Evaluation of Osteoporosis in Indian Women and Men using Peripheral Dual-Energy X-ray Absorptiometry (pDXA)

M Anburajan, D Ashok Kumar, V Sapthagirivasan

Department of Biomedical Engineering
SRM University
Kattankulathur – 603 203, Tamil Nadu, India
e-mail: anbufelix@yahoo.com

W D Evans

Dept. of Medical Physics and Clinical Engineering
University Hospital of Wales
Cardiff CF14 4XW, Wales, UK
e-mail: wil.evans@wales.nhs.uk

Abstract—**It has been claimed that osteoporosis is becoming more common in India although its prevalence in the country has not been established. Because of the lack of facilities for measurement of bone mineral density (BMD), very little population-based research on osteoporosis has been done in India. The primary objective of this study was to establish the prevalence of osteoporosis in a group of otherwise normal volunteers using forearm BMD measured by peripheral dual-energy x-ray absorptiometry (pDXA). A total of 179 Indian men and women aged 20 years or more attended a free screening camp; of these, 167 were eligible to participate in the study. Total distal forearm BMD (g cm^{-2}) was measured using an Osteometer DTX-200 pDXA bone densitometer. Data were analyzed by dividing the participants into sex and age-specific groups and using descriptive statistics. For each participant, the T-score was calculated as the difference between BMD and the mean BMD of a group of young persons of the same sex (peak BMD), divided by the group standard deviation (SD). For both women and men, peak BMD occurred in the 20-29 year age group. The mean (±SD) values were 0.393 (±0.031) and 0.433 (±0.073) g cm^{-2} respectively; the difference (9.2% relative to the male mean) was significant (p=0.01, unpaired t-test). These Indian total distal forearm peak BMD values were less than published corresponding values for Japanese and Caucasian populations. In Indian women and men aged 60 years or more, mean total distal forearm BMD values were significantly reduced (by 13% and 12% respectively) compared to those obtained for women and men aged 20-40 years. Using published Osteometer DTX-200 pDXA device-specific T-score thresholds, 31.8% (7/22) of Indian women aged 50 years or more were classified as having osteoporosis (T-score ≤-2.6) while 36.4% (8/22) were found to be at risk of osteoporosis (T-score between -1.5 and -2.5). Using the same T-score thresholds, no Indian male was found to have osteoporosis but 16.7% (4/24) of men aged 50 years or more were classified as being at risk of osteoporosis.**

Keywords-osteoporosis, Indian women, Indian men, peripheral dual energy x-ray absorptiometry (pDXA), T-score, total distal forearm peak BMD, Indian normative forearm BMD

I. INTRODUCTION

Osteoporosis is recognized as a world-wide health problem and in India it has become more common for medical practitioners to see post-menopausal women and older people suffering from osteoporotic fractures. Because of the progressive loss of bone mineral mass with advancing age, the prevalence of osteoporosis has increased with life expectancy. Numerous studies have shown that bone mineral density (BMD, g cm^{-2}) correlates significantly with bone strength and hence BMD is able to predict the future risk of bone fracture. This predictive ability is comparable in its magnitude to that of blood pressure for stroke and better than that of serum cholesterol for coronary artery disease. For the evaluation of osteoporosis in a particular ethnic group, it is necessary to collect reference normative BMD data for the same population and to compare individual patient BMD values with this reference data. Results may be expressed as a T-score, which is the difference between individual BMD and the mean BMD of a group of young persons of the same sex (peak BMD), divided by the group standard deviation (SD).

The prevention of osteoporotic fracture is an important clinical goal since it will reduce morbidity and mortality and also expenditure on health care. The relevance of identifying those with osteoporosis before fracture has occurred is well recognized because there are several drugs which can increase BMD and reduce fracture risk. These medications can achieve significant reductions in fracture rate even in elderly patients with low bone mass and previous fractures [1-2].

A range of quantitative and semi-quantitative techniques are available for the measurement of BMD. These vary from methods based on plain x-radiography to more sophisticated radiation absorptiometry techniques [3]. The first quantitative method was single-photon absorptiometry (SPA); it measured BMD in the peripheral skeleton, particularly the radius, and used a gamma emitting radioactive source [4]. SPA was extended to dual-photon absorptiometry (DPA) which allowed measurements to be made at more important sites of osteoporotic fracture in the central skeleton such as spine and hip. SPA and DPA have been superseded by single-energy x-ray absorptiometry (SXA) and dual-energy x-ray absorptiometry (DXA) respectively; in both these methods the radionuclide has been replaced by an x-ray tube as the radiation source. In particular, DXA has become established as the reference 'gold standard' technique for measuring BMD at both peripheral and central skeletal sites.

Its main advantages are low radiation dose and high precision (reproducibility).

A peripheral dual-energy x-ray absorptiometry (pDXA) bone densitometer is a special portable device that is used to measure BMD at peripheral skeletal sites such as forearm, hand, finger and heel. Like central DXA, pDXA measurements can predict the risk of future osteoporotic fracture. The method measures BMD directly, unlike other peripheral techniques such as quantitative ultrasound (QUS) and radiographic absorptiometry (RA). Compared with central DXA, the advantages of pDXA include portability; low capital and operational costs, minimal operational space and even lower patient radiation dose [5].

In India, conventional radiography is relatively inexpensive and widely available; it plays a major role in the evaluation of osteoporosis [6-7] but does not measure BMD directly. Because of its cost, central DXA is not widely available and so pDXA offers an attractive alternative method for direct BMD estimation. However, little population based research on osteoporosis has been done in India and, to the best of our knowledge, there are no published normative BMD data measured by pDXA in an Indian population.

II.   OBJECTIVES

The objectives of this study were: (i) to collect normative data for forearm BMD in Indian women and men; (ii) to investigate the nature, extent and significance of the loss of forearm BMD that accompanies aging in both sexes and (iii) to evaluate the prevalence of osteoporosis in study participants aged 50 years or more using calculated pDXA T-scores and published bone densitometer-specific T-score threshold values.

III.   MATERIALS AND METHODS

A.   Subjects

A total of 179 Indian men and women aged 20 years or more participated in a free screening camp for osteoporosis. This was conducted at the campus of SRM University, Kattankulathur, Tamil Nadu, India during the month of March 2010. Participants with chronic liver or kidney diseases, malignancy, malabsorption syndrome, inflammatory arthritis, hypo- or hyper-thyroidism, previous gastrointestinal surgery or previous osteoporotic fractures were excluded. Also excluded were those on chronic medications known to affect bone metabolism e.g. thiazides, diuretics, estrogen and calcium. After applying these exclusion criteria, 167 subjects (77 females and 90 males) remained and were included in the study; their ages ranged from 20 to 79 years.

B.   Measurements

For all participants, total distal BMD (g cm^{-2}) was measured in the right forearm using an Osteometer DTX-200 pDXA bone densitometer (Osteometer MediTech Inc., Hawthorne, California, USA). In addition, height (m) and weight (kg) were measured and body mass index (BMI) calculated as weight/height^2 (kg m^{-2}).

C.   Data Analysis

Data for males and females were analyzed separately. Participants were divided by age using two different approaches: (i) six or seven decade age-groups ranging from 20-29 years to 70-79 years; (ii): three age-groups defined as follows: young 20-40 years, mid 41-59 years and old ≥ 60 years. In addition, females were divided into pre-menopausal post-menopausal groups. For all groups, mean (±SD) BMD values were calculated and comparisons made using an unpaired t-test. Associations between variables were examined with linear regression and correlation. All data analysis was done using the SPSS/PC statistical software package.

D.   Evaluation of Osteoporosis

T-scores were calculated using the sex-matched mean and SD BMD for the 20-29 years age group. These values represent peak total distal forearm BMD in normal young adult Indian men and women.

In order to evaluate osteoporosis in the study population, published device-specific T-score thresholds were used. Blake and co-investigators [8] studied 393 Caucasian women using an Osteometer DTX-200 pDXA bone densitometer for forearm BMD and a central DXA scanner for spine and hip BMD. They found that 113 were osteoporotic at either spine or hip as defined by the World Health Organization (WHO) [9] and derived the following T-score thresholds for the Osteometer DTX-200: Upper Threshold -1.4 and Lower Threshold -2.6. These thresholds were used to classify subjects in the study population aged 50 years or more according to T-score as follows: Normal: ≥ -1.4; At risk of osteoporosis: -1.5 to -2.5; Osteoporosis: ≤ -2.6.

IV.   RESULTS

A.   Peak Value of Total Distal Forearm BMD

Table I shows the reference data for total distal forearm BMD as measured by pDXA in young normal Indian women and men aged 20-29 years. The mean (±SD) peak BMD values were 0.393 (±0.031) and 0.433 (±0.073) g cm^{-2} respectively. In the evaluation of osteoporosis, these values were used to calculate the T-score as

$$\frac{(\text{Individual BMD}) - (\text{Sex-matched Mean Peak BMD})}{\text{SD of BMD in Sex-matched Young Adults.}}$$

TABLE I.   PEAK FOREARM BMD IN INDIAN SUBJECTS

Variable	Indian Women	Indian Men
Number of subjects	12	22
Age (years)	24.1 ±3.0	24.9±2.6
Body mass index BMI (kg m^{-2})	23.6± 3.3	23.5± 3.7
Peak forearm BMD (g cm^{-2})	0.393±0.031	0.433±0.073

B. Age-related Changes in Total Distal Forearm BMD

For all the Indian females subjects (n = 77), there was a significant negative correlation between total distal forearm BMD and age (r = -0.30, p = 0.01). The same was true for all the Indian male subjects (n = 90, r = -0.23, p = 0.05).

Tables II A and II B show age-related changes in BMD for Indian women and men by decade age groups. Mean total distal forearm BMD reached its peak value at a mean age of 24.1 and 24.9 years in male and female subjects respectively.

TABLE II.   A   FEMALE BMD BY DECADE AGE GROUP

Indian women (n = 77)					
Age-group (years)	Number of subjects (% of total)	Age (years)	BMI (kg m^{-2})	BMD (g cm^{-2}) (% decrease)	Calculated T-score
20-29	12 (15.6%)	24.1 ±3.0	23.6± 3.3	0.393±0.031 (0%)	0.00± 0.99
30-39	20 (26.0%)	35.3 ±3.1	26.4 ±4.8	0.384 ±0.041 (2.3%)	-0.29± 1.33
40-49	25 (32.5%)	44.5 ±2.9	27.5 ±5.3	0.379± 0.099 (3.6%)	-0.45± 2.19
50-59	14 (18.1%)	54.4 ±3.2	27.4 ±6.5	0.331 ±0.048 (15.8%)[a]	-2.00± 1.55
60-69	6 (7.8%)	62.2 ±1.5	24.1± 2.4	0.334 ±0.036 (15.0%)[b]	-1.90± 1.17

a) P = 0.001 significance when compared to decade age group 20-29 years

b) p = 0.008 significance when compared to decade age group 20-29 years

TABLE II.   B   MALE BMD BY DECADE AGE GROUP

Indian men (n =90)					
Age-group (years)	Number of subjects (% of total)	Age (years)	BMI (kg m^{-2})	BMD (g cm^{-2}) (% decrease)	Calculated T-score
20-29	22 (24.4%)	24.9±2.6	23.5± 3.7	0.433±0.073 (0%)	0.00± 1.00
30-39	22 (24.4%)	32.9 ±2.7	24.2±3.2	0.411 ±0.050 (5.1%)	-0.30± 0.69
40-49	23 (25.6%)	43.9±3.0	25.0±2.9	0.415± 0.047 (4.2%)	-0.25± 0.64
50-59	12 (13.3%)	55.4±2.5	26.2 ±4.8	0.412±0.077 (4.8%)	-0.14± 1.14
60-69	8 (9.0%)	63.8±3.4	23.5 ± 3.9	0.375±0.051 (13.4%)[a]	-0.79± 0.71
70-79	3 (3.3%)	72.3 ±2.1	25.7±7.0	0.357± 0.043 (17.6%)	-1.04± 0.60

a) p = 0.03 significance when compared to decade age group 20-29 years

Subsequently, mean BMD decreased with advancing age for both sexes, but this decrease was faster and more significant in women than in men. In Indian female subjects, a 15.8% reduction in BMD compared with their young counterparts at the age of peak BMD (p = 0.001) was seen at a mean age of 54.4 years. On the other hand, in Indian men a significant BMD decrease (13.4%, p=0.03) was not seen until a mean age of 63.4 years, one decade later than in women.

Table III A and III B show age-related changes in total distal forearm BMD in Indian women and men respectively when split into young, mid and old age groups. For female and male subjects aged 60 years or more, the percentage decreases in BMD were significant at 13% and 12% respectively compared to young subjects aged 20-40 years.

TABLE III.   A   FEMALE BMD BY AGE GROUP

Indian women (n = 77)			
Variable	Young age 20-40 years	Mid age 41-59 years	Old age ≥ 60 years
Number of subjects (% of total)	35 (70.1%)	36 (23.4%)	6 (6.5%)
Age (years)	31.8 ±6.5	49.1 ±5.8	62.2 ±1.5
BMI (kg m^{-2})	26.1 ± 5.1	26.9 ±5.5	24.1 ±2.4
BMD (g cm^{-2})	0.385 ±0.037	0.361 ±0.090	0.334 ± 0.036[a]
Calculated T-score	-0.26± 1.20	-1.03± 2.90	-1.84± 1.17
BMD ratio compared to young age-group (% decrease)	1.00 (0%)	0.94 (6%)	0.87 (13%)

a) p = 0.015 significance when compared to young age group

TABLE III.   B   MALE BMD BY AGE GROUP

Indian men (n = 90)			
Variable	Young age 20-40 years	Mid age 41-59 years	Old age ≥ 60 years
Number of subjects (% of total)	48 (69.7%)	31 (23.7%)	11 (6.6%)
Age (years)	29.8±5.5	48.8±5.9	66.1±5.0
BMI (kg m^{-2})	24.1± 3.4	25.3±3.8	24.1±4.6
BMD (g cm^{-2})	0.421±0.063	0.415±0.058	0.370± 0.048 [a]
Calculated T-score	-0.17± 0.86	-0.19± 0.85	-0.87± 0.66
BMD ratio compared to young age-group (% decrease)	1.00 (0%)	0.98 (2%)	0.88 (12%)

a) p = 0.008 significance when compared to young age group

C. Menopause-related Changes in BMD in Women

In Indian post-menopausal women, the mean total distal forearm BMD was significantly less (by 13.8%) than that in pre-menopausal women (p = 0.002, Table IV).

TABLE IV.   MENOPAUSE-RELATED CHANGES IN BMD

Indian women (n = 77)		
Variable	Pre-menopausal women	Post-menopausal women
Number of subjects	57	20
Age (years)	37.0 ± 8.5	57.4 ± 4.4
Years since menopause	-	12.4 ± 5.4
BMI (kg m^{-2})	23.6 ± 3.3	23.5 ± 3.7

Total Distal BMD (g cm⁻²)	0.384 ± 0.07	0.331 ± 0.043ᵃ

a) P = 0.002 significance when compared to pre-menopausal group

D. Evaluation of Osteoporosis

The results of the evaluation of osteoporosis are shown in Tables V A and V B.

TABLE V. A EVALUATION OF OSTEOPOROSIS IN WOMEN

Indian Women ≥ 50 years (n = 22) Mean (± SD) age 58.3 (± 8.1) years					
Classification	T-score range	Number of subjects (% of total)	Age (years)	BMI (kg m⁻²)	BMD (g cm⁻²)
Normal	≥ -1.4	7 (31.8%)	57.0±4.4	27.2±6.2	0.391±0.042
At risk of osteoporosis	-1.5 to -2.5	8 (36.4%)	57.4±5.1	25.0±8.1	0.332±0.013
Osteoporosis	≤ -2.6	7 (31.8%)	58.3±3.2	25.9±2.9	0.263±0.055

TABLE V. B EVALUATION OF OSTEOPOROSIS IN MEN

Indian Men ≥ 50 years (n=24) Mean (± SD) age 60.3 (± 6.6) years					
Classification	T-score range	Number of subjects (% of total)	Age (years)	BMI (kg m⁻²)	BMD (g cm⁻²)
Normal	≥ -1.4	20 (83.3%)	59.5±6.2	25.9±4.6	0.419±0.061
At risk of osteoporosis	-1.5 to -2.5	4 (16.7%)	58.4±8.8	21.2±2.3	0.295±0.022
Osteoporosis	≤ -2.6	0	-	-	-

Using the Osteometer DTX-200 device-specific T-score ranges, 31.8% (7/22) of Indian women aged 50 years or more were classified as having osteoporosis whereas no Indian men were placed in this category. Furthermore, 36.4% (8/22) and 16.7% (4/24) of Indian women and men aged 50 years or more respectively were found to be at risk of osteoporosis.

V. DISCUSSION AND CONCLUSION

In this study of Indian women and men, the peak value of total distal forearm BMD measured by pDXA was achieved at mean ages of 24.1 and 24.9 years respectively. These ages are younger than the 42 and 32 years respectively found in Japanese women and men who were measured using the same bone densitometer [10]. The female age is also younger than the 30 years for peak proximal femur BMD found in Indian women measured by central DXA. However, it is similar to the 22 years for peak proximal femur BMD found in American white women [11].

For Indian women, the mean peak total distal forearm BMD was 0.393g cm⁻²; this is 19% less than the value for both Japanese women (0.484 g cm⁻²) and Caucasian women (0.488 g cm⁻²) [8,10]. For Indian men, the mean peak BMD was 0.433g cm⁻² which is 27% less than the value for Japanese men (0.590 g cm⁻²) [10].

When a pDXA device-specific T-score threshold was used, it was found that 31.8% of female subjects aged 50 years or more were classified as having osteoporosis. No Indian male was found to have osteoporosis. Furthermore, 36.4% and 16.7% of female and male subjects aged 50 years or more respectively were found to be at risk of osteoporosis and the women were advised to have a central DXA investigation for confirmation of the disorder.

The study has several limitations: there were relatively few subjects aged 50 years or more; data on risk factors for osteoporosis were not collected; central DXA was not done as a confirmation test and T-score threshold values derived in Caucasian women were applied to Indian male and female subjects. However, the derived normal reference data on total distal forearm BMD in Indian women and men can serve as a valuable tool for both clinical work as well as research studies on osteoporosis.

REFERENCES

[1] D. M. Black, S. R. Cummings, D. B. Karpf, J. A. Canley, D. E. Thompson, M. C. Nevitt, D. C. Bauer, H. K. Genant, W. L. Haskell, R. R. Marcus, S. M. Ott, J. C. Torner, S. A. Quandt, T. F. Reiss and K. E. Ensrud for the Fracture Intervention Trial Research Group, "Randomised trial of effect of alendronate on risk of fracture in women with existing vertebral fractures", Lancet, vol. 348, pp. 1535-1541, 1996.

[2] M C Chapuy, M E Arlot, F Duboeuf, J Brun, B Crouzet, S Arnaud, P D Delmas and P J Meunier, "Vitamin D3 and calcium to prevent hip fractures in elderly women", New England Journal of Medicine, vol. 327, pp. 1637-1642, 1992.

[3] M. Jergas and H. K. Genant, "Quantitative bone mineral analysis', in "Diagnosis of Bone and Joint Disorders", vol. 4, D. L. Resnick, Ed. Philadelphia: W B Saunders Company, 1995, pp. 1854-1884.

[4] J. R. Cameron and J. A. Sorenson, "Measurement of bone mineral in-vivo: an improved method", Science, vol. 142, pp. 230-232, 1963.

[5] D. B. Hans, J. A. Shepherd, E. N. Schwartz, D. M. Reid, G. M. Blake, J. N. Fordham, T. Fuerst, P. Hadji, A. Itabashi M. A. Krieg and E. M. Lewiecki, "Peripheral dual-energy x-ray absorptiometry in the management of osteoporosis: The 2007 ISCD Official Positions", Journal of Clinical Densitometry, vol. 11, no. 1, pp. 188-206, 2008.

[6] M. Anburajan M, C. Rethinasabapathi, M. P. Korath, B. G. Ponnappa, A. Govindan, W. D. Evans and K. Jagadeesan, "Evaluation of post-menopausal osteoporosis using DXA, Singh's index, radiographic hip geometry, and serum biochemical analysis: a comparison", Journal of the International Medical Sciences Academy, vol. 14, pp. 186-190, 2001.

[7] M. Anburajan, C. Rethinasabapathi, M. P. Korath, B. G. Ponnappa, T. M. R. Panicker, A. Govindan, G. N. S. Prasad, W. D. Evans and K Jagadeesan, "Low cost mass screening tool for evaluating post-menopausal osteoporosis: A breakthrough for the developing world", Bombay Hospital Journal, vol. 43, pp. 253-260, 2001.

[8] G. M. Blake, D. J. Chinn, S. A. Steel, R. Patel, E. Panayiotou, J. Thorpe, J. N. Fordham, "A list of device-specific thresholds for the

clinical interpretation of peripheral x-ray absorptiometry examinations", Osteoporosis International., vol. 16, pp. 2149–56, 2005.

[9] World Health Organization (WHO) Technical Report Series 843, "Assessment of fracture risk and its application to screening for postmenopausal osteoporosis", Geneva: WHO, 1994.

[10] K. Nakamura Y. Tanaka, K. Saitou M. Nashimoto and M. Yamamoto, "Age and sex differences in the bone mineral density of the forearm based on health checkup data of 6343 Japanese", Osteoporosis International, vol. 11, pp. 772-777, 2000.

[11] M. Anburajan, C. Rethinasabapathi, M. P. Korath, B. G. Ponnappa, K. S. Kumar, T. M. R. Panicker, A. Govindan and K. Jagadeesan, "Age-related proximal femur bone mineral loss in south Indian women: a dual energy x-ray absorptiometry study", Journal of the Association of Physicians of India, vol. 49, pp. 442-445, 2001.