Tohoku J. Exp. Med., 1999, **187**, 141-147

Age-Related Bone Loss: Relationship between Age and Regional Bone Mineral Density

TSUTOMU KAMEI, KIYOSHI AOYAGI,[1] TADASHI MATSUMOTO,[2] YUTAKA ISHIDA,[3] KENTARO IWATA,[4] HIROAKI KUMANO,[5] YOSHIO MURAKAMI[6] and YUZURU KATO[6]

Shimane Institute of Health Science, Izumo 693-0021, [1]Department of Public Health and [2]Department of Pediatrics, School of Medicine, Nagasaki University, Nagasaki 852-8523, [3]Nagasaki Mitsubishi Hospital, Nagasaki 850-0063, [4]Okinawa Chubu Hospital, Gushikawa 904-2243, [5]Department of Human Behavioral Science, School of Medicine, Tohoku University, Sendai 980-8575, and [6]The First Division, Department of Medicine, Shimane Medical University, Izumo 693-0021

KAMEI, T., AOYAGI, K., MATSUMOTO, T., ISHIDA, Y., IWATA, K., KUMANO, H., MURAKAMI, Y. and KATO, Y. *Age-Related Bone Loss: Relationship between Age and Regional Bone Mineral Density.* Tohoku J. Exp. Med., 1999, **187** (2), 141-147 —— We assessed the changes in regional bone mineral density according to age and examined the relationship between various regional bone mineral densities. The study was conducted in 985 Japanese women divided into <50-years group ($n=435$) and ≧50 years group ($n=550$). The total body bone mineral density and that of the head, arm, leg, thoracic (T)-spine, lumbar (L)-spine, ribs, and pelvis were measured using dual energy x-ray absorptiometry. There was a significant generalized reduction of bone mineral density in all regions after the age of 50 years. The most marked age-related decrease was observed in the L-spine. Bone mineral densities in all regions significantly correlated to each other in both age groups, but the degree of significance varied among regions. The relationship between bone mineral density of the L-spine and that of T-spine regions was the most significant in both groups. In the <50-years group, the correlation between bone mineral density of the pelvis and that of L-spine and T-spine was the highest, followed by that between the pelvis and the leg. On the other hand, in the ≧50-years group, the correlation between bone mineral density of the pelvis and that of the leg was the highest, but not the L-spine or T-spine. Since spine measurements are affected by vertebral deformity and/or aortic calcification, our findings suggest the pelvis may be a useful region for screening measurements of bone mineral density, especially in older women. ——— age; bone mineral density; dual energy x-ray absorptiometry (DEXA); pelvis

Received January 14, 1998; revision accepted for publication February 1, 1999.
Address for reprints: Tsutomu Kamei, M.D., Shimane Institute of Health Science, 223-7 Enya-cho, Izumo 693-0021, Japan.

Fractures associated with osteoporosis lower the quality of life (QOL) and have become a serious problem in developed countries where the aging population has been increasing (Ross 1997). While many risk factors are involved in the development of fractures, reduced bone mineral density is one of the most common causes of such fractures. Measurement of bone mineral density is most useful for the evaluation of fracture risk (Hui et al. 1988; Cummings et al. 1990; Wasnich 1991). Any decision regarding the treatment of osteoporosis is dependent upon an accurate diagnosis. In clinical practice, osteoporosis is preferably diagnosed by a single measurement of bone mineral density at one site. Lately, it has become possible to measure regional bone mineral density of the total body. However, there is a disagreement as to the region/site most suitable for such measurement (Van Berkum et al. 1989; Black et al. 1992; Melton et al. 1993; Sogaard et al. 1994; Nordin et al. 1996).

Bone mineral density decreases after menopause, and pre- and postmenopausal bone metabolism varies greatly. To our knowledge, there are only a few studies of regional bone mineral density that take age into account. We assessed the changes in regional bone mineral density by age group and the relationship between various regional bone mineral densities in women.

Subjects and Methods

Among women who underwent osteoporosis examination at Silver Center in Shimane Institute of Health Science in 1995, a total of 985 women were enrolled in the study. Individuals with a previous history of metabolic bone disease and those who received medications that affected bone metabolism were not included in the present study. Subjects were between 31 and 69 years (mean 51.4 years) of age. Bone mineral densities of the total body, head, arms, legs, thoracic (T)-spine, lumbar (L)-spine, ribs, and pelvis were measured with QDR 2000™ (Hologic Inc., Waltham, MA, USA), according to the standard protocols recommended by the manufacturer (Hologic Inc. 1994) and were analyzed using version 7.10 software. The coefficient of variation for total body bone mineral density is 1.1%, and for the regions, it ranges from 1.1% (for the pelvis) to 4.0% (for the arm) (Chilibeck et al. 1994). For the arms, legs and ribs, the averages of the left

Table 1. *Mean (standard deviation) of total and regional*

Age group	Number	Total	Head	Arm
30-	197	1.05 (0.08)	2.04 (0.23)	0.66 (0.04)
40-	238	1.05 (0.09)	2.06 (0.26)	0.65 (0.04)
50-	306	0.93 (0.09)	1.72 (0.27)	0.61 (0.05)
60-	244	0.86 (0.08)	1.55 (0.24)	0.57 (0.05)
ANOVA		$F=286$ $p<0.0001$	$F=228$ $p<0.0001$	$F=165$ $p<0.0001$

and right sides were calculated and used.

Regional bone mineral density was analyzed in 10-years-age-class groups. Furthermore, the relationships between various regional bone mineral densities were assessed by dividing the subjects into <50-years-old group and ≧50-years group. Regional bone mineral density classified by age group was assessed by analysis of variance. We also determined the Pearson's moment correlation coefficient in the analysis of the relationship between various regional bone mineral densities.

Results

The mean total and regional bone mineral densities were similar in the 30's and 40's age groups, but the density was significantly lower in the ≧50's group (Table 1). Classified by region, the L-spine showed the most marked reduction (by −28%) in bone mineral density in the 60's group, compared with that in the 30's group. On the other hand, the mineral density of the arm showed the lowest decrease of −13% in the 60's group, or nearly half of that for the L-spine in the same group.

Because changes in regional bone mineral density by age group differed between <50's and ≧50 years groups, the relationship among regional bone mineral densities were assessed by dividing the subjects into <50-years group and ≧50 years-group. Bone mineral densities of all regions significantly correlated in both groups ($p<0.0001$), but the degree of significance varied between regions (Table 2). The total body bone mineral density correlated significantly with that of all regions ($r=0.751$-0.829 in <50-years group, $r=0.797$-0.886 in ≧50-years group). The relationships between the bone mineral density of the head and that of other regions, with the exception of total body (total), were low ($r=0.441$-0.579 in <50-years group, $r=0.582$-0.663 in ≧50-years group). The correlation between bone mineral density of L-spine and that of T-spine was the highest in both groups, followed by that between the pelvis and ribs in <50-years group and between ribs and pelvis in ≧50-years group. The correlation between bone mineral density of the leg and that of the arm was the highest followed by that with the pelvis. In <50-years group, the correlations between bone mineral

bone mineral density in women by age group

Leg	T-spine	L-spine	Rib	Pelvis
1.06 (0.08)	0.85 (0.10)	1.03 (0.14)	0.58 (0.05)	1.05 (0.12)
1.06 (0.09)	0.86 (0.11)	1.02 (0.15)	0.57 (0.05)	1.05 (0.12)
0.98 (0.09)	0.74 (0.10)	0.83 (0.16)	0.51 (0.05)	0.95 (0.12)
0.91 (0.09)	0.69 (0.09)	0.75 (0.15)	0.48 (0.05)	0.87 (0.12)
F=157	F=166	F=206	F=218	F=126
$p<0.0001$	$p<0.0001$	$p<0.0001$	$p<0.0001$	$p<0.0001$

TABLE 2. *Pearson correlation coefficients (r)*

		Total	Head	Arm	Leg
Total			0.886	0.814	0.881
Head		0.829		0.582	0.624
Arm		0.751	0.471		0.827
Leg		0.811	0.441	0.712	
T-spine		0.779	0.577	0.637	0.597
L-spine		0.801	0.543	0.673	0.659
Rib	<50 years	0.805	0.579	0.729	0.675
Pelvis	group	0.778	0.537	0.659	0.681

density of the pelvis and that of the L-spine and T-spine were the highest, and a relatively close relationship was also observed between the pelvis and the leg. On the other hand, in ≧50-years group, the bone mineral density of the pelvis was most highly correlated with that of the leg but not that of the L-spine or T-spine.

DISCUSSION

There is a disagreement regarding the site and region most suitable for the measurement of bone mineral density when assessing fracture risk in osteoporosis. In particular, should a measurement be taken at the sites of potential fractures, or can a measurement in another region serve as an indicator for fracture-occurring sites? Previous studies have indicated that lumbar bone mineral density is more closely associated with vertebral compression fractures than that of the forearm (Sogaard et al. 1994) and that measurements of bone mineral density of peripheral bones are of limited value (Van Berkum et al. 1989). However, other reports have demonstrated that measurements of bone mineral density of peripheral bones and those of lumbar vertebrae were equally useful for the diagnosis of osteoporosis and for predicting fractures (Black et al. 1992; Melton et al. 1993). Technological advances in the design of densitometers have made it possible to measure bone mineral density of the whole body and other sites and regions.

Nordin et al. (1996) measured the total body bone mineral density as well as that of other regions in postmenopausal women. They reported that the bone mineral density of the L-spine alone was not reliable for distinguishing between women with and without vertebral compression fracture. Lumbar bone mineral density can be affected by osteophyte, vertebral compression fracture and aortic calcification, causing variations in measurement values, and thus may produce higher bone densities (Ross et al. 1988). Since complications occur more frequently in more advanced ages, care should be exercised in assessing bone mineral density of the L-spine in elderly people.

The L-spine, T-spine and pelvis are axial bones in which cancellous bone is dominant, whereas leg and arm bones are peripheral bones in which cortical bone *between measurements*

T-spine	L-spine	Rib	Pelvis	
0.817	0.822	0.834	0.797	≧50 years
0.655	0.633	0.637	0.584	group
0.722	0.721	0.827	0.736	
0.743	0.736	0.786	0.791	
	0.846	0.792	0.761	
0.840		0.759	0.751	
0.712	0.729		0.751	
0.715	0.756	0.695		

is dominant. Our results showed that the onset and rate of reduction of bone mineral density differed between cancellous and cortical bones. Specifically, the bone mineral density of the L-spine was closely related to that of the T-spine and pelvis in both age groups, and that of the leg was closely related to the arm. These findings may be attributable to the similar features of these bones.

As discussed above, it is possible that the bone mineral density of L-spine in the elderly could be overestimated because of osteophyte and/or aortic calcification. However, in the present study, the bone mineral density of L-spine showed marked reduction during aging, compared to the other regions. L-spine consists predominantly of cancellous bone, and the cancellous bone mass is mainly reduced during the estrogen-deficient period (Davis et al. 1994). These findings suggest that the bone mineral density of L-spine may undergo a more rapid reduction during early postmenopausal period, rather than an overestimation due to osteophyte and aortic calcification.

Osteoporosis is generally regarded as a reduction in total body bone mineral density, although at the individual level, the extent of osteoporosis may show heterogeneity. Measurement of bone mineral density at four sites in Japanese-American women by Davis et al. (1994) demonstrated that a reduction in bone mineral density in a particular site was associated with a similar finding in at least two other sites in over 85% of the women. Furthermore, the bone mineral density was low in some sites but high in other sites in 15% of the women. The reasons for these findings are thought to include (1) different rates of reduction of bone mineral density between cancellous bone and cortical bone as bone mineral density decreases more in cancellous than in cortical bone during the estrogen-deficient period, and (2) effects of deformities, fractures and aortic calcification on, for example, the spine (especially in elderly people). Since the cancellous bone is predominant in the pelvis and spine, our finding that the pelvis showed a close relationship to the L-spine in the <50-years group but not in ≧50-years group may be attributable to the possible influence of vertebral deformity, fracture and aortic calcification on bone mineral density in the L-spine in the ≧50-years group.

Previous studies (Slosman et al. 1990; Duboeuf et al. 1994) have indicated that dual energy x-ray absorptiometry (DEXA) of the spine may provide a better discrimination between fracture and nonfracture cases when measured in the late ral projection instead of anteroposterior projections, thus eliminating the effects of aortic calcification and/or posterior spinal elements. However, the precision of the lateral view of the spine is less than that of the anteroposterior view (Slosman et al. 1990; Duboeuf et al. 1994). Therefore, we did not include the bone mineral density of lateral spine in the present study.

Our results showed that bone mineral density of the pelvis correlated with that of the spine and the leg. Anatomically, the pelvis is located between the spine and the leg (including femoral neck), and has the same feature of loaded bone. The prevalence of deformities and fractures affecting the pelvis are lower than those of the spine and leg. Although the spine and leg (femoral neck) are typical sites of osteoporotic fractures, the presence of deformities and fractures overestimates the site-specific bone mineral density. Although bone mineral density measurements of the spine and hip may be useful for the assessment of fracture risk of the spine and hip, it takes much longer time to measure, thus it is not good for screening. Nordin et al. (1996) reported that bone mineral density of the pelvis was more distinguishable than of the spine or the leg when comparing vertebral fracture and nonfracture cases in postmenopausal women. Based on the findings of this study, it seems that the pelvis may be a useful region for screening measurement of bone mineral density and assessment of fracture risk of osteoporosis, particularly in elderly women. Further studies are needed to investigate whether the measurement of bone mineral density of the pelvis is useful in distinguishing between cases of hip fracture, which may cause a serious decline in QOL, and non-hip-fracture cases.

Acknowledgments

We would like to thank to Mr. Akira Bessho and Mr. Kazuyuki Yamashita from Shimane Institute of Health Science for their technical assistance.

References

1) Black, D.M., Cummings, S.R., Genan, T.H.K., Nevitt, M.C., Palermo, L. & Browner, W. (1992) Axial and appendicular bone density predict fractures in older women. *J. Bone Miner. Res.*, **7**, 633-638.
2) Chilibeck, P., Calder, A., Sale, D.G. & Webber, C. (1994) Reproducibility of dual-energy x-ray absorptiometry. *Can. Assoc. Radiol. J.*, **45**, 297-302.
3) Cummings, S.R., Black, D.M., Nevitt, M.C., Browner, W.S., Cauley, J.A., Genant, H.K., Mascioli, S.R., Scott, J.C., Seeley, D.G., Steiger, P., Vogt, T.M. & The Study of Osteoporotic Fractures Research Group (1990) Appendicular bone density and age predict hip fracture in women. *JAMA*, **263**, 665-668.
4) Davis, J.W., Ross, P.D. & Wasnich, R.D. (1994) Evidence for both generalized and regional low bone mass among elderly women. *J. Bone Miner. Res.*, **9**, 305-309.
5) Duboeuf, F., Pommet, R., Meunier, P.J. & Delmas, P.D. (1994) Dualenergy x-ray

absorptiometry of the spine in anteroposterior and lateral projection. *Osteoporos. Int.*, **4**, 110-116.

6) Hologic Inc. (1994) X-ray bone densitometer user's guide. Waltham, MA, USA.
7) Hui, S.L., Slemenda, C.W. & Johnston, C.C., Jr. (1988) Age and bone mass as predictors of fracture in a prospective study. *J. Clin. Invest.*, **81**, 1804-1809.
8) Melton, L.J., III., Atkinson, E.J., O'Fallon, W.M., Wahmer, H.W. & Riggs, B.L. (1993) Long-term fracture prediction by bone mineral assessed at different skeletal sites. *J. Bone Miner. Res.*, **8**, 1227-1233.
9) Nordin, B.E.C., Chatterton, B.E., Schltz, C.G., Need, A.G. & Horowitz, M. (1996) Regional bone mineral density interrelationships in normal and osteoporotic post menopausal woman. *J. Bone Miner. Res.*, **1**, 849-856.
10) Ross, P.D., Wasnich, R.D. & Vogel, J.M. (1988) Detection of prefracture spinal osteoporosis using bone mineral absorptiometry. *J. Bone Miner. Res.*, **3**, 1-11.
11) Ross, P.D. (1997) Fractures among the elderly: An old problem. *J. Bone Miner. Res.*, **12**, 1005-1008.
12) Slosman, D.O., Rizzoli, R., Donath, A. & Bonjour, J.P. (1990) Vertebral bone mineral density measured laterally by dual-energy x-ray absorptiometry. *Osteoporos. Int.*, **1**, 23-29.
13) Sogaard, C.H., Hermann, A.D., Hasling, C. & Mosekilde, L. (1994) Spine deformity index in osteoporotic women: Relations to forearm and vertebral bone mineral measurements and to iliac crest ash density. *Osteoporos. Int.*, **4**, 211-219.
14) Van Berkum, F.N.R., Birkenhager, J.C., Van Veen, L.C., Zeelenberg, J., Birkenhager-Frenkel, D.H., Trouerbach, W.T., Stijnen, T. & Pols, H.A. (1989) Noninvasive axial and peripheral assessment of bone mineral content: A comparison between osteoporotic women and normal subjects. *J. Bone Miner. Res.*, **4**, 679-685.
15) Wasnich, R.D. (1991) Bone mass measurements in diagnosis and assessment of therapy. *Am. J. Med.*, **91**, 54S-58S.