

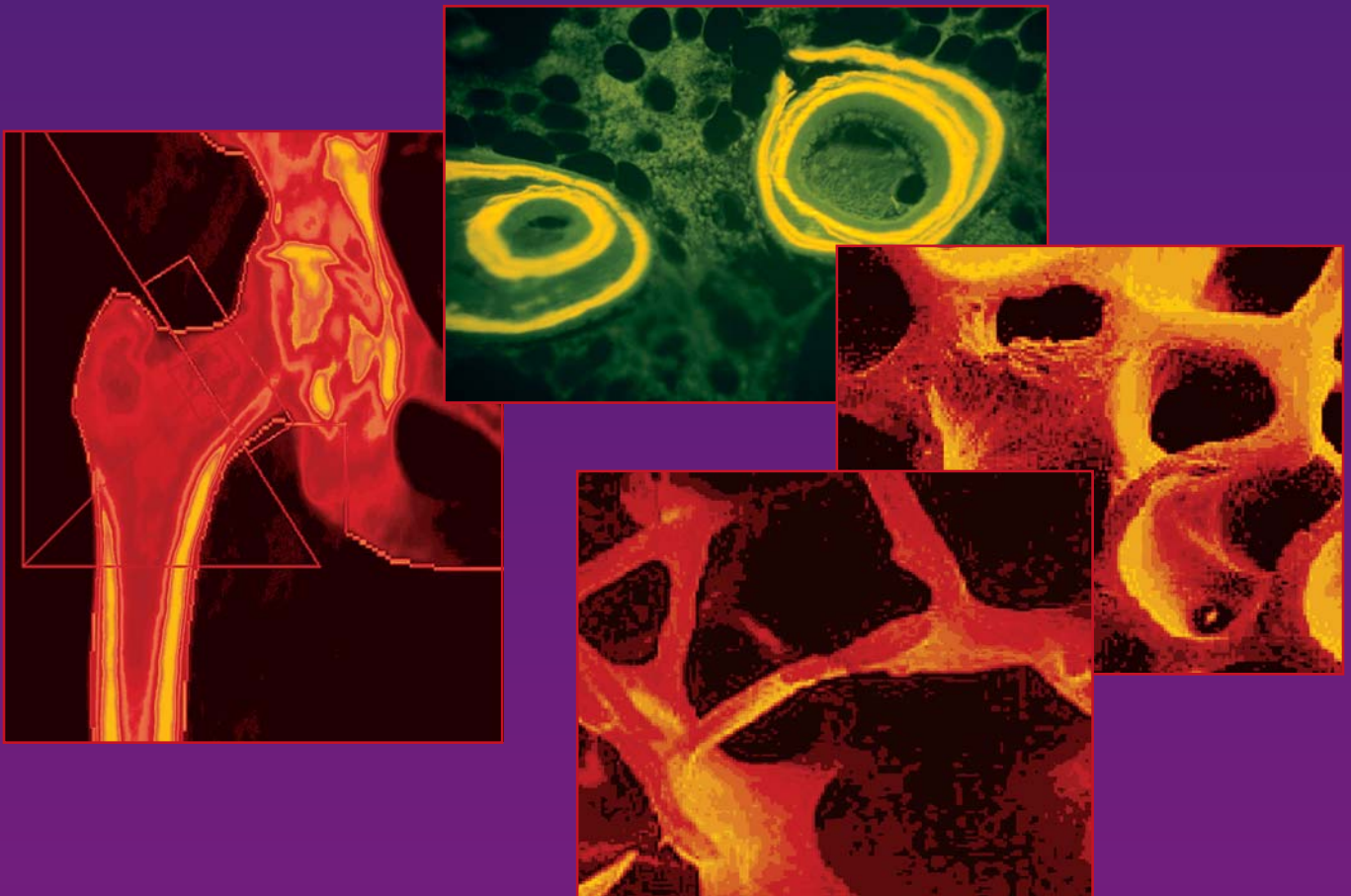
Volume 6 Number 4 Winter 2003 ISSN: 1094-6950

Journal of Clinical Densitometry

 **ISCD**
THE INTERNATIONAL SOCIETY
FOR CLINICAL DENSITOMETRY

The Official Journal of
The International Society for
Clinical Densitometry

Editor-in-Chief
Paul D. Miller, MD



 **HUMANA PRESS**

HumanaJournals.com
Search, Read, and Download

Original Article

Reference Database for Dual X-Ray and Laser Calscan Bone Densitometer

Ragnar Kullenberg*

Department of Radiology, County Hospital, SE-301 85 Halmstad, Sweden

Abstract

The new dual X-ray and laser technology (DXL) gives a more accurate determination of bone mineral density (BMD) than ordinary dual X-ray absorptiometry (DXA) technology because of the ability to eliminate fat tissue both inside and outside the measured bone. In this study the reference database for BMD measured at the calcaneus by the DXL Calscan device is reported. The database was obtained from 993 healthy women and 459 healthy men in a population from southern Sweden. Inclusion criteria were: healthy Swedish Caucasians, 15–85 yr of age for women and 19–85 yr of age for men, no history of osteoporosis treatment, no use of corticosteroids for more than 3 mo, and no extended bed rest. The young adult reference mean BMD for women was found to be 0.483 ± 0.062 g/cm² and for men 0.556 ± 0.074 g/cm². The age-adjusted odds ratio was 3.7 for a history of fracture among women aged 50 yr and over, comparing subjects with a 1-SD reduction in bone density to subjects with a bone density above this value. The DXL Calscan device used for the study was calibrated weekly against a heel bone phantom. The precision of these measurements was 0.5%. The in vivo precision was 1.2%, as assessed by duplicate measurements on 35 healthy individuals (mean age 52 yr, range 25–72 yr).

Key Words: Bone densitometry; DXL; osteoporosis; reference data.

Introduction

The purpose of this study was to establish a database of bone mineral density (BMD) measured at the calcaneus for women and men. A dual X-ray and laser technology (DXL) Calscan device (Demetech AB, Stockholm, Sweden) was used for the study, performed at different locations in southern Sweden.

BMD in the calcaneus can be used for fracture risk assessment, with predictive power similar to

measurements made at the spine or hip (1–3). The calcaneus has greater than 95% trabecular bone by volume and the age-related bone loss in this bone is similar to that in the lumbar spine (4).

Accuracy of BMD measurements is important for diagnosis of the individual patient and precision for monitoring response to therapeutic intervention. The precision achieved in measuring BMD by conventional dual-energy X-ray absorptiometry (DXA) is typically better than 2%, but accuracy is considerably worse. Errors of up to 20% have been reported, resulting from inhomogeneous distribution of both extraskelatal and intraskelatal fat (5–7). Meunier and associates (8) have shown that yellow marrow fat

varies between 15% and 80% by volume in the trabecular marrow spaces for both healthy and osteoporotic individuals. An inhomogeneous distribution of fat within as well as between individuals causes errors with conventional DXA measurements. This is because of the basic limitation of a two-component tissue model, which consists only of bone mineral and soft tissue and which assumes that the proportion of fat is constant and homogenous. However, the X-ray absorption properties of fatty tissues are significantly different from those of both bone mineral and other tissues (9). A more realistic model of tissues is a three-component model consisting of bone mineral, lean soft tissues, and fatty tissues. In order to measure the bone mineral density without influences of fatty tissues, three different quantities have to be measured separately. The DXL technique uses two X-ray energies in combination with laser measurement of the object thickness in order to determine all three tissue components (10). Since the total thickness of the object being measured is composed of the individual thickness of bone mineral, lean soft tissue, and fat, it is possible to combine the thickness measurement with the two X-ray measurements and get a unique solution of the three different components at the measurement site. Further studies are needed to validate if the increased accuracy can improve the fracture prediction power of the DXL technology.

Materials and Methods

Healthy Swedish Caucasians, 15–85 yr of age for women and 19–85 yr of age for men, were enrolled in the study. All participants were given a questionnaire for reporting medical history, medication use, fracture history, smoking habits, alcohol habits, and menopausal status. The candidates were recruited from workplaces, universities, nursing homes, and pensioner associations in southern Sweden. The recruitment process was by advertisements and visits. Exclusion criteria that were applied during the data analysis were: history of osteoporosis treatment by active agents such as bisphosphonate or calcitonine, use of corticosteroids for more than 3 mo, and extended bed rest. Every participant in the study signed an informed-consent form, and an ethics committee approved the study.

Table 1
Characteristics and Anthropometric Data
of the Study Population

	Women	Men
Number	993	459
Mean age (\pm SD)	48.2 \pm 15.2	47.0 \pm 15.2
Weight (kg), mean (\pm SD)	67.3 \pm 11.1	82.8 \pm 12.0
Height (cm), mean (\pm SD)	165.6 \pm 6.3	179.1 \pm 6.8
Body mass index (kg/m ²), mean (\pm SD)	24.5 \pm 3.8	25.8 \pm 3.4

BMD was measured at the nondominant foot (usually the left) using DXL Calscan. This device uses fan-beam X-rays at 35 and 68 kV. At the same time, the heel thickness was measured with a triangular laser technology.

The DXL Calscan device was checked by weekly measurements of hydroxyapatite in different concentrations incorporated in a solid, water-based, human-like phantom (Computerized Imaging Reference Systems, Inc., USA). The study duration was 3 mo. From these phantom measurements the in vitro precision of the device was determined. In vivo precision was assessed by duplicate measurements, with reposition of the foot between the measurements, on 35 healthy individuals (mean age 52 yr, range 25–72 yr) from the total study group.

The relationship between BMD and fracture history was assessed for women aged 50 yr and over. The age-adjusted odds ratio (OR) is reported.

Results

The total study population consisted of 1102 women and 493 men. After exclusion criteria were applied, 993 women and 459 men were included in the study. The mean age of the women were 48.2 \pm 15.2 yr and for men 47.0 \pm 15.2 yr. The characteristics and anthropometric data of the study population are shown in Table 1.

The age-dependent BMD values in 10-yr bands for women and men are shown in Table 2 and are plotted in Fig. 1.

Because the peak bone mass (PBM) for women was found at an age of 22 yr and for men at an age of 25 yr the young adult reference mean and standard deviation

Table 2
Age-Stratified BMD Values With Standard Deviations for Women and Men

Age band (yr)	Women			Men		
	Number	BMD (g/cm ²)	SD (g/cm ²)	Number	BMD (g/cm ²)	SD (g/cm ²)
15–19	32	0.461	0.055	—	—	—
20–29	95	0.477	0.069	67	0.556	0.074
30–39	140	0.466	0.064	89	0.551	0.084
40–49	246	0.454	0.060	87	0.552	0.080
50–59	288	0.428	0.066	128	0.517	0.074
60–69	93	0.401	0.065	51	0.503	0.084
70–79	78	0.339	0.069	25	0.483	0.072
80–85	21	0.306	0.085	12	0.463	0.087

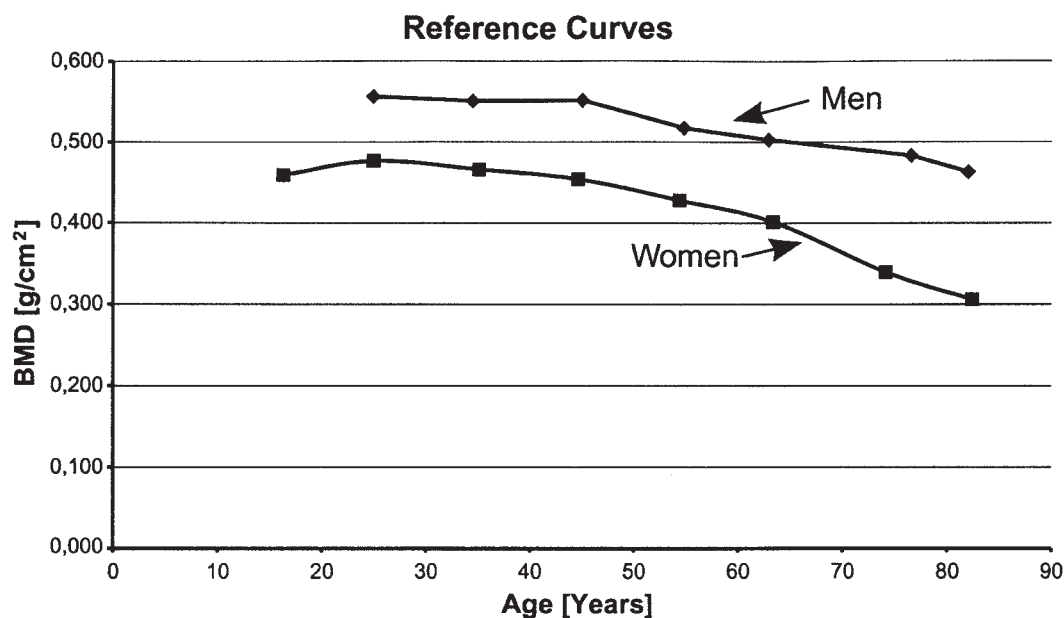


Fig. 1. BMD values for women and men plotted as a function of age for the DXL Calscan device.

were derived from the age interval between 18 and 27 yr for women and between 20 and 29 for men. The age of PBM was found by plotting the age-dependent BMD values in 5-yr bands. The young adult reference mean for women was found to be 0.483 ± 0.062 g/cm² and for men 0.556 ± 0.074 g/cm².

The rate of bone mass loss per year from age 50 and onwards was 1% for women and 0.5% for men.

To estimate the stability of the apparatus, a bone phantom was measured weekly during the study. The

coefficient of variation (CV) from these measurements was 0.5%.

The in vivo short-term precision was determined in 35 healthy individuals (mean age 52 yr, range 25–72 yr) from the total study group. The root-mean-square (rms) CV from these measurements was 1.2%.

In 31 of the study subjects, both the right and left calcaneus was measured (Fig. 2). No significant differences could be found between the right and left measurements.

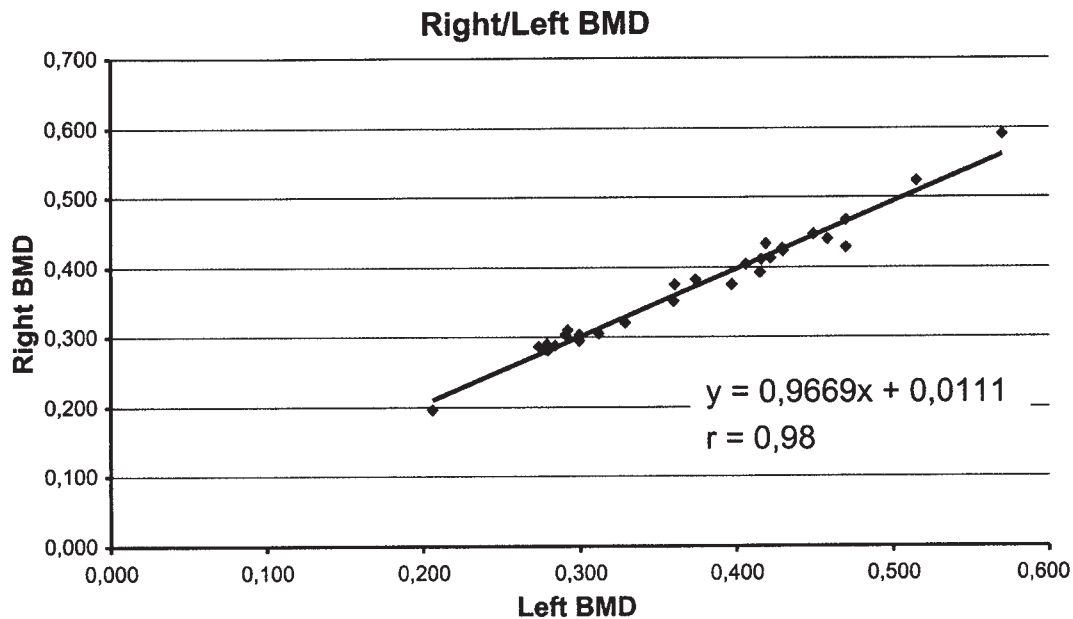


Fig. 2. Scatterplot of BMD values in left and right heel in 31 healthy subjects. Regression line and correlation shown.

Table 3

Correlation (Pearson Correlation) Between BMD and Body Weight, Height, and Body Mass Index (BMI)

	Body weight	Body height	BMI
Women	0.26	0.28	0.14
Men	0.25	0.23	0.15

The correlation between BMD and body weight, height, and body mass index is shown in Table 3. All correlations were highly significant ($p < 0.001$) although of low magnitude.

There were 480 women aged 50 yr and older. In this group there were 163 women with a history of fracture and 317 women without a history of fracture. Among the fractured women, 38 reported at least two fractures. The most commonly reported fracture sites were forearm ($n = 51$), arm ($n = 37$), and ankle ($n = 17$). The age-adjusted odds ratio for a history of fracture for women aged 50 yr and over with a BMD level 1 SD below the mean value, compared to women of the same age group with a BMD level more than 1 SD below the mean value, was estimated to 3.7 with a

95% confidence interval of 2.2–6.0. The values for mean and SD were estimated from the group of 317 women in the reference database over 50 yr old and without previous fractures. Of the 480 women aged 50 yr and over, 109 had a 1-SD reduction in bone density, whereas 371 had BMD levels above this value.

Discussion

The data obtained in this age-related study of the BMD of the reference population with DXL Calscan allows analysis of different behaviors of the BMD over the lifetime for both women and men.

This reference database is of Swedish origin and may not be appropriate for all regions of the world. The variations in BMD values for northern European regions are small (11), but larger discrepancies exist for BMD values between southern and northern Europe (12) and between Asia and the United States (13,14). This implies that reference databases should be established for each region of the world. One limitation of the study is that these data are cross-sectional and therefore are an estimate of the actual mean BMD changes through time. Another limitation is that the recruitment process was not random, because the subjects were recruited from advertisements and visits to

workplaces. The recruitment should preferably be done by an electoral or population register.

The frequent use of *T*-scores for the diagnosis of osteoporosis emphasizes that the peak bone mass (PBM) values and magnitude of the standard deviation are of utmost importance. Many bone mineral measurement devices use the mean BMD of ages 20 to about 45 yr for the estimation of the PBM (15). However, in the present study we found that the PBM values were obtained at age 22 for women and 25 for men. From the age of PBM to 45 yr the women lost 6.4% in BMD and men only 0.7%.

The rate of loss for postmenopausal women (1%/yr) is similar to the rate of loss found at measurements of the lumbar spine (16), which indicates similarities in trabecular bone remodeling in the vertebral bodies and the Calcaneus.

BMD measurement of the heel bone is as predictive as BMD measured at the forearm and spine to assess fracture risk at these sites (17). Heel BMD has been shown to be the second best predictor of hip fracture after hip BMD (2,18). In women with lumbar osteoarthritis, with falsely elevated BMD in the spine when measured by DXA, the heel bone is a more relevant site than the lumbar spine in the evaluation of skeletal status. BMD in the heel can thus be used to assess fracture risk, with predictive power similar to measurements made at the hip and spine (3,19). Other studies have shown the usefulness of peripheral measurements to identify postmenopausal women at risk of osteoporosis (20).

This study provides a reference database for a Swedish population for DXL Calscan. The *in vivo* precision was high, and BMD measurements of the heel bone using the DXL technology may be useful in the evaluation of bone fragility.

References

- Black DM, Cummings SR, Genant HK, Nevitt MC, Palermo L, Browner W. 1992 Axial and appendicular bone density predict fractures in older women. *J Bone Miner Res* 7:633–638.
- Miller PD, Siris ES, Barrett-Connor E, et al. 2002 Prediction of fracture risk in postmenopausal white women with peripheral bone densitometry: Evidence from the National Osteoporosis Risk Assessment. *J Bone Miner Res* 17:2222–2230.
- Seikoka Y, Kushida K, Yamazaki K, Inoue T. 1999 Calcaneus bone mineral density using single X-ray absorptiometry in Japanese women. *Calcif Tissue Int* 65:106–111.
- Vogel JM, Wasnich RD, Ross PD. 1998 The clinical relevance of calcaneus bone mineral measurements: a review. *Bone Miner* 5:35–58.
- Bolotin HH, Sievänen H. 2001 Inaccuracies inherent in dual-energy X-ray absorptiometry *in vivo* bone mineral density can seriously mislead diagnostic/prognostic interpretations of patient-specific bone fragility. *J Bone Miner Res* 16:799–805.
- Kupier JW, van Kuijk C, Grashuis JL, Ederveen AGH, Schutte HE. 1996 Accuracy and the influence of marrow fat on quantitative CT and dual-energy X-ray absorptiometry measurements of the femoral neck *in vitro*. *Osteoporos Int* 6:25–30.
- Lochmuller EM., Miller P., Burklein D., Wehr U. Rambeck W., Eckstein F. 2000 *In situ* femoral dual-energy X-ray absorptiometry related to ash weight, bone size and density, and its relationship with mechanical failure loads of the proximal femur. *Osteoporos Int* 11:361–367
- Meunier P, Aaron C, Edouard C, Vignon G. 1971 Osteoporosis and the replacement of cell populations of the marrow by adipose tissue. *Clin Orthoped* 80:147–154.
- Jonson R. 1993 Mass attenuation coefficients, quantities and units for use in bone mineral determinations. *Osteoporos Int* 3:103–106.
- Swanpalmer J, Kullenberg R. 2000 A new measuring device for quantifying the amount of mineral in the heel bone. *Ann N Y Acad Sci* 904:115–117.
- Wetzel R, Neumann M, Pfandl S, Puhl W. 1998 Knochendichte—Referenzwerte deutscher Männer. *Z Orthop* 136:260–267.
- Hadjidakis D, Kokkinakis E, Giannopoulos G, Merakos G, Raptis SA. 1997 Bone mineral density of vertebrae, proximal femur and os calcis in normal Greek subjects as assessed by dual-energy X-ray absorptiometry: comparison with other populations. *Eur J Clin Invest* 27:219–227.
- Thoo FL, Chng SM, Lam KS, et al. 2002 To establish the normal bone mineral density reference database for the Singapore male. *Ann Acad Med Singapore* 31:21–55.
- Liao EY, Wu Xp, Deng XG, et al. 2002 Age-related bone mineral density, accumulated bone loss rate and prevalence of osteoporosis at multiple skeletal sites in Chinese women. *Osteoporos Int* 13:669–676.
- Sekioka Y, Kushida K, Yamazaki K, Inoue T. 1990 Calcaneus bone mineral density using single X-ray absorptiometry in Japanese women. *Calcif Tissue Int* 6:106–111.
- Pouilles JM, Tremollieres F, Ribot C. 1995 Effect of menopause on femoral and vertebral bone loss. *J Bone Miner Res* 10:1531–1536.
- D. Marshall, O. Johnell, H. Wedel. 1996 Meta-analysis of how well measures of bone density predict occurrence of osteoporotic fractures. *Br Med J* 312:1254–1259.
- Cummings SR, Black DM, Nevitt MC, et al. 1993 Bone density at various sites for prediction of hip fractures. *Lancet* 341:72–75.
- Wasnich RD, Ross PD, Heilbrum LK, Vogel JM. 1987 Selection of the optimal site for fracture risk prediction. *Clin Orthoped* 216:262–268.
- Siris ES, Miller PD, Barrett-Connor E, et al. 2001 Identification and fracture outcomes of undiagnosed low bone mineral density in postmenopausal women. *JAMA* 286(22):2815–2822.

