Original Article

Assessing Bone Mineral Density Among Female Medical Students Of Pakistan: Unveiling The Impact Of Lifestyle Factors On Skeletal Health- An Analytical Cross-Sectional Study

Afifa Kulsoom[1], Mehreen Noor[2], Eeman Naeem[3], Khola Noreen[4], Muhammad Umar Mansoor[5], Tahir Mahmood[6]

Abstract

Objective: To assess the frequency of low bone mineral density (BMD) and its association with lifestyle factors among female medical students in Pakistan.

Methods: A cross-sectional study was conducted at Rawalpindi Medical University between January and June 2025.. A total of 184 undergraduate female medical students were included using non-probability consecutive sampling. BMD was assessed using Quantitative Ultrasound (QUS) of the calcaneus, with T-scores recorded for each participant. Data on demographic details and lifestyle factors, including physical activity, dietary intake, BMI, and screentime, were collected through a structured questionnaire. Statistical analysis was performed using SPSS 26.0. Pearson correlation and chi-square tests were applied, with p-values less than 0.05 considered statistically significant.

Results: Among 184 female participants, the mean age was 22.00 ± 1.056 years. QUS revealed that only 36 students (19.6%) had normal bone mineral status, 134 (72.8%) had osteopenia, and 14 (7.6%) had osteoporosis. A significant positive correlation was observed between BMI and T-score ($r = 0.347$, p value of 0.000). Bone status was significantly associated with year of study ($p = 0.002$), physical activity (p 0.000), carbonated drink intake ($p = 0.009$), overeating ($p = 0.005$), and coffee consumption ($p = 0.038$).

Conclusion: Most young female medical students had low BMD, with modifiable lifestyle factors contributing significantly, highlighting the need for early screening and preventive strategies targeting bone health in this vulnerable population.

Keywords: Bone Density, Osteoporosis, Lifestyle, Students, Medical.

Introduction

Bone Mineral Density (BMD) is a critical indicator of skeletal health across all age groups—adolescents, adults, and the elderly—and serves as a reliable predictor for the development of osteopenia and osteoporosis.[1] Globally, low BMD has emerged as a significant public health concern, with approximately 75 million individuals identified as osteoporotic by 2017.[2] Alarmingly, this number continues to rise and is projected to make osteoporosis the leading cause of fractures by 2050.[3] In Asian countries such as Vietnam and Indonesia, nearly 50% of women are at risk of developing osteoporosis by the age of 70.[4] According to recent data from Pakistan (2024), 36.55% of the population is affected by osteoporosis, while 58.63% exhibit osteopenia.[1]

Environmental and lifestyle factors play a pivotal role in influencing BMD. These include physical activity, nutritional intake, smoking, low calcium consumption, frequent intake of carbonated beverages, and a low body mass index (BMI).[5-6] Osteoporosis is characterized by reduced bone mass and density, which increases the risk of fragility fractures. The gold standard for evaluating BMD is Dual-Energy X-ray Absorptiometry (DXA), which measures T-scores at the proximal femur and spine.[1] The World Health Organization (WHO) defines a T-score of $\geq$ -1 as normal, between -1 and -2.5 as osteopenia, and $\leq$ -2.5 as osteoporosis.[7,8]

Despite its accuracy, DXA is limited by high costs, limited availability, and exposure to ionizing radiation, making it impractical for population-wide screening.[1] As a result, Quantitative Ultrasound (QUS) of the calcaneus has emerged as a cost-effective, portable, non-invasive, radiation-free alternative for assessing BMD.[9] Studies have shown that QUS indices of the calcaneus can effectively detect fracture risks in both men and women and serve as meaningful predictors of morbidity and mortality outcomes associated with bone health.[10]

This study focuses on the critical stage of young adulthood—a period during which peak bone mass is established, laying the foundation for lifelong skeletal health. Medical students are susceptible to poor bone health due to demanding academic schedules, irregular eating habits, high stress, and insufficient physical activity. Despite this, there is limited research employing QUS to assess BMD and the prevalence of osteoporosis specifically in this high-risk population.

Therefore, this study aims to address this gap by evaluating the BMD of medical students in the Rawalpindi district using QUS and investigating its association with various lifestyle factors. These include dietary habits (e.g., tea, coffee, carbonated beverage consumption), smoking status, and physical activity levels. Understanding these associations can guide preventive strategies, raise awareness about bone health, and encourage the adoption of healthier lifestyles among young adults.

Contributions:
AK, MN, EN, KN, MUM, TM - Conception, Design
AK, MN, EN, KN, MUM, TM - Acquisition, Analysis, Interpretation
AK, MN, EN, KN, MUM, TM - Drafting
AK, MN, EN, KN, MUM, TM - Critical Review

All authors approved the final version to be published & agreed to be accountable for all aspects of the work.

Conflicts of Interest: None
Financial Support: None to report
Potential Competing Interests: None to report

Materials And Methods

This descriptive cross-sectional study was conducted in Rawalpindi Medical University over the period of January 2025 to April 2025, following approval from the Institutional Review Board (IRB) on 20th January 2025 under approval number 1232/IREF/RMU/2025. The study adhered to the ethical standards outlined in the Declaration of Helsinki. A non-probability consecutive sampling technique was employed to recruit participants. The sample size was calculated using the OpenEpi sample size calculator by keeping frequency of the outcome factor as 36.55%[1], a confidence level of 95%, and absolute precision of ±10%, the required minimum sample size was calculated to be 90 participants. However, to enhance the statistical power and generalizability of the study, the sample size was increased to 190 participants.

The study included all medical students of either gender and academic years currently enrolled in Rawalpindi medical University who were willing to participate and provided informed consent. Participants with known bone disorders such as osteogenesis imperfecta or chronic conditions like chronic kidney disease which could independently influence bone mineral density (BMD) were excluded. Additionally, students using medications known to affect bone metabolism, such as corticosteroids, were also excluded.

Data was collected using a semi-structured questionnaire administered through Google Forms. The questionnaire, adapted from a previous study[5], gathered information on sociodemographic characteristics and lifestyle factors, including exercise habits, tea and coffee consumption, carbonated drink intake, and smoking status. BMD parameters such as T-score and Z-score were assessed using Quantitative Ultrasound (QUS) of the calcaneus. The ultrasound bone densitometry scans were carried out in collaboration with the Haleon pharmaceutical company, using a portable QUS device (manufacturer: Sonost 3000, OsteoSys Co., Ltd., Seoul, South Korea).

During the scan, participants were seated comfortably to minimize movement. The right heel was selected as the scanning site and properly positioned in the foot cradle of the ultrasound device. A small amount of conductive gel was applied to the skin at the measurement site to enhance the transmission of ultrasound waves. The transducer was then placed on the prepared site and activated. The device measured the Speed of Sound (SOS) and Broadband Ultrasound Attenuation (BUA) parameters used to estimate BMD. From these measurements, T-scores and Z-scores were calculated to assess bone health relative to reference populations. After the scan, the gel was removed, and the readings were recorded directly into the Google Form.

Data was entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables such as age, height, weight, BMI, t and z scores were presented as mean ± standard deviation (SD), while qualitative variables like gender, smoking status, and beverage consumption and other lifestyle factors were expressed as frequencies and percentages. Normality of the data was tested using the Shapiro-Wilk test to determine the appropriate statistical tests. The Chi-square test was used to assess associations between categorical variables. The Pearson correlation coefficient was applied to evaluate the relationship between continuous variables, such as BMI and T-scores.

All tests and procedures were conducted free of cost, with no financial burden on participants. Data collection commenced after IRB approval, and informed consent was obtained from all participants after explaining the procedure, potential risks, and voluntary nature of participation. Aseptic, painless procedures were ensured, and the health and safety of participants were prioritized throughout the study. Strict confidentiality was maintained in handling and reporting participant data.

Results

A total of 190 participants were included in the study, the majority were female (n = 184, 96.8%), with only 6 males (3.2%). The mean age of participants was 22.08 ± 1.15 years. The mean BMI was 21.04 ± 3.89 kg/m². Most students were in their third year of study (47.4%), followed by those in the fourth year (38.9%). A higher proportion of students were non-boarders (61.1%) compared to boarders (38.9%) (Table 1)

Table 1: Sociodemographic Characteristics

Variable	Category	Frequency	Percentage
Gender	Male	6	3.2
	Female	184	96.8
Year of Study	Second Year	6	3.2
	3rd Year	90	47.4
	4th Year	74	38.9
	Final Year	20	10.5
Student's Residence	Boarder	74	38.9
	Non-Boarder	116	61.1

Regarding lifestyle characteristics (Table 2), a large proportion of participants reported not engaging in regular physical exercise (78.9%). None of the participants were current smokers. Fast food consumption was reported as "sometimes" by 62.1% of participants, while 32.6% consumed it "often." Carbonated drinks were consumed "sometimes" by 41.1%, with 34.7% rarely consuming them. Tea was the most consumed beverage, with 64.2% reporting frequent use. In contrast, coffee consumption was relatively lower, with 69.5% reporting minimal intake. Most students reported screen time of more than 4 hours daily (58.9%), and 45.3% acknowledged occasional overeating.

Based on T-scores obtained using quantitative ultrasound (QUS) of the calcaneus, only 18.9% (n = 36) of participants had normal bone mineral density (BMD). A significant proportion (73.7%, n = 140) were diagnosed with osteopenia, and 7.4% (n = 14) were classified as osteoporotic as shown in Figure 1. The mean T-score was −1.60 ± 0.72. Most of the participants fell in the osteopenia category, highlighting the early onset of reduced BMD among young adults, particularly females, despite being in their peak bone mass years.

Pearson correlation analysis (Table 3) revealed a statistically significant positive correlation between BMI and T-score (r = 0.330, $p < 0.001$), indicating that higher BMI was associated with better bone mineral density. However, there was no statistically significant correlation between age and T-score (r = −0.082, p = 0.261)

Table 2: Lifestyle Factors

| Variable	Category	Frequency	Percentage
Exercise	No	150	78.9
	Yes	40	21.1
Smoking	No	190	100.0
	Yes	0	0
Fast food consumption	Almost none	10	5.3
	Often	62	32.6
	Sometimes	118	62.1
Carbonated Drink Consumption	Almost none	66	34.7
	Often	46	24.2
	Sometimes	78	41.1
Tea Consumption	Almost None	36	18.9
	Often	122	64.2
	Sometime	32	16.8
Screentime	2-4 hours	70	36.8
	Less than 2 hours per day	8	4.2
	More than 4hours	112	58.9
Overeating	Almost None	84	44.2
	Often	20	10.5
	Sometimes	86	45.3
Coffee Consumption	Almost none (2times a month or fewer)	132	69.5
	Often (More than 3 times a week)	28	14.7
	Sometimes (3times a week or fewer)	30	15.8
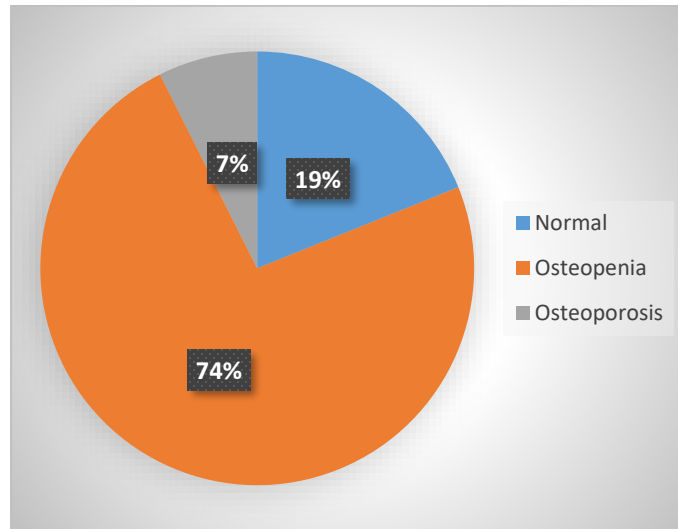
Figure 1: Distribution of Bone Mineral Density Status Based on T-Scores

Table 3: Pearson Correlation Between Age, BMI, and T-Score

		Age	Tscore	BMI
Age	Pearson Correlation	1	-0.082	0.089
	Sig. (2-tailed)		0.261	0.222
	N	190	190	190
Tscore	Pearson Correlation	-0.082	1	0.330[**]
	Sig. (2-tailed)	0.261		<0.001
	N	190	190	190
BMI	Pearson Correlation	0.089	0.330[**]	1
	Sig. (2-tailed)	0.222	<0.001	
	N	190	190	190

[**]. Correlation is significant at the 0.01 level (2-tailed).

Chi-square analysis was conducted to explore associations between bone health status and various categorical variables (Table 4). A statistically significant association was observed between the year of study and bone status (p = 0.002), with third-year students showing the highest proportion of osteoporotic cases. Physical activity was significantly associated with bone health (p < 0.001); students who exercised regularly had higher rates of normal BMD compared to non-exercisers. A significant association was also found between carbonated drink consumption and bone health (p = 0.008), with frequent consumers showing higher rates of osteopenia and osteoporosis. Similarly, overeating was significantly associated with poor bone status (p = 0.004), with those reporting "almost none" or "occasional" overeating faring better than frequent overeaters. Coffee consumption was found to be borderline significant (p = 0.050), suggesting a potential link between frequent coffee intake and lower BMD

Table 4: Association Between Lifestyle Variables and Bone Status (Chi-square Test)

Variables	Categories	Bone Status			Total	
		Normal	Osteopenia	Osteoporosis		p-value
Study Year	2nd year	0	6	0	6	
	3rd year	20	56	14	90	
	4th year	12	62	0	74	0.002
	Final year	4	16	0	20	
Exercise	No	20	18	2	40	<0.001
	Yes	36	140	14	190	
Carbonated drink	Almost none	8	52	6	66	
	Often	4	40	2	46	0.008
	Sometimes	24	48	6	78	
Overeating	Almost None	20	52	12	84	
	Often	2	18	0	20	0.004
	Sometimes	14	70	2	86	
Coffee Consumption	Almost none (2times a month or fewer)	20	100	12	132	
	Often (More than 3 times a week)	10	16	2	28	0.050
	Sometimes (3times a week or fewer)	6	24	0	30	

Discussion

This study reveals a concerning prevalence of compromised bone health among medical students. Only 18.9% of participants demonstrated normal bone mineral status, while 73.7% were osteopenia and 7.4% osteoporotic, despite being in a young adult age group with a mean age of just 22.08 years. These findings align with a study conducted in Karachi, Pakistan, which found that among young adults aged 21 to 35 years, 49.1% had osteopenia and 17.2% had osteoporosis, highlighting the early onset of bone mineral loss in this demographic.[12]

A significant positive correlation between BMI and T-score (r = 0.330, p < 0.001) was observed, indicating that individuals with lower BMI were more likely to exhibit reduced bone density. This is consistent with a 2024 cross-sectional study conducted in Beijing, China, which found a strong association between low BMI and reduced BMD among older adults (p < 0.001).[13] Although this study focused on an older population, the physiological principle of mechanical loading and lean mass influencing bone density remains applicable to younger groups as well.

Interestingly, the year of study showed a significant association with bone status (p = 0.002), with third-year students displaying the highest proportion of osteoporosis. This may be attributed to increased academic pressure, disrupted sleep, and poor self-care during clinical rotations. This emphasizes the need to integrate wellness and preventive health practices into medical training curricula.

Among lifestyle factors, physical activity and regular light exercise emerged as a highly protective factor (p < 0.001), with active participants exhibiting healthier T-scores. A 2024 study from Brazil similarly reported that physical fitness components were significant predictors of BMD in adults, with higher activity levels correlating positively with bone mass (p < 0.05).[14] These findings reiterate the importance of physical exercise in maintaining skeletal integrity, even in early adulthood.

Dietary behaviour also played a critical role. Participants who reported frequent carbonated drink consumption had significantly lower BMD (p = 0.008). This supports the findings of a 2023 Chinese cohort study that linked soft drink intake to an increased risk of fractures in postmenopausal women (p < 0.05), emphasizing the negative impact of high-phosphate, low-calcium beverages on skeletal health.[15]

Additionally, overeating was significantly associated with low BMD (p = 0.004), possibly reflecting poor dietary quality despite caloric excess. A 2022 systematic review and meta-analysis found that individuals with binge-eating behaviors exhibited lower BMD compared to healthy controls, highlighting the detrimental effects of disordered eating patterns on bone health.[16]

Coffee consumption showed a borderline association with bone status (p = 0.050). The relationship between caffeine and BMD remains debated in literature. A 2024 Mendelian randomization study conducted in China demonstrated a potential positive association between moderate coffee intake and total body BMD, particularly in individuals aged 30–45 (p = 0.005).[17] In contrast, a 2022 study using NHANES data from China found mixed effects—improved BMD in younger females, but decreased BMD in males aged 40–49 (p < 0.05).[18] These conflicting findings suggest that the impact of coffee on bone health may be dose-dependent and population-specific..

Conclusions

This study highlights a high prevalence of reduced bone mineral density among young medical students, with 73.7% classified as osteopenic and 7.4% as osteoporotic. Most of the students exhibited lifestyle patterns—such as low physical activity, frequent carbonated drink intake, overeating, and low BMI—that significantly compromised bone health. The strong correlation between BMI and T-score, along with significant associations across modifiable lifestyle variables, underlines the urgent need for targeted interventions.

Original Article

Given that bone health established during early adulthood sets the foundation for skeletal integrity later in life, these findings emphasize the importance of early screening, lifestyle counselling, and nutritional education—especially within high-stress academic environments like medical school. Incorporating bone health awareness into student wellness programs is not only essential but overdue. Proactive prevention now can reduce the burden of osteoporosis and related complications in the future medical workforce.

Author Information

1. Assistant Professor of Community Medicine, Rawalpindi Medical University 2. Post Graduate Trainee, Rawalpindi Medical University 3,5. Final Year Student, Rawalpindi Medical University 4. Associate Professor, Rawalpindi Medical University 6. Associate Professor of Pediatrics, Wah Medical College
Corresponding author: Dr. Afifa Kulsoom ⓘD docafifak@gmail.com

References

1. Farooq M, Shaheen S, Farooq M, Zafar H, Saleem A. Frequency of low bone mineral density and its age and gender related association in Pakistani population. Pak Armed Forces Med J. 2024;74(3):835–8.
2. Amin S, Mukti NA. Assessment of knowledge level on osteoporosis among private university students in Malaysia. Int J Interdiscip Res. 2017;3(3):141–5.
3. Kling JM, Clarke BL, Sandhu NP. Osteoporosis prevention, screening, and treatment: a review. J Womens Health. 2014;23(7):563–723. https://doi.org/10.1089/jwh.2013.4611
4. Kruger MC, Todd JM, Schollum LM, Kuhn-Sherlock B, McLean DW, Wylie K. Bone health comparison in seven Asian countries using calcaneal ultrasound. BMC Musculoskelet Disord. 2013;14:81. https://doi.org/10.1186/1471-2474-14-81
5. Lim HS, Ji SI, Hwang H, Kang J, Park YH, Lee HH, et al. Relationship between bone density, eating habits, and nutritional intake in college students. J Bone Metab. 2018;25(3):181–6. https://doi.org/10.11005/jbm.2018.25.3.181
6. Han CS, Kim HK, Kim S. Effects of adolescents' lifestyle habits and body composition on bone mineral density. Int J Environ Res Public Health. 2021;18(11):6170. https://doi.org/10.3390/ijerph18116170
7. Johns Hopkins Medicine. Osteoporosis: what you need to know as you age. Available from: https://www.hopkinsmedicine.org/health/conditions-and-diseases/osteoporosis/osteoporosis-what-you-need-to-know-as-you-age
8. Varacallo M, Seaman TJ, Jandu JS, Pizzutillo P. Osteopenia. StatPearls [Internet]. StatPearls Publishing; 2023 [cited 2024 Nov 4]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK499878/
9. Ali K, El Said SM, Adly NN, Abdul-Rahman SA. The relation between calcaneus stiffness index as a measure of bone density and body mass index in an Egyptian cohort. J Multidiscip Healthc. 2019;12:1085–90. https://doi.org/10.2147/jmdh.s230730
10. Jones G, Boon P. Which bone mass measures discriminate adolescents who have fractured from those who have not? Osteoporos Int. 2008;19(2):251–5. https://doi.org/10.1007/s00198-007-0458-1
11. OpenEpi. Sample size for cross-sectional, cohort, and clinical trials. Available from: https://www.openepi.com/SampleSize/SSCohort.htm
12. Shahid MA, Khan AN, Nisar M, Shah MA, Roshan P, Baig S. High frequency of osteopenia in young adults of Karachi. Pak J Med Dent. 2019;8(4):20–4. https://doi.org/10.36283/pjmd8-4/004
13. Cui Y, Liu L, Wei S, Wang Y, Xu Y, Zhu Z. Association between body mass index and bone mineral density in older adults: a cross-sectional study. BMC Musculoskelet Disord. 2024;25(1):46. https://doi.org/10.1186/s12891-024-07782-7
14. da Costa JC, de Freitas MCM, Barbosa CCL, Guzmán AB, Corrêa de Campos LF, Gómez-Campos R, et al. Physical fitness components are bone mineral density predictors in adulthood: cross-sectional study. BMC Musculoskelet Disord. 2024;25:714. https://doi.org/10.1186/s12891-024-07801-7
15. Li L, Zhang Y, Wang Y, Xu H, Wang Z. Soft drink consumption and risk of fractures among postmenopausal women: a prospective cohort study. Nutrients. 2023;15(2):312. https://doi.org/10.3390/nu15214619
16. Lopes MP, Robinson L, Stubbs B, dos Santos Alvarenga M, Martini LA, Campbell IC, et al. Associations between bone mineral density, body composition and amenorrhoea in females with eating disorders: a systematic review and meta-analysis. J Eat Disord. 2022;10(1):173. https://doi.org/10.1186/s40337-022-00694-8
17. Ye Y, Zhong R, Xiong X, Wang C. Association of coffee intake with bone mineral density: a Mendelian randomization study. Front Endocrinol (Lausanne). 2024;15:1328748. https://doi.org/10.3389/fendo.2024.1328748
18. Wang H, Fang H, Liu X, Chu C, Li Y, Zhao Y. Association between caffeine intake and lumbar spine bone mineral density in US adults: a cross-sectional study using NHANES data. Front Endocrinol (Lausanne). 2022;13:1008275. https://doi.org/10.3389/fendo.2022.1008275