Changes in Bone Mineral Density of the Proximal Femur and Spine with Aging

DIFFERENCES BETWEEN THE POSTMENOPAUSAL AND SENILE OSTEOPOROSIS SYNDROMES

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ABSTRACT We measured bone mineral density (BMD) of the proximal femur, lumbar spine, or both by dual photon absorptiometry in 205 normal volunteers (123 women and 82 men; age range 20 to 92 yr) and in 31 patients with hip fractures (26 women and 5 men; mean age, 78 yr). For normal women, the regression of BMD on age was negative and linear at each site; overall decrease during life was 58% in the femoral neck, 53% in the intertrochanteric region of the femur, and 42% in the lumbar spine. For normal men, the age regression was linear also; the rate of decrease in BMD was two-thirds of that in women for femoral neck and intertrochanteric femur but was only one-fourth of that in women for lumbar spine. This difference may explain why the female/male ratio is 2:1 for hip fractures but 8:1 for vertebral fractures. The standard deviation (Z-score) from the sex-specific age-adjusted normal mean in 26 women with hip fracture averaged -0.31 ($P < 0.05$) for the femoral neck, -0.53 ($P < 0.01$) for the intertrochanteric femur, and $+0.24$ (NS) for the lumbar spine; results were similar for 5 men with hip fractures. By contrast, for 27 additional women, ages 51–65 yr, with only nontraumatic vertebral fractures, the Z-score was -1.92 ($P < 0.001$) for the lumbar spine. Thus, contrary to the view that osteoporosis is a single age-related entity, our data suggest the existence of two distinct syndromes. One form, "postmenopausal osteoporosis," is characterized by excessive and disproportionate trabecular bone loss, involves a small subset of women in the early postmenopausal period, and is associated mainly with vertebral fractures. The other form, "senile osteoporosis," is characterized by proportionate loss of both cortical and trabecular bone, involves essentially the entire population of aging women and, to a lesser extent, aging men, and is associated with hip fractures or vertebral fractures or both.

INTRODUCTION

Of the various fractures associated with osteoporosis, those of the proximal femur are by far the most serious. To enhance our understanding of the pathogenesis of this fracture, we need more information on (*a*) the pattern of bone loss from the proximal femur with aging in the general population, (*b*) whether differences in rates of bone loss with age account for differences in the incidence of hip fractures in men and women, (*c*) whether all or only a minority of elderly persons are at risk for fracture because of low bone mineral density (BMD)[1] of the proximal femur, and (*d*) whether patterns of bone loss are similar or dissimilar in patients with hip fracture and with vertebral fracture.

These issues could not be addressed previously because BMD of the proximal femur could not be ac-

Received for publication 12 February 1982 and in revised form 1 June 1982.

[1] *Abbreviations used in this paper*: BMC, bone mineral content; BMD, bone mineral density.

TABLE I
Number of Subjects Having BMD Measurements at Various Measurement Sites

Group	Description	Proximal femur	Lumbar spine and radius
A	Normal	147	205
	Women	95	123
	Men	52	82
B	Hip fracture	31	31
	Women	26	26
	Men	5	5
C	Only vertebral fractures		
	Women	—	84

curately measured. Precise measurement is now possible, however, with our modification (1) of the method of dual photon absorptiometry (2). Thus, we have measured BMD in two regions of the proximal femur and at the lumbar spine, midradius, and distal radius as a function of age in normal women and men and in patients with hip fractures.

METHODS

Normal subjects and patients. We made bone mineral measurements in three groups of investigational subjects. All subjects had BMD measurements made at the lumbar spine, midradius, and distal radius; some also had BMD determined at the intertrochanteric and femoral neck regions of the proximal femur (Table I). Group A consisted of 205 normal subjects (123 women and 82 men), ages 20–92 yr, who were residents of Rochester, MN. All were volunteers and gave informed consent. None had a history of back pain or fractures of the hip, vertebrae, or wrist. On roentgenograms of the spinal column, there was no evidence of vertebral fractures or severe osteoarthritis. Data on BMD measurements of the lumbar spine and radius in 105 of the normal women and 82 of the normal men have been reported by us (3). Group B consisted of 31 patients (26 women and 5 men), whose mean age was 78 yr (range, 55 to 91 yr), with fracture of the proximal femur who were residents of Rochester, MN. We included only patients whose hip fractures occurred after falls from a standing height or less; those whose hip fractures occurred after severe trauma, including vehicle accidents and falls from heights, were excluded. All patients had a prosthesis inserted surgically within 48 h after hip fracture, and all began ambulation within 5 d postoperatively. The hip fractures were classified as either "femoral neck" or "intertrochanteric" on the basis of radiographic and surgical findings. All had roentgenograms of the spinal column, and 11 of them were found to have vertebral compression fractures. The mean interval between hip fracture and the BMD measurement was 2.4 yr (range, 1 to 5 yr). Group C consisted of 84 women with nontraumatic vertebral fractures due to osteoporosis; of these, 27 were 51–65 yr of age, 38 were 66–75 yr of age, and 19 were ≥75 yr of age. None had a history of hip fracture. Their mean age was 70 yr (range, 54 to 94 yr). Data from 76 of these women have been reported (3). In addition, we studied 12 women with nontraumatic vertebral fractures, who were older than 80 yr and were randomly selected from the Rochester, MN, population as part of an ongoing epidemiology study.

For groups A, B, and C, all subjects were ambulatory. One elderly woman, age 86 yr, in group C had localized Paget's disease of the pelvis. One of the patients in group B with hip fracture and 65 of the patients in group C with vertebral fractures were receiving treatment with calcium, vitamin D, or sex steroids; none had previously received treatment with sodium fluoride. One patient in group A was receiving an oral hypoglycemic agent for diabetes mellitus. A few patients (4 in group A, 6 in group B, and 6 in group C) were taking thiazide diuretics. Otherwise none of the subjects had a history of renal, gastrointestinal, or hepatic diseases or any other diseases known to affect bone or were taking drugs known to affect bone. All had normal values for serum calcium and phosphorus and, with the exception of the one patient with coexistent Paget's disease, normal values for serum alkaline phosphatase.

Bone densitometry. BMD was determined at the midradius and distal radius, 2 cm proximal to the styloid process, by using the ^{125}I absorptiometric technique as described by Cameron and Sorenson (4). In our laboratory, this technique has a coefficient of variation of 3% for the midradius and 3–5% for the distal radius (5). Bone mineral content (BMC) of the lumbar spine and proximal femur was determined by dual photon absorptiometry by our modification (1, 3) of the method of Mazess et al. (2). Transmission scanning was done by using the two separate photon energies (44 and 100 keV) from a ^{153}Gd source to allow computation of the BMC of bone independent of soft tissues. BMD, expressed in g/cm^2, was derived by dividing BMC by the projected area of the scanned bone. Edge-detection, point-by-point BMD measurements, and data acquisition were computer-assisted. Intensity-modulated images of the spine and proximal femur were displayed on a 64 by 64 matrix with 16 gray levels. Interaction with a photoelectric pen allowed determination of the area of interest, which was translated into BMD values by computer algorithm. The areas of interest determined in our study were the L_1-L_4 region of the lumbar spine and the intertrochanteric and cervical regions of the femur. For normal subjects, the right proximal femur was scanned; for the patients with hip fractures, the contralateral femur was scanned. For this method, the coefficient of variation is 2.3% for the lumbar spine and 2.2% for the proximal femur.

The approximate contribution of the cortical and trabecular components of bone at the five scanning sites is as follows: midradius, >95% cortical bone; distal radius, 75% cortical and 25% trabecular bone; lumbar spine, >66% trabecular bone; intertrochanteric region of the femur, 50% cortical and 50% trabecular bone; and cervical region of the femur, 75% cortical and 25% trabecular bone. The estimates for the radius and proximal femur were based on analysis of bone obtained at autopsy from two subjects for each site. That for the vertebrae was obtained from the medical literature (6).

Statistical methods. The regression of bone mineral measurements on age was approached in two ways. First, separate linear regressions were calculated for all ages, ages 20–50, 51–65, 66–75, ≥51, ≥66, and ≥76 yr, respectively. The slopes of linear regression in the various age groups were compared for assessment of consistency of the relationship with age. Second, evidence of a curvilinear relationship with age was assessed by successively fitting linear, parabolic, cubic, and quartic polynomial regressions on age. The significance of the regression coefficients was then evaluated.

For some comparisons, we expressed BMD values for pa-

tients with fractures as the number of standard deviations (SD) from the sex-specific age regression in normal subjects (Z-score). The SD for these comparisons was calculated from the formula $O - P/S_{y \cdot x}$, in which O is the observed value of BMD, P is the value predicted from the sex-specific age regression of BMD in normal subjects, and $S_{y \cdot x}$ is the residual standard deviation (standard error of estimate) from that regression.

Two- and one-sample *t* tests were also performed. All *P* values were two-tailed.

RESULTS

Control subjects (group A). Table II gives the parameters for the regression equations for BMD on age in women. The age regression of the proximal femur was linear at both the cervical and intertrochanteric scanning sites. For the cervical region, bone diminution occurred at the rate of 0.0129 g/cm^2 per year (Fig. 1). Overall, the predicted mean at age 90 yr was 58% less than the predicted mean at age 20 yr (Fig. 1). For the intertrochanteric region, bone diminution occurred at a rate of 0.0108 g/cm^2 per year (Fig. 2). Overall, the predicted mean at age 90 yr was 53% less than the predicted mean at age 20 yr (Fig. 2). For both sites, regression analysis supported a simple linear function at all ages. There was no evidence of curvilinearity or of a more negative slope during the age interval of 51 to 65 yr. The age regression for BMD of the lumbar spine was linear. Bone diminution occurred at a rate of 0.0082 g/cm^2 per year and, overall, the predicted mean at age 90 yr was 42% less than the predicted mean at age 20 yr. The age regression for BMD was best fit with cubic equations for the distal radius and midradius. The 18 additional control subjects older than 80 yr of age did not significantly change the previously reported (1) age regressions at the midradius and distal radius sites; the slope of bone diminution for the lumbar spine, however, was slightly flatter.

For men, bone diminution in the proximal femur also was linear at both sites; however, the rate was approximately two-thirds of that for women (Table III and Figs. 3 and 4).

Patients with hip fractures (group B). Table IV gives mean values for the deviation of BMD from normal (Z-score) in women with hip fractures, and Figs. 5 and 6 show individual values for BMD at the two measurement sites in the proximal femur. The small but significant decrease from normal was greater at the intertrochanteric scanning site than at the cervical scanning site. Patients with femoral neck and intertrochanteric fractures were indistinguishable by differences in BMD at either site. Values for BMD of the lumbar spine, midradius, and distal radius sites in the patients with hip fracture did not differ significantly from normal. For the five men with hip fracture, the

TABLE II
Parameters of Linear Regression of Bone Variables on Age in Normal Women†

	N	A	B	$S_{y \cdot x}$
Midradius, g/cm				
Overall	120	1.22	−0.0060§	0.113
20–50 yr	42	0.93	0.0025	
51–65 yr	24	1.56	−0.0118*	
66–75 yr	27	1.30	−0.0069	
≥76 yr	27	1.30	−0.0071	
≥51 yr	78	1.31	−0.0072§	
≥66 yr	54	1.35	−0.0078§	
Distal radius, g/cm				
Overall	120	1.21	−0.0067§	0.121
20–50 yr	42	0.96	0.0004	
51–65 yr	24	1.44	−0.0108	
66–75 yr	27	1.27	−0.0074	
≥76 yr	27	1.09	−0.0057	
≥51 yr	78	1.29	−0.0080§	
≥66 yr	54	1.37	−0.0089§	
Lumbar spine, g/cm^2				
Overall	120	1.54	−0.0082§	0.146
20–50 yr	42	1.57	−0.0083‡	
51–65 yr	24	1.60	−0.0099	
66–75 yr	27	0.87	0.0012	
≥76 yr	27	0.58	0.0037	
≥51 yr	78	1.29	−0.0048§	
≥66 yr	54	1.15	−0.0030	
Proximal femur—cervical region, g/cm^2				
Overall	95	1.81	−0.0129§	0.196
20–50 yr	38	1.94	−0.0164§	
51–65 yr	21	1.34	−0.0050	
66–75 yr	16	3.23	−0.0329	
≥76 yr	20	1.20	−0.0056	
≥51 yr	57	1.73	−0.0118§	
≥66 yr	36	1.80	−0.0127‡	
Proximal femur—intertrochanteric region, g/cm^2				
Overall	95	1.65	−0.0108§	0.183
20–50 yr	38	1.69	−0.0122‡	
51–65 yr	21	1.53	−0.0083	
66–75 yr	16	3.67	−0.0394*	
≥76 yr	20	1.64	−0.0107	
≥51 yr	57	1.75	−0.0121§	
≥66 yr	36	1.76	−0.0123‡	

For significance of difference from zero: * $P < 0.05$, ‡ $P < 0.01$, § $P < 0.001$.

† N is the number of subjects and A is the *y*-intercept, B the slope, and $S_{y \cdot x}$ the residual standard deviation for the linear regression equation.

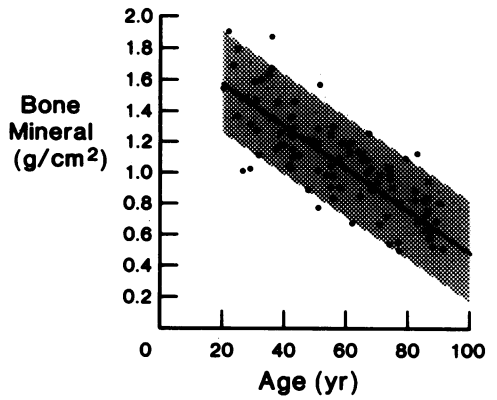

FIGURE 1 Regression of BMD for cervical region of proximal femur in 95 normal women without previous hip fracture. Equation for regression, $y = 1.811 - 0.01291 \cdot age$.

mean, SD, and t statistic for the deviation of BMD from predicted normal (Z-score) were −0.64, 0.89, and −1.60, respectively, for the femoral neck and −1.03, 0.77, and −2.98, respectively, for the intertrochanteric region of the femur. The latter mean was significantly <0 at $P = 0.04$.

Patients with vertebral fractures (group C). Fig. 7 shows individual values of BMD for the lumbar spine in women who had nontraumatic vertebral fractures but no hip fractures. The slope of the age regression for this group did not differ significantly from zero; this suggests that the level of BMD at which vertebral fractures begin to occur was relatively constant at all ages. Table V shows the mean deviation from predicted normal in SD at the midradius, distal radius, and lumbar spine scanning sites for women with vertebral compression fractures for three age groups—ages 51–65, 66–75, and ≥76 yr. Patients with fractures

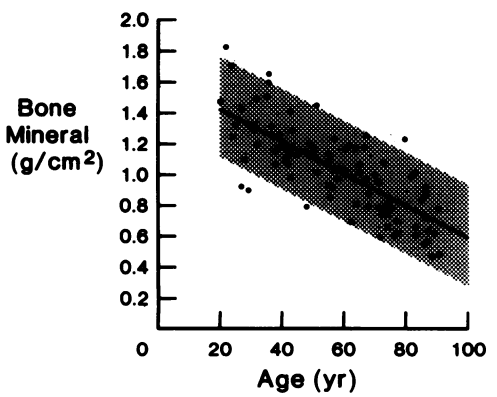

FIGURE 2 Regression of BMD for intertrochanteric region of proximal femur in 95 normal women without previous hip fracture. Equation for regression, $y = 1.654 - 0.01082 \cdot age$.

TABLE III
Parameters of Linear Regression of Bone Variables on Age in Normal Men†

	N	A	B	$S_{y \cdot x}$
Midradius, g/cm				
Overall	82	1.34	−0.0005	0.160
20–50 yr	39	1.25	0.0023	
51–65 yr	17	1.79	−0.0084	
66–75 yr	15	1.49	−0.0026	
≥76 yr	11	2.10	−0.0098	
≥51 yr	43	1.38	−0.0011	
≥66 yr	26	1.39	−0.0013	
Distal radius, g/cm				
Overall	82	1.45	−0.0032‡	0.173
20–50 yr	39	1.31	0.0011	
51–65 yr	17	1.51	−0.0035	
66–75 yr	15	1.04	0.0024	
≥76 yr	11	−0.92	0.0253	
≥51 yr	43	1.61	−0.0055*	
≥66 yr	26	1.34	−0.0020	
Lumbar spine, g/cm²				
Overall	82	1.33	−0.0021*	0.159
20–50 yr	39	1.41	−0.0044	
51–65 yr	17	1.95	−0.0133	
66–75 yr	15	2.48	0.0185	
≥76 yr	11	0.72	0.0060	
≥51 yr	43	1.25	−0.0010	
≥66 yr	26	1.05	0.0018	
Proximal femur—cervical region, g/cm²				
Overall	52	1.56	−0.0078§	0.152
20–50 yr	23	1.59	−0.0082*	
51–65 yr	14	2.58	−0.0266*	
66–75 yr	8	1.48	−0.0065	
≥76 yr	7	1.03	−0.0006	
≥51 yr	29	1.38	−0.0052	
≥66 yr	15	1.26	−0.0034	
Proximal femur—intertrochanteric region, g/cm²				
Overall	52	1.57	−0.0071§	0.155
20–50 yr	23	1.54	−0.0064	
51–65 yr	14	2.57	−0.0247*	
66–75 yr	8	1.17	−0.0014	
≥76 yr	7	1.41	−0.0051	
≥51 yr	29	1.63	−0.0080‡	
≥66 yr	15	1.44	−0.0054	

For significance of difference from zero: * $P < 0.05$, ‡ $P < 0.01$, § $P < 0.001$.

† N is the number of subjects and A is the y-intercept, B the slope, and $S_{y \cdot x}$ the residual standard deviation for the linear regression equation.

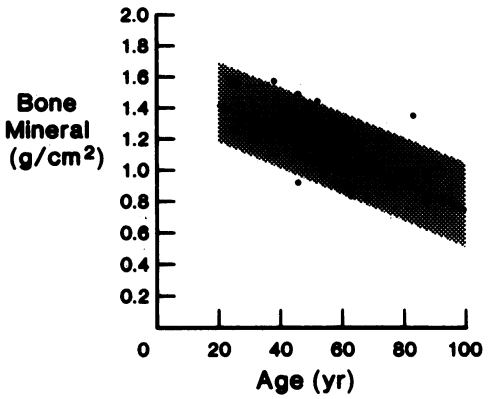

FIGURE 3 Regression of BMD for cervical region of proximal femur in 52 normal men without previous hip fracture. Equation for regression, $y = 1.562 - 0.00780 \cdot \text{age}$.

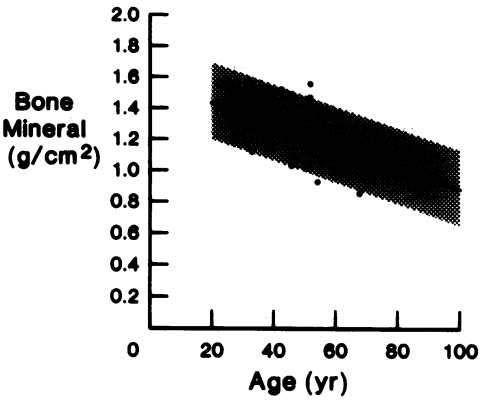

FIGURE 4 Regression of BMD for intertrochanteric region of proximal femur in 52 normal men without previous hip fracture. Equation for regression, $y = 1.570 - 0.00711 \cdot \text{age}$.

occurring in the youngest age group were classified as having "postmenopausal osteoporosis," those with fractures in the oldest group were classified as having "senile osteoporosis," and those in the intermediate age group were classified as "transitional." In the age group 51–65 yr, deviations were significantly lower than normal at all three scanning sites; the deviation was much greater, however, at the lumbar spine. For those women older than 75 yr of age, the decrease from normal was not significant at any of the three scanning sites. The 66–75-yr age group had intermediate values.

Relationship of age to fracture occurrence. The fracture threshold is the level of BMD of a given bone below which the risk of fracture (in the absence of major trauma) begins to increase. Using data from our study, we arbitrarily defined this level as the 90th percentile for BMD of the proximal femur for patients with hip fracture and for BMD of the lumbar spine for patients with vertebral fracture. For women, this value was 0.95 g/cm² for the femoral neck, 0.92 g/cm² for the intertrochanteric region of the femur, and 0.97 g/cm² for the lumbar spine. These values were −2.4, −2.2, and −2.3 SD, respectively, below the mean BMD for a normal woman 30 yr of age.

DISCUSSION

In normal women, the age-related decrease in BMD for the proximal femur was best described with a single linear function. We have previously reported (3) that the age regression for vertebral BMD assessed by dual photon absorptiometry was linear also. Because both the present and the previous study were cross-sectional, no firm conclusion on linearity or nonlinearity of bone loss with aging can be made. In a longitudinal study using quantitative computed tomography, however, Cann et al. (7) demonstrated accelerated loss of

TABLE IV

Deviation from Predicted Normal in SD (Z-score) for BMD at Various Scanning Sites in Women with Hip Fractures

	All cases				Femoral neck fracture				Intertrochanteric fracture			
	N	Mean†	SD†	t@	N	Mean	SD	t	N	Mean	SD	t
Midradius	26	0.12	1.15	0.5	17	0.16	1.09	0.6	9	0.05	1.33	0.1
Distal radius	26	0.41	1.11	1.9	17	0.26	1.07	1.0	9	0.67	1.20	1.7
Lumbar spine	22	0.24	1.33	0.9	15	0.32	1.05	1.2	7	0.09	1.89	0.1
Femoral neck	26	−0.31	0.69	−2.3*	17	−0.43	0.74	−2.4*	9	−0.09	0.56	−0.5
Intertrochanteric region of femur	26	−0.53	0.77	−3.5‡	17	−0.60	0.80	−3.1‡	9	−0.39	0.74	−1.6

For significance of difference from zero: * $P < 0.05$ and ‡ $P < 0.01$.

† Mean refers to the mean deviation in SD from the sex-specific age regression for normal subjects; SD refers to the group variability (in SD) about the mean deviation.

@ t statistic from one-sample t test.

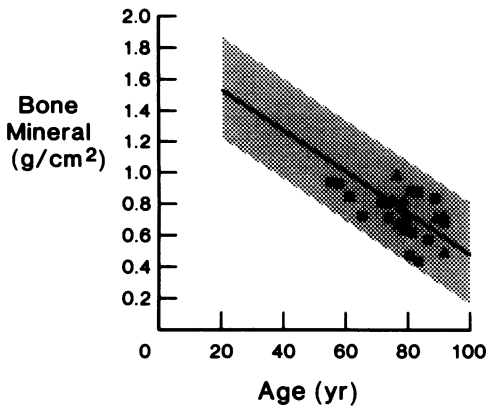

FIGURE 5 Individual values of BMD for cervical region of proximal femur in 28 women with hip fractures (■ = femoral neck and ▲ = intertrochanteric fractures). Line denotes age regression for normal women, and shaded area represents 90% confidence limits.

trabecular bone from the centrum of vertebra during the first few years after oophorectomy.

The decrease in BMD in the proximal femur for men was approximately two-thirds of that for women. This contrasts with the decrease in BMD in the lumbar spine for men, which was only approximately a fourth of that observed for women (3). This difference may explain why the female/male ratio for hip fractures is only 2:1 (8), whereas for vertebral fractures it is about 8:1.[2]

By age 75 yr, the age regression for proximal femoral BMD in women had decreased to a level > 2 SD below that of young adulthood, and almost all individual values were below the threshold for hip fracture. Thus, the entire population of elderly women appears to be at risk for hip fracture. This may be true for men also, but to a lesser extent and at a later age.

The patients with hip fracture whom we studied were representative of the general population of elderly women. They did not have any recognizable disease known to cause bone loss. Although Aaron et al. (9) found histologic osteomalacia in 30% of patients having hip fracture in northern England, Wixson et al. (10) found that it occurred only rarely in patients having hip fractures in Detroit, MI. Even though we did not do bone histomorphometry studies on our patients with hip fracture, all of them had normal serum concentrations of calcium, phosphorus, and alkaline phosphatase, findings that suggest they did not have significant osteomalacia.

Although elderly women with hip fractures had lower values for BMD of the contralateral hip than their peers, the decrease was small and the overlap considerable. Vose and Lockwood (11) have reported similar findings using a less sensitive and less accurate method of radiographic photodensitometry. Thus, although lower BMD of the proximal femur may play a partial role, the occurrence of falls may be a major factor predisposing some but not others in the population of aging women to fracture the hip. This hypothesis is consistent with the observation that falls occur with increasing frequency in elderly persons (12) and with the preliminary finding of Johnston et al. (13) that those elderly women with fractures have fallen more in the past than have their peers.

The degree of deviation of BMD from normal was similar for the women with femoral neck fracture and for the women with intertrochanteric fracture at each of the five measurement sites, regardless of whether the deviation was significantly different from zero (for the proximal femur) or not (for the lumbar spine and radius). Because these five sites vary considerably in their proportional content of cortical and trabecular bone, our results suggest that women with both types of hip fractures have proportionate loss of cortical and trabecular bone.

34 yr ago, Albright and Reifenstein (14) suggested that there were two types of involutional osteoporosis—a postmenopausal form caused by estrogen deficiency and a senile form caused by aging. Because subsequent investigators failed to find a bimodal distribution (15), the concept of two osteoporotic syndromes did not gain wide acceptance. In 1968, Newton-John and Morgan (16) hypothesized that the increase in fracture incidence in elderly persons could be satisfactorily explained by the age-related decrease in bone density. They questioned whether there was

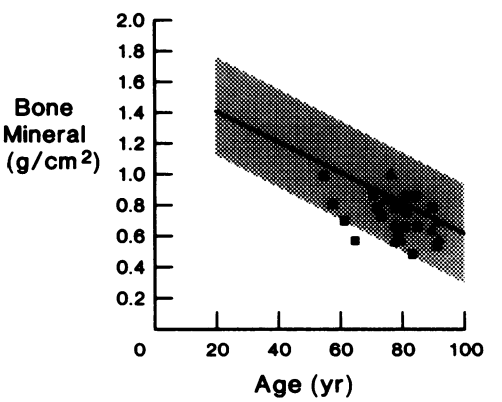

FIGURE 6 Individual values of BMD for intertrochanteric region of proximal femur in 28 women with hip fractures (■ = femoral neck and ▲ = intertrochanteric fractures). Line denotes age regression for normal women, and shaded area represents 90% confidence limits.

[2] Riggs, B. L., and L. J. Melton III. Unpublished data.

a syndrome of osteoporosis due to bone loss in excess of that which occurs universally with aging. Nordin and his group (17, 18) distinguished between simple osteoporosis (bone loss commensurate with age) and accelerated osteoporosis (bone loss in excess of that associated with aging). Nordin (17) found, as had Newton-John and Morgan (16), a good agreement between bone density of the appendicular skeleton by decades of age and the corresponding annual fracture rate for the forearm and for the hip. But because postmenopausal women with nontraumatic vertebral compression fractures generally were found to have bone density values for the appendicular skeleton that were similar to or only slightly less than those in age-comparable normal subjects, both Nordin (17) and we (19) postulated that these women had lost excessive trabecular bone from the axial skeleton.

These previously reported observations and the results that we obtained by directly measuring BMD of the proximal femur and spine do, in fact, strongly suggest that two distinct syndromes of osteoporosis exist. One form, "postmenopausal osteoporosis," occurs in a small subset [probably 5–10% (20)] of the female population within the first 15–20 yr after menopause and is manifested mainly by vertebral fractures. Compared with peers, these women have lost excessive and disproportionate amounts of trabecular bone. More rarely, a similar syndrome develops in men of comparable age.

The other form, "senile osteoporosis," occurs in persons older than 75 yr, is manifested as vertebral fractures, hip fractures or both (8, 15),[2] and may affect more than half of the population of aging women and a fourth of the population of aging men (8).[2] Bone loss in this form of osteoporosis is proportionate for both cortical and trabecular bone and is only slightly more

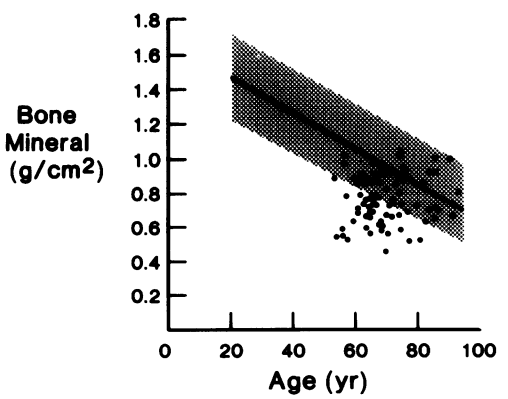

FIGURE 7 Individual values of BMD for lumbar spine in 84 women with one or more nontraumatic vertebral fractures. Line denotes age regression for normal women, and shaded area represents 90% confidence limits.

TABLE V

Deviations from Predicted Normal in SD (Z-score) for BMD at Various Scanning Sites for Women with Only Nontraumatic Vertebral Fractures by Age Groups

	N	Mean†	SD†	t@
Midradius				
Overall	84	−0.71	1.15	−5.6§
51–65 yr	27	−1.03	1.11	−4.8§
66–75 yr	38	−0.59	1.16	−3.1‡
≥76 yr	19	−0.48	1.14	−1.8
Distal radius				
Overall	84	−0.48	1.08	−4.0§
51–65 yr	27	−0.75	1.08	−3.6‡
66–75 yr	38	−0.38	1.05	−2.2*
≥76 yr	19	−0.30	1.14	−1.1
Lumbar spine				
Overall	84	−1.31	1.12	−10.7§
51–65 yr	27	−1.92	0.98	−10.1§
66–75 yr	38	−1.27	0.98	−8.0§
≥76 yr	19	−0.50	1.10	−2.0

For significance of difference from zero: * $P < 0.05$, ‡ $P < 0.01$, § $P < 0.001$.

† Means refers to the mean deviation in SD from sex-specific age regression for normal subjects (Z-score); SD refers to the group variability (in SD) about the mean deviation.

@ t statistic from one-sample t test.

for patients with fracture than for the remainder of the aging population. This form appears to correspond to Newton-John and Morgan's model (16); as age-related bone loss ensues, more and more members of the aging population have BMD values below the threshold for fracture. Persons in whom fractures due to osteoporosis develop in the decade from 66 to 75 yr may represent a transitional phase.

Thus, both epidemiologic and bone densitometric findings suggest that postmenopausal and senile osteoporosis, although perhaps related, are not identical. Further studies should be conducted to determine whether the two syndromes of osteoporosis have different etiologic mechanisms.

ACKNOWLEDGMENT

This study was supported in part by research grant AM-27065, US Public Health Service, National Institutes of Arthritis, Metabolism, and Digestive Diseases.

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