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Mineral content of upper tibia assessed by dual photon densitometry

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Bone mineral content (BMC, g/cm) and bone mineral density (BMD, g/cm^2) of the proximal tibia were determined by dual photon absorptiometry (DPA). Measurements just distal to the subchondral plates of the tibia condyles, where the bone structure is predominantly trabecular, proved to give the most consistent results. The precision of BMC measurements in this region, expressed as the coefficient of variation, was 1.1 per cent and of BMD measurements 2.5 per cent.

In a cross-sectional study on 63 normal women and men, BMC and BMD showed a decrease with age at a rate of about 8 and 9 per cent per decade, respectively, in women, but not in men. In normal women, BMC of proximal tibia was correlated with BMC of lumbar spine, femoral neck, and femoral shaft, as well as with body weight and height. DPA may be useful in the study of bone reactions, such as in patients undergoing arthroplasty of the knee.

The bone mineral content (BMC) in both the axial and peripheral skeleton can be measured by dual photon absorptiometry (DPA) accurately and precisely (Roos 1975, Wilson & Madsen 1977, Mazess 1979, Krølner & Pors Nielsen 1980, Riggs et al. 1981, Schaadt & Bohr 1982). Since it can be assumed that individual bones adapt to different functional demands (Rubin 1984), it is relevant to examine various parts of the skeleton and their relation to each other (Dalén & Jacobson 1974, Dalén & Lamke 1974, Mazess 1982). We have made DPA measurements of BMC (g/cm) and bone mineral density (BMD, g/cm^2) of the proximal tibia.

Patients and methods

Measurements were made on 41 normal women, aged 24–85 years, and on 22 normal men, aged 17–69 years. In 25 of the women, BMC of the lumbar spine and femoral neck and shaft was determined at the same time or within 6 months.

Measurements of BMC were made by dual photon absorptiometry (DPA) using the radiation energy peaks of 44 and 100 keV from 1 Ci ^{153}Gd. With the scanning apparatus previously described for BMC measurements of lumbar spine and femoral neck and shaft, linear correlations between BMC and mineral equivalents and between BMC and ash weight of bone specimens have been demonstrated (Schaadt & Bohr 1982, Bohr & Schaadt 1985). For BMC measurements of the proximal tibia, the collimator opening was reduced from 13 to 4 mm in diameter to improve resolution. Scanning was performed transversely to the bone axis from the tibial tuberosity to the knee joint. The distance between each scan path was 2 mm and the scanning speed was 2 mm per second. At measurement the subject was supine with the knee extended and the foot in an upright position, stabilized with sandbags around the ankle.

The precision of BMC and BMD of the proximal tibia was determined for 12 tibias of 9 normal persons measured twice at intervals from 3 days to 5.5 months (average 61 days). The radiation dose to the bone marrow by the total examination was below 0.1 mGy (10 mrad). Calibration

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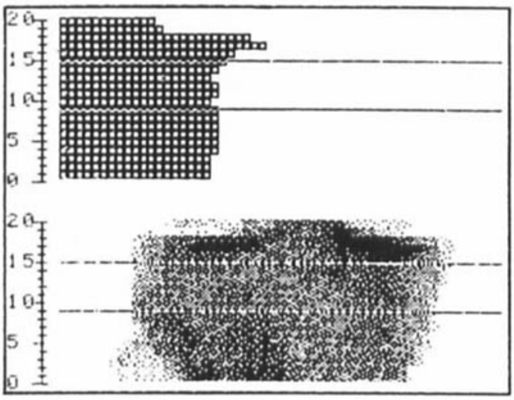

Figure 1. Scan plot of right proximal tibia with integrated values of each scan path indicated by horizontal rows above. The region corresponding to the five scan integrals distal to the subchondral plates is denoted between the two horizontal lines. The head of the fibula appears to the left below this region.

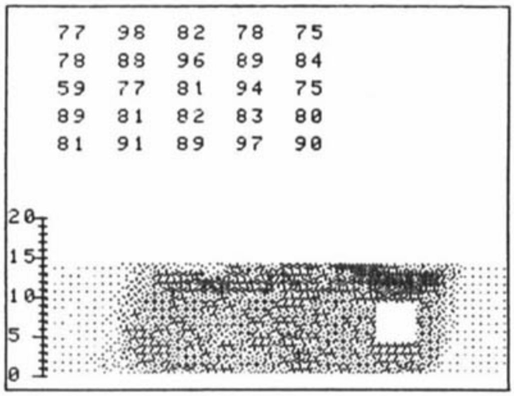

Figure 2. Scan plot demonstrating measurement of BMD (g/cm^2) in a selected area (white) of 1 cm^2 in the medial tibial condyle. The numbers indicate the integrated values in each measured point (pixel).

measurements were made on four aluminum tubes of different mass and diameter.

The Student's t-test and linear regression analysis were used.

Results

DPA measurements of different aluminum standards showed a linear relationship ($r = 0.999$). For measurements of BMC in the region corresponding to the eight most proximal scan integrals, the precision, expressed as the coefficient of variation (CV), was 1.5 per cent and in the region just distal to the subchondral plates (Figure 1), 1.1 per cent. The CV for BMD measurements in these regions was 3.0 and 2.5 per cent, respectively.

BMC and BMD were found to decrease with age in normal women at a rate of about 8 and 9 per cent each decade, respectively, while there was no decrease of either BMC or BMD in normal men (Table 1). There was a correlation between BMC of proximal tibia and body height and weight in normal women, but not in men (Table 2). BMC of the proximal tibia correlated with BMC of the lumbar spine and femoral neck and shaft in normal women (Table 3). Measurements of BMD in selected areas of the computerized scan plot, distal to the subchondral plates, revealed about 10 per cent higher values for the medial tibial condyle than for the lateral condyle ($P < 0.05$) in both women and men. The lowest values were obtained for the intercondylar space.

Table 1. Bone mineral content (BMC) and bone mineral density (BMD) of proximal tibia in relation to age

Sex	Age	Mean age	n	BMC g/cm	SD	BMD g/cm^2	SD
F	20–40	32	13	6.2	0.7	0.88	0.09
F	41–60	45	16	5.2[a]	0.7	0.74[a]	0.08
F	61–85	71	12	4.4[b]	0.8	0.61[b]	0.11
M	17–40	28	12	6.9	0.9	0.87	0.13
M	41–69	57	10	6.8	1.1	0.85	0.13

[a] Values different from those for age-group 20–40 ($P < 0.01$).
[b] Values different from those for age-group 41-60 ($P < 0.01$).

Table 2. Bone mineral content in relation to age, body height and weight in 41 women and 22 men

	Sex	r	P
Age	F	−0.72	< 0.001
	M	−0.03	NS
Height	F	+0.75	< 0.001
	M	−0.14	NS
Weight	F	+0.38	< 0.002
	M	−0.38	NS

Table 3. Relation between bone mineral content (BMC) of tibia and lumbar spine, femoral neck, and femoral shaft in normal women

	n	r	P
Tibia and lumbar spine	24	+0.78	< 0.001
Femoral neck	25	+0.83	< 0.001
Femoral shaft	25	+0.64	< 0.001

Discussion

The most consistent measurements of BMC and BMD in the proximal tibia were obtained in the region just distal to the subchondral plates, where the trabecular structure transfers weight load to cortical bone of the tibial shaft (Hall 1966). Due to the relatively uniform mineral distribution and the distinct demarcation towards the subchondral plates, this region is well suited for measurements of BMC and especially of BMD in selected areas where the precision is dependent upon the variation between the values obtained for each measured point.

The decrease with age of BMC and BMD of the proximal tibia in women is comparable to that of BMC of the femoral neck (Bohr & Schaadt 1985). The positive correlation with body weight in women is consistent with the demonstrated influence of weight bearing and physical activity (Andersson 1978, Margulies et al. 1986). Analogously, it has been shown in paraplegic patients, immobilized in a wheel chair after spinal injury, that BMC of the proximal tibia decreased by about 40 per cent during the first year after the accident, as compared to a decrease of 20 and 10 per cent, respectively, in the femoral neck and shaft (Bohr et al. 1986). The finding that average bone density was higher in the medial than in the lateral tibial condyle accords with investigations showing greater weight-bearing capacity of the medial than the lateral condyle (Behrens et al. 1974, Goldstein et al. 1983). Measurements of BMC and MBD of proximal tibia may provide information about bone reactions as described following knee arthroplasty (Bohr & Lund 1987).

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