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Association of Age and Body Mass Index with Bone Mineral Density in a Hospital-Based Cohort from Karachi, Pakistan

Arsalan Shahid*, Anjum Fahad, Muhammad Sarmad Khan

Liaquat College of Medicine and Dentistry, Karachi, Pakistan

*Corresponding Author

Arsalan Shahid

shahid.arsalan1996@gmail.com

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Abstract

Objective: To investigate the correlation of bone mineral density (BMD) with age and body mass index (BMI) in patients undergoing DEXA scans.

Methodology: This was a retrospective observational study conducted at the Medicare Cardiac and General Hospital, Karachi, crossing over the period from 8th September 2022 to September 2023. The study retrospectively analyzed the data of 154 patients who had undergone DEXA scans. Demographic details included age and sex, while anthropometric measurements included height, weight, and BMI. T-scores of both the lumbar spine and femoral neck were noted. Patients with systemic bone disorders, cancer, kidney diseases, and those on hormonal therapy or smoking were excluded. Data analyses were done on SPSS version 25, applying descriptive statistics and Spearman correlation tests; p-values less than 0.05 were considered significant.

Results: The mean age was 60.6 ± 10.1 years, while the mean BMI was 30.6±6.27 kg/m². For the T-score, the mean was -1.023± 1.66 at the lumbar spine and -.908±1.2 at the femur. The lumbar BMD status was significantly associated with age p = 0.001, whereby older patients have higher proportions of osteopenia and osteoporosis. No significant associations were noted between either BMI or gender and BMD status; however, Spearman correlation demonstrated a weak negative association of age with BMD in both sites and a positive correlation with BMI, especially in the femoral neck (r = 0.285).

Conclusion: With increasing age, there was a strong association with decreasing lumbar BMD, whereas increasing BMI showed a protective effect on the femoral BMD. Routine osteoporosis screening is essential for early detection and prevention, especially in people above 50 years. Lifestyle and hormonal factors should be included in further studies to strengthen the evidence.

Keywords: Aging, Body Mass Index (BMI), Bone Mineral Density (BMD), Dual-Energy X-ray Absorptiometry, Osteoporosis.

Introduction

Osteoporosis is a progressive skeletal disorder characterized by reduced bone mass and microarchitectural deterioration, leading to increased bone fragility and fracture risk. It usually does not manifest clinically until a fracture occurs, and therefore, early detection is important.[1] Osteoporosis is becoming more common worldwide as life expectancy rises, particularly in low- and middle-income nations where resources are scarce and the population is ageing. A major public health concern, osteoporosis increases the risk of fractures, which can result in serious illness, death, and a lower quality of life.[2] BMD, measured using dual-energy X-ray absorptiometry (DEXA), is the gold standard for diagnosing osteoporosis.[3] The World Health Organization defines osteoporosis based on BMD T-scores, with values ≤ –2.5 indicating significant bone loss.[4]

Since the mid-1990s, it's been established that achieving high BMD before late adolescence is crucial, as this period marks the peak of BMD acquisition, impacting bone health and fracture risk later in life.[5] Calcium and other BMD-associated nutrients are critical for fortifying BMD and for bone health, and it seems a prerequisite to increase consumption of calcium-rich and various food items, and weight-loaded physical exercise from childhood to adolescence.[6]Age and BMI are among the most widely studied determinants of BMD. Advancing age is strongly associated with bone loss, and BMI influences skeletal loading, with lower BMI often linked to lower BMD and higher fracture risk.[7,8]

In Pakistan, osteoporosis represents an emerging public health concern. Evidence suggests that nearly 40% of postmenopausal women may be affected, underscoring the need for improved screening and preventive strategies.[9] However, local data on BMD patterns and their association with age and BMI remain limited, particularly in tertiary-care settings. This study adds to the

national data by evaluating BMD trends in an urban Karachi population. Therefore, this study aimed to assess BMD at the lumbar spine and femoral neck and to explore its association with age and BMI in adults undergoing DEXA scanning at a tertiary care hospital in Karachi, Pakistan.

Methodology

This retrospective observational study was conducted at Medicare Cardiac and General Hospital, Karachi, between September 2022 and September 2023. Ethical approval for this study was obtained from the Institutional Review Board of Sohail University, Karachi, Pakistan (Protocol No. 000203/22; approved on 8 September 2022). As this was a retrospective review of hospital records, the IRB granted a waiver of individual informed consent. All data were anonymized before analysis to ensure confidentiality.

We chose a retrospective design because DEXA scanning is not routinely performed in the general population in Karachi, and existing hospital records provided a cost-effective means of exploring early associations in our setting. To minimize the limitations of retrospective data, we used a pre-specified data extraction form, only included records with complete demographic, anthropometric, and T-score entries, and rechecked all entries independently by two reviewers. Completeness thresholds were set (>90% of the data available), and extreme outliers (for example, BMI > 60 kg/m^2) were analyzed for robustness with and without those cases. The primary aim is to explore the relationship of BMD with age and BMI among patients who have undergone DEXA scanning. DEXA scan reports had been routinely archived in the Radiology Department. Each report gave details on demographic and anthropometric information (age, sex, height, weight), calculated BMI, referral clinical notes including chief complaints, and BMD as T-scores for the lumbar spine (L2–L4) and femoral neck. All DEXA scans were carried out by trained radiology technicians according to the hospital's SOPs. Throughout the study period, only two operators carried out all scans. A Medix 90 DEXA system (MEDILINK, France; software version 4.1) was used. Daily calibration of the machine using manufacturer-supplied phantom standards was performed throughout to maintain accuracy and instrument reliability. Sample size calculation was done using OpenEpi v3.01. The required sample size for detecting a correlation of r = 0.48 from the study (S. Sultana1et.al 2021)[23], which shows the T-score of LS and BMI were positively correlated (r=0.484) with a significance level of $\alpha = 0.05$, and a power of 80% was calculated using Fisher's z-transformation formula. The estimated sample size was 50 participants. To enhance the reliability of this study and also take missing data into account, a total of 154 participants were included in this research study. Since this is a retrospective review, all eligible records fitting the inclusion criteria within the study period were recruited until sample size was achieved.

The study enrolled all patients who underwent BMD testing during the study period; thus, both male and female patients were eligible for the study. These patients were excluded if they had systemic conditions known to affect bone metabolism such as hyperparathyroidism, Paget's disease, osteocalcin disorders, renal osteodystrophy, or osteogenesis imperfecta. Subjects with a history of cancer or chronic kidney diseases were excluded. Similarly, patients who had taken hormonal therapy, as well as current or past smokers, were also excluded from the study. Current and past smokers were excluded due to the fact that smoking is an important independent risk factor for osteoporosis. Including smokers in this study could thus introduce a strong confounding effect that will make it difficult to establish the relationship between BMD, age, and BMI in a non-smoking population.

Patients had been selected for BMD testing based on clinical referrals, which included criteria such as possible osteoporosis, fracture risk assessment, or other relevant clinical problems. The careful inclusion of all the relevant records during the study period reduces selection bias and offers a representative overview of persons undergoing DEXA scanning in this clinical setting, although the sample is hospital-based and may not be representative of the general public.

The data analysis was done using IBM SPSS version 25. Continuous variables such as age, BMI, and T-scores were presented as mean ± SD. Categorical variables were presented as frequencies and percentages for gender and BMD categories. Spearman's correlation coefficient was used to test the association between continuous variables of age, BMI, and BMD. The Chi-square test was conducted for categorical comparisons including age group and BMI categories with gender in relation to BMD status. A p-value < 0.05 was considered statistically significant. Scatter plots with regression lines were used to illustrate trends.

Results

A total of 154 patient records met the inclusion criteria and were analyzed to determine the relationships between age, BMI, and bone mineral density. The basic anthropometric characteristics of these patients are presented in Table 1.

Table 1: Characteristics of Study Populations

Variable	Mean(Std. Deviation)	Minimum	Maximum
Age	60.60(10.18)	34	84
BMI	30.6(6.27)	19	48
Lumbar (T-score)	-1.0(1.66)	-4.1	5.8
Femur (T-score)	-.90(1.20)	-5.0	2.0

The relationship between age, gender, and BMI with BMD status of both the lumbar spine and femur was analyzed (Tables 2 and 3).

Table 4 presents the Spearman correlation coefficients between BMD at different skeletal sites (femoral neck and lumbar spine) and two variables: age and BMI. A weak negative correlation was observed between age and femoral neck BMD (r = -0.205), as well as between age and lumbar spine BMD (r = -0.182), suggesting a slight decline in BMD with increasing age at both sites. In contrast, BMI demonstrated a positive correlation with BMD. Specifically, a moderate positive correlation between BMI and femoral neck BMD was observed (r = 0.285), with a weaker positive correlation observed with respect to lumbar spine BMD (r

Table 2: Lumbar Spine BMD Status of the Study Patients

Variable	Normal n (%)	Osteopenia n (%)	Osteoporosis n (%)	p-value
Age (years)				
< 50 years	9 (37.5%)	3 (9.7%)	8 (8.7%)	0.001
≥ 50 years	15 (62.5%)	28 (90.3%)	84 (91.3%)	
BMI (kg/m²)				
Underweight	1 (4.2%)	1 (3.2%)	3 (3.3%)	
Normal weight	1 (4.2%)	1 (3.2%)	14 (15.2%)	
Overweight	8 (33.3%)	7 (22.6%)	31 (33.7%)	0.093
Obese Type I	6 (25.0%)	9 (29.0%)	27 (29.3%)	
Obese Type II	3 (12.5%)	11 (35.5%)	12 (13.0%)	
Obese Type III	5 (20.8%)	2 (6.5%)	5 (5.4%)	
Gender				
Male	1(4.2%)	4(12.9%)	4(4.3%)	0.521
Female	23(95.8%)	27(87.1%)	88(95.7%)	

% and Frequency, *P-value measured by Chi-square (<0.05 considered significant)

= 0.187). This suggests that increasing BMI might result in higher bone density, most notably at the femoral neck. Another finding revealed that there was no significant association between age and BMI (r = 0.003), reflecting again that these are independent variables in this population. These correlation analyses complement the categorical analysis: age was significantly associated with lumbar BMD status in chi-square analysis (Table 2); suggesting BMD categories change across age groups. However, in the context of age as a continuous variable, the association with lumbar and femoral neck BMD was weakly negative, consistent with the relatively younger age distribution of our sample.

Table 3: Femoral Neck BMD Status of the Study Patients

Variable	Normal n (%)	Osteopenia n (%)	Osteoporosis n (%)	p-value
Age (years)				
< 50 years	11(14.7%)	9(13.0%)	0(0%)	0.432
≥ 50 years	64(85.3%)	60(87.0%)	10(100%)	
BMI (kg/m²)				
Underweight	1(1.3%)	3(4.3%)	1(10%)	
Normal weight	9(12.0%)	5(7.2%)	2(20%)	
Overweight	23(30.7%)	24(34.8%)	1(10%)	
Obese Type I	17(22.7%)	24(34.8%)	3(30%)	0.170
Obese Type II	16(21.3%)	8(11.6%)	3(30%)	
Obese Type III	9(12.0%)	5(7.2%)	0(0%)	
Gender				
Male	7(9.3%)	3(4.3%)	0(%)	0.410
Female	68(90.7%)	66(95.7%)	10(100%)	

% and Frequency, *P-value measured by Chi-square (<0.05 considered significant)

Table 4: Spearman Correlation between Age, BMI, and Bone Mineral Density

Variable Pair	Spearman r	Interpretation
Age vs Lumbar Spine BMD	–0.182	Weak negative correlation
Age vs Femoral Neck BMD	–0.205	Weak negative correlation
BMI vs Lumbar Spine BMD	0.187	Weak positive correlation
BMI vs Femoral Neck BMD	0.285	Moderate positive correlation
Age vs BMI	0.003	No correlation

Note: For the assessment of associations between continuous variables, Spearman's rank correlation coefficient (r) was computed; $p < 0.05$ was considered to indicate statistical significance.

Figure 1 A and B describe the types of correlations. BMD with age demonstrates a negative trend of bone density over time. The Femoral neck BMD demonstrates a clearer downward slope with some clustering around the regression line, reflecting a more consistent pattern of age-related bone loss. In contrast, the lumbar spine BMD shows a much weaker negative slope, with data points more widely spread, indicating greater variability and a less consistent relationship with age.

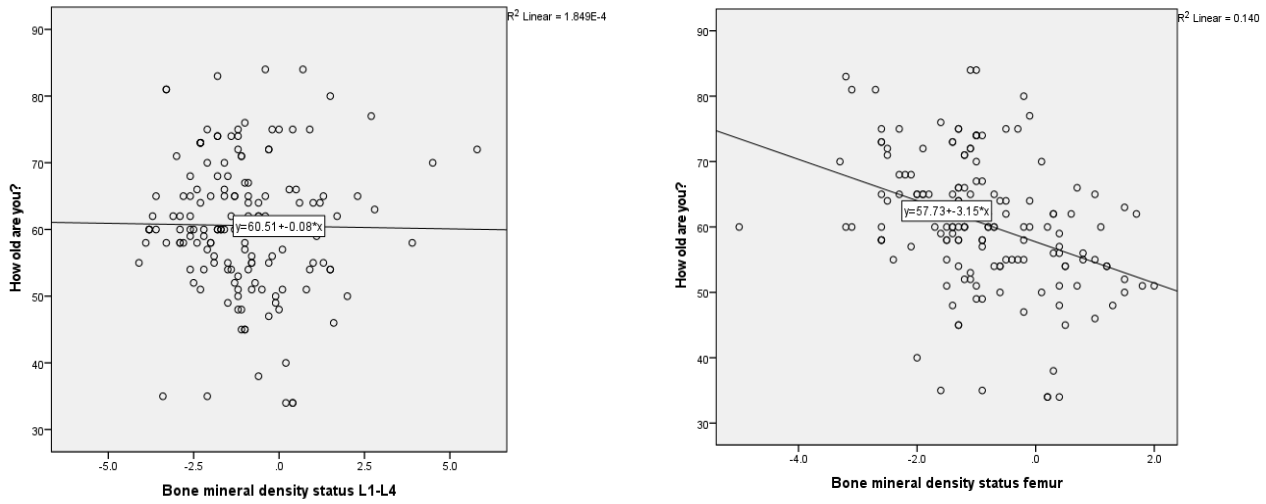

Figure 1. Scatter-plot of (A) lumbar spine BMD and (B) Femoral neck BMD against age.

Multivariable linear regression was considered to adjust for potential confounders such as age, BMI, and menopausal status. While this was not implemented in the current analysis, future phases of this study will incorporate stratified regression models to enhance interpretability

Discussion

This study on 154 patients in Karachi revealed that age was strongly associated with reduced lumbar spine BMD, with osteoporosis and osteopenia more prevalent after 50 years (Tables 2 and 3). As the mean age of 60.6 years reflects a group entering the phase of accelerated age-related bone, which is aligned with worldwide data that indicates a significant decrease in BMD after the fifth decade of life (Table 1).[10] The participant's mean BMI of 30.6 kg/m² indicates that they are obese, which is similar to studies that report obesity incidence is rising in South Asian population, including Pakistan [11]. It is known that lumbar degenerative alterations, such as osteophytes, vertebral sclerosis, and facet hypertrophy, can artificially increase lumbar BMD in older persons, which could be the reason for the higher values that are reported.[12] BMI showed no significant association overall; however, a higher BMI correlated positively with Femoral neck BMD and weakly with lumbar spine BMD, while gender had no significant impact. Notably, the results for the lumbar spine and femoral neck were not always aligned, suggesting that relying on a single skeletal site may miss patients at risk. In our setting, age above 50 years emerged as the strongest predictor of lumbar spine bone loss (Table 2), while BMI demonstrated a modest protective effect at the femur in (Table 3). These findings closely resemble reports from South Asian cohorts, where lumbar spine BMD tends to decline earlier and more sharply with increasing age, particularly in urban populations with high levels of overweight and obesity.[13] In patients with very high BMI, DEXA interpretation can be complicated due to soft-tissue artifacts; however, even after excluding extreme BMI values, the direction and strength of associations in our study remained unchanged. Despite a predominance of overweight and obese participants, bone loss continued to progress with advancing age, reinforcing the need for routine screening in older adults irrespective of body mass.[14] Such findings are consistent with recent Pakistani and Indian studies reporting that high BMI does not uniformly protect the spine against age-related osteoporosis, possibly due to central adiposity related inflammation impairing trabecular bone.[15] Our findings on age-related bone loss align with both local and international reports indicating a higher prevalence of osteopenia and osteoporosis after 50 years, consistent with WHO and FRAX-based assessments.[16,17] However, in contrast to many global datasets, we did not find significant relationships between BMI and either lumbar or femoral BMD.

The lack of a significant BMI–BMD association may reflect unmeasured confounders such as low calcium intake, widespread vitamin D deficiency in Pakistan, limited physical activity, or variations in body fat distribution. All of these factors can attenuate the expected protective effect of BMI on BMD.[18] Previous Studies have shown that higher BMI correlates more strongly with femoral BMD than with lumbar spine BMD, partly due to site-specific mechanical loading.[19,20] Although these correlations were weak (r = 0.285 for femoral neck and r = 0.187 for lumbar spine), our results showed that BMI had a stronger association with femoral BMD than with lumbar spine BMD (Table 4). Taken together, the chi-square analysis showing a significant association between age and lumbar BMD status and the weak negative correlations shown in the table and figure (Table 4 and Figure 1) suggest early-stage bone mineral loss in a relatively young, predominantly middle-aged cohort. Gender showed no significant impact on BMD, likely due to methodological limitations, including the small number of male participants (Table 2 and 3), the markedly skewed sex distribution, and the inherent constraints of a hospital-

based retrospective dataset, all of which may limit the ability to detect true sex-related variations in BMD. Regarding the femur, we observed that no significant association between age and femoral BMD existed, which is somewhat surprising given the common belief that age-related osteoporosis predominantly affects the femoral region, particularly the neck of the femur. A study conducted by (Chen et al. 2013) proposed that the femoral neck is often one of the earliest sites to show osteoporotic changes with advancing age.[21] Our study supported this literature as all the patients with femoral osteoporosis were above 50 according to the data shown in the table (Table 3). However, no significant age-related trend was seen due to homogeneity of the sample as most of them are females which may have masked the real age-related effect on femoral BMD. The literature regarding the adverse effects of ageing on BMD is supported our results. Various studies demonstrated that BMD decreases with advancing age, especially in weight bearing skeletal regions of the lumbar spine and femoral neck, which are the usual sites affected by osteoporosis and fractures in elderly individuals.[22] The weak correlations may indicate that the study population represented the early stage of BMD loss or a relatively younger age group, as BMD is known to decline more steeply in older age groups. Age and BMI did not exhibit any significant association (Table 4). These findings are consistent with previous literature that, although there is a positive correlation between BMI and BMD, age does not appear to be a modifier of this relationship.

In the Pakistani clinical setup, which is burdened by high levels of obesity, widespread vitamin D deficiency, and lack of random sampling, BMI alone cannot be used as a reliable predictor of either lumbar or femoral BMD. In contrast, age remains the single strongest and most consistent determinant of bone loss, particularly in the lumbar spine. Our overall findings indicate that, although BMI exerts a limited site-specific influence on BMD, it cannot serve as a reliable standalone predictor of osteoporosis in clinical settings in Pakistan. Age remains the key determinant of bone loss, especially at the lumbar spine, and should therefore remain central to screening and risk assessment strategies. The weak correlations further underscore the likely contribution of unmeasured lifestyle and biological factors, including but not limited to vitamin D status, physical activity, diet, and hormonal influences, which deserve attention in future prospective studies.

Limitations

This study was conducted at only one private tertiary hospital, which is a limitation to the generalizability of our findings. Being a retrospective design, analysis was done only for systematically recorded variables; records with a lack of essential data were excluded. Lifestyle and hormonal factors, such as dietary intake, physical activity, vitamin D status, menopausal status, and medications, were not available, which may introduce residual confounding. Smokers and patients with systemic bone disorders were excluded, which further limits the applicability to the general population. The male sample was small, further restricting the assessment of sex-specific differences. Despite these limitations, consistency in our results using sensitivity analyses, for example, the exclusion of extreme cases of BMI, lends support to the reliability of the results. Future prospective studies are recommended that would include these additional determinants for a comprehensive assessment of osteoporosis risk factors.

Conclusion

While age is significantly related to BMD decline, especially at the lumbar spine, higher BMI only exerts a modest protective effect at the femoral neck. These findings would, therefore, suggest that adults above 50 years, regardless of BMI, are to be considered the priority for osteoporosis screening among clinicians in Karachi. When there is a difference between the lumbar spine and hip results, the lower score is to be considered clinically relevant. Overweight and obesity may offer only partial protection and should not delay screening in high-risk patients. Further studies are recommended to also include lifestyle and hormonal factors in order to strengthen risk stratification and guide preventive strategies. This paper will help inform local osteoporosis screening and prevention policies, emphasizing early assessment in adults above 50 years of age and ensuring standardized evaluation of both lumbar and hip sites in routine practice

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Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: The data that support the findings of this study, apart from the data already presented in the results section, are available from the corresponding author upon reasonable request.

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