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Relationship Between Bone Mass Density and Nutritional Status of Women Diagnosed with Type 2 Diabetes Mellitus in Charsadda

Aneesa Zeb[1] and Iftikhar Alam[1*]

[1]Department of Human Nutrition and Dietetics, Bacha Khan University, Charsadda, Pakistan

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***Corresponding Author:**
Iftikhar Alam
Department of Human Nutrition and Dietetics, Bacha Khan University, Charsadda, Pakistan
iftikharalam@bkuc.edu.pk

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ABSTRACT

The prevalence of low bone density among women is common but remains under-documented. **Objectives:** To assess bone mass density (BMD) levels and their relationship with nutritional status in type 2 diabetes mellitus (T2DM) women visiting the NEAT Clinic in Charsadda, Khyber Pakhtunkhwa (KPK). **Methods:** Using an observational, cross-sectional design, data were collected from 408 women through a structured self-reported questionnaire covering osteoporosis risk factors, sociodemographic information, anthropometrics, general health, BMD, and dietary intake. BMD was measured via Quantitative Ultrasound Scan (QUS) at the calcaneus using the Sahara clinical bone sonometer. Initially, 605 women expressed interest, but data were collected for 450 participants due to drop-out and incomplete questionnaires. **Results:** The mean T-score was –1.76 ± 0.81 (median: –1.72), ranging from –3.5 to 1.4. Women classified as normal, osteopenic, and osteoporotic had mean T-scores of –0.42 ± 0.43, –1.66 ± 0.34, and –2.66 ± 0.25, respectively. The prevalence of osteopenia was 59.8% and that of osteoporosis was 22.2%, while only 18% had normal BMD. QUS scores showed significant correlations ($p<0.05$) with age, menopausal duration, BMI, waist-hip ratio (WHR), and education level. Nutritional factors such as energy, protein, calcium, and phosphorus intake were also positively associated with QUS scores. **Conclusions:** The study reveals a high prevalence of osteopenia and osteoporosis among women in this population, with bone health strongly linked to both demographic and dietary factors.

INTRODUCTION

Bone is a very active tissue that remodels continuously throughout life. It also serves as a storehouse of calcium (Ca), magnesium (Mg), phosphorus (P), and other elements that are required for homeostasis [1]. Optimal bone health can be achieved with a balanced diet and adequate dietary energy [2]. These include essential nutrients such as Ca, P, protein [4], potassium (K), vitamins A and K [3], fluorine, zinc, copper, and boron [4, 5]. Though adolescence is a key time for reaching optimal peak bone mass, scientific inquiry into the determinants of bone remodeling over this window of development is fairly underdeveloped. Of the many environmental determinants, nutritional status is especially crucial for ensuring healthy bone growth and mineralization. Sufficient calcium, vitamin D, protein, and other micronutrient intake is necessary to maintain the high rate of skeletal growth that characterizes this stage of life [6]. Yet, a recent and shocking finding from adolescent health surveys has been the following: around 25% of adolescents fall into the underweight category, with the other 75% sitting at the edge of normal body weight. This low-weight prevalence across most of the population is troubling in terms of potential suboptimal bone accrual since less body mass has been linked to impaired BMD and delayed skeletal maturation [7]. Although it is generally agreed across the literature that body weight and bone health are positively associated, less is known in terms of

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the effect of thinness or undernutrition on adolescent bone outcomes. Few empirical studies have explicitly tested this association, so more intensive research efforts are warranted to clarify the late-emerging implications of thinness in adolescents for osteoporosis risk and susceptibility to fracture. The specific objectives were to determine BMD levels in female of different age groups and to determine the relationship between BMD and nutritional status.

This study aims to determine the relationship between nutritional status and BMD of women who have been diagnosed with type 2 diabetes mellitus (T2DM) in Charsadda.

METHODS

The cross-sectional observational study was carried out in Charsadda in collaboration with NEAT Clinics at Charsadda between 2021 and 2022. The ethical approval was taken from the institute with reference no: 1835. Convenient sampling was used to enroll women aged 18 years and above who were literate and did not have speech or hearing impairment. Calculating using Cochran's formula at a 99% level of confidence and 5% precision, the sample size worked out to 408, with a malnutrition prevalence of about14.9% as indicated in the National Nutrition Survey Pakistan, 2018. To prepare for possible dropouts, the sample was boosted by 10%, targeting 450 participants. Information was gathered using standardized questionnaires on age, socioeconomic status (urban or rural), education, income, occupation, and history of bone fractures and osteoporosis in the family. The main anthropometrics (body weight, height, waist, and hip circumferences) were taken as previously reported [8]. Body Mass Index (BMI) was calculated (weight (kg) divided by the square of height (m^2). Waist-to-hip ratio was computed simply by dividing the waist circumference by the hip circumference. Dietary consumption data were obtained via the 24-hour dietary recall method and the Food Frequency Questionnaire (FFQ). Face-to-face interviews were conducted, and data were recorded in the questionnaires [8]. Nutrient consumption was estimated utilizing the Pakistan Dietary Composition Tables. Quantitative Ultrasound Scanning (QUS) at the right calcaneus was employed. Speed of Sound (SOS), Broadband Ultrasound Attenuation (BUA), Stiffness Index (SI), and estimated BMD (eBMD) were determined. WHO criteria were used to categorize participants as normal, osteopenic, or osteoporotic based on T-scores [9]. The ethical committee of Bacha Khan University approved the research. The informed consent of all respondents was taken, maintaining the confidentiality of individual data.

RESULTS

A total of 450 women participated in this study. Initially, 605 women expressed interest in participating. Of these, 90 did not fulfil the inclusion criteria. Out of the remaining 515, data could be completed for 450 women due to drop-out and incomplete questionnaires. This number was greater than the required sample size (408) and was considered for analysis in order to achieve more statistical power. The mean T-score was −1.76 ± 0.81 (median: −1.72) (range: −3.5 to 1.4). Normal BMD women had a mean T-score of −0.42 ± 0.43, followed by osteopenic women (mean T-score, −1.66 ± 0.34) and osteoporotic women (mean T-score, −2.66 ± 0.25). There was a high percentage of osteopenic (59.8%) and osteoporotic women (22.2%). Only 18% had normal BMD. Table 1 displays the osteoporotic and sociodemographic conditions. QUS-score (normal BMD, osteopenia, and osteoporosis) was significantly correlated with some independent variables (age, anthropometric indicators, e.g. BMI and WHR), and educational level ($p<0.05$) (Table 1).

Table 1: Characteristics of Subjects (n=450)

Variables	Total Sample (Mean ±SD) or n (%)	QUS Score, n (%)			p-Value
		Normal BMD	Low BMD		
		Normal	Osteopenia	Osteoporosis	
		81 (18.0%)	269 (59.8%)	100 (22.2%)	
Age (Years)	50.7 ± 8.23	46.7 ± 8.61	51.7 ± 10.6	54.2 ± 12.62	0.040^{a*}
Menopausal Age (Years)	44.1 ± 1.83	45.6 ± 2.21	48.9 ± 5.72	48.3 ± 1.98	0.015^{b*}
Menopausal Duration (Years)	6.8 ± 7.81	1.0 ± 2.45	6.79 ± 8.71	9.9 ± 5.56	0.002^{b*}
BMI, kg/m^2	24.9 ± 4.41	23.4 ± 4.89	25.6 ± 3.26	25.9 ± 5.9	0.000^{b*}
Waist to Hip Ratio	0.9 ± 0.07	0.9 ± 0.11	0.9 ± 0.16	0.9 ± 0.11	0.003^{a*}
Educational levels					
No Formal Education	312 (69.3%)	80 (30.7%)	110 (35.3%)	122 (39.1%)	0.013c*
Formal Education	138 (30.7%)	40 (28.9%)	70 (50.7%)	28 (20.3%)	
Monthly Income					
>5000 PKR	119 (26.4%)	39 (32.8%)	60 (50.4%)	20 (16.8%)	0.002^{c}
< 5000 PKR	331 (73.6%)	81 (24.5%)	120 (36.3%)	130 (39.2%)	

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Menopausal Status					
Postmenopausal	210 (46.7%)	30 (14.3%)	76 (36.2%)	104 (49.5%)	0.502 c
Premenopausal	240 (53.3%)	90 (37.5%)	70 (32.0%)	80 (33.5%)	
Employment Status					
Not Working	360 (80.0%)	90 (25.0%)	140 (38.9%)	130 (36.1%)	0.003 c
Working	90 (20.0%)	30 (33.3%)	40 (44.4%)	20 (22.2%)	
Living Place					
Urban	280 (62.3%)	35 (12.5%)	125 (44.6%)	120 (42.9%)	0.004 c
Rural	170 (37.7%)	85 (50.0%)	55 (32.4%)	30 (17.6%)	
Family History of Osteoporosis					
Yes	232 (51.6%)	55 (23.7%)	82 (34.5%)	95 (40.8%)	0.462 c
No	218 (48.4%)	65 (29.8%)	98 (45.0%)	55 (25.2%)	
Family History of Fracture					
Yes	223 (49.6%)	56 (25.1%)	83 (37.2%)	84 (37.7%)	0.208 c
No	217 (48.2%)	64 (29.5%)	97 (44.7%)	56 (25.8%)	
Weight Status					
Overweight	300 (66.4%)	20 (6.7%)	138 (46.0%)	142 (47.3%)	0.003 c
Normal Weight	160 (35.6%)	100 (62.5%)	42 (26.3%)	18 (11.3%)	

Continuous data are presented as mean, followed by Mean ± standard deviation (Mean ± SD). The p-values were derived from one-way ANOVA (for continuous variables normally distributed); b Continuous data are presented as mean ±standard deviation (M±SD). The p-values were derived from the Kruskal-Wallis test (for continuous variables not normally distributed); Categorical variables, expressed as frequency (percentage, %) of sample and p-values were derived from the Chi-square test; BMD, bone mineral density; LBMD, low bone mineral density; PKR, Pakistani Rupees; QUS, quantitative ultrasound; *p<0.05.

Findings compare the mean daily intake of various nutrients (± standard deviation) across three bone health categories: Normal BMD, Osteopenia, and Osteoporosis and show statistically significant differences for nearly all variables (Table 2).

Table 2: Nutrient Intake and Bone Health Status with Nutrition-Related Data

Parameters	Normal	Osteopenia	Osteopenia	p-Values
Energy Intake (Kcal/dy)	2851 (144.3%)	2448 (714.6%)	2609 (827.2%)	<0.001*
Proteins ((g)	90.8 (64.4%)	60.5(27.9%)	75.6 (51.7%)	<0.001*
Proteins (Animal) (g)	67.9 (42.4%)	40.2 (23.8%)	54.0 (45.1%)	<0.001*
Proteins (Vegetable) (g)	21.9 (41.5%)	19.7 (9.3%)	20.7 (15.6%)	<0.001*
Total Fat (g)	101.6 (60.4%)	74.8 (42.5%)	87.5 (55.5%)	<0.001*
Saturated Fats (g)	45.4 (27.3%)	41.41 (23.6%)	8.5 (26.7%)	<0.001*
Polyunsaturated Fatty Acids (g)	20.9 (14.1%)	16.9 (9.1%)	18.8 (12.5%)	<0.001*
Monounsaturated Fatty Acids (g)	44.5 (26.5%)	26.5 (19.1%)	40.5 (23.2%)	<0.001*
Carbohydrates (g)	180 (21.6%)	152 (80.2%)	166 (165.8%)	<0.001*
Vegetable Fibers (g)	26.7 (23.2%)	14.3 (12.5%)	20.6 (19.5%)	<0.001*
Vitamin C (mg)	141.5 (121.2%)	118.5 (102.0%)	124.7 (101.8%)	<0.001*
Vitamin D (µg)	9.9 (5.2)	6.4 (7.5%)	7.78 (6.8%)	<0.001*
Phosphorus (mg)	1012.3 (425.3%)	1142.3 (340.5%)	1071.3 (221.2%)	<0.001*
Calcium (mg)	964.9 (516.3%)	918.8 (211.0%)	942.8 (222.7%)	0.366
Potassium (mg)	6442 (3241.4%)	4433 (1562.0%)	5243 (1482%)	<0.001*
Magnesium (mg)	534 (235%)	441 (156.2%)	451 (189.7%)	<0.001*
Zinc (mg)	17.8 (9.0%)	14.2 (5.2%)	14.8 (7.3%)	<0.001*

In addition, the intake of different nutrients as % of RDA for these nutrients differed among the three groups. The intake of nutrients as % of RDA was ≥RDA for the majority of nutrients except vitamin D, Calcium and phosphorus (Figure 1).

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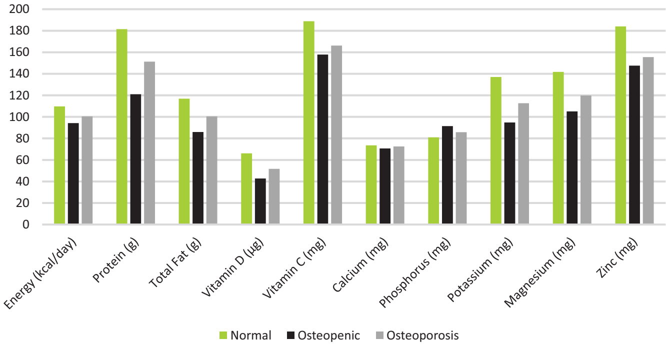

Figure 1: Intake of Nutrients as % of RDA

DISCUSSION

The current research evaluated bone mineral density (BMD) in a group of 450 women through the use of Quantitative Ultrasound (QUS) technology, generating significant information regarding the prevalence and severity of osteopenia and osteoporosis among them. The average T-score of the overall sample (-1.76 ± 0.81) suggests that the typical respondent lies within the osteopenic range, revealing an alarming trend of at-risk bone health in a significant percentage of the study sample. The grouping of mean T-scores also corroborates this observation, with osteopenic and osteoporotic subjects having much lower mean values (-1.66 ± 0.34 and -2.66 ± 0.25, respectively) than subjects with normal BMD (-0.42 ± 0.43). The application of QUS provides depth to the analysis. Mean values for BUA (48.9 ± 8.13 dB/MHz), SOS (1514.3 ± 7.14 m/s), SI (67.09 ± 15.40), and eBMD (0.41 ± 0.07 g/cm^2) reflect a range of bone health, the lower values of which in these parameters are usually related to weakened bone strength and fracture risk [10, 11]. The fact that QUS can measure both structural and elastic properties of bone qualifies it as a highly valuable, radiation-free substitute for DXA in community practice, particularly where DXA facilities are scarce. Dual-energy X-ray absorptiometry (DXA) has been deemed the gold standard in measuring bone mineral density (BMD) because of its accuracy and reproducibility. For this particular study, quantitative ultrasound (QUS) was chosen over DXA for several practical and ethical reasons. First, QUS is a radiation-free method, which makes it more suitable for adolescent or repeat-assessment populations. This is with ethical considerations for limiting radiation exposure, particularly among younger subjects. Second, QUS is non-invasive, portable, and affordable, making it suitable to be employed in field or community-based studies where access to sophisticated imaging equipment such as DXA is not available. The logistical convenience of QUS proved vital for this study involving semi-rural dwellers. Thirdly, while QUS is not a direct measurement of BMD like DXA, it gives clinically useful information pertaining to bone quality (e.g., stiffness index, speed of sound), which has predictive value for fracture risk as well. Various studies have established QUS as a valid screening tool for evaluating bone health, especially in population-based epidemiological research. The present research found a high prevalence of osteopenia (59.8%) and osteoporosis (22.2%) among the participants, with only 18% exhibiting normal BMD. These results concur with various population-based research studies showing an increasing low bone mass prevalence among females, especially menopausal women, as a result of hormonal alterations, inadequate calcium and vitamin D nutrition, and physical inactivity [12, 13]. The high percentage of women with suboptimal BMD in this study indicates that a high proportion of the population is at higher risk for fragility fractures, especially hip and vertebral fractures, that may cause considerable morbidity, mortality, and economic strain [14]. The current results underscore important nutritional distinctions among women with normal BMD and osteopenia or osteoporosis. In particular, women with normal BMD had greater energy and protein intake, specifically from animal sources, indicating that sufficient caloric and protein intake might prevent bone loss [15]. Protein not only contributes to the formation of bone matrix but also increases the absorption of calcium and the production of insulin-like growth factor 1 (IGF-1), both essential for bone formation [16]. The greater consumption of unsaturated fats, particularly monounsaturated and polyunsaturated fatty acids, by the normal BMD group is consistent with research that states they have an anti-inflammatory function in preventing bone resorption [17]. In addition, higher intakes of dietary fiber, vitamin D, vitamin C, magnesium, potassium, and zinc were positively linked with normal BMD status. These micronutrients are implicated in bone metabolism by providing cofactors and nutrients for collagen synthesis, osteoblast function, and mineralization [18, 19]. Even though the values in Table 2 suggest that calcium intake among the osteopenic and osteoporotic groups did not differ significantly, it is of interest that both groups had mean intakes that were below the RDA, specifically 91.88% for the osteopenic group and 94.27% for the osteoporotic group. This minimal inadequacy could perhaps remain of clinical importance, considering the cumulative impact of prolonged suboptimal calcium consumption on bone turnover. Notably, calcium's function to preserve bone mineral density is not singular. Its efficacy is affected by the availability and sufficiency of cofactors like vitamin D, magnesium, and phosphorus, which help assimilate and utilize calcium. In our population, although levels of calcium intake were generally similar, significant differences were seen in magnesium and vitamin D intakes, both of which were greater in the osteoporotic group,

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perhaps as a compensatory dietary response following diagnosis or through supplementation. This could partly account for why calcium on its own did not exhibit a distinguishing influence between groups. Thus, these results highlight the intricacy of nutrient interactions in bone metabolism and indicate that correcting calcium intake without securing the sufficiency of its synergistic nutrients would confine its protective action against bone loss [20]. Accordingly, our findings support the multifactorial etiology of dietary impact on bone, highlighting the value placed upon a well-balanced, nutrient-rich diet in osteoporosis prevention in women. As shown in Table 1, notable correlations were found between QUS scores and a number of demographic and anthropometric variables such as age, menopausal years, BMI, WHR, and educational level. These parameters can be potential confounders in the interaction between diet and BMD. For example, age and menopause duration are directly related to hormonal alterations, i.e., decreased levels of estrogen, which stimulate bone resorption and contribute to osteoporosis risk regardless of dietary consumption. In the same way, BMI and WHR can represent body composition and fat patterning, respectively, both of which can impact bone loading and estrogen synthesis from fat tissue, thereby altering outcomes for bone health. Increased BMI tends to be linked with increased bone density from mechanical loading, whereas central body fat (as indicated by WHR) has been shown to impair bone quality via inflammatory mechanisms. In addition, education level, as it relates to health literacy and socioeconomics, can shape food choices, consumption of nutrient-dense foods, and participation in bone-protective activities. Each of these factors can independently impact both patterns of nutritional intake and outcomes in bone health. Hence, in interpreting the relationships between diet and BMD, it should be noted that these demographic and anthropometric factors can confound or mediate the reported associations. Future studies utilizing multivariate modeling or stratified analyses are advised to adjust for these confounding influences and further remove the independent effect of diet on bone. This research demonstrates that low bone status in Charsadda women is associated with inadequate consumption of these important nutrients, such as vitamin D, protein, magnesium, and potassium, although calcium intake was similar between groups. Strong correlations with age, menopausal status, BMI, and WHR indicate that both nutritional and non-nutritional variables are related to bone status. To correct these, there is a requirement for specific public health interventions such as dietary education programs in the community, promotion of dietary intakes rich in nutrients, and exercise. Local dietary fortification and supplementation programs should be investigated as well. Future studies must test such interventions as well as investigate more general determinants influencing bone health among this population. Malnutrition is common in this part of the world [21-24], which needs appropriate strategic actions on local and national levels.

CONCLUSIONS

It was concluded that poor bone health among women in Charsadda is linked to suboptimal intake of key nutrients like vitamin D, protein, magnesium, and potassium, despite comparable calcium intake across groups. Significant associations with age, menopausal duration, BMI, and WHR suggest that both nutritional and non-nutritional factors influence bone status.

Authors Contribution

Conceptualization: AZ
Methodology: AZ, IA
Formal analysis: AZ, IA
Writing review and editing: AZ, IA

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

All the authors declare no conflict of interest.

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