls or men with femoral neck fractures had. Although the numbers of cases in each group were small, this finding might be pursued in a larger study. Risk factors for trochanteric and femoral neck fractures have been found to differ among women, and it is suggested that etiologies may be unique for each fracture type (16–19). To our knowledge, differences in trochanteric soft tissue thickness have not been reported between fracture types. This research has implications for etiology and prevention studies of hip fracture in men and women. We found that trochanteric soft tissue thickness, as measured from whole-body DXA scans, is reproducible and comparable to QCT measurements. Mean intraanalyzer CV of three repeated measures (2.6%) was similar to that previously reported using nine repeated DXA measurements (3.7%) (20). Trochanteric soft tissue thickness as measured by DXA has been reported to be highly correlated with that obtained by ultrasound (0.90) (20), and we also found high correlations to measures obtained by QCT (0.80). These data suggest that DXA measures of thickness are precise and accurate, given the limitations of measurements made in the supine position. Although measures of tissue thickness are currently labor intensive, the development of automated techniques may improve the availability of reliable data in large studies.

This study has considerable strengths, including that the parent study, MrOS, is a prospective, longitudinal evaluation of a large number of older men in the United States. This is the first report to our knowledge to evaluate trochanteric soft tissue thickness and hip fracture in men. Furthermore, we demonstrated that DXA-based measures of tissue thickness appear to be precise and accurate. On the other hand, we lacked information on the specific composition of trochanteric soft tissue and its relative effect on the loads encountered in a fall. Moreover, the character of the falls that occurred within the follow-up period are unknown, and they may be an important mediator of the association between hip soft tissue thickness and fracture. Future studies are required to examine these issues.

In summary, these results indicate that trochanteric soft tissue thickness has little effect on the overall risk of hip fractures in men, although men with intertrochanteric fractures did have significantly lower soft tissue thickness than nonfractured controls. Trochanteric soft tissue thickness in this sample of older men is considerably lower than previously reported in women, suggesting that the biomechanical determinants of fracture may be sex specific. This study provides further evidence of the need to understand the risk factors for hip fracture in both sexes.

Acknowledgments

We thank all the participants in the Osteoporotic Fractures in Men Study for their continued participation. We are grateful to Lori C. Lambert, M.A., for her thoughtful comments on the analytic approach.

Address all correspondence and requests for reprints to: Eric S. Orwoll, M.D., Bone and Mineral Unit, Oregon Health and Science University, 3181 SW Sam Jackson Park Road, Mailcode CR113, Portland, Oregon 97239-3098. E-mail: orwoll@ohsu.edu.

The Osteoporotic Fractures in Men (MrOS) Study is supported by National Institutes of Health (NIH) funding. The following institutes provide support: the National Institute of Arthritis and Musculoskeletal and Skin, the National Institute on Aging, the National Center for Research Resources, and NIH Roadmap for Medical Research under the following Grants: U01 AR45580, U01 AR45614, U01 AR45632, U01 AR45647, U01 AR45654, U01 AR45583, U01 AG18197, U01-AG027810, and UL1 RR024140.

Disclosure Statement: M.L.B. has received research, consulting, or speaking support from the Alliance for Better Bone Health, Eli Lilly & Co., Novartis, Merck & Co., GlaxoSmithKline, Roche, and Acceleron Pharma. E.S.O. receives research, consulting, or speaking support from Aventis, Pfizer, Eli Lilly & Co., Novartis, Merck & Co., Procter & Gamble, and GlaxoSmithKline. All other authors have nothing to disclose.

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