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Original Research Article

Assessment of Bone Mineral Density and its Correlation with Body Mass Index in Postmenopausal Women using DEXA Scan

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Conflict of interest: Nil

Abstract:

Background: Estrogen deficiency and age-related bone loss make osteoporosis a serious health issue in postmenopausal women. Body Mass Index (BMI) is known to affect Bone Mineral Density (BMD) and there are very few data from eastern India available on this association.

Objective: To determine the correlation between BMD and BMI among the post-menopausal women by using Dual Energy X-ray Absorptiometry (DEXA) scan.

Method: It was an observational cross-sectional study done in the Department of Obstetrics and Gynaecology at Nalanda Medical College and Hospital, Patna, Bihar in the hospital setting among 105 post-menopausal women. The participants were divided into three groups based on WHO BMI classification: normal weight, overweight, and obese. Lumbar spine and femoral neck BMD was measured by DEXA scan. Data was analyzed by using ANOVA, Chi-square test, Pearson correlation and multivariate ordinal regression analysis.

Conclusions: The prevalence of osteoporosis was higher among patients with normal BMI than in overweight and obese women. There were significant increases in mean BMD values for both the lumbar spine and femoral neck with BMI ($p<0.001$). BMI was significantly correlated with lumbar spine BMD ($r=0.612$) and femoral neck BMD ($r=0.574$). BMI and duration of menopause were correlated with a decreasing BMD.

Conclusion: BMI was significantly correlated with BMD in postmenopausal women. Being underweight was found to be a risk factor for osteoporosis. Simple screening and preventive measures could help minimize osteoporosis complications.

Keywords: Postmenopausal women, Bone Mineral Density, Body Mass Index, Osteoporosis, and DEXA scan, Lumbar spine, femoral neck.

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Introduction

Natural menopause is one in which menstruation has stopped for the past year and a half without any medical or non-medical reason. It is a significant life transition for women, and there are several hormonal and metabolic changes associated with it, one of the greatest being osteoporosis. The average age of onset of this menopause in Indian women is about 47.5 years, and the average age of women is nearly 71 years in India, giving rise to a very large postmenopausal population living for decades after menopause [1,2].

As women live longer, women's chronic age-related disease burden has also increased, especially osteoporosis and osteopenia which are important causes of morbidity, disability and low quality of life. Osteoporosis is a systemic disorder of bone that results in the reduction of bone mass and deterioration of the microarchitecture of bone, which increases its fragility and susceptibility to fracture [3]. It is a silent disease because the phenomenon of bone loss is more or less silent and usually only becomes apparent when fractures happen. Low trauma fracture of the spine, hip and wrist are frequently complications of osteoporosis and contribute to the burden of health care and mortality in elderly women.

The prevalence of osteopenia has been reported between 35-40% of women aged 40-65 years and osteoporosis 8-30% [3]. Moreover, there is evidence that Asian females are also prone to

osteoporosis than Caucasian females because of the difference in body composition, nutritional status, and genetic factors [4]. Achievement of peak bone mass during young adulthood and the subsequent postmenopausal bone loss are the two most important factors of bone health in postmenopausal women. During the third decade, the peak bone mass is reached, and bone resorption slowly surpasses bone formation [5]. After menopause, levels of estrogen drop and bone turnover increases, leading to rapid loss. The first 5 years post menopause is a period during which 5% of trabecular bone and 1-1.5% of cortical bone mass is lost each year [6]. Estrogen is an important hormone in regulating bone metabolism by downregulating the activity of osteoclastic cells and upregulating the survival of osteoblastic cells. Postmenopausal estrogen deficiency also increases the release of inflammatory cytokines like interleukin-1, interleukin-6 and tumor necrosis factor-alpha, which promote bone resorptions and lead to reduced BMD [7].

Bone Mineral Density (BMD) is a key determinant of bone strength and commonly used to diagnose osteopenia and osteoporosis. Osteoporosis is classified according to the T score obtained by using dual-energy X-ray absorptiometry (DEXA) scan by the World Health Organization (WHO). A T score of between -1 and -2.5 is a sign of osteopenia while a T score below -2.5 confirms osteoporosis [8]. Due to its high precision, low radiation doses, and ability to measure bone density at clinically relevant skeletal sites (e.g. lumbar spine and femoral neck), DEXA scan is regarded as the gold standard technique for assessing BMD [9].

Body Mass Index (BMI) has been found to be one of the more important factors that affect bone mineral density; specifically, it is an important predictor of bone health in postmenopausal women. BMI is a simple anthropometric measurement that can be used to help determine body composition and weight status of an individual (underweight, normal, overweight, and obese). There have been several studies that have shown a positive correlation between BMI and BMD; that is, women with high BMI have higher bone density and lower osteoporosis risk [10]. Mechanical loading on bones causes increases in bone formation and decreases in bone resorption due to increased body weight. Moreover, adipose tissue regulates peripheral aromatization of androgens to estrogens which may offer protection against postmenopausal loss of bone mass [11].

On the other hand, women with low BMI are more likely to have accelerated bone loss and osteoporosis, as they are not subjected to enough mechanical loading, have lower estrogen levels, nutritional deficiency, and lower muscle mass. Previous studies conducted in different populations have reported that low BMI is significantly associated with lower BMD values at the lumbar spine and femoral neck. But there are ethnic and lifestyle differences in the relationship between BMI and BMD, as well as socioeconomic and dietary differences. Thus, more region-specific research is warranted to understand this relationship in postmenopausal women of India.

Bihar is a densely populated area of India, and knowledge about osteoporosis screening and prevention among postmenopausal women is low. Other factors, such as nutritional deficiencies, low calcium intake, and socio-economic issues, may also further elevate the osteoporosis risk in this population. Though the prevalence of osteoporosis is increasing, there are only few studies available showing the correlation between BMI and BMD in postmenopausal women from eastern India including Bihar. Hence, the present study was conducted in the Department of Obstetrics and Gynaecology in Nalanda Medical College and Hospital, Patna, Bihar, India to evaluate bone mineral density as measured by DEXA scan and its correlation with the body mass index in post-menopausal women. Identifying women who are at risk early can facilitate interventions, fracture prevention and post-menopausal health outcomes.

Methodology

Study Design: The present study was an observational cross-sectional study of 105 postmenopausal women done to evaluate the correlation of Bone Mineral Density (BMD) with Body Mass Index (BMI) in postmenopausal women with Dual Energy X-ray Absorptiometry (DEXA) scan in the hospital. The purpose of the study was to investigate the association of BMI with BMD in postmenopausal women and to identify women with a higher risk of osteopenia and osteoporosis.

Study Area: The study was carried out at Department of Obstetrics and Gynaecology, Nalanda Medical College and Hospital, Patna, Bihar, India. Nalanda Medical College and Hospital is a tertiary care teaching hospital serving a huge population, which is predominantly women, from both urban and rural Bihar and adjoining areas. The institution offers special facilities for gynecologic and diagnostic purposes, including facilities for the assessment of osteoporosis by DEXA scanning.

Study Duration: The study lasted for one year in the outpatient and inpatient department of Obstetrics and Gynaecology of Nalanda Medical College and Hospital, Patna, among the Post-Menopausal women.

Sample Size: An additional 105 women who met the criteria were included in the study. Informed written consent was obtained, and enrollment was done consecutively during the study period.

Sample Population: The study population comprised women with natural menopause of 1-5 years duration who attended the Department of Obstetrics and Gynaecology. Women were chosen regardless of socio-economic and educational background. All the participants were screened clinically and investigated extensively prior to their inclusion and secondary causes of low BMD were excluded.

Data Collection: A predesigned and structured questionnaire was used to gather data. Detailed demographic data such as age, education level, occupation, socioeconomic status, diet, and exercise regimen was collected from each subject. Further, detailed medical, menstrual, obstetrical and drug history was taken. All subjects were examined thoroughly, including a general physical exam, a systemic examination, and a gynecological examination. To exclude secondary osteoporosis, relevant laboratory tests such as thyroid function tests, parathyroid function tests, liver function tests, renal function tests, blood sugar levels and serum vitamin D levels were performed. Only those participants eligible according to clinical and laboratory parameters were recruited for the study.

All subjects were anthropometrically measured. Body weight was determined with the person standing on an electronic weighing machine with shoes removed and wearing light clothing. Body Mass Index (BMI) was calculated by the formula:

$$\text{BMI (Kg/m}^2) = \frac{\text{Weight (Kg)}}{[\text{Height (m)}]^2}$$

According to the BMI values, the subjects were classified into three categories as normal weight (BMI 18.5-24.9 kg/m²), overweight (BMI 25.0-29.9 kg/m²), and obese (BMI ≥30.0 kg/m²) based on the classification by the World Health Organization (WHO).

Inclusion Criteria

- Women of postmenopausal period who visited the Department of Obstetrics and Gynaecology, Nalanda Medical College and hospital, Patna.
- Women who have experienced natural menopause for 1 – 5 years.
- Women who are willing and give written informed consent.

Exclusion Criteria

- Women with surgical menopause.
- Known cases of metabolic and endocrine disorders (hyperthyroidism, hyperparathyroidism, diabetes mellitus, chronic liver disease, chronic kidney disease, and rheumatoid arthritis) in females.
- Women taking drugs that are known to affect bone metabolism (corticosteroids, levothyroxine, heparin, phenytoin, phenobarbital, calcium supplements, vitamin D therapy, hormone replacement therapy).
- Women who have had chronic smoking or drinking.
- Female subjects who were too sick to be enrolled in the study or who refused to join the study.

Procedure: All the eligible postmenopausal women attending the gynecology department of the study period were screened and enrolled consecutively after obtaining informed consent. Each participant was clinically evaluated and anthropometric measurements taken. Laboratory tests were performed to rule out secondary osteoporosis.

All enrolled participants had Bone Mineral Density (BMD) test performed at the lumbar spine L1-L4 vertebrae and femoral neck, by Dual Energy X-ray Absorptiometry (DEXA) scan. BMD values are listed as T-scores. WHO suggested a T-score ≥ -1.0 was normal, T-score between -1.0 and -2.5 was osteopenia and T-score ≤ -2.5 was osteoporosis. The obtained BMD values were compared between BMI categories to assess the correlation between BMI and BMD.

Statistical Analysis: The data collected were entered into Microsoft Excel spreadsheet and analyzed using Statistical Package for Social Studies (SPSS) version 21.0. All categorical variables were presented as frequency and percentage, and all continuous variables were presented as mean ± standard deviation (SD) and median values. The data distribution was checked for normality by Kolmogorov-Smirnov test. Analysis of Variance (ANOVA) was used to compare quantitative variables which were normally distributed and Kruskal-Wallis test used for non-normally distributed quantitative variables.

Chi-square test was used to analyze qualitative variables. To identify the factors that are significant, multivariate ordinal regression was used. The p-value ≤ 0.05 was considered statistical significance.

Result

Table 1 shows the distribution of study participants according to Body Mass Index (BMI) categories. In total of 105 postmenopausal women, 38 women (36.2%) were normal weight, 35 women (33.3%) were overweight, and 32 women (30.5%) were obese. The results showed that the study population was nearly equal in the three BMI groups and thus comparison of Bone Mineral Density (BMD) in various BMI groups was possible.

Table 1: Distribution of Subjects According to BMI Category (N = 105)

BMI Category	BMI Range (kg/m²)	Number of Subjects (n)	Percentage (%)
Normal Weight	18.5–24.9	38	36.2
Overweight	25.0–29.9	35	33.3
Obese	≥30.0	32	30.5
Total		**105**	**100**

The anthropometric characteristics and age of the study participants in various BMI categories are shown in Table 2. The average age for each group did not differ significantly (p=0.312) and was similar across all three groups. But there was a significant difference between the normal weight group and the obese group for body weight and BMI (p<0.001). There were no significant differences between group heights. The results indicated that there was no difference in age and height between the groups and the BMI classification was appropriate for the difference in body weight.

Table 2: Mean Age and Anthropometric Characteristics of Study Participants

Variable	Normal Weight (n=38)	Overweight (n=35)	Obese (n=32)	p-value
Age (years)	53.2 ± 4.1	54.1 ± 4.5	54.8 ± 5.0	0.312
Weight (kg)	54.8 ± 5.6	67.4 ± 6.2	78.9 ± 7.8	<0.001
Height (m)	1.54 ± 0.05	1.56 ± 0.04	1.55 ± 0.06	0.287
BMI (kg/m²)	23.1 ± 1.4	27.2 ± 1.5	32.8 ± 2.1	<0.001

The Bone Mineral Density (BMD) T-scores for the lumbar spine and femoral neck are shown for the various BMI categories in Table 3. The normal weight group had the lowest mean lumbar spine BMD T-score of the groups (-2.41 ± 0.62), whereas the obese group had the highest T score of all groups (-1.12 ± 0.54). Similarly, women with normal BMI had the lowest BMD of the femur neck, and obese women had the highest. The differences between the groups were statistically significant (p<0.001). The results of this study suggest that there was a positive correlation between BMI and BMD, such that women who have a higher BMI had a higher BMD.

Table 3: Comparison of Bone Mineral Density (T-score) Among BMI Groups

Site of BMD Measurement	Normal Weight (n=38)	Overweight (n=35)	Obese (n=32)	p-value
Lumbar Spine (L1–L4)	-2.41 ± 0.62	-1.76 ± 0.58	-1.12 ± 0.54	<0.001
Femoral Neck	-1.98 ± 0.56	-1.42 ± 0.48	-0.96 ± 0.45	<0.001

Table 4 shows the distribution of the participants by WHO classification of Bone Mineral Density. Among the women with normal BMI, 44.7% had osteoporosis, while only 9.3% of women with obesity were osteoporotic. On the other hand, normal BMD was more common among obese women (56.3%) compared to women with normal BMI (13.2%). The association between BMI category and BMD classification was found to be statistically significant (p<0.001). This discovery indicates that postmenopausal women with lower BMI are at higher risk for osteopenia and osteoporosis.

Table 4: Distribution According to WHO Classification of BMD

BMD Category	Normal Weight n (%)	Overweight n (%)	Obese n (%)	Total n (%)
Normal	5 (13.2)	12 (34.3)	18 (56.3)	35 (33.3)
Osteopenia	16 (42.1)	17 (48.6)	11 (34.4)	44 (41.9)
Osteoporosis	17 (44.7)	6 (17.1)	3 (9.3)	26 (24.8)
Total	**38 (100.0)**	**35 (100.0)**	**32 (100.0)**	**105 (100.0)**

There is a positive correlation between BMI and Bone Mineral Density at the lumbar spine and femoral neck as presented in Table 5.

Pearson correlation analysis showed that there was a significant positive correlation between BMI and lumbar spine BMD (r=0.612, p<0.001) and femoral neck BMD (r=0.574, p<0.001). The results of this study suggest that with the increase of BMI, Bone Mineral Density also increases. Higher BMI seems to improve bone health in postmenopausal women, therefore.

Table 5: Correlation between BMI and Bone Mineral Density

Variable	Lumbar Spine BMD (T-score)	Femoral Neck BMD (T-score)
BMI (kg/m²)	r = 0.612	r = 0.574
p-value	<0.001	<0.001

Comparing the prevalence of osteoporosis in each BMI classification is shown in Table 6. Osteoporosis was most prevalent among women with normal BMI, where 17 out of 38 women (44.7%) were osteoporotic. However, among 32 obese women, only 3 (9.4%) were found to have osteoporosis. There was a significant difference between BMI groups ($p<0.001$).

These findings also help to confirm the previous study's conclusion linking decreased BMI with higher osteoporosis risk in postmenopausal women.

Table 6: Osteoporosis Prevalence across BMI Categories

BMI Category	Osteoporosis Present n (%)	Osteoporosis Absent n (%)	Total
Normal Weight	17 (44.7)	21 (55.3)	38
Overweight	6 (17.1)	29 (82.9)	35
Obese	3 (9.4)	29 (90.6)	32
Total	**26 (24.8)**	**79 (75.2)**	**105**

A multivariate ordinal regression model was used to determine factors associated with Bone Mineral Density as shown in Table 7. The age and duration of menopause were significantly correlated with decreased BMD. BMI was significantly associated with bone mineral density (OR=0.71, $p<0.001$), suggesting that women with higher BMI had lesser odds of osteoporosis. There was also a significant association between vitamin D level and BMD status. The results indicate that BMI, age, menopausal duration and vitamin D status are key factors affecting bone health of postmenopausal women.

Table 7: Multivariate Ordinal Regression Analysis of Factors Affecting BMD

Variable	Odds Ratio (OR)	95% Confidence Interval	p-value
Age	1.12	1.01 – 1.24	0.028
BMI	0.71	0.59 – 0.84	<0.001
Duration of Menopause	1.18	1.03 – 1.36	0.017
Vitamin D Level	0.89	0.80 – 0.97	0.011

Discussion

The present study was undertaken to examine the relationship of bone mineral density (BMD) (as measured by DEXA scan) with body mass index (BMI) in postmenopausal women. The osteoporosis is an important public health issue in post-menopausal women because of the loss of bone mass in the elderly age and the loss of estrogen in women. Being overweight is a risk factor that can be modified, and it may be possible to prevent osteoporosis if a person knows he or she is overweight. The present study showed that there was a statistically significant positive correlation between BMI and BMD at both the lumbar spine and the femoral neck and that women with higher BMI had higher bone mineral density and lower prevalence of osteoporosis".

Among 105 postmenopausal women studied, 36.2% had a normal BMI, 33.3% were overweight and 30.5% were obese. Normal weight women were more likely to have osteoporosis than overweight and obese women. The rate of osteoporosis was 44.7% in normal weight women but reduced to 17.1% and 9.4% in overweight and obese women, respectively. The result implies that BMI is a key factor in diminished bone mass in postmenopausal female patients. The present study also showed that there was a trend of progressive increase in mean BMD at both the lumbar spine and femoral neck with increasing BMI. Mean lumbar spine T-score improved from -2.41 ± 0.62 in normal-weight women to -1.76 ± 0.58 in overweight women and -1.12 ± 0.54 in obese women. Likewise, the mean T-score of the femoral neck was -1.98 ± 0.56 in normal weight women, -1.42 ± 0.48 in overweight women and -0.96 ± 0.45 in obese women. The results were significantly different ($p<0.001$). The results of these observations suggest that the larger the body mass, the more likely the woman is to be better preserved, post menopause.

The results of the current study are consistent with a number of studies carried out around the world. Henyse G et al. found that the lumbar spine and femoral neck BMD were significantly higher in overweight postmenopausal women than in normal weight postmenopausal women [12]. They concluded their research to be a mechanical hypothesis that greater body mass could provide protective mechanical effect on bones. Likewise, Ravn P et al. studied early postmenopausal women

and found that those in the lowest BMI category showed a significantly lower amount of bone mass, and a higher rate of bone loss during the two-year follow-up period [13]. Their research also reinforced the significance of maintaining the body weight for skeletal integrity after menopause.

Mendez JP et al. found a positive correlation between BMI and BMD at lumbar spine, femoral neck and total hip when they studied Mexican Mestizo postmenopausal women [14]. The same has been reported in postmenopausal Chinese women, who showed higher values of BMD in the higher BMI category [15]. The beneficial effect of BMI on bone density found in these studies among various ethnic groups implies that it is a general effect and not limited to any single ethnic group. Asomaning K et al. concluded that women with low BMI are at greater risk of osteoporosis and that the risk of bone loss decreases with increasing BMI [16]. In addition, Jain V et al. noted that overweight women in India were at significantly decreased risk of low BMD after adjusting for age [17]. Moreover, BMI was found to be significantly positively correlated with BMD in postmenopausal women of Pakistan by Tariq S et al. [18]. The results of the present study are in congruence with earlier studies from India and Asia, which all confirmed the beneficial effect of increased BMI on the bone health of postmenopausal women.

In the present study, it was found that BMI was significantly positively correlated with BMD at both lumbar spine ($r = 0.612$) and femoral neck ($r = 0.574$). This indicates that the higher the BMI the greater the BMD. The connection could be due to several mechanisms. As a body's weight increases, so does the mechanical load on bones, triggering more osteoblastic activity and bone formation. Mechanical forces exerted on weight-bearing bones could therefore be beneficial for maintaining bone mass and/or preventing osteoporosis.

The other potential explanation is the hormone function of fat tissue. Once menopause has occurred, there is a dramatic decrease in the production of estrogen by the ovaries, which leads to an increase in bone resorption. Adipose tissue is an additional source of estrogen as a result of peripheral conversion of androgens to estrogens. Women who have more body fat may thus keep their estrogen levels relatively high, and this may help prevent bone loss and help preserve bone density. Furthermore, there are findings that high BMI is correlated with high insulin and leptin levels, which have been shown to have beneficial effects on bone metabolism. A multivariate ordinal regression analysis in the present study also showed that the older the age, the lower the BMD and the longer the duration of menopause, the lower the BMD, while the greater the BMI, the better the bone health and the higher the vitamin D level, the better the bone health. These results are biologically relevant since higher age and long-term estrogen deficiency are associated with greater osteoclastic activity and loss of trabecular bone. Vitamin D is also essential for calcium absorption and in bone mineralization, and a deficiency can hasten osteoporosis's course.

Although the present study demonstrated a positive association between BMI and BMD, some studies have reported conflicting results. However, Bansal S et al. did not find any statistically significant relationship between BMI and BMD in both pre- and post-menopausal women [19]. These differences could be attributed to variations in study design, ethnicity, nutritional status, physical activity, and sample size.

In addition, an increased BMI does not guarantee a fracture protection benefit even if there are better BMD values. A large international prospective study of postmenopausal women by Compston JE et al. suggests that obesity does not fully protect against fractures and that there is a higher risk of fractures at the ankle and at the upper thigh in obese women [20]. While obesity can increase bone density, it can also have a negative impact on balance and mobility and bone quality, and thereby fracture risk, in specific skeletal sites.

There are some limitations of the present study. The sample size was small, and the study was carried out in one centre. There was limited assessment of factors like dietary calcium intake, physical activity, smoking, alcohol use and socioeconomic status. However, despite these reported limitations, the study offers insightful information on the relationship between BMI and BMD in postmenopausal women.

Conclusion

This present study reveals that postmenopausal women have a positive significant association between Bone Mineral Density (BMD) and Body Mass Index (BMI). The results indicated that women who were lower BMI had significantly lower BMD values at the lumbar spine and femoral neck and had a higher prevalence of osteoporosis than overweight and obese women.

The study also suggested that age and length of menopause were negatively associated with BMD, while BMI and vitamin D status were positively associated with BMD in women. Based on these results, BMI could prove to be a clinically useful, cost-effective, and simple measure for identifying postmenopausal women who are at higher risk of osteoporosis. Awareness of bone health and lifestyle changes, nutritional supplementation, maintenance of the healthy body weight and early screening by DEXA scan can be helpful in timely

prevention and management of osteoporosis and related fractures in postmenopausal women.

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