Relationship between Body Mass Index and Bone Mineral Density assessed by Dual-Energy X-ray Absorptiometry Scan: Single Institute based Experience

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ABSTRACT

Background: Osteoporosis is a metabolic skeletal disease characterized by bone mineral density reduction, leading to increased susceptibility to fractures. Although several studies have investigated the association between body mass index (BMI) and bone mineral density (BMD), the results are inconsistent. The aim of this study was to further investigate the relation between BMI and BMD.

Patients and Methods: The retrospective study included 113 patients without any apparent illness referred to have a dual-energy x-ray absorptiometry (DEXA) examination in INMAS, Suhrawardy, in the period from October 2023 to November 2024. The following anthropometric data were collected: body mass index, body weight, height, dual-energy x-ray absorptiometry T-score, and bone mineral density (BMD), as well as some other data.

Results: The mean age was 56.17 years, the mean weight was 59.97 kg, and the mean height was 158.1 cm. There were 70 participants in the group of normal body mass index < 25.0 kg/m2, 34 participants were overweight (BMI 25.0-30.0 kg/m2), and 09 were obese (BMI > 30 kg/m2). In the obese group, 55.56% of participants had osteoporosis, 33.33% had osteopenia, and 11.11% had the normal T-score. In the overweight group, 14.71% of the participants had osteoporosis, 26.47% had osteopenia, and 58.82% had the normal T-score. In the normal body mass index group, 32.86% of the participants had osteoporosis, 34.29% had osteopenia, and 32.86% had the normal T-score.

Conclusion: This study reveals that the prevalence of osteoporosis and osteopenia is higher in obese patients. It is obvious that there was a stronger correlation between body mass index and bone mineral density of the lumbar spine than between body mass index and bone mineral density of the total hip.

Keywords: Body Mass Index, Osteoporosis, Fractures, Bone, Obesity, Bone Density, Dual energy X-ray Absorptiometry.

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INTRODUCTION

Osteoporosis is defined as a progressive, systemic, skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissues with a consequent increase in bone fragility and susceptibility to fracture. Studies have shown that bone loss starts from the age of 30–40 years in both men and women (1). Obesity and osteoporosis are two important and growing public health problems worldwide (2). Numerous diet and lifestyle factors, including body weight, influence BMD, and in turn, fracture risk (3). Bone density is the main measurable determinant of risk of occurrence of a fragility fracture (4). Today, BMD measurements have an important role in the evaluation of patients at risk of osteoporosis and in the appropriate use of antifracture treatment. In general, the preferred method of testing is to use DXA scans of the central skeleton to measure BMD of the lumbar spine and hip (5). The obesity affects practically all age groups in the population; its influence on health is manifested mostly at higher ages as a risk factor of diabetes, cardiovascular diseases, etc. The relation between obesity and the onset of metabolic, endocrine, and cardiovascular diseases is clearly approved (6). Low bone mineral density (BMD) is a major risk factor for osteoporosis and its related fractures (2, 3, 5). Therefore, undoubtedly the load on bones is the key factor for osteogenesis (3). BMD in the total body, hip, and lumbar spine is weakly to moderately correlated to body weight, fat mass, and lean body mass in adolescent, perimenopausal, and elderly women, possibly as the result of stress on the skeleton from the mechanical loading of body w(4). t alone (4). Body weight or BMI has been found to be inversely related to the risk of osteoporosis in most but not all studies. Thus, the role of obesity as a risk factor for low BMD, osteoporosis, and its related fractures remains usettled (2). In contrast, the relation between obesity and osteoporosis is not so unambiguous. For example, there is a question of whether obesity associated with endocrine and metabolic diseases, immobilization, etc., will result in osteoporosis because of these diseases or because of the obesity itself. However, the open question is whether this positive effect of body weight burden is not hindered by concomitant disorders associated with osteoporosis (3). From both a clinical and public health perspective, it is essential to clarify the relationship between BMI, weight, and BMD. Our study addresses this topic by exploring the relationship between BMI, weight, and BMD among apparently healthy patients who were referred for dual-energy X-ray absorptiometry (DXA) scans. We hypothesize that obesity (BMI $\geq$ 30 kg/m²) plays a role in the etiology of low BMD, while overweight (BMI = 25-30 kg/m²) may be linked to higher BMD, although BMD and body weight can vary depending on other factors.

PATIENTS AND METHODS

The retrospective study included 113 patients without any apparent illness who were referred to have a dual-energy x-ray absorptiometry (DEXA) examination at the Institute of Nuclear Medicine and Allied Sciences, Suhrawardy, in the period from October 2023 to November 2024, with a mean (standard deviation (SD)) age of 56.17 (12.46) (range 22–86) years. Patients who reported chronic medical conditions or were using medications affecting bone metabolism or had a family history of osteoporosis were excluded. Informed consent was taken from each of the participants chosen for this study.

Each patient's height and weight were measured in light clothes without shoes. Weight was measured using a calibrated anthropometric scale. Height was measured using a stadiometer attached to the anthropometric scale. We calculated BMI as the ratio of weight (kg) to height squared (m2) by applying the Quetelet equation (5). Participants were categorized in three BMI groups according to World Health Organization (WHO) criteria: normal weight, BMI < 25.0 kg/m^2; overweight, 25-30 kg/m2; and obese, BMIMeasurements> 30 kg/m^2.

Measurements of BMD (g/cm^2) and bone mineral content (BMC) (g) were made using an APELEM 3-D DXA (D7M-40-008 Revision Ø). BMDs of the lumbar vrtebrae (L2–L4) and the hip region (total hip, femoral neck, trochanter, and femoral shaft) were measured according to protocols. The scanner was calibrated daily against the standard calibration block supplied by the manufacturer to control possible baseline drift, and proper positioning of patients was ensured. T-scores and Z-scores were also obtained. The diagnosis of osteoporosis/osteopenia was done according to T-score values: normal if T-score ≥ -1.0; osteopenia if $-2.5 <$ T-score < -1.0; osteoporosis if T-score ≤ -2.5 (2, 5).

Statistical analysis: Categorical variables (BMI groups and osteoporosis/osteopenia presence) are being dealt with; hence, a Chi-Square Test for Independence was appropriate to check if osteoporosis prevalence is significantly associated with BMI categories. Data was entered into Excel and exported to the SPSS software, version 16, for subsequent statistical analysis. Later, logistic regression analysis of the data was done to assess the odds of having osteoporosis in different BMI categories while adjusting for other variables. In logistic regression analysis, the dependent variable was the presence of osteoporosis/osteopenia (1 = Yes, 0 = No), and the independent variable was the BMI group, represented as categorical variables.

RESULT

Number of study subjects were 113 (age, 56.17±12.46 years; range, 22-86 years), who were categorized into 3 groups based on BMI. Study population included 91 females (80.5%) and 22 males (19.5%) with a mean age of 56.36 ± 11.61 years and 55.36±15.60 years respectively.

Anthropometric Characteristics

Anthropometric variables have been described in Table 1, where mean values are listed along with the standard deviations of the individual parameters, except for BMI categories, where the number of BMI cases and the percentages are shown in parentheses. Men were significantly taller, had higher weight, but lower BMI than women. The percentage of obesity (BMI > 30 kg/m2) was significantly higher in women than in men ($P < 0.05$). No significant differences were seen between men and women with respect to age and normal BMI percentage indicating that they were at par with respect to these parameters ($P > 0.05$).

Table 1: Anthropometric and bone parameters in the study participants

Parameters	Male (n=22)	Female (n=91)
Age (years)	55.36 (±15.60)	56.36±11.61
Height (cm)	163.36 (±10.07)	156.82±9.86
Weight (kg)	64.55 (±11.84)	58.87±10.38
BMI categories (%)		
Normal (<25)	59.09	62.63
Overweight (25-30)	40.91	27.47
Obese (>30)	0.00	9.89
Lumbar Spine (L1-L4)		
T-score	-0.36±1.73	-1.48±1.69
BMD (g/cm^2)	0.98±0.18	0.81±0.18
BMC (g)	54.76±14.63	40.53±10.87
BA (cm2)	56.70±7.88	49.65±6.27
Total Hip (left)		
T-score	0.05±0.92	-0.20±1.09
BMD (g/cm^2)	1.02±0.14	0.89±0.14
BMC (g)	35.75±6.54	27.79±4.88
BA (cm2)	35.14±3.21	31.45±3.52
Total Hip (right)		
T-score	-0.10±0.88	-0.37±1.37
BMD (g/cm^2)	0.99±0.13	0.87±0.17
BMC (g)	34.57±5.80	26.14±6.31
BA (cm2)	34.66±2.63	30.06±3.87
	Overall (n=113)	
BMI<25		
BMD (g/cm^2)	0.85±0.17	
T-score	-0.79±1.50	
BMI 25-30		
BMD (g/cm^2)	0.96±0.15	
T-score	-0.03±1.25	
BMI>30		
BMD (g/cm^2)	0.83±0.18	
T-score	-0.96±1.59	

All values are mean±SD except BMI categories (%). All values are found in 95% CI.
SD: Standard deviation, BMC: Bone mineral content, BA: Bone area,
BMD: Bone mineral density, BMI: Body mass index.

The data also showed lower values of densitometric parameters like T-scores, BMD, BMC, and BA of the right hip when compared to the left hip, which points to the majority of righty persons in this demography, both in the case of men and women. When the data of the lumbar region is compared to the hip region, the densitometric parameters like T-score and BMD have been observed to be lower for the spinal region compared to the total hip region, which may suggest the dominance of bone density loss in the spinal regions over the hip region.

Prevalence of Osteoporosis & Osteopenia in different BMI groups

Results from the DXA machine show that, according to the WHO definition based on T-score, the overall prevalence of osteoporosis was 32.86% in the normal weight group (BMI < 25 kg/m²), 14.71% in the overweight group (BMI 25-30 kg/m²), and 55.56% in the obese group (BMI > 30 kg/m²). The overall prevalence of osteopenia was 34.29% in normal, 26.47% in overweight, and 33.33% in the obese group. Normal T-scores were observed for 32.86% normal, 58.82% overweight, and 11.11% obese patients. The distribution of osteoporosis, osteopenia, and normal cases is shown in Table 2. If the number of osteoporosis and osteopenia patients is considered together against the normal findings, a significant difference in observations is seen, which are represented in the Figure 1. In the bar diagram, there is a significant decrease of osteoporosis/osteopenia cases (41.18%) in the oveweight group (BMI 25-30 kg/m²), which enforces the conventional assumption about lowered risk of osteoporosis in comparatively healthier people. On the other hand, when the BMI went into the obese range, there was a spike of osteoporosis and osteopenia cases, which resulted in an aggregate value of 88.89% compared to normal findings (11.11%). As the sample size of the obese group was comparatively smaller than the other groups, a statistical significance test was carried out using the chi-squared analysis according to diagnosis groups and one-way analysis of variance (ANOVA) of BMD and T-score with BMI groups.

Table 2: Pattern of osteoporosis, osteopenia & normal cases according to BMI groups

BMI Group	Normal	Osteopenia	Osteoporosis	Percentage
BMI <25 kg/m²	32.86%	34.29%	32.86%	100 %
BMI 25-30 kg/m²	58.82%	26.47%	14.71%	100 %
BMI >30 kg/m²)	11.11%	33.33%	55.56%	100 %
Total	**38.94%**	**31.86%**	**29.20%**	**100 %**

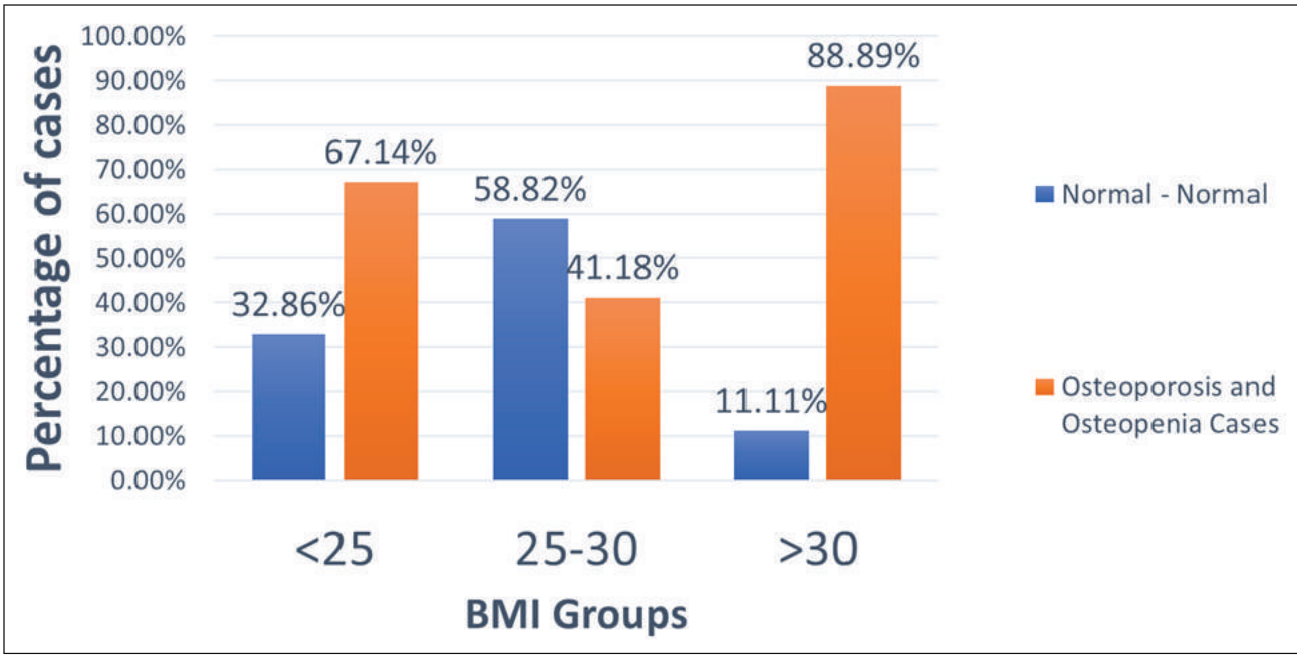

Figure 1: Distribution of osteoporosis and osteopenia cases against normal according to BMI groups.

The Chi-Square Test for Independence was done to check if osteoporosis prevalence is significantly associated with BMI categories, and later logistic regression analysis was done. The chi-square statistic (χ^2) was 9.67 with 2 degrees of freedom (df), and the p-value was 0.00793, which is less than 0.05 (95% confidence interval), so the null hypothesis was rejected. This means there is a significant association between BMI groups and the presence of osteoporosis. The observed values for BMI > 30 kg/m² show a higher proportion of osteoporosis cases than expected, supporting the claim that individuals with BMI > 30 kg/m² have a higher prevalence of osteoporosis.

A one-way analysis of variance (ANOVA) demonstrated statistically significant differences in BMD ($P = 0.000002$) and T-score ($P = 0.00009$) among BMI groups. However, post hoc pairwise t-tests comparing the BMI > 30 cohort to the combined BMI < 25 kg/m²) and 25-30 kg/m²) cohorts did not yield statistically significant differences for BMD ($p = 0.0976$) or T-score ($p = 0.2031$) at the conventional 95% confidence level. These findings indicate substantial variation of BMD and T-scores with BMI, but statistical significance was not achieved in pairwise comparisons. Although pairwise comparisons did not show statistical significance, lower T-scores in people with a BMI > 30 kg/m² may suggest potential predisposition towards osteopenia and, in some cases, osteoporosis.

Prevalence of Osteoporosis and Osteopenia in Spinal and Hip Regions

Analysis of the prevalence of osteoporosis and osteopenia cases in different regions of the body revealed a majority of osteoporosis and osteopenia cases in the spinal region compared to the hip region. Osteoporosis cases were dominated by the spinal regions, resulting in 73.68% and 100% of cases for females and males, respectively. In the case of osteopenia data, the spinal region covered 41.43% of cases in females and 46.15% of cases in males. When the left and right hip regions were compared, dominance of right femur observations was observed in males (7.69% more in the right hip) than females (-1.43% in the right hip). This may suggest an influence of lefty and righty characteristics in males that is different from that in females.

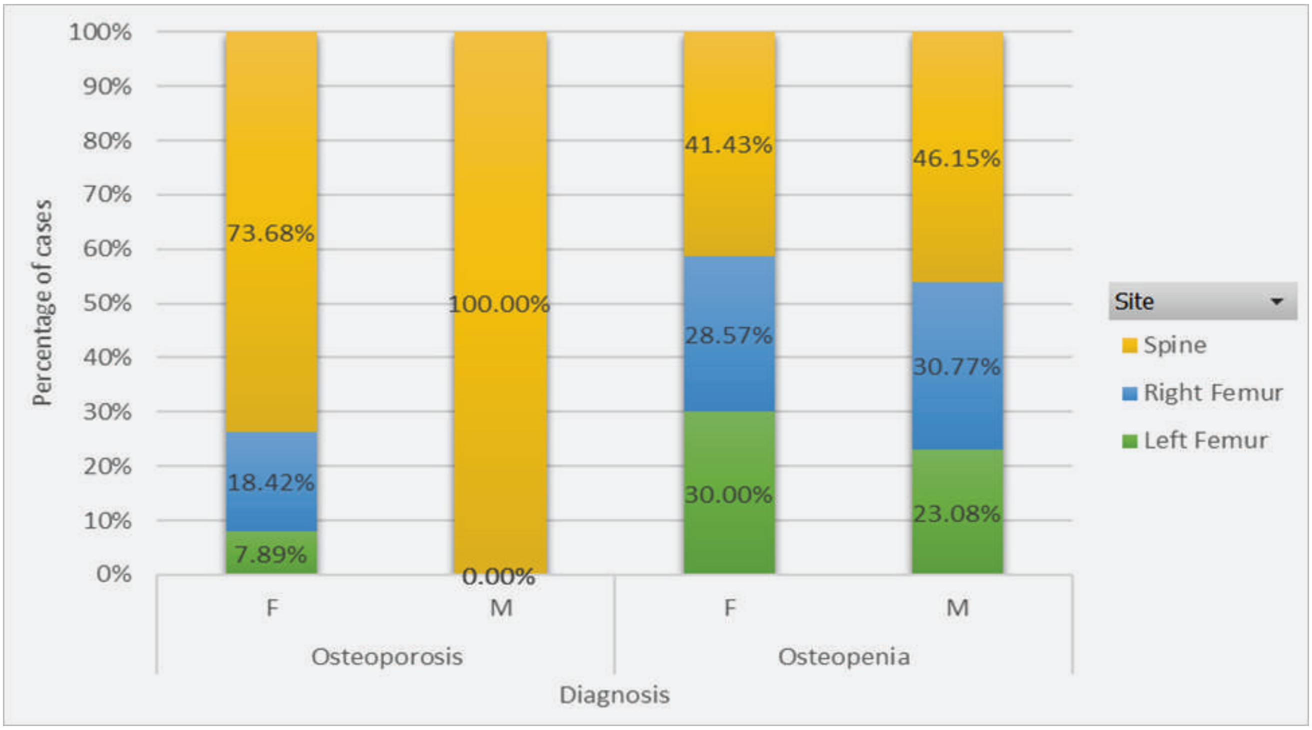

Figure 2: Prevalence of sites in osteoporosis and osteopenia cases

The number of spinal BMD scans that resulted in osteoporosis (27.43%) and osteopenia (30.97%) was higher than that in the hip region, where osteoporosis cases were 2.65% and 6.19% and osteopenia cases were 21.24% in both the left and right hips, according to a site-specific analysis shown in Figure 3.

Based on the aforementioned data, it may be concluded that the spinal region is more susceptible to osteoporosis and osteopenia than the hip regions.

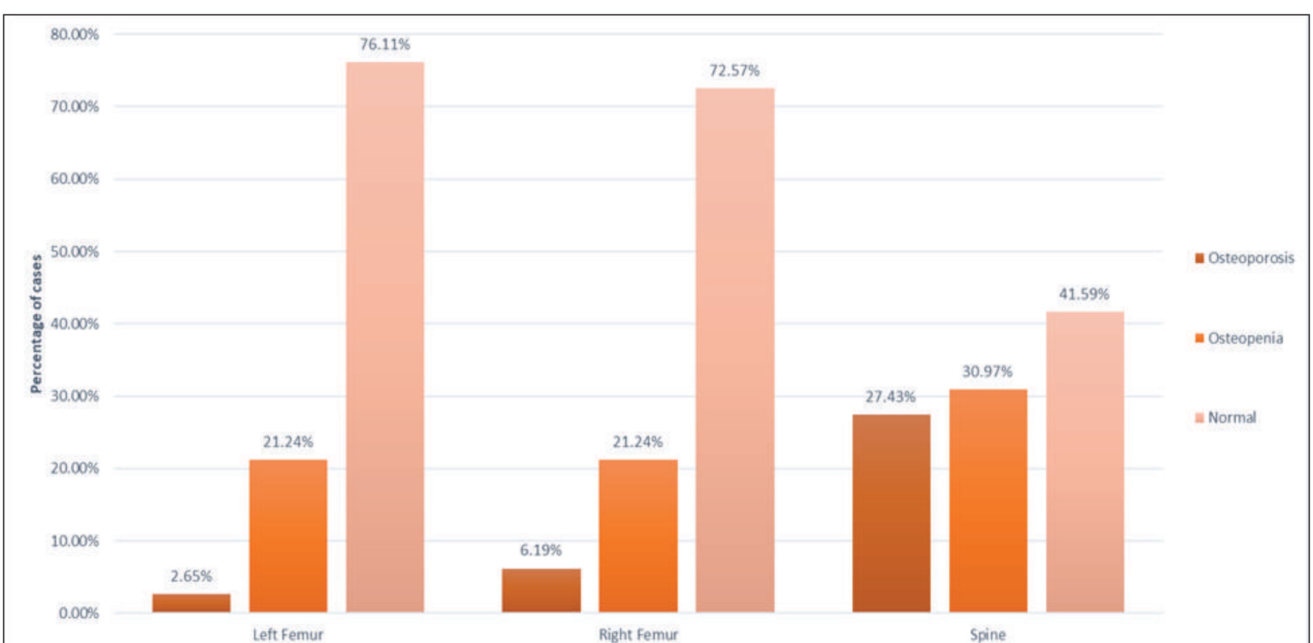

Figure 3: Comparison of the three sites (left femur, right femur, spine) and the pattern of bony changes in Dexa study.

DISCUSSION

This study examined the relationship between body mass index (BMI) and bone mineral density (BMD) and T-score, with an emphasis on whether individuals classified as obese ($BMI \geq 30$) exhibit significantly lower values in these parameters. The dataset was stratified into three BMI categories (<25 kg/m², 25-30 kg/m², and >30 kg/m²), and rigorous statistical analyses were performed to evaluate the significance of the observed differences.

The mean BMD values for the three BMI groups were as follows: BMI < 25 kg/m² (0.856), BMI 25-30 kg/m² (0.954), and BMI > 30 kg/m² (0.827). Correspondingly, the mean T-scores were -0.772, -0.047, and -0.956, respectively. These findings suggest that individuals with a BMI in the 25-30 kg/m² range demonstrate the highest BMD and T-score. These are consistent with most previous studies, which indicated low BMI and weight associated with lower BMD (2, 3, 4, 5), whereas those classified as obese (BMI > 30 kg/m²) exhibit a decline in both parameters.

A one-way ANOVA revealed statistically significant differences in BMD ($p = 1.96e\text{-}06$) and T-score ($p = 8.94e\text{-}05$) across the BMI categories. However, subsequent pairwise t-tests comparing the $BMI \geq 30$ group to the combined BMI < 25 kg/m² and 25-30 kg/m² groups failed to yield statistical significance for BMD ($p = 0.0976$) or T-score ($p = 0.2031$) at the conventional $\alpha = 0.05$ threshold. These results indicate that while BMD and T-score demonstrate significant variability across BMI classifications, the specific impact of obesity is not independently significant within this sample.

These findings align with existing literature that highlights the intricate relationship between BMI and bone health. While increased BMI has historically been associated with greater mechanical loading and, consequently, higher BMD, excessive adiposity may exert deleterious effects on bone metabolism via inflammatory cytokines and alterations in hormonal regulation (5, 7). Despite a lower prevalence of osteoporosis in obesity found in this study, it is important to note that not all types of fat are beneficial for bone mass. Subcutaneous and visceral fat have opposite effects on the bone structure. Visceral fat promotes systemic inflammation, which can lead to bone loss, besides having an association with increased levels of proinflammatory cytokines such as TNF and IL-6, which increase bone resorption and promote osteoporosis. Hypercortisolism, which is associated with lower levels of bone mass, also displays an association with visceral fat accumulation (5). The observed peak in BMD within the 25-30 kg/m² BMI range suggests that moderate overweight status may exert a protective effect on bone health, whereas obesity does not provide the same advantage.

There was a higher prevalence of osteoporosis and osteopenia in females compared to males at all bone sites. Osteoporosis was present in 29.2% of subjects (female, 26.55%; male, 2.65%) and osteopenia in 31.86% of subjects (female, 25.66%; male, 6.19%). These findings are in concurrence with another study reporting prevalence rates in urban communities from India. That study yielded a similar prevalence of 12.85% in females and 3.7% in males for osteoporosis and 41.4% in females and 33.33% in males for osteopenia, respectively (7).

A high prevalence of osteoporosis and osteopenia in both men and women at the LS than hip was observed in this study. Another study with Indian healthy adults above 40 years reported a prevalence of osteoporosis of 18% at LS and 12.7% at the hip in women and a prevalence of osteoporosis of 14.5% at LS and 4.7% at the hip in males (1).

BMD was found to be normal at the right hip (total) in 82 (72.57%) among the study subjects, while 24 (21.24%) subjects had osteopenia, and 07 (6.19%) subjects had osteoporosis. Agarwal et al. from India studied 200 healthy Indian males from the community and reported that BMD was normal at the right hip (total) in 104 (52%) study subjects, while 82 (41%) subjects had osteopenia, and 14 (7.0%) subjects had osteoporosis (6). In Asian populations, particularly those of South and Southeast Asian descent, tend to have a lower BMD compared to Caucasians. For example, total mean BMD in the spine is 0.81 ± 0.18, and in the hip, it is 0.88 ± 0.17. Araujo et al. provide data on the complex associations between age, race/ethnicity, and BMD, where total BMD is higher in other races like Hispanic (1.03 ± 0.013 in spine and 1.04 ± 0.013 in total hip), Black ($1.11 \pm$

0.01 in spine and 1.09 ± 0.009 in total hip), and Caucasians (1.02 ± 0.008 in spine and 0.99 ± 0.009 in total hip).

CONCLUSION

According to the study, bone mineral density (BMD) in the hip and spinal areas is correlated with weight and BMI. While overweight people may have higher BMD, which could reduce the risk, obese patients are more likely to have osteoporosis and osteopenia. The most prevalent place is the spine, and the effect is greater in females.

LIMITATIONS

The study's evaluation is hindered by insufficient data on factors like sunlight exposure, dietary habits, and socio-demographics. Future research should include a wider range of variables and use longitudinal techniques to better understand the long-term effects of obesity on bone health.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

REFERENCES

1. Kadam NS, Chiplonkar SA, Khadilkar AV, Khadilkar VV. Prevalence of osteoporosis in apparently healthy adults above 40 years of age in Pune City, India. Indian journal of endocrinology and metabolism. 2018 Jan 1;22(1):67-73.
2. Salamat MR, Salamat AH, Abedi I, Janghorbani M. Relationship between weight, body mass index, and bone mineral density in men referred for dual-energy X-ray absorptiometry scan in Isfahan, Iran. Journal of osteoporosis. 2013;2013(1):205963.
3. Wardlaw GM. Putting body weight and osteoporosis into perspective. The American journal of clinical nutrition. 1996 Mar 1;63(3):433S-6S.
4. Mazocco L, Chagas P. Association between body mass index and osteoporosis in women from northwestern Rio Grande do Sul. Revista brasileira de reumatologia. 2017;57(4):299-305.
5. Blake, G.M. and Fogelman, I., 2007. The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. Postgraduate medical journal, 83(982), pp.509-517.
6. Frčová B, Kožehubová L, Snitková M, Dluholucký S. Relationship between Body Weight, BMI and Bone Mineral Density in Patients from the Point of View of the Nurse Working in a Densitometric Clinic. Int J Nurs Health Care Res. 2022; 5:1336.
7. Kaushal N, Vohora D, Jalali RK, Jha S. Prevalence of osteoporosis and osteopenia in an apparently healthy Indian population-a cross-sectional retrospective study. Osteoporosis and sarcopenia. 2018 Jun 1;4(2):53-60.
8. Araujo AB, Travison TG, Harris SS, Holick MF, Turner AK, McKinlay JB. Race/ethnic differences in bone mineral density in men. Osteoporosis International. 2007 Jul; 18:943-53.
9. Agrawal NK, Sharma B. Prevalence of osteoporosis in otherwise healthy Indian males aged 50 years and above. Archives of osteoporosis. 2013 Dec; 8:1-7.