Measurement of Bone Mineral Content and Bone Density in Healthy Twelve-Year-Old White Females

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Bone mineral content (BMC) and bone mineral density (BMD) measurements were made by dual-energy x-ray absorptiometry (DEXA) in 112 healthy 12-yr-old white girls for the purposes of: (1) establishing reference data on total-body mineral content of 12-yr-old girls and (2) comparing the lumbar spinal bone density values from a dedicated scan with the lumbar region of interest bone density values from a whole-body scan. Total BMC ranged from 799 g to 2083 g with mean and median values of 1276 g and 1218 g. Total-body bone density ranged from 0.75 to 1.03 g/cm^2 with mean and median values of 0.88 and 0.87 g/cm^2. The mean and median lumbar bone density values from the lumbar scan mode were 0.74 and 0.73 g/cm^2 and were not significantly different from the mean and median lumbar bone density values of 0.71 and 0.70 g/cm^2 obtained from the region of interest data from the total-body scan. These results establish baseline bone mass and bone density values for our longitudinal study of bone accretion in young women and validate the use of lumbar vertebral bone density values obtained from whole-body scans.

J Nucl Med 1992; 33:1143–1145

There is general agreement that those women who obtain higher peak bone mass and higher peak bone density early in life are less likely to develop osteoporosis later in life (*1,2*). This fact has led to numerous studies on the timing and determinants of peak bone mass and density. Several groups of investigators have measured bone density in healthy premenopausal women between the ages of 20–40 and the common finding from these studies is that peak bone mass and peak bone density are obtained by the age of 20 (*3–6*). Whether premenopausal bone loss occurs from age 20 onwards remains under investigation (*7–9*).

Until recently, quantitative measurement of trabecular or integral bone of normal children was hampered by the radiation exposure associated with quantitative computed tomography (*3,10,11*) or with dual-photon absorptiometry utilizing ^{153}Gd sources (*12*). The relatively recent development of dual-energy x-ray absorptiometry (DEXA) has allowed a reduction in radiation exposure to 2-3 mrads per scan, or the radiation exposure equivalent to a transcontinental airplane trip. This advance has been pivotal in obtaining studies which are necessary to characterize the determinants of peak bone mass involving children (*13,14*).

The results from cross-sectional studies of young people between ages 5 and 20 yr indicate that the most rapid increases in total bone mass and in total bone density occur during puberty (*11,13*). We have undertaken a 5-yr longitudinal study of determinants of bone accretion for 112 white girls who were premenarchal at entry into the study. Baseline bone mass and bone density results of this study group along with a comparison of two techniques for measuring lumbar spinal bone density are presented in this report.

SUBJECTS AND METHODS

All procedures involving human subjects were reviewed by the Institutional Review Board for Clinical Research Studies of the Pennsylvania State University College of Medicine. Study subjects were recruited from four local school districts. School district officials reviewed and approved the study plan and distributed the study recruitment information to parents of all fifth grade girls. The study population is representative of white girls attending public school in Pennsylvania. This study was limited by design to descendants of Northern Europeans. Pedigree information was obtained to insure that the grandparents of all subjects were descendants of Northern Europeans. Parents or legal guardians provided informed consent for all study subjects. One hundred and twelve premenarchal white females, ages 10.1–13.3 yr, were enrolled in the study. A medical history for each subject was obtained from the parent to determine whether the applicant could be included in the study. All subjects were between 80%–120% of ideal weight for height, did not take any medication on a regular basis, did not have any medical history known to affect bone development and did not have any known disorders of dietary behavior.

All bone mineral content (BMC) and bone mineral density (BMD) measurements were made with a Hologic QDR-1000W

Received Jul. 23, 1991; revision accepted Jan. 11, 1992.

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bone absorptiometer (Hologic, Inc., Waltham, MA). Each child was scanned twice: once with a total-body scan requiring 12 min of scanning and then with a dedicated lumbar spine scan requiring 8–9 min. The details of this methodology and its reproducibility have been previously reported (*13*). Statistical analyses were accomplished with a range of procedures available within SAS (*15*).

RESULTS

The study population descriptive statistics are shown in Table 1. The study subjects are healthy average girls and their height and weight characteristics are unremarkable. Their mean and median values for total BMC are similar, reflecting a normal distribution among our study group. The range of total BMC values of 799 to 2083 g is shown in Figure 1 and is similar to the range of individual weight values for this group. In contrast, the range of values for total BMD is much smaller, 0.75 to 1.03 g/cm^2, and is similar to the range of ages for this group.

The values obtained by the two scanning techniques for BMD of the lumbar spine are not significantly different. However, the values obtained from the lumbar area region of interest (ROI) mode from the total-body scan are consistently lower than those obtained from the dedicated lumbar spine scan mode. The BMD for the lumbar spine using the whole-body mode is 0.714 g/cm^2 with a standard deviation of 0.104 and a standard error of the mean of 0.00984. The BMD for the lumbar spine using the dedicated mode is 0.742 g/cm^2 with a standard deviation of 0.0926 and a standard error of the mean of 0.00875. The strong correlation ($R^2 = 0.873$) between the two methods is shown in Figure 2.

DISCUSSION

Recent epidemiologic studies have described an increase in the past 40 yr in the frequency of osteoporosis and hip fracture in each decade of life after age 50. These findings may suggest that some of the underlying causes of osteoporosis are related to changes in lifestyle and/or environment during the past several decades (*16,17*). Since peak bone mass is a strong predictor of osteoporosis risk, and there is evidence that peak bone mass is achieved before the age of 20, investigations of bone development during puberty should be useful. The major objectives of our longitudinal study of bone development in white women are to establish normative reference values for total-body BMC, total and regional BMD and to evaluate the longi-

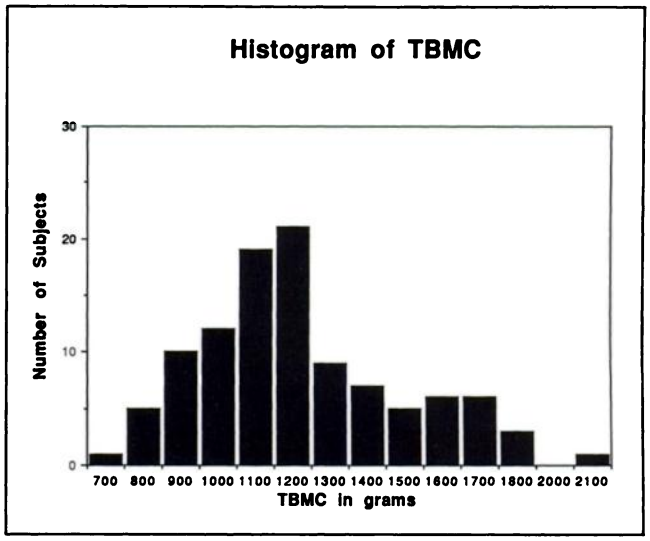

FIGURE 1. Distribution of total BMC values among 112 healthy premenarchal Caucasian females, age range: 11.3–13.3 yr. All measurements were obtained from a whole-body scan with a Hologic QDR 1000W absorptiometer.

TABLE 1
Descriptive Statistics of the Study Group (n = 112)

Variable	Mean/Median	Std. Dev.	Range Min.–Max.
Age, yr	11.9/11.9	0.49	10.7–13.3
Height, cm	149/149	6.74	135–168
Weight, kg	41.5/39.8	7.36	29–60
Total BMC, g	1276/1218	272	799–2083
Total BMD, g/cm^2	0.88/0.87	0.06	0.75–1.03
*L1-L4 BMC, g Scan 1	30.9/29.2	7.44	19.4–55.1
*L1-L4 BMC, g Scan 2	28.5/27.5	7.91	12.9–52.8
*L1-L4 BMD, g/cm^2 Scan 1	0.74/0.73	0.094	0.58–1.07
*L1-L4 BMD, g/cm^2 Scan 2	0.71/0.70	0.103	0.53–1.07

* Scan 1 data were obtained from the dedicated lumbar spine scan mode and Scan 2 data were obtained from the lumbar area ROI from the total-body scan. Paired t-tests showed that the mean and median values from Scan 1 and Scan 2 for BMC were significantly different ($p = <0.01$), whereas the values for BMD were not significantly different ($p = >0.05$).

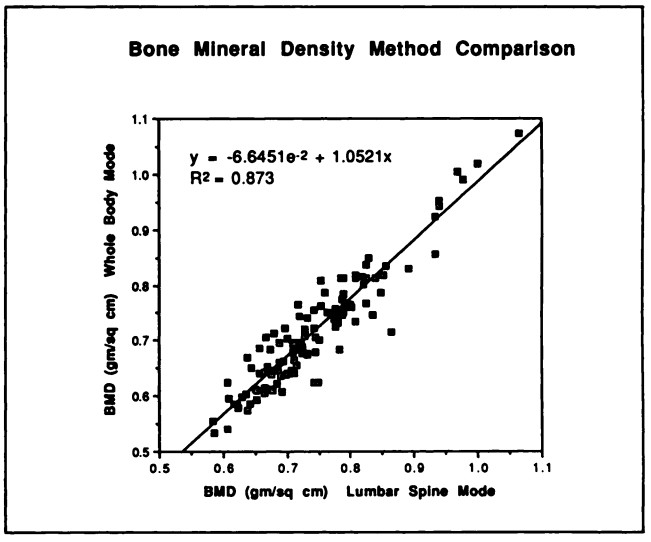

FIGURE 2. Comparison of lumbar spine BMD density values obtained with the lumbar spine ROI in whole-body mode and values obtained with the dedicated lumbar spine mode.

tudinal relationships among selected endocrine, nutritional and activity patterns upon bone development.

Data from total BMC and total BMD measurements, which will become more common as DEXA instrumentation becomes more widespread, allow us to inspect the dynamics of bone accretion and bone remodeling in a much more thorough manner. We were especially interested in determining whether ROI data from a whole-body scan was a valid measurement. In the example reported here, measurement of lumbar spine BMD from the total-body scan versus the site-specific mode provided comparable results. This might be anticipated since BMD is expressed in terms of grams of mineral per unit area. Although the lumbar spine ROI is not as precise as that in the dedicated lumbar spine mode, the normalization to unit area compensates for any limitation in ROI selection.

Measurement of total-body BMD and total-body BMC in healthy premenarchal girls has not, to our knowledge, been previously reported. Our lumbar spine BMD value of 0.70–0.74 g/cm^2 is in good agreement with values reported by Glastre et al. (*13*). The range of values for total BMC among our study group was similar to the variation seen with other markers of BMC (*18*). When our data are compared to those of normal premenopausal adult women (ages 21–40), we note that our 12-yr-old subjects have achieved, on average, 90% of their adult height, 68% of their adult weight, 83% of their adult total BMD and only 53% of their adult total BMC (*8,19*). The patterns of increase of BMC and BMD among our study group as they proceed through adolescence should provide us with new insight into the dynamics of bone accretion in young women.

ACKNOWLEDGMENTS

Supported by PHS grant R01-HD25973 and by a grant from the Proctor and Gamble Co., Cincinnati, OH.

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