NORTH BENGAL MEDICAL COLLEGE JOURNAL [2020], VOL., 6, No. 2 : 03-13

Anthropometric and other Determinants of Peak Bone Mineral Density: A Hospital Based Study among Healthy Bangladeshi Volunteers

*Syed Mohammad Monowar Ali,[1] Md Nazrul Islam,[2] Syed Atiqul Haq[3]

ARTICLE INFO

Article history:

Received: 06 October 2019

Accepted: 08 March 2020

Online:

www.nbmc.ac.bd

Keywords:

Peak bone mineral density, Hospital based healthy Bangladeshi volunteers, Dual energy X-ray absorptiometry (DXA)

ABSTRACT

Introduction: *The peak bone mineral density (PBM) status is one of the most important determinants of future development of osteoporosis. As such data on bone mineral density (BMD) and related information is important in the assessment and prevention of osteoporosis.* ***Objectives:*** *To study the anthropometric and other determinants of PBM status, in a hospital based healthy Bangladeshi volunteers.* ***Methods****: This cross-sectional observational study was conducted from July to September 2014. A total of 207 young (21-39 years) healthy volunteers of both genders were recruited. The anthropometric parameters, dietary evaluation to quantify calcium and protein intake, bone mineral density (BMD) by dual energy X-ray absorptiometry (DXA) was measured. PBM at different sites for both male and female were determined from quadratic regression model of BMD on age.* ***Results:*** *PBM (gm/cm^2) values for female of lumbar spine (L1-L4) and total femur were found 1.147 and 1.019 respectively and the age of attainment of those peaks were 30, and 29 years respectively. For male those values were 1.148 and 1.091 (gm/cm^2) and 28 and 21 years, respectively. Mean intake of calcium (303±202 mg/day) and protein (54.17±16.69 gm/day) was lower than the recommended daily allowances (RDA). On multiple regressions analysis, weight was the most significant predictor of BMD of total femur in female subjects. In male, age was the most significant negative predictor of BMD of both lumbar spine and total femur. On the basis of BMD, Z-score of lumbar spine, 4.9% female and 11% male subjects suffered from low bone mass.* ***Conclusion:*** *A significant proportion of clinically healthy young subjects suffered from low bone mass. Intervention at various levels may help to improve PBM and prevent osteoporosis thereby.*

[1] *Associate Professor, Department of Medicine, Shaheed M Monsur Ali Medical College, Sirajganj, Bangladesh*

[2] *Professor, Department of Rheumatology, BSMMU, Dhaka, Bangladesh*

[3] *Professor, Department of Rheumatology, BSMMU, Dhaka, Bangladesh*

****Corresponding author:*** syed.monowar_ali@yahoo.com

INTRODUCTION

Peak bone mineral density (PBM) is the bone mass during stable period following growth and accrual of bone mass, prior to subsequent bone loss.[1] It is the average maximum bone mass achieved by healthy sex and race-matched adults which is normally achieved after puberty. Bone mass at any time in life is a function of the PBM and the amount lost from maturity.[2] Genetic, environmental or life style factors contribute to PBM accrual.[3,4] Genetic factor is the most important among them; about three-fourth of the variance of PBM in a population is determined by genetic factor. This heritable component of PBM accrual is assumed to be polygenic in nature.[5] Environmental and life style factors (like, calcium and protein intake, vitamin D status, exposition to sunlight, physical activity, nutrition, effect of drugs) account for the rest.[6] Up to 90% of PBM is acquired by age 18 in girls and by age 20 in boys, which makes youth the best time to "invest" in one's bone health.[7] High levels of physical activity and good calcium intake during childhood and puberty can help achieve maximal peak bone mass.[8]

Osteoporosis, the most common metabolic bone disease affects one in three women and one in five men over the age of 50 years.[9] Osteoporosis is directly related to improper accrual of PBM; studies estimated that 60% of the risk of osteoporosis can be explained by low PBM. Subsequent bone loss accounts for the remaining risk (of osteoporosis).[10] Thus, even though most osteoporotic fractures occur in elderly people, the risk of osteoporosis may be profoundly affected by events in early life. Osteoporosis related fracture is associated with increased mortality, concomitant morbidity, and reduced quality of life.[11]

Determination of PBM and the time of its attainment are essential for targeting interventions aimed at achieving optimal PBM and thus reducing the risk of future osteoporosis. In Bangladesh, till date we don't have population based information on PBM. This study was aimed to determine BMD at different sites, PBM at each site along with some of its important determinants among healthy hospital based young individuals.

METHODS

This cross-sectional observational study was conducted in the Department of Rheumatology, Bangabandhu Sheikh Mujib Medical University (BSMMU) in 2014. Young apparently healthy 207 hospital based subjects (doctors, hospital stuffs e.g. stuff nurse, ward boy, porter, cleaner, laboratory personnel , security guards and attendants of patients), aged 21-39 years of both genders (female 107, male 100), who had no apparent constraints to bone growth and mineralization were recruited. After obtaining the informed written consent of the study subjects, study questionnaire was served. Pregnant and lactating women, current tobacco user, persons with medical disorders or those who had received drugs likely to affect bone mineral density (BMD) in last 2 years, and those who had sustained a fracture within the same period were excluded from the study. Subjects who were on calcium and vitamin D supplements for more than 3 months were also excluded from the study.

After screening, BMD of 200 subjects was done (female 102, male 98, dropped out 7) by dual energy X-ray absorptiometry (DXA, by Lunar Prodigy PA+350263 scanners by 'GE Healthcare') of lumbar spine (L1-4), neck of femur (NOF) and total femur, was done. Quality control of the scanner was done by phantom scan, on a daily basis, during the study period. Verification of phantom mean BMD was done on the densitometer followed by corrective action threshold where needed, according to "The International Society for Clinical Densitometry" (ISCD) guideline.[12] Anthropometric parameters including weight, standing height, body mass index (BMI) was obtained.

Food recall interview was done by an experienced nutritionist. Subjects stated about the food and beverages they consumed in the last 24 hours (24 hour food recall), from which daily calcium intake (mg/day), and elemental protein intake (gm/day), were determined. The calcium and protein content of more than 80 food items, which includes staple food, pulses, vegetables, fruits, animal protein, and junk food, were derived from reference book.[13] Total daily calcium (mg/day), and protein (gm/day) intake was calculated from coded food chart, after serving study subjects real food items, photographs or dough, followed by measuring /assessing the amount consumed. Any inconsistency was dealt with by re-interviewing.

BMD was expressed as gm/cm^2 and Z- score, which is a comparison of the patient's BMD to an age-matched 'normal reference population'. Value of Z- score lower than two standard deviations from the mean was considered as osteopenia.[14] Osteopenia with ≥1 fragility (low impact) fracture was considered as osteoporosis. The reference population is a 'Combined National health and nutrition examination survey (NHANES III)'/Lunar based 'Asia' population whose data base was incorporated in the DXA densitometer.[15] The Z-score thus determined were entered. All scans were carried out on the same machine by the same operator and analyzed by the same software. Simple descriptive measures like percentage, mean and standard deviation of different variables were used. Peak BMD at different sites for both male and female was determined from quadratic regression model of BMD on age. Student's t test (unpaired) was used to examine differences between the mean BMD levels of 2 different age groups. Stepwise multiple regression analysis was performed using BMD as the dependent variable and others as the independent variables, to determine predictors of BMD. All data analysis was done using the SPSS/PC statistical software package.

RESULTS

A total of 230 individuals participated in the study, 23 were excluded. Baseline demographic data of remaining 207 was collected (Table I). Bone mineral density was done by DXA of 200 subjects. Mean age of the study subject was 28. 99±5.39 years. The body mass index (BMI) of female (24.28±3.78 kg/m^2) was higher than that of male (23.72±3.42 kg/m^2). Mean monthly income was 12354±9329 and 12874±9359 taka for female and male respectively. Dietary intake of calcium (mg/day) by male and female were 312±216, and 294 ±189 respectively. Protein intake (gm/day) by them was 60.72±18.11 and 48.05±12.53 respectively. The difference between male and female protein intake was statistically significant.

Table I: Baseline characteristics of the study subjects (n-207)

Characteristics of the study subjects	Female (n-107) Mean±SD	Male (n-100) Mean±SD	Total subjects (n-207) Mean±SD
Age (years)	28.92±5.34	29.07±5.48	28. 99±5.39
Height (cm)	152.31±5.96	164.52±6.58	158.35±8.75
Weight (kg)	56.5±10.65	64.15± 8.5	60.28±10.36
BMI (kg/m^2)	24.28±3.78	23.7±3.42	24.01±3.61
Monthly income (Tk.)	12354±9329	12874±9359	12627±9323
Calcium intake (mg/day)	294±189	312±216	303±202
Protein intake (gm/day)	48.05±12.53	60.72±18.11	54.17±16.69

BMD, its trend at different sites, and peak

Bone mineral density (gm/cm^2) of L1-L4 was 1.128±0.118 for male and 1.133±0.114 for female were comparable, but BMD at other sites are better for male (1.006 vs. 957 neck of femur, 1.049 vs. 1.002 total femur). Z-score at all measured sites for female was better than those for male (Table II). Overall, BMD was observed better at L1-L4 (Figure 1), but the Z-score was observed better at total femur (-0.1±0.9).

Table II: Bone mineral density by dual energy X-ray absorptiometry and corresponding Z- score of the study subjects (n-200)

Investigations BMD (DXA), n=200	**Female (n-102)** **Mean ± SD**	**Male (n-98)** **Mean ± SD**	**Total subject (n-200)** **Mean ± SD**	***p***
BMD, L1-L4 (gm/cm^2),	1.133 ± 0.114	1.128 ± 0.118	1.131± 0.115	0.803
L1-L4 Z-Score	-0.40 ± 0.9	-0.74 ± 0.9	-0.5 ± 0.9	0.011
BMD NOF(gm/cm^2)	0.957± 0.136	1.006 ± 0.126	0.9 81± 0.133	0.008
NOF Z-Score	-0.46 ± 0.9	-0.48 ± 0.9	-0.4 ± 0.9	0.870
BMD, Total femur(gm/cm^2)	1.002 ± 0.125	1.049 ± 0.122	1.025± 0.125	0.007
Total femur Z-Score	0.01 ± 0.9	-0.29 ± 0.8	-0.1 ± 0.9	0.018

* Student's 't' test (unpaired)

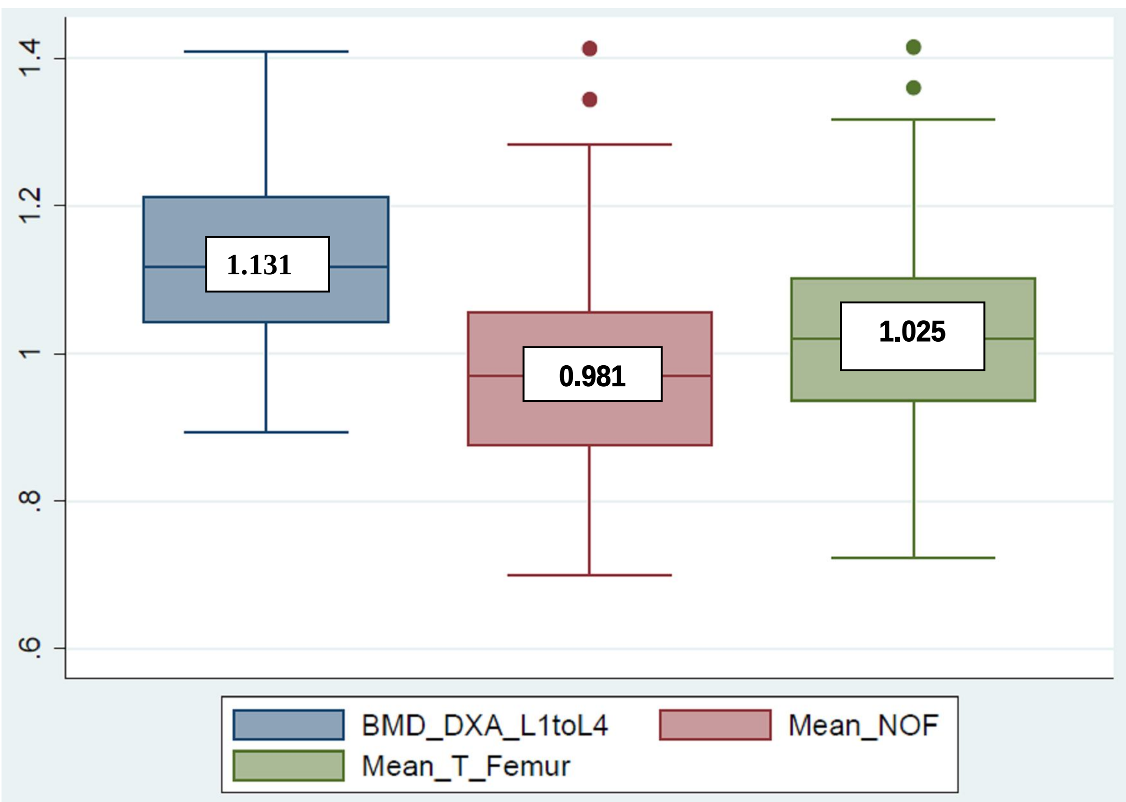

Figure 1: Box plot of mean BMD (DXA) values (of all study subjects)

Computer based quadratic regression model for BMD values on age in both female and male study population was plotted. Based on regression analysis of different BMD values on age, peak bone mineral density (PBM) value and age of its attainment were determined. For female PBM value at L1-L4, NOF, total femur were 1.147±0.016, 0.982±0.019, 1.019±0.017 (gm/cm^2), respectively and the age of attainment of those peaks were 30, 29, and 29 years. For male those figures were, 1.148±0.016, 1.097±0.028, 1.091±0.028 (gm/cm^2) and 28, 21 and 21 years respectively. Predicted PBM values and the age of attainment of peaks were shown in the Table III. Quadratic regression model of BMD on age at L1-L4 for female and male were depicted in Figure 2 and Figure 3 respectively.

Table III: Predicted peak bone mineral density value and the age of attainment of peak of the study subjects (n- 200)

Predicted peak BMD (gm/cm^2)	Gender Female-102 Male -98	Predicted value ± SE	95% CI	Age of attainment of peak BMD
BMD L1 to L4 predicted peak	Female	1.147±0.016	(1.115 , 1.180)	30
	Male	1.148±0.016	(1.115 , 1.181	28
BMD mean NOF predicted peak	Female	0.982±0.019	(0.943 , 1.020)	29
	Male	1.097±0.028	(1.042 , 1.152)	21
BMD total femur predicted peak	Female	1.019±0.017	(0.984 , 1.054)	29
	Male	1.091±0.028	(1.036 , 1.147)	21

SE= Standard error, CI =confidence interval.

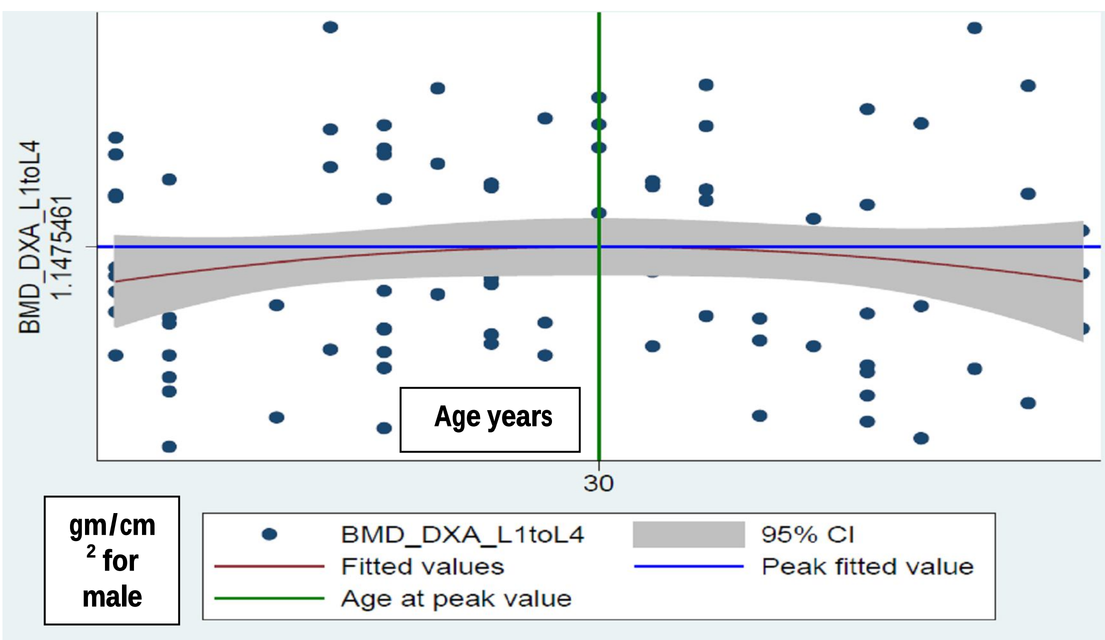

Figure 2: Quadratic regression model of BMD on age for female L1-L4, peak BMD was 1.147±0.016, age of attainment 30

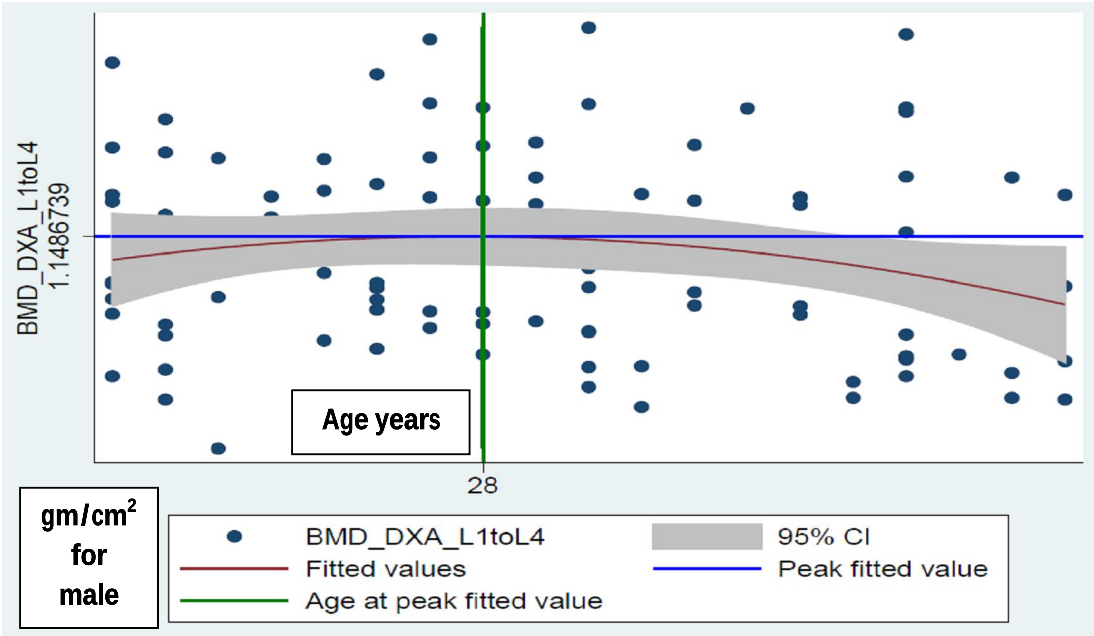

Figure 3: Quadratic regression model of BMD on age for male L1-L4, peak BMD was 1.148±0.016, age of attainment 28

Predictors of BMD in regression analysis:

On multiple regressions analysis of BMD on predictor variables (e.g. weight, height, protein intake), weight was the most significant predictor of BMD of neck of femur and total femur for female subjects (*p*-0.00 and *p*-0.00 respectively).

For male, age was the most significant and most consistent negative predictor of BMD at all the measured sites (*p*-0.009, *p*-0.028, *p*-0.041, for L1-L4, NOF, and total femur respectively) (Table IV and V).

Table IV: Multiple regression analysis of bone mineral densityscore on predictor variables (female subjects, n-102)

Independent Variable	Dependent Variable: BMD L1-L4 (gm/cm2)			Dependent Variable: BMD Neck of femur (gm/cm^2)			Dependent Variable: BMD Total femur (gm/cm^2)		
	Reg. coeff. (b)	*t*	*p*-value	Reg. coeff. (b)	*t*	*p*-value	Reg. coeff. (b)	*t*	*p*-value
Age	0.00	0.09	0.927	-0.004	-1.56	0.124	-0.005	-1.90	0.062
Weight	0.002	1.43	0.157	0.006	3.83	0.000	0.007	4.57	0.000
Height	0.005	1.82	0.074	0.001	0.23	0.816	-0.002	-0.88	0.380
Protein	0.001	0.72	0.477	0.002	1.83	0.073	0.002	1.47	0.148
(Constant)	0.185	0.48	0.632	0.501	1.17	0.248	1.012	2.44	0.017
R Square	0.192			0.286			0.288		

Reg. coeff.=regression coefficient

Table V: Multiple regression analysis of bone mineral density score on predictor variables (male subjects, n-98)

Independent Variable	Dependent Variable								
	BMD (DXA) L1-L4 (gm/cm2)			Mean-NOF			Mean-T. Femur		
	Reg. coeff. (b)	*t*	*p*-value	Reg. coeff (b)	*t*	*p*-value	Reg. coeff. (b)	*t*	*p*-value
Age	-0.019	-2.90	0.009	-0.014	-2.37	0.028	-0.016	-2.19	0.041
Weight	0.007	1.79	0.09	-0.001	-0.32	0.749	0.001	0.15	0.881
Height	0.002	0.52	0.611	0.006	1.34	0.195	0.007	1.43	0.169
Protein	0.002	1.33	0.198	0.001	0.48	0.638	0.002	0.99	0.336
(Constant)	1.016	1.48	0.157	0.552	0.88	0.389	0.319	0.43	0.675
R Square	0.403			0.455			0.350		

Z-score and osteopenia/osteoporosis

Z-score of ≤ -2 is considered as "low bone mass" or bone mass "below the expected range for age". According to that at L1-L4, NOF and total femur, Z- score ≤ -2 was observed in 4.9%, 2.9% and 0.98% in female and 11.2%, 3% and 2% in male subjects respectively. When total subjects are taken into account, the values (below the expected range) were 8%, 3% and 1.5 %, respectively of those sites. Z-score based distribution of study subjects, were shown in Table VI.

Table VI: Z- score based distribution of study subjects (n-200)

BMD sites	Low bone mass "below the expected range for age"(Z-score ≤-2)			
	Female n-102 (%)*	Male n-98 (%)*	Total n-200 (%)*	**p* value
Lumbar spine (L1-L4)	05 (4.9)	11 (11.2)	16 (8)	0.17
Neck of femur	03 (2.9)	03 (3)	06 (3)	0.70
Total Femur	01 (0.98)	02 (2)	03 (1.5)	0.99

* Z proportion test

Comparison of BMD with other study and manufacturer's data

Female study subjects in our series were segregated into 2 age groups, then BMD values at L1-L4 and NOF were recalculated after cross calibration of values (from GE Lunar to 'Hologic'),[15] for the purpose of comparison of those values to an Indian study.[16] Recalculated values of our female population for L1-L4 were 14.3% and 9.8% better than those of corresponding Indian study (for 21-30 and 31-40 age groups respectively). The difference was statistically significant. For NOF those values were 5.9% and 0.3% better for those age groups (Table VII).

Table VII: Comparison of bone mineral density with Indian population, in spine and dual neck of femur (Bangladesh n-64, n-38, Indian n-50, n-50)

Age group (year)	Sites	Bangladesh (Female n-64 (21-30) n-38(31-40) **		Indian (Female) [28] n-50(21-30),n-50(31-40)		% difference	*p-value
		Mean±SD	CV	Mean±SD	CV		
21-30	Spine	1.054±0.104	9.9	0.903±0.159	17.6	14.3	0.000
31-40	Spine	1.044±0.119	11.4	0.942±0.1 14	12.1	9.8	0.000
21-30	NOF	0.795±0.121	15.2	0.748±0.214	28.6	5.9	0.141
31-40	NOF	0.775±0.111	14.3	0.773±0.120	15.5	0.3	0.936

*Students t test (unpaired), **(Recalculation from the NHANES Database[15])

Similar comparison to NHANES III[15] population database (both male and female) of total femur showed that there was no significant difference between the values of female subpopulation. But NHANES values for male were 3.9% higher than those of our series. The difference (*p*-0.04) was significant (Table VIII).

Table VIII: Comparison of bone mineral density with NHANES III population at total femur

Gender	Bangladesh (21-30) n-64 (F), n-62 (M)		NHANES (20-29)[15] n-409 (F), n-382 (M)		% diff.	*p-value
	Mean ± SD	CV	Mean±SD	CV		
Female	0.944±0.125	13.2	0.942±0.122	13.0	0.2	1.00
Male	1.002±0.111	11.1	1.041±0.144	13.8	-3.9	0.04

*Students t test, SD= standard deviation, CV = coefficience of variance

DISCUSSION

The peak bone mineral density (PBM) status is one of the most important determinants of the future development of osteoporosis.[17] With the view to measure the PBM, we determined the bone mineral density (BMD) status of 200 study subjects. Different other studies had similar study population[2,18]; some other study had larger population.[19-21] Age range of this study subjects was 21-39 years. Other study had similar (21-40 years)[19] or dissimilar (25-35years)[18,20] study population. Mean age of our study subjects (28.99 years), was comparable to other study.[18,20] Both height and weight of female in this series were lower than those in male and the difference was significant (for both variables *p* - 0.00), although BMI of female, was higher. This observation (higher values for male) was comparable to the Indian series.[20]

Mean daily calcium and protein intake was low in this series (262.66 mg, 52.48 gm), which was below the RDA (400 mg/d and 1gm/kg/day respectively). It was also low in comparison to other studies.[18,20] Significant difference of protein intake between male and female was observed in our series (60.72 gm vs. 48.05 gm, *p*-0.00), which is similar to the Indian study[20] (67.7 gm vs. 50.92 gm). Such a low daily intake may be related to lack of knowledge, and/or poor buying capability or other social factor(s).

Mean BMD (gm/cm^2) by DXA, of all study subjects of L1-L4 was better than other measured sites. Other studies[20,21] also revealed similar higher

BMD trend at that same area. BMD (in gm/cm^2) for male was comparable to or better than female, but Z- score at all measured sites of female was better than male. Discrepancies between gm/ cm^2 and Z-score value of BMD in our series is an interesting observation which might be an indication that 'NHANES III' reference population database is not working well in Bangladesh. We had to apply Z-score, as per ISCD guidelines.[12] (Z-scores, not T-scores, are preferred for BMD reporting in females prior to menopause and in males younger than age 50.)

Ideally, PBM is estimated from a longitudinal study in which a large number of male and female is followed from the age 5 till the age 30, but such a study is not practically feasible; [22] although there are a number of longitudinal study.[1,7,23-26] Our study is a cross sectional one; we found a good number of similar cross sectional study.[2,4,18-21] PBM determination strategy from cross sectional studies also differed from one study to another. Some study protocol categorized male and female population into 2 (or more) different age sub-groups and better mean BMD values for a subgroup was considered PBM and that age (group), considered as the age of attainment of PBM. Shivane's[20] study in this manner, calculated that PBM at some scanned area appeared earlier and at other areas later. Similar method was applied in other studies as well.[18,19,21]

We used a computer based regression model to determine PBM. There are other studies,[22,27] who used similar model. Based on regression of different BMD values on age, peak BMD value and age of its attainment were calculated. PBM at all measured sites in our series were higher for male & the age of attainment were earlier for them (male). For both genders, lumbar peak was higher. Bagher et al.,[21] had similar higher lumber peak (all study population) and earlier age of peak attainment by male. Study conducted in Vietnam[22] had all those PBM values lower than those of our series and age of attainment were earlier for female.

On regression analysis weight for female and negative correlation of age for male, was the most significant predictor of BMD (female 2 sites, male all sites) in our series. Although height didn't predict BMD in our series, Shivane et al.,[20] found height along with weight as the most significant predictors of BMD at all sites. Height, weight, and total body fat were the most significant predictors of BMD by Fuleihan et al.[18] Weight was the most consistent contributor to variance in BMD by Marwaha et al.[19] Age, lean body mass, physical activity and dietary calcium intake accounted for PBM in the study by Suzanne et al.[28]

Z– Score based BMD study revealed that up to 11.2% healthy male and 4.9% healthy female subjects had "low bone mass." (At L1-L4). Comparison of BMD value with that of Ranu P et al.,[16] revealed that, our female subpopulation had up to 14.3% better BMD value than their Indian counterpart. When compared to NHANES III population database for total femur, there was no significant difference between the values of female subpopulation. But our male subpopulation were trailing significantly (p-0.04) by that NHANES database. So, our female subpopulation had comparatively better BMD, although they were trailing by their male counterpart in the study.

Limitations

The study was conducted on a group of population mainly of urban background, which may not be the representative population. As the study was not a longitudinal one, any result of PBM may be an underestimate of the true PBM of the study population. Sampling was not random (rather convenient), which might be subjected to bias. Many other possible determinants of PBM were not studied, like serum calcium, Vitamin D, bone markers, Inorganic phosphate and others. 24 hours food recall may not represent the food habit and average energy consumption of the study subjects. Determination of PBM requires a healthy population with no constraints to growth, nutrition, and bone mineralization. Low intake of dietary calcium and protein by our population might not represent them as “healthy young population.” A bigger sample would have a better representation of the PBM and its determinants.

CONCLUSION

Nutrition status needs to be improved in order to optimize peak bone mineral density and to prevent or retard future development of osteoporosis. Diet (with supplementation) providing adequate protein, vitamin D, calcium, and other elements in the years prior to peak bone mass is very important. To the best of knowledge it was the first population based BMD study in Bangladesh. Results obtained and the observations made in this study may help to generate population based database, and encourage comprehensive study on this field in future.

Acknowledgements: We would like to thanks the department of Rheumatology, BSMMU and Anower Khan Modern Hospital Dhaka for their full Laboratory support.

Conflict of interest: The authors declare no conflicts of interest.

REFERENCES

1. Berger C, Goltzman D, Langsetmo L, Joseph L, Jackson S, Kreiger N, et al. Peak bone mass from longitudinal data: Implications for the prevalence, pathophysiology, and diagnosis of osteoporosis. JBMR. 2010; 25(9): 1948–1957.
2. Bonjour JP, Theintz G, Buchs B, Slosman D, Rizzoli R. Critical Years and Stages of Puberty for Spinal and Femoral Bone Mass Accumulation during Adolescence. JCEM. 1991; 73(3): 555-563.
3. Pocock NA, Eisman JA, Hopper JL, Yeates MG, Sambrook PN, Eberl S. Genetic determinants of bone mass in adults: A twin study. J Clin Invest. 1987; 80(03): 706–710.
4. Kelly PJ, Morrison NA, Sambrook PN, Nguyen TV, Eisman JA. Genetic influences on bone turnover, bone density and fracture. Euro J Endocrinol. 1995; 133(3): 265–271.
5. Heaney RP, Abrams S, Hughes BD, Looker A, Marcus AR , Matkovic V, et al. Peak Bone Mass. Osteoporos Int. 2000; 11(12): 985–1009.
6. Rizzoli R, Bonjour JP, Ferrari SL. Osteoporosis, genetics and hormones. J Mol Endocrinol. 2001; 26(2): 79–94.
7. Osteoporosis: Peak Bone Mass in Women. NIH Osteoporosis and Related Bone Diseases. National Resource Center. 2018; NIH Pub. No. 18-7891.
8. Lawrence GR, Barbara EK, Joseph AL. Metabolic Bone Disease. In: Larsen PR, Kronenberg HN, Melmed S, Polonosky KS (Eds): Williams Textbook of Endocrinology 10th ed.,W.B. Saunders. Philadelphia. Pennsylvania, 2003; 1612.
9. Melton LJ, Elizabeth J, Atkinson, Michael K, Connor O, Michael W, et al. Bone Density and Fracture Risk in Men. JBMR. 1998; 13(12): 1915-1923.
10. Hui SL, Slemenda CW, Johnston CC. The contribution of bone loss to post menopausal osteoporosis. Osteop Int. 1990; 1: 30 –34.
11. Randell AG**,** Nguyen TV**,** Bhalerao N, Silveman SL, Sambrook PN and Eisman JA.Deterioration in quality of life following hip fracture. Osteoporos Int. 2000; (11): 460–466.
12. The International Society for Clinical Densitometry (ISCD). Official Positions-Adult.2019 https://www.iscd.org/official-positions/2019-iscd-official-positions-adult/.
13. Islam SK. Food consumption tables and database for Bangladesh with special reference to selected ethnic foods.” Institute of Nutrition and Food Science University of Dhaka 1st Ed. Dhaka 2012: (ISBN: 9789843352378).

14. Binkley N, Bilezikian JP, Kendler DL Leib ES, Lewiecki EM, Petak SM. Summary of the International Society For Clinical Densitometry 2005 Position Development Conference. J Bone Miner Res. 2007; 22(5): 643-645.

15. Binkley N, Kiebzak GM, Lewiecki EM, Krueger D, Gangnon RE, Miller PD, et al. Recalculation of the NHANES Database SD Improves T-Score Agreement and Reduces Osteoporosis Prevalence. J Bone Miner Res. 2005; 20(2): 195-201. DOI: 10.1359/JBMR.041115.

16. Ranu P.'Normal BMD values for Indian females aged 20–80 years.' J Midlife Health. 2010; 1(2): 70–73.

17. Johnston CC, Miller JZ, Slemenda CW, Reister TK, Hui S, Christian JC, et al. Calcium supplementation and increases in bone mineral density in children. N Engl J Med 1992; 327: 82-87. DOI: 10.1056/NEJM199207093270204.

18. Fuleihan GE, Baddoura, Awada H, Salam N, Salamoun M, Rizk P. Low Peak Bone Mineral Density in Healthy Lebanese Subjects.Bone. 2002; 31(4): 520-528.

19. Marwaha RK, Tandon N, Shivaprasad C, Kanwar R, Mani K, Aggarwal R, et al. Peak bone mineral density of physically active healthy Indian men with adequate nutrition and no known current constraints to bone mineralization. 2009. J Clin Densitom; 12(3): 314-321.

20. Shivane VK, Sarathi V, Anurag Rl, Tushar B, Shashank RJ, Padmavathy, et al. 'Peak Bone Mineral Density and Its Determinants in an Asian Indian Population'. J Clin Densitom: (Assessment *of* Skeletal Health). 2012; 15(2): 152-158.

21. Bagher L, Alireza M, Abbas AK, Arash HN, Akbar S, Amir B, et al. Peak Bone Mass of Iranian Population: The Iranian Multicenter Osteoporosis Study. J Clin Densitom. 2006*;* 9*(*3): 367-374. DOI: 10.1016/j.jocd.2006.05. 001.

22. Lan T H, Nguyen UD, Pham HN, Nguyen ND, and Nguyen TV. Reference Ranges for Bone Mineral Density and Prevalence of Osteoporosis in Vietnamese Men and Women. BMC musculoskeletal disorder. 2011; 12(182): 1-7.

23. Walsh JS, Henry YM. Fatayerji D, Eastell R. Lumbar spine peak bone mass and bone turnover in men and women: a longitudinal study. Osteoporos Int. 2009; 20(3): 355-362.

24. McKay HA, Bailey DA, Mirwald RL, Davison KS, Faulkner RA. Peak bone mineral accrual and age at menarche in adolescent girls: a 6-year longitudinal study. J Pediatr. 1998; 133(5): 682-687.

25. Nilsson M, Ohlsson C, Ode´n A, Mellstro¨m D, Lorentzon M. Increased Physical Activity Is Associated With Enhanced Development of Peak Bone Mass in Men: A Five-Year Longitudinal Study. J Bone Miner Res. 2012; 27(5): 1206-1214. DOI: 10.1002/jbmr.1549.

26. Bachrach LK, Hastie T, Wang MC, Narasimhan B, Marcus R. Bone Mineral Acquisition in Healthy Asian, Hispanic, Black, and Caucasian Youth: A Longitudinal Study. J Clin Endocrinol Metab. 1999*;* 84(12)*:* 4702-4712. DOI: 10. 1210/jcem. 84.12.6182.

27. Meja GT, Pineda RG, Téllez-Rojo MM, Ponce EL. Peak bone mass and bone mineral density correlates for 9 to 24 year–old Mexican women, using corrected BMD. Salud Publica Mex. 2009; 51(1): S84-92. DOI: 10.1590/s0036-36342009000700011.

28. Suzzane CH, Wong E, Chan SG, Lau J, Chan S, Leung PC. Determinants of peak bone mass in Chinese woman aged 21-40 years, Physical activity and bone mineral density. J Bone Miner Res. 1997; 12(8): 1262-1271.