

Normative bone mineral density data at multiple skeletal sites in Indian subjects

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Abstract

Summary Age-related change in bone mineral density (BMD) varied according to skeletal site in Indian subjects. A larger proportion of subjects was classified as osteoporotic and osteopenic using the Caucasian database than newly derived peak BMD values at most skeletal sites. Results establish useful normative data for reliable interpretations of individual dual-energy X-ray absorptiometry (DEXA) values

Introduction Osteoporosis is believed to occur at a relatively younger age in the Indian population. With increasing knowledge on significant differences in BMD between various racial groups, there is increased emphasis for the use of population-specific reference database.

Methods BMD at multiple skeletal sites was measured using DEXA (Prodigy, Lunar) in 615 Indian women (20–86 years) and 489 Indian men (20–83 years). Best-fit models were drawn for each skeletal site. Osteopenia and osteoporosis diagnosis rates were calculated using Caucasian and derived Indian peak BMD values.

Results Age-related change in BMD varied with skeletal site in both sexes. Peak BMD in women was observed between 31 and 40 years of age at the hip, spine, and radius

33% and between 20 and 30 years at the ultradistal radius. Peak BMD in men was attained between 20 and 30 years at the hip and radius 33% and between 31 and 40 years at the spine and ultradistal radius. A larger proportion of Indian subjects was classified as osteoporotic and osteopenic based on the Caucasian database than newly derived Indian peak BMD values at all skeletal sites except radius 33% and femoral neck in females above 40 years of age.

Conclusion Results establish useful normative data for the Indian population for reliable interpretations of individual DEXA values.

Keywords Osteoporosis · BMD–DEXA · Lunar Prodigy · Normative data · Indian population

Introduction

Osteoporosis, a silently progressing metabolic bone disease that leads to loss of bone mass, is widely prevalent in India, and osteoporotic fractures are a common cause of morbidity and mortality in adult Indian women and men [1]. Expert groups peg the number of osteoporosis patients in India at approximately 26 million with the numbers projected to increase to 36 million by the year 2013 [2]. Although relatively little is known about osteoporotic risk factors in women in the Indian subcontinent, osteoporotic fractures usually occur 10–20 years earlier in Indian women and men than their western Caucasian counterparts [3]. It has also been suggested that osteopenia and osteoporosis may occur at a relatively younger age in the Indian population [4, 5].

Age-related change in bone mineral density (BMD) and fracture risk have been associated with many factors including heredity, race, region, environment, nutrition, lifestyle, etc. [6, 7] and there are significant differences in

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BMD between peer age groups of different sexes and areas [7, 8]. Reference ranges may thus vary in different populations [9, 10]. The World Health Organization densitometric definition of osteoporosis, based on fracture risk, strictly pertains only to postmenopausal Caucasian women [11]. However, due to lack of adequate prospective data, quantitative relationship between BMD and fracture risk and treatment guidelines designed for Caucasian women have routinely been applied worldwide to non-Caucasian women and even men, despite the lack of any direct evidence and marked differences in skeletal size, height, body weight, etc. [12]. Based on currently available data, it is now becoming increasingly apparent that there are significant differences in BMD between various racial groups. Locally derived reference values are thus important to avoid false-positive or false-negative findings during work-up in patients evaluated for osteoporosis [13]. Assessment of risk of osteoporosis in Asian women by comparing their BMD with the reference Caucasian population may, therefore, have limited validity primarily because of the influence of skeletal size on such measurements.

The present study was aimed to (a) establish normative data for BMD at the three major skeletal sites of osteoporotic fractures viz. total hip including femoral neck, Ward's triangle and trochanter, lumbar spine and forearm [11, 14] in healthy adult Indian women and men, stratified in 10-year age bands, using dual-energy X-ray absorptiometry (DEXA); (b) compare the BMD of Indian females and males with the US/European BMD values provided by the manufacturer [15, 16, and personal communication]; (c) examine correlation between BMD and age; (d) establish osteoporosis cut off limits for Indian women and men for calculation of *T* scores that allowed more realistic categorization of people as normal, osteopenic, or osteoporotic than with the use of the manufacturer's reference range based on Caucasian population; and (e) define prevalence of osteoporosis at different skeletal sites in postmenopausal women and men >50 years of age. Pertinently, few earlier studies using DEXA have reported lower mean BMD at the spine and hip in Indian women than the reference North American and European population [17–20]. In addition, reports on Indian women and men based on methods such as Singh's index [21], calcaneal index [22], visual assessment [4, 5], quantitative ultrasound [23], digital X-ray radiogrammetry [24], and quantitative computed tomography [25] are also available.

Materials and methods

Subjects

In this cross-investigational study, a total of 615 healthy women aged between 20 and 86 years and 489 healthy men

aged between 20 and 83 years residing in Lucknow and its surrounding areas were recruited between April 2004 and December 2007. Out of 615 women, 342 were postmenopausal. The recruitment was made in part among the staff of the institute and medical university and lay people contacted by word of mouth. Care was taken to ensure representativeness of the general population with particular regard to the inclusion of subjects belonging to a wide range of socioeconomic strata, body size, and physical activity. The subjects included medical and research professionals; university and school teachers; engineers; medical and research students; nursing staff; technical, administrative, bank, and railway employees; security guards; businessmen; farmers; housewives; and housemaids. All participants were screened using a detailed questionnaire concerning health, daily dietary calcium intake, sun exposure, physical activity level and patterns, occupational activities, and tobacco and alcohol use. Medical, surgical, reproductive, fracture, and low backache history was recorded by one of us (BPS). The study was approved by the Institutional Ethics Committee and informed consent was obtained from all participants. Exclusion criteria were bilateral hip replacement, ankylosing spondylitis, low trauma fracture, primary hyperparathyroidism, hyperthyroidism, hyperprolactinemia, current pregnancy, lactation, bilateral oophorectomy, amenorrhea ≥ 6 months before the age of 40 years except during pregnancy and lactation, kidney or liver disease, organ transplantation, Paget's disease, malabsorption, history of cancer, current use of hormone/estrogen replacement therapy, and history of immunosuppressant, antiepileptic, bisphosphonate, selective estrogen receptor modulator, calcitonin, or teriparatide usage and was based on information provided by the volunteers.

Anthropometric data

Body weight and height of each subject were measured with light indoor clothing without shoes at the time of bone densitometry measurement. The body weight was recorded to the nearest tenth of a kilogram using an electronic scale and standing height was measured to the nearest centimeter by a calibrated wall-mounted Harpenden stadiometer with coefficient of variability of <0.5%. Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared.

Bone mineral density measurements

BMD expressed in gram per centimeter squared was measured using DEXA fanbeam bone densitometer (Prodigy, Lunar, Madison, WI, USA) at the (a) total hip including femoral neck, Ward's triangle, and trochanter;

(b) lumbar spine (L2–L3) in lateral projection; and (c) left forearm including radius 33% and ultradistal radius (radius UD). As we did not specifically exclude subjects with spinal osteoarthritis or aortic calcification that can confound BMD measurement [26, 27], we assessed the lateral instead of anteroposterior spine, which largely excludes these confounders from the scanning field. All measurements were made by the same operator and none of the scan devices was changed during the study. The in vivo precision was assessed by three repeated BMD measurements in 15 subjects. Percent coefficient of variance ranged from 0.5% to 1.1% depending on the measurement site. To ensure reproducibility, the instrument was calibrated daily with hydroxyapatite anthropomorphic spine phantom provided by the manufacturer before use.

Statistical analysis

SPSS 10.0 was used for statistical analysis of the data. BMD at various sites in subjects with age-related change was evaluated and the best-fit model found by a comparison of different regression models for linear, logarithmic, quadratic, cubic, compound, power, growth, and exponential equations. Analysis of variance with Tukey's post hoc test was used to determine differences in BMD among different age groups. All subjects were stratified in 10-year age groups and the BMD, body weight, height, and BMI in each group were reported as the mean and standard deviation (SD). Peak BMD was determined from the age group with the highest mean BMD value and outliers of more or less than 3 SD beyond the main peak BMD were excluded.

The mean BMD for each decade of age at all the skeletal sites was compared with the mean values for Caucasian women and men provided in the Caucasian database supplied by the manufacturer of the densitometer using Student's *t* test. *T* scores were calculated using the Caucasian BMD means and standard deviations as well as

our newly derived Indian cohort's BMD means and standard deviations using the following equation:

$$T \text{ score} = \frac{\text{BMD}_{\text{subject}} - \text{peak BMD}}{\text{SD}_{\text{peak}}}$$

T score <−2.5 was used as the cut off value in the diagnosis of osteoporosis, *T* score between −2.5 and −1 was diagnostic of low bone mass (osteopenia), and *T* score >−1 was considered as normal [11, 14].

Results

The anthropometric data of the subjects are shown in Table 1. The study sample was divided into six subgroups according to age for cross-sectional analysis.

Female subjects

Hip

For total hip and its components, peak BMD was observed between ages 31 and 40 years (Tables 2 and 3). Figure 1a–d displays the polynomial regression equations that describe the relationship between age and BMD at each site. The cubic regression model was the simplest model that significantly improved fit to the data at every site except total hip where the quadratic model fitted this criterion. BMD of hip at different sites, viz. Ward's ($R^2=0.5241$, $P<0.001$), femoral neck ($R^2=0.3667$, $P<0.001$), trochanter ($R^2=0.2335$, $P<0.05$), and total hip ($R^2=0.3229$, $P<0.001$) in Indian women was significantly negatively regressed with age. A highly significant negative correlation between age groups and BMD at any site of the hip was found in Indian women ($P<0.001$). The actual decrease of BMD between the age of peak BMD and 86 years was highest for Ward's triangle (43%; average change per decade was 8.6%) and ranged between 25% and 29% for total hip,

Table 1 Anthropometric characteristics in normal Indian women and men

| Indian women | | | | | Indian men | | | | |
|--------------|--------------|-------------|------------------|--------------------------|--------------|--------------|-------------|------------------|--------------------------|
| Age in years | Total number | Height (cm) | Body weight (kg) | BMI (kg/m ²) | Age in years | Total number | Height (cm) | Body weight (kg) | BMI (kg/m ²) |
| 20–30 | 114 | 159.83±4.33 | 53.13±7.95 | 20.87±3.05 | 20–30 | 85 | 172.51±8.58 | 65.11±10.23 | 21.35±3.93 |
| 31–40 | 99 | 156.36±5.25 | 63.31±9.38 | 25.98±4.05 | 31–40 | 70 | 170.76±8.92 | 72.13±13.74 | 24.63±3.56 |
| 41–50 | 119 | 156.34±5.79 | 62.17±9.34 | 25.59±3.43 | 41–50 | 95 | 171.00±6.62 | 71.48±10.49 | 24.44±3.09 |
| 51–60 | 108 | 154.68±5.16 | 62.45±10.70 | 26.23±4.22 | 51–60 | 98 | 167.16±5.66 | 68.68±12.22 | 24.53±3.67 |
| 61–70 | 106 | 153.56±6.01 | 59.89±11.24 | 25.40±4.07 | 61–70 | 90 | 168.33±7.61 | 67.84±12.89 | 23.99±2.98 |
| 71–86 | 69 | 150.07±5.83 | 55.81±12.35 | 24.91±5.89 | 71–83 | 51 | 165.75±6.39 | 65.14±9.01 | 23.56±3.02 |

BMI body mass index

Table 2 Age-related change in BMD in Indian women in comparison to the manufacturer's BMD values

| Skeletal site and age in years | Present study* | | Manufacturer's normal database** | | T score | Difference (%) | P value |
|--------------------------------|----------------|----------------------|----------------------------------|-------|---------|-----------------|-----------|
| | Mean | SD | Mean | SD | | | |
| Total hip | | | | | | | |
| 20–30 | 0.904 | 0.092 ^{b,c} | 0.970 | 0.130 | -7.44 | -0.066 (-6.80) | 0.0001*** |
| 31–40 | 0.987 | 0.121 ^d | 0.990 | 0.130 | -0.59 | -0.003 (-0.30) | 0.556 NS |
| 41–50 | 0.922 | 0.111 ^c | 0.976 | 0.130 | -5.20 | -0.054 (-5.53) | 0.0001*** |
| 51–60 | 0.861 | 0.118 ^b | 0.927 | 0.130 | -4.74 | -0.066 (-7.11) | 0.0001*** |
| 61–70 | 0.852 | 0.128 ^b | 0.896 | 0.130 | -9.25 | -0.044 (-4.91) | 0.0001*** |
| 71–86 | 0.738 | 0.097 ^a | 0.781 | 0.130 | -14.94 | -0.043 (-5.5) | 0.0001*** |
| Femoral neck | | | | | | | |
| 20–30 | 0.871 | 0.091 ^c | 0.956 | 0.120 | -9.64 | -0.085 (-8.89) | 0.0001*** |
| 31–40 | 0.967 | 0.107 ^d | 0.965 | 0.120 | +0.16 | +0.002 (+0.20) | 0.876 NS |
| 41–50 | 0.868 | 0.111 ^c | 0.941 | 0.120 | -6.94 | -0.073 (-7.75) | 0.0001*** |
| 51–60 | 0.801 | 0.114 ^b | 0.871 | 0.120 | -6.02 | -0.070 (-8.03) | 0.0001*** |
| 61–70 | 0.750 | 0.115 ^b | 0.801 | 0.120 | -0.93 | -0.051 (-6.36) | 0.356 NS |
| 71–86 | 0.682 | 0.090 ^a | 0.741 | 0.120 | -4.69 | -0.059 (-7.96) | 0.0001*** |
| Femur Ward's | | | | | | | |
| 20–30 | 0.787 | 0.094 ^{d,e} | 0.897 | 0.130 | -12.22 | -0.11 (-12.26) | 0.0001*** |
| 31–40 | 0.837 | 0.128 ^e | 0.886 | 0.130 | -3.72 | -0.049 (-5.53) | 0.0001*** |
| 41–50 | 0.727 | 0.125 ^d | 0.840 | 0.130 | -9.45 | -0.113 (-13.45) | 0.0001*** |
| 51–60 | 0.633 | 0.133 ^c | 0.740 | 0.130 | -7.98 | -0.107 (-14.46) | 0.0001*** |
| 61–70 | 0.560 | 0.138 ^b | 0.644 | 0.130 | -6.02 | -0.084 (-13.04) | 0.001** |
| 71–86 | 0.476 | 0.070 ^a | 0.518 | 0.130 | -3.27 | -0.042 (-8.10) | 0.001** |
| Femur trochanter | | | | | | | |
| 20–30 | 0.697 | 0.077 ^{c,b} | 0.754 | 0.110 | -7.56 | -0.057 (-7.55) | 0.0001*** |
| 31–40 | 0.790 | 0.118 ^d | 0.785 | 0.110 | +0.34 | +0.005 (+0.63) | 0.737 NS |
| 41–50 | 0.723 | 0.100 ^{c,b} | 0.780 | 0.110 | -5.84 | -0.057 (-7.30) | 0.0001*** |
| 51–60 | 0.683 | 0.113 ^b | 0.742 | 0.110 | -5.16 | -0.059 (-7.95) | 0.0001*** |
| 61–70 | 0.668 | 0.109 ^b | 0.699 | 0.110 | -9.54 | -0.031 (-4.43) | 0.0001*** |
| 71–86 | 0.589 | 0.080 ^a | 0.641 | 0.110 | -4.54 | -0.052 (-8.11) | 0.0001*** |
| Lateral spine | | | | | | | |
| 20–30 | 0.654 | 0.108 ^b | 0.768 | 0.120 | -11.18 | -0.114 (-14.84) | 0.0001*** |
| 31–40 | 0.712 | 0.126 ^b | 0.767 | 0.120 | -4.29 | -0.055 (-7.17) | 0.0001*** |
| 41–50 | 0.662 | 0.142 ^b | 0.706 | 0.120 | -3.23 | -0.044 (-6.23) | 0.001** |
| 51–60 | 0.560 | 0.121 ^a | 0.618 | 0.120 | -4.78 | -0.058 (-9.38) | 0.0001*** |
| 61–70 | 0.508 | 0.152 ^a | 0.443 | 0.120 | +4.31 | +0.065 (+14.67) | 0.0001*** |
| 71–86 | 0.503 | 0.167 ^a | 0.475 | 0.120 | +1.36 | +0.028 (+5.89) | 0.177 NS |
| Radius 33% | | | | | | | |
| 20–30 | 0.784 | 0.672 ^{d,e} | 0.888 | 0.089 | -16.49 | -0.104 (-11.71) | 0.0001*** |
| 31–40 | 0.826 | 0.058 ^c | 0.888 | 0.089 | -10.65 | -0.062 (-6.98) | 0.0001*** |
| 41–50 | 0.784 | 0.070 ^{d,e} | 0.888 | 0.089 | -16.23 | -0.104 (-11.71) | 0.0001*** |
| 51–60 | 0.723 | 0.087 ^c | 0.863 | 0.089 | -21.52 | -0.140 (-16.22) | 0.0001*** |
| 61–70 | 0.668 | 0.117 ^b | 0.775 | 0.089 | -19.22 | -0.107 (-13.81) | 0.0001*** |
| 71–86 | 0.583 | 0.114 ^a | 0.684 | 0.089 | -10.81 | -0.101 (-14.77) | 0.0001*** |
| Radius UD | | | | | | | |
| 20–30 | 0.521 | 0.100 ^c | 0.469 | 0.045 | +5.55 | +0.052 (+11.09) | 0.0001*** |
| 31–40 | 0.468 | 0.058 ^d | 0.469 | 0.045 | -0.18 | -0.001 (-0.21) | 0.855 NS |
| 41–50 | 0.431 | 0.056 ^c | 0.469 | 0.045 | -7.30 | -0.038 (-8.10) | 0.0001*** |
| 51–60 | 0.380 | 0.058 ^b | 0.448 | 0.045 | -11.85 | -0.068 (-15.18) | 0.0001*** |
| 61–70 | 0.371 | 0.119 ^b | 0.412 | 0.045 | -14.45 | -0.041 (-9.95) | 0.0001*** |
| 71–86 | 0.314 | 0.077 ^a | 0.367 | 0.045 | -5.42 | -0.053 (-14.44) | 0.0001*** |

Comparison of means was done using one-way analysis of variance (ANOVA) with age as varying factor followed by Tukey's test for significance; values followed by different letters (a, b, c, d, e) are statistically different at $P < 0.0001$

NS statistically nonsignificant

*As calculated by the formula provided by the manufacturer based on the age and weight of the individual concerned

**SD values as provided by the manufacturer [15, 16, and personal communication]

Table 3 Regression of BMD on age at different skeletal sites in the respective peak bone mass age group of female and male subjects

| BMD | Regression within peak group | R ² | P value |
|------------|-------------------------------|----------------|---------|
| Female | | | |
| Wrist | $y=0.003x^2-0.0994x+2.325$ | 0.0609 | >0.05 |
| Radius UD | $y=-0.004x^2+0.0936x-1.009$ | 0.0713 | >0.05 |
| Hip | $y=0.0016x^2-0.124x+3.3014$ | 0.0474 | >0.05 |
| Spine | $y=0.0004x^2-0.038x+1.575$ | 0.0644 | >0.05 |
| Neck | $y=0.001x^2-0.0826x+2.6016$ | 0.0812 | >0.05 |
| Wards | $y=-0.0006x^2+0.0314x+0.4909$ | 0.0704 | >0.05 |
| Trochanter | $y=-0.0004x^2+0.0237x+0.4061$ | 0.0065 | >0.05 |
| Male | | | |
| Wrist | $y=-0.0026x^2+0.1211x-0.0839$ | 0.0849 | >0.05 |
| Radius UD | $y=0.0018x^2-0.1217x+2.4829$ | 0.0984 | >0.05 |
| Hip | $y=-0.0016x^2+0.0634x+0.4151$ | 0.0565 | >0.05 |
| Spine | $y=0.0057x^2-0.3895x+1.3848$ | 0.0874 | >0.05 |
| Neck | $y=-0.0025x^2+0.1139x-0.2191$ | 0.0441 | >0.05 |
| Wards | $y=-0.0029x^2+0.1267x-0.4008$ | 0.0643 | >0.05 |
| Trochanter | $y=0.0002x^2-0.0219x+0.3087$ | 0.0810 | >0.05 |

femoral neck, and trochanter. The mean BMD values in Indian women were 0.3–14.5% lower at the total hip and its components from the Caucasian Lunar BMD database supplied by the manufacturer. However, when peak BMD values of total hip and its components obtained for this study population were compared with the reference peak BMD values for Caucasian women provided by the manufacturer, significant difference (5.5%, $P<0.001$) was observed only at the Ward's triangle.

T scores for total hip and its components calculated using peak BMD and SD values of this study population were different from those obtained using the Caucasian BMD means and SD provided by the manufacturer (Table 4). The percent postmenopausal population classified as osteoporotic (*T* score <-2.5) and osteopenic (*T* score >-2.5 to <-1) differed substantially depending on the skeletal site of interest where BMD was determined. Of the postmenopausal women, 61.2% was characterized as osteoporotic at the Ward's triangle using the Caucasian Lunar BMD database, whereas only 30.1% was characterized as osteoporotic using the reference range for the Indian population defined in this study. Higher peak BMD value in Indian women at the femoral neck led to a larger percentage of women classified as osteoporotic with the Indian reference values defined in this study than with the Caucasian Lunar BMD database (26.6% versus 20.7%). At the trochanter region, *T* scores calculated using the Indian peak BMD values obtained in this study resulted in marked decrease in the number of postmenopausal women classified as osteoporotic (5.3% versus 10.5%; $P<0.05$) in the 41–50 years age group and (11.6% versus 18.8%, statistically nonsignificant) in 70–86 year age group than the manu-

facturer's reference value. The difference in other age groups with the two reference ranges was not significant. A 2.8% (statistically nonsignificant) decrease in osteoporotics in women aged 50–70 years was observed at the total hip with the newly derived Indian peak BMD values when compared to the manufacturer's reference values. There was no difference in other age groups.

The cut off values for osteoporosis of the total hip, femoral neck, Ward's triangle, and trochanter in women using the Indian reference values were 0.685, 0.699, 0.517, and 0.495 g/cm², respectively. The corresponding values according to manufacturer's reference database were 0.665, 0.665, 0.572, and 0.510 g/cm², respectively.

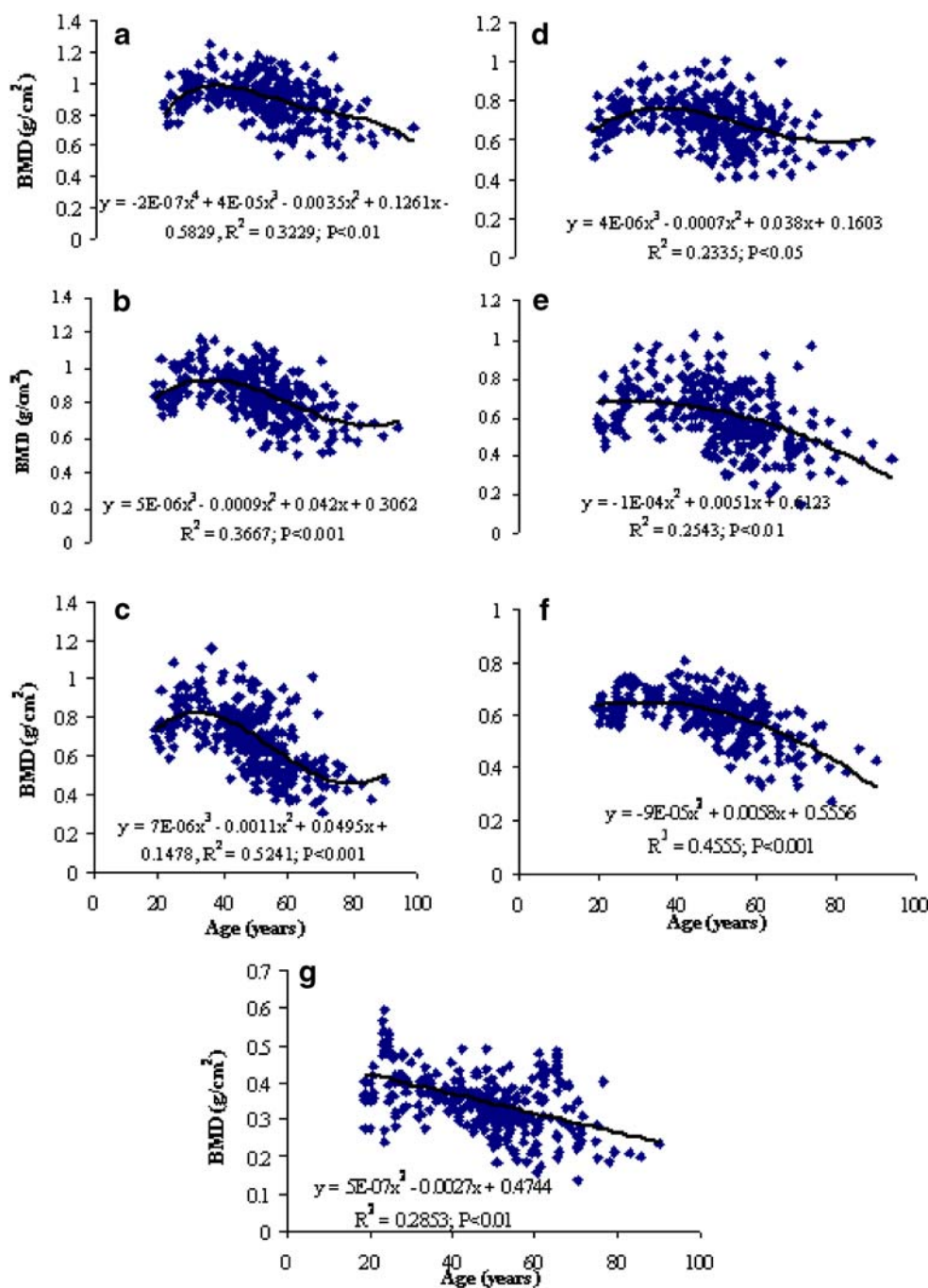
Lumbar spine

At the lumbar spine, BMD among Indian women remained stable between ages 20 and 50 years and declines thereafter (Table 2). Though there was no statistically significant difference in the BMD values for ages 20–50 years, peak BMD (i.e., the highest mean BMD at a particular site) was identified in the 31–40 years age group. The best-fitting curve was a polynomial equation of the second degree ($R^2=0.2543$, $P<0.01$; Fig. 1e). The mean decrease between the fourth and fifth decade was 15% after which there was a nonsignificant decline in BMD with increasing age. The decrease of BMD between the age of peak BMD and 86 years in women was 29% (average of 5.8% per decade). Compared to the manufacturer's Lunar reference values, BMD in Indian women was 6.2–14.8% ($P<0.001$) lower at the lumbar spine between ages 20 and 60 years. However, the BMD of Indian women for the decade beginning at 61 years was 14.7% higher ($P<0.0001$) than Lunar reference values for this age group. The difference was nonsignificant for the 70–86 years age group; 6.0% more postmenopausal Indian women were diagnosed with osteoporosis using Lunar reference peak BMD and SD values than newly derived Indian peak BMD and SD values obtained in this study for the calculation of *T* scores (Table 4). The cut off value for osteoporosis at this site in women was 0.397 g/cm² compared to 0.468 g/cm² with the Lunar reference values.

Forearm

The best-fitting curve for the forearm was a polynomial function of the second degree (Fig. 1f–g). Peak BMD was achieved in the age group 31–40 years at the radius 33% and 20–30 years at the radius UD (Tables 2 and 3), followed by a decrease with age ($R^2=0.4555$, $P<0.001$ and $R^2=0.2853$, $P<0.01$, respectively). The decrease in BMD between the age of peak BMD and 86 years was 29.4% for radius 33% (average of 5.8% per decade) and 39.7% for

Fig. 1 Regression equations and trend lines of BMD of total hip (a), femoral neck (b), Ward's triangle (c), trochanter (d), lateral spine (e), radius 33% (f), and radius UD (g) in relation to age (20–86 years) in Indian women



radius UD (average of 6.6% per decade). Compared to Lunar reference values, BMD in Indian women was 6.9–16.2% lower at radius 33% and 0.2–15.2% lower at the radius UD (Table 2). At radius 33%, the peak BMD of the study population was 6.9% lower than the reference population. However, smaller variance in the study population compared to the Caucasian population (0.058 versus 0.08875 SD) resulted in 3.2% more postmenopausal women classified as osteoporotic with the Indian than Caucasian reference values.

At the radius UD, peak BMD of study population was 11.1% higher than the reference Caucasian population and the incidence of osteoporosis decreased by 22.4% using the Indian peak BMD and SD values obtained in this study (Table 4). The cut off values for osteoporosis of the radius 33% and radius UD site using the Indian reference values were 0.681 and 0.271 g/cm², respectively. The corresponding values according to manufacturer's reference database were 0.665 and 0.356 g/cm², respectively.

Table 4 Prevalence of osteoporosis and osteopenia at different skeletal sites in postmenopausal Indian women using the Indian versus the Caucasian peak BMD values

| Skeletal site | Study | Age in years | | | | | | | |
|------------------|------------------------------|--------------|------------|--------------|------------|--------------|------------|--------------|------------|
| | | 41–50 | | 51–60 | | 61–70 | | 71–86 | |
| | | Osteoporotic | Osteopenic | Osteoporotic | Osteopenic | Osteoporotic | Osteopenic | Osteoporotic | Osteopenic |
| Total hip | Present study | 7.89 | 42.11 | 7.48 | 44.86 | 11.32 | 35.85 | 28.99 | 65.22 |
| | Caucasian Lunar BMD Database | 7.89 | 47.37 | 10.28 | 44.86 | 14.15 | 35.85 | 28.99 | 65.22 |
| Femoral neck | Present study | 7.89 | 62.65 | 19.63 | 47.66 | 17.92 | 49.06 | 60.87** | 31.88* |
| | Caucasian Lunar BMD database | 5.26 | 65.79 | 13.08 | 53.27 | 15.09 | 40.57 | 49.28 | 43.48 |
| Femur Ward's | Present study | 10.53** | 60.53* | 15.89** | 58.88* | 27.36** | 58.49** | 66.67** | 33.33** |
| | Caucasian Lunar BMD database | 31.58 | 47.37 | 41.12 | 41.12 | 79.25 | 12.26 | 92.75 | 7.25 |
| Femur trochanter | Present study | 5.26* | 42.11 | 4.67 | 44.86 | 10.38 | 33.96 | 11.59 | 63.77 |
| | Caucasian Lunar BMD database | 10.53 | 39.47 | 6.54 | 43.93 | 10.38 | 36.79 | 18.84 | 62.32 |
| Lateral spine | Present study | 7.89* | 44.74* | 8.41 | 59.81 | 18.87 | 49.06 | 28.99 | 50.72 |
| | Caucasian Lunar BMD database | 18.42 | 34.21 | 12.15 | 58.88 | 22.64 | 43.40 | 34.78 | 50.72 |
| Radius 33% | Present study | 10.53 | 50.00* | 22.43 | 43.93* | 45.28 | 34.91 | 75.00 | 25.00 |
| | Caucasian Lunar BMD database | 7.89 | 68.42 | 15.89 | 63.55 | 41.51 | 45.28 | 75.00 | 25.00 |
| Radius UD | Present study | 0.00** | 52.63 | 4.67* | 73.83* | 13.20* | 28.30* | 29.41** | 57.35** |
| | Caucasian Lunar BMD database | 13.16 | 42.11 | 19.63 | 60.75 | 29.25 | 12.26 | 75.00 | 11.76 |

Values represent the percentage of total subjects in each age group. The *T* scores were calculated as [(BMD–peak bone mass)/SD peak bone mass] [14]

* $P < 0.05$, ** $P < 0.001$, versus corresponding Caucasian Lunar BMD database (Fisher's exact *t* test)

Male subjects

Hip

Peak BMD for the total hip and its components in Indian men, unlike women, was observed between ages 20 and 30 years (Tables 3 and 5). The best-fitting models were cubic equation for total hip ($R^2=0.0462$, $P>0.05$) and trochanter ($R^2=0.0430$, $P>0.05$) and quadratic equations for femoral neck ($R^2=0.1449$, $P<0.05$) and Ward's ($R^2=0.3009$, $P<0.001$) regions (Fig. 2a–d). Although a significant negative correlation between age and BMD of the hip and its regions was seen in men ($P<0.001$), only BMD of femoral neck and Ward's regions was significantly negatively regressed with age (Fig. 2b–c). The BMD of total hip showed nonsignificant decline up to 70 years of age after which a decline of 5.5% was observed. A 5.8% decline in BMD of the trochanter region was observed between the second and the fourth decade beyond which the BMD showed nonsignificant decline. The decrease of BMD between the age of peak BMD and 83 years was highest for Ward's

triangle (32.0%, i.e., 5.3% per decade) and lowest for trochanter (8.6%, i.e., 1.4% per decade). The mean BMD values in Indian men were 0.5–10.2% lower at the total hip and its components than the calculated Lunar reference values provided by the manufacturer (Table 5). Significant differences in peak BMD values of the study population and reference peak BMD values were observed at the total hip and trochanter regions (4.5%, $P<0.001$ and 4.4%, $P<0.01$, respectively; Table 5). A larger proportion of Indian men >50 years of age was classified as osteoporotic on the basis of *T* scores calculated using the database provided by the manufacturer than with the reference values of the present study population (6.3% versus 1.3% at total hip; 11.3% versus 4.6% at femoral neck; 34.5% versus 19.2% at Ward's triangle; 9.2% versus 1.4% at trochanter; Table 6). The cut off values for osteoporosis of the total hip, femoral neck, Ward's triangle, and trochanter in men using the Indian reference values were 0.686, 0.687, 0.566, and 0.574 g/cm², respectively. The corresponding values according to the manufacturer's reference database were 0.741, 0.726, 0.627, and 0.629 g/cm², respectively.

Table 5 Age-related change in BMD in Indian men in comparison to the manufacturer's BMD values

| Skeletal site and age in years | Present study* | | Manufacturer's normal database** | | T score | Difference (%) | P value |
|--------------------------------|----------------|----------------------|----------------------------------|-------|---------|-----------------|-----------|
| | Mean | SD | Mean | SD | | | |
| Total hip | | | | | | | |
| 20–30 | 1.018 | 0.133 ^b | 1.066 | 0.130 | -3.29 | -0.048 (-4.50) | 0.0001*** |
| 31–40 | 0.979 | 0.131 ^b | 1.055 | 0.130 | -4.57 | -0.076 (-7.20) | 0.0001*** |
| 41–50 | 0.976 | 0.125 ^b | 1.026 | 0.130 | -3.78 | -0.050 (-4.87) | 0.0001*** |
| 51–60 | 0.971 | 0.125 ^b | 0.993 | 0.130 | -1.69 | -0.022 (-2.21) | 0.094 NS |
| 61–70 | 0.972 | 0.103 ^b | 0.968 | 0.130 | +0.29 | +0.004 (+0.41) | 0.774 NS |
| 71–83 | 0.919 | 0.139 ^a | 0.954 | 0.130 | -2.30 | -0.035 (-3.66) | 0.024 NS |
| Femoral neck | | | | | | | |
| 20–30 | 1.019 | 0.133 ^c | 1.051 | 0.130 | -2.18 | -0.032 (-3.04) | 0.031 NS |
| 31–40 | 0.961 | 0.117 ^b | 1.036 | 0.130 | -4.53 | -0.075 (-7.23) | 0.0001*** |
| 41–50 | 0.918 | 0.127 ^b | 0.992 | 0.130 | -5.50 | -0.074 (-7.45) | 0.0001*** |
| 51–60 | 0.919 | 0.148 ^b | 0.944 | 0.130 | -1.65 | -0.025 (-2.64) | 0.102 NS |
| 61–70 | 0.892 | 0.098 ^{a,b} | 0.904 | 0.130 | -1.05 | -0.012 (-1.32) | 0.297 NS |
| 71–83 | 0.852 | 0.133 ^a | 0.856 | 0.130 | -0.26 | -0.004 (-0.46) | 0.795 NS |
| Femur Ward's | | | | | | | |
| 20–30 | 0.941 | 0.150 ^d | 0.952 | 0.130 | -0.65 | -0.011 (-1.15) | 0.515 NS |
| 31–40 | 0.829 | 0.116 ^c | 0.907 | 0.130 | -5.22 | -0.078 (-8.59) | 0.0001*** |
| 41–50 | 0.762 | 0.148 ^b | 0.849 | 0.130 | -5.78 | -0.087 (-10.24) | 0.0001*** |
| 51–60 | 0.741 | 0.162 ^b | 0.785 | 0.130 | -2.61 | -0.044 (-5.60) | 0.05* |
| 61–70 | 0.719 | 0.134 ^b | 0.726 | 0.130 | -0.47 | -0.007 (-0.96) | 0.640 NS |
| 71–83 | 0.640 | 0.165 ^a | 0.658 | 0.130 | -1.06 | -0.018 (-2.73) | 0.293 NS |
| Femur trochanter | | | | | | | |
| 20–30 | 0.859 | 0.114 ^b | 0.899 | 0.110 | -3.12 | -0.040 (-4.44) | 0.001** |
| 31–40 | 0.830 | 0.100 ^{a,b} | 0.904 | 0.110 | -5.68 | -0.074 (-8.18) | 0.0001*** |
| 41–50 | 0.809 | 0.103 ^a | 0.888 | 0.110 | -7.19 | -0.079 (-8.89) | 0.0001*** |
| 51–60 | 0.816 | 0.108 ^a | 0.865 | 0.110 | -4.31 | -0.049 (-5.66) | 0.0001*** |
| 61–70 | 0.815 | 0.103 ^a | 0.849 | 0.110 | -2.93 | -0.034 (-4.00) | 0.001** |
| 71–83 | 0.785 | 0.134 ^a | 0.826 | 0.110 | -2.81 | -0.041 (-4.96) | 0.006 NS |
| Lateral spine | | | | | | | |
| 20–30 | 0.778 | 0.125 ^b | 0.964 | 0.120 | -13.42 | -0.186 (-19.29) | 0.0001*** |
| 31–40 | 0.847 | 0.136 ^{b,c} | 0.935 | 0.120 | -5.26 | -0.088 (-9.41) | 0.0001*** |
| 41–50 | 0.787 | 0.159 ^b | 0.879 | 0.120 | -5.61 | -0.092 (-10.46) | 0.0001*** |
| 51–60 | 0.789 | 0.167 ^b | 0.795 | 0.120 | -0.39 | -0.006 (-0.76) | 0.695 NS |
| 61–70 | 0.785 | 0.144 ^{a,b} | 0.722 | 0.120 | +4.14 | +0.063 (+8.72) | 0.0001*** |
| 71–83 | 0.730 | 0.151 ^a | 0.686 | 0.120 | +2.73 | +0.044 (+6.41) | 0.008 NS |
| Radius 33% | | | | | | | |
| 20–30 | 0.891 | 0.085 ^b | 1.002 | 0.100 | -12.11 | -0.111 (-11.08) | 0.0001*** |
| 31–40 | 10.873 | 0.139 ^b | 1.002 | 0.100 | -7.84 | -0.129 (-12.87) | 0.0001*** |
| 41–50 | 0.877 | 0.079 ^b | 1.002 | 0.100 | -12.94 | -0.125 (-12.47) | 0.0001*** |
| 51–60 | 0.874 | 0.098 ^b | 0.984 | 0.100 | -11.06 | -0.110 (-11.18) | 0.0001*** |
| 61–70 | 0.878 | 0.089 ^b | 0.946 | 0.100 | -7.26 | -0.068 (-7.19) | 0.0001*** |
| 71–83 | 0.796 | 0.137 ^a | 0.907 | 0.100 | -7.59 | -0.111 (-12.24) | 0.0001*** |
| Radius UD | | | | | | | |
| 20–30 | 0.525 | 0.064 ^c | 0.528 | 0.051 | -0.40 | -0.003 (-0.57) | 0.692 NS |
| 31–40 | 0.531 | 0.065 ^c | 0.528 | 0.051 | +0.45 | +0.003 (+0.57) | 0.653 NS |
| 41–50 | 0.499 | 0.075 ^b | 0.528 | 0.051 | -3.64 | -0.029 (-5.49) | 0.0001*** |
| 51–60 | 0.495 | 0.071 ^b | 0.518 | 0.051 | -3.25 | -0.023 (-4.44) | 0.001** |
| 61–70 | 0.473 | 0.058 ^{a,b} | 0.499 | 0.051 | -4.24 | -0.026 (-5.21) | 0.0001*** |
| 71–83 | 0.458 | 0.093 ^a | 0.479 | 0.051 | -2.15 | -0.021 (-4.38) | 0.05* |

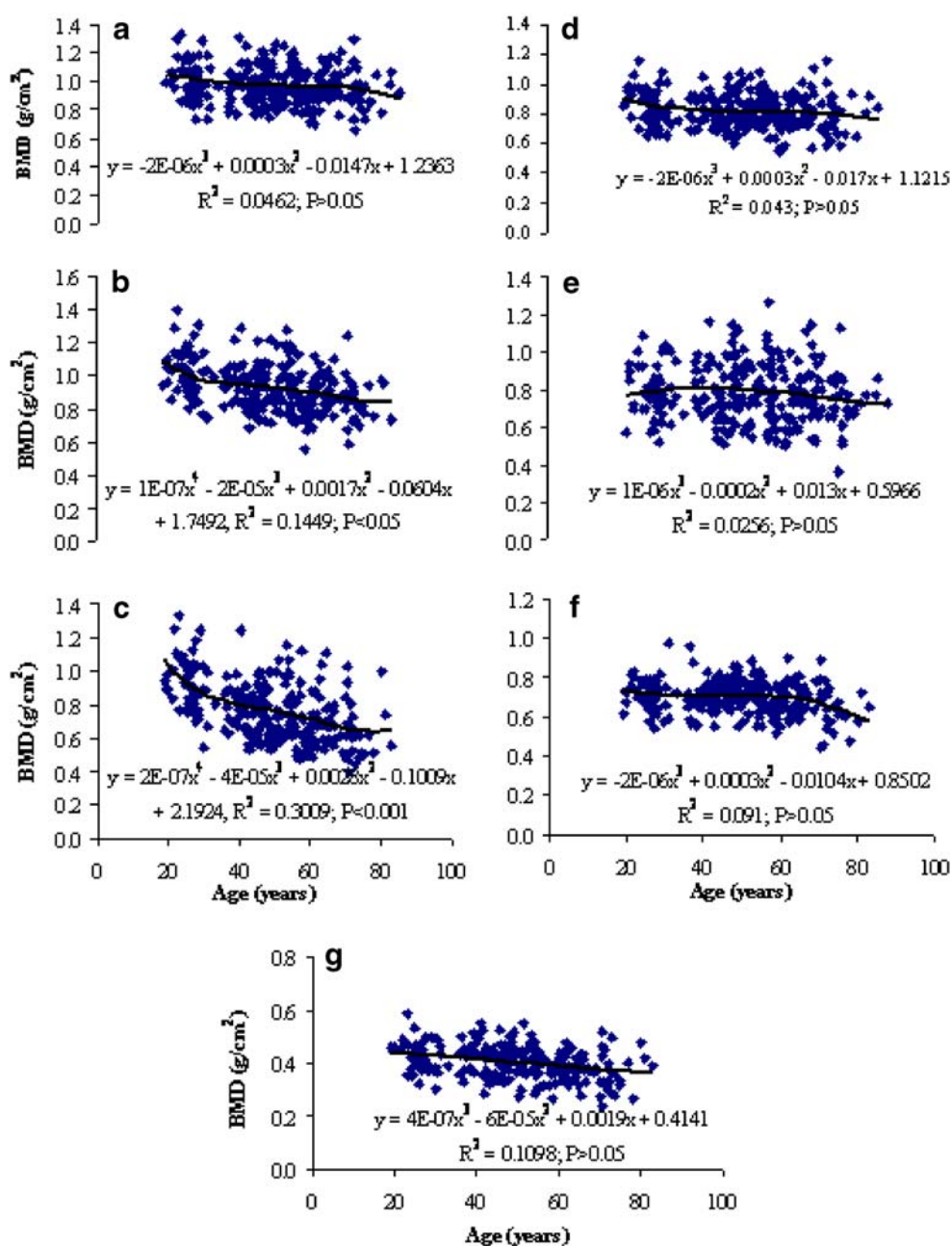
Comparison of means was done using one-way ANOVA with age as varying factor followed by Tukey's test for significance; values followed by different letters (a, b, c, d) are statistically different at $P < 0.01$

NS statistically nonsignificant

*As calculated by the formula provided by the manufacturer based on the age and weight of the individual concerned

**SD values as provided by the manufacturer [15, 16, and personal communication]

Fig. 2 Regression equations and trend lines of BMD of total hip (a), femoral neck (b), Ward's triangle (c), trochanter (d), lateral spine (e), radius 33% (f), and radius UD (g) in relation to age (20–83 years) in Indian men



Lumbar spine

As in the case of Indian women, the highest mean BMD (viz. peak BMD) at the lumbar spine was identified in the 31–40 years age group after which the best-fitting curve was a cubic polynomial ($R^2=0.0256$, $P>0.05$; Fig. 2e, Table 5). A 13.8% decrease in BMD between the age of peak BMD and 83 years of age was observed at the lumbar spine. However, a negative correlation between age and BMD at lumbar spine could not be established owing to large SD values ($P>0.05$). The proportion of men >50 years of age classified as osteoporotic at the lumbar spine were comparatively higher with the manufacturer's refer-

ence values than with the reference values of the present study population (8.9% versus 1.6%; Table 6). The cut off value for osteoporosis at this site in men was 0.507 g/cm² compared to 0.664 g/cm² with the manufacturer's Lunar reference values.

Forearm

The polynomial function of cubic regression model had the best goodness of fit at the radius 33% ($R^2=0.091$, $P>0.05$) and radius UD ($R^2=0.1098$, $P>0.05$) in Indian men (Fig. 2f–g). A highly significant negative correlation of BMD with age was observed at both these sites in men ($P<$

Table 6 Prevalence of osteoporosis and osteopenia at different skeletal sites in Indian men using the Indian versus the Caucasian peak BMD values

| Skeletal site | Study | Age in years | | | | | |
|------------------|------------------------------|--------------|------------|--------------|------------|--------------|------------|
| | | 51–60 | | 61–70 | | 71–83 | |
| | | Osteoporotic | Osteopenic | Osteoporotic | Osteopenic | Osteoporotic | Osteopenic |
| Total hip | Present study | 0.00 | 27.55** | 0.00 | 26.67** | 3.92** | 29.41 |
| | Caucasian Lunar BMD database | 3.06 | 48.98 | 0.00 | 53.33 | 15.69 | 35.29 |
| Femoral neck | Present study | 2.04 | 40.82* | 0.00 | 53.33* | 11.76* | 43.14 |
| | Caucasian Lunar BMD database | 7.14 | 53.06 | 3.33 | 67.78 | 23.53 | 37.25 |
| Femur Ward's | Present study | 10.20** | 58.16* | 12.22** | 64.44* | 35.29* | 43.14 |
| | Caucasian Lunar BMD database | 25.51 | 48.98 | 28.89 | 50.00 | 49.02 | 33.33 |
| Femur trochanter | Present study | 2.04 | 20.41** | 2.22 | 28.90** | 0.00** | 37.25 |
| | Caucasian Lunar BMD database | 6.12 | 55.10 | 2.00 | 60.00 | 19.61 | 39.22 |
| Lateral spine | Present study | 1.02** | 31.63 | 0.00* | 31.11 | 3.92 | 31.37 |
| | Caucasian Lunar BMD database | 10.20 | 24.49 | 6.67 | 26.67 | 9.80 | 37.25 |
| Radius 33% | Present study | 1.02** | 22.45** | 0.00* | 25.56** | 15.69** | 25.49 |
| | Caucasian Lunar BMD database | 13.27 | 46.94 | 6.67 | 53.33 | 35.29 | 31.37 |
| Radius UD | Present study | 7.14 | 22.45 | 4.44 | 36.67* | 15.69** | 39.22 |
| | Caucasian Lunar BMD database | 13.27 | 20.41 | 8.89 | 48.89 | 31.37 | 31.37 |

Values represent the percentage of total subjects in each age group. The *T* scores were calculated as [(BMD–peak bone mass)/SD peak bone mass]] [14]

* $P < 0.05$, ** $P < 0.001$, versus corresponding Caucasian Lunar BMD database (Fisher's exact *t* test)

0.001). The highest mean BMD was identified in the 20–30 years age group at this site, which was 11.1% lower than manufacturer's peak BMD value (Table 5). At the ultradistal region of the radius in males, peak BMD was achieved in the 31–40 years age group and no significant difference was observed between peak BMD value of this study population and the manufacturer's peak BMD (Table 5). The decrease of BMD between the age of peak BMD and 83 years was 10.7% (i.e., 1.8% per decade) for radius 33% and 13.8% for radius UD (i.e., 2.8% per decade). Compared to the Lunar reference values, BMD in Indian men was 7.2–12.9% lower at the radius 33% and 0.6–5.5% at the radius UD (Table 5). *T* scores calculated using peak BMD of the Indian men at the radius 33% and ultradistal sites resulted in 5.6% and 9.1% men, respectively, being classified as osteoporotic compared to 18.4% and 17.8%, respectively, with the Caucasian Lunar BMD database (Table 6). The cut off values for osteoporosis of the radius 33% and radius UD using the Indian reference values were 0.679 and 0.369 g/cm², respectively. The corresponding values according to the manufacturer's reference database were 0.751 and 0.399 g/cm², respectively.

Discussion

The results of the present study demonstrate age-related change in BMD at all measured skeletal sites in both Indian women and men. While peak BMD in women was

observed between 31 and 40 years of age at the hip, spine, and radius 33% and between 20 and 30 years at the ultradistal radius, that in men was attained between 20 and 30 years at the hip and radius 33% and between 31 and 40 years at the spine and ultradistal radius. There was no regression of BMD on age in the age group showing peak BMD in both the sexes. Bone loss in both women (43%) and men (32%) was highest at Ward's triangle. Pertinently, a larger proportion of Indian subjects was classified as osteoporotic based on *T* scores calculated using the Caucasian database than the newly derived Indian peak BMD values at all skeletal sites except radius 33% and femoral neck in females above 40 years of age. The BMD normative data generated in healthy adult Indian women and men in this study might thus facilitate the clinician for effective diagnosis and management of osteoporosis in the Indian population.

Based on currently available data, it is becoming increasingly apparent that there are significant differences in BMD between various racial groups. Assessment of risk of osteoporosis in Asian women by comparing their BMD with the reference Caucasian population may have limited validity primarily because of the influence of skeletal size on such measurements. Moreover, suitable diagnostic cut off values for men, too, are less well-defined and the same absolute values for BMD used for women are used for men [11]. Since locally derived reference values are important to avoid false-positive or false-negative findings during work-up in patients evaluated for osteoporosis [13], BMD

referent databases have been created for Taiwanese [27], Chinese, Japanese [28, 29], Spanish [30], Swedish [31], and Italian [32] populations. A few studies from India have reported lower mean spinal and hip BMD in Indian women compared to the reference North American and European population [17–20]. These studies were based on BMD measurements using the Hologic QDR densitometer. Different densitometers may have different ranges of scan for different bone sites, for which adequate cross calibration may not be possible. Moreover, while standardized BMD has been proposed for comparison of spine between densitometers of different manufactures, BMD values at the hip sites (except total hip) are still not interchangeable [27].

In comparison to Caucasian women, Indian women in the present study showed significantly lower BMD at all measured skeletal sites across the spectrum of age groups. The age range at which peak BMD attained in Indian females in the present study was 31–40 years at all skeletal sites except radius UD where peak BMD occurred in the 20–30 years age group. In a previous study on Indian women [17] using the Hologic QDR densitometer, peak BMD at the total hip, femoral neck, and Ward's region was reported to occur in the 20–29 years age group. Calculated mean BMD values based on the data provided by Lunar indicate that the peak BMD in the referent Caucasian population occurs in the age group of 20–30 years in the case of radius 33%, radius UD, Ward's triangle, and lateral spine and in the age group of 31–40 years at the total hip, femoral neck, and trochanter. Peak bone mass in Indian females was significantly lower at Ward's and lateral spine compared to the manufacturer's referent population. As a result, the prevalence of osteoporosis at these sites was significantly higher using the manufacturer's database in comparison with the normative data generated for Indian women in this study. The lower spinal BMD observed in this study is in accordance with that observed for the immigrant Indo-Asian women compared to Caucasian population [33]. However, since we have measured areal BMD in our population, it remains unclear whether true volumetric BMD or bone mineral apparent density in grams per cubic centimeter was lower among Indian women than Caucasian women. Estimated volumetric BMD derived from the calculation of anteroposterior and lateral spine BMD data showed strong correlation with lateral spine than anteroposterior spine in Taiwanese men [27].

BMD of lumbar vertebrae in Indian women was found to be virtually constant between 20 and 50 years of age and declined thereafter, which is in accordance with other similar studies [30–32]. It might reflect the inability of this cross-sectional study to show a slight premenopausal decrease in BMD evident in longitudinal studies [34,

35]. Decrease in BMD of the lateral spine between 51 and 86 years of age observed in the present study was statistically nonsignificant. We also did not observe an increase in BMD of the lumbar vertebrae in women >70 years of age as also reported by other investigators [36, 37]. Pertinently, the lateral view of the spine [27] as evaluated in this study more likely reflects age-related decrease of cancellous bone compared to the anteroposterior view used in previous studies [14, 38]. In the age range of 61–86 years, BMD values in this study were higher than those of the manufacturer's reference values. The possibility that these values might have been affected by the selection criteria used by the manufacturer cannot be entirely ruled out.

In Indian men, BMD at the lumbar spine and radius UD reaches a peak in the age range of 31–40 years, whereas, at all other skeletal sites, peak BMD occurred between 20 and 30 years of age. Peak BMD for all skeletal sites were 1.9–15.9% higher in Indian men than in Indian women. The prevalence of osteoporosis was higher at the distal forearm compared with the total hip as reported previously [39]. Unlike females where BMD at all skeletal sites regressed negatively with age, only BMD of the femoral neck and Ward's triangle was found to be significantly negatively regressed with age in males.

BMD in both sexes correlated negatively with age, though this was statistically highly significant at all sites in women only. In men, the negative correlation between age and BMD was nonsignificant at the lumbar spine and less significant at the total hip and trochanter compared to other sites. These findings for Indian women are similar to that reported for Austrian women [37].

Age-related bone loss between age of peak BMD and 86 years in women and 83 years in men varied according to skeletal site and was of lower magnitude in men (8.6–31.99%) than in women (25–43%). This finding is in agreement with the previously published cross-sectional studies in Caucasian subjects [40]. Similar to previous reports [14, 39], decrease in BMD was steepest at Ward's triangle and smallest at the trochanter in both the sexes. Also, the use of total femur BMD identified fewer women and men as osteoporotic compared with neck and Ward's BMD because of the stronger influence of trochanteric BMD on the total femur region as suggested by Mazess and Barden [15]. Pertinently, despite showing maximum age-related bone loss, Ward's triangle is rarely selected for the diagnosis of osteoporosis because of its inconsistency with fracture risk evaluation [27].

There is a paucity of data on the prevalence of osteoporosis in the Indian population using DEXA for estimating BMD. Most of the available reports are based on methods such as Singh's index [21], calcaneal index [22], visual assessment [4, 5], quantitative ultrasound [23],

digital X-ray radiogrammetry [24], and quantitative computed tomography [25]. The data available with DEXA are mainly for Indian women [17, 41–43] or for certain selected population groups [44, 45]. Analysis of Indian normative data revealed that the average incidence of osteoporosis at the total hip, femoral neck, Ward's, trochanter, lateral spine, radius 33%, and radius UD was 13.9%, 26.6%, 30.1%, 8.0%, 16.0%, 38.3%, and 11.8%, respectively, for postmenopausal Indian women and 1.3%, 4.6%, 19.2%, 1.4%, 1.7%, 5.6%, and 9.1%, respectively, for Indian men above 50 years of age. However, using the manufacturer's database, corresponding values were 15.3%, 20.7%, 61.2%, 11.6%, 22.0%, 35.1%, and 34.3%, respectively, for postmenopausal Indian women and 6.3%, 11.3%, 34.5%, 9.2%, 8.9%, 18.4%, and 17.8%, respectively, for Indian men above 50 years of age. While the use of the US/European database provided by Lunar versus the Indian data generated in this study might lead to different *T* score designations and therapeutic decisions for an individual, neither score is currently linked to relevant fracture risk data for the Indian population. These findings highlight the need to establish a quantitative relationship between BMD and fracture risk in the Indian population so that pertinent diagnostic and treatment guidelines can ultimately be established.

The findings of this study must be considered in the context of several limitations. Firstly, the prevalence of osteoporosis according to age and site is based on a definition of osteoporosis in women that is not necessarily appropriate for men. Secondly, subjects in this study were all volunteers and ambulatory and presumably healthier than the general population. Moreover, data on BMD of the anteroposterior spine, not evaluated in this study, together with that of LP spine could have potential implications for the Indian scene. Also, the study is cross-sectional rather than longitudinal and the observed BMD peaks should, therefore, be interpreted with caution. Despite these limitations, the results of the present study establish useful BMD normative data with direct relevance to the Indian population. The present study adds to our knowledge of BMD variations between populations that would recommend the use of local reference ranges for reliable interpretations of individual DEXA data.

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Conflicts of interest None.

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