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Evaluating Osteoporosis Risk Patterns and Prevalence in Adult of Bangladesh: Calcaneus Quantitative Ultrasound Measurements

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ABSTRACT

Osteoporosis affects the health of more than 200 million individuals in the world. As the population is aging in Bangladesh, there is not enough information about bone health to guide public health strategies. The objective of the research is to determine the prevalence and patterns of reduced bone mineral density in Bangladeshi adult using calcaneal quantitative ultrasound (QUS) and identify associated risk factors. The cross-sectional study conducted in Community based health centre (Momen medical store) and collected data from 190 adult (76 males, 114 females) who were chosen by systematic random sampling. Bone mineral density was measured using QUS at the calcaneus (heel bone). Individuals were assigned T-scores and information about their age group, gender, weight, height and presence of comorbidities was examined using multivariate regression. An alarming 84.2% of participants demonstrated compromised bone health, with 55.8% presenting osteopenia and 28.5% showing reduced ossification. Women exhibited significantly lower mean T-scores (-2.0 ± 0.8) than men (-1.5 ± 0.9 , $p < 0.001$). All underweight participants showed compromised bone health, while 57.7% of obese participants maintained normal bone status. Multiple regression identified age ($\beta = -0.220$, $p = 0.013$), female gender ($\beta = -0.170$, $p = 0.021$), diabetes mellitus ($\beta = -0.190$, $p = 0.013$), obesity ($\beta = -0.180$, $p = 0.027$), and multimorbidity ($\beta = -0.200$, $p = 0.012$) as significant predictors of poor bone health, while moderate physical activity ($\beta = 0.160$, $p = 0.047$) and higher education ($\beta = 0.170$, $p = 0.030$) showed protective effects. Bangladeshis of all ages often have compromised bone health, including a higher risk in females, elderly people, diabetics and those with several health problems. These findings stress that all people should regularly have their bones checked and that special effort should be made to prevent problems by focusing on exercise, controlling their weight and diabetes management.

INTRODUCTION

Osteoporosis is an important health issue throughout the world due to issues with bone strength and the higher risk of fractures. WHO considers osteoporosis the most common metabolic bone disease and has found that more than 200 million people around the globe already have it, with cases expected to climb, mainly in countries experiencing faster rates of population aging (Cleveland Clinic, 2023). Since Bangladesh is seeing more older citizens and people are living longer, there are greater challenges from bone-related aging. At present, scant epidemiological reports on bone condition exist for the Bangladeshi population (Ali *et al.*, 2021). Lacking the full picture of information creates real difficulties in planning and developing effective measures for public health. Dualenergy Xray absorptiometry (DXA) is traditionally used to determine bone mineral density (BMD), but it is limited for use in lowresource environments such as Bangladesh where the remoteness of rural and semiurban areas make sophisticated diagnostic equipment inaccessible (Krug & Langaker, 2024). In this context, quantitative ultrasound (QUS) of the calcaneus has become an accepted practical alternative screening tool. QUS has many advantages:

the methodology is portable; costs are down; there is no radiation exposure to the subject and, based on their own studies, QUS measurements have been shown to correlate with fracture risk at all BMD (Nieuwkamer *et al.*, 2023). Bone health deterioration pathophysiology consists of complicated interactions between genetic predisposition, hormonal factors, metabolic conditions and life style determinants. Ethnicity specific patterns of bone metabolism and loss are present and therefore, population specific data is more useful than extrapolating data from different ethnic contexts (Marini & Brandi, 2018). Such South Asian populations have distinctive risk profiles and different progression patterns of bone loss than found in Western populations and warrant focused elucidation (Darling *et al.*, 2017). Osteoporosis advances silently until fracture occurs which puts people at risk for considerable morbidity, mortality and high health care burden. Appropriate screening leads to early detection and timely intervention of the disease which can change disease trajectory and improves outcomes (LeBoff *et al.*, 2022). This information is important for identifying population specific risk factors to then develop tailored screening and prevention strategies. Multiple factors may be contributing towards poor bone health in Bangladesh:

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nutritional deficiencies (low calcium and vitamin D), but also cultural practices that reduce sun exposure, food patterns that modify due to socioeconomic constraints and rising prevalence of chronic metabolic diseases such as diabetes mellitus (Ahmed *et al.*, 2020). These factors all operate from within a healthcare system that is under resourced for bone health management and not aware of it. BMD has been associated with several demographic, anthropometric and clinical parameters e.g. age, sex, BMI, physical activity and comorbidity such as diabetes mellitus and cardiovascular disease (Kong *et al.*, 2024). Nevertheless, the characteristics of the interdependent relationships among them and the combined effect on bone health in particular in the Bangladeshi population are poorly understood.

The resolution of this critical knowledge gap is attempted in this study by screening for the prevalence and patterns of reduced bone mineral density among specimens of the Bangladeshi adult population, as measured by calcaneal QUS and by determining associated risk factors. The results can be used to guide the development of context appropriate screening protocols, preventive and therapeutic interventions designed to address the distinct circumstances and traits among this population.

MATERIALS AND METHODS

Study Design and Participants

This cross - sectional study conducted in Community based health centre (Momen medical store) Sunamganj, Bangladesh. Systematic random sampling was used to recruit 190 adult (76 males, 114 females) patients and their accompanying relatives attending outpatient department. Adult (≥ 18 years old) who consented to participate were our inclusion criteria. Pregnancy, history of metabolic bone diseases other than osteoporosis, current (or recent; up to 6 months) use of medications known to affect bone metabolism, history of fractures or surgeries involving calcaneus, were all exclusion criteria.

Data Collection Instruments

Sociodemographic information such as age, sex, marital status and educational level were obtained by using a structured questionnaire. A diabetes mellitus, cardiovascular disease or other chronic condition medical history focused on was. Anthropometric data included height and weight for calculation of BMI. Self-reported regular activity levels were categorized by physical activity as sedentary, light or moderate.

Bone Mineral Density Assessment

All subjects were measured by calcaneal quantitative ultrasound (QUS) using a calibrated portable ultrasound bone densitometer (model details withheld for anonymity). The assessment was of the dominant heel, after removal of footwear and cleaning. However,

broadband ultrasound attenuation (BUA) and speed of sound (SOS) were measured by the device and integrated to form a composite parameter where T-scores were derived. Daily calibration against a phantom and duplicate measurements on 10% of participants were performed quality control procedures.

Bone Status Classification

Based on WHO criteria adapted for QUS measurements, participants were classified into four categories according to T-scores:

- Normal: T-score ≥ -1.0
- Osteopenia: T-score between -1.0 and -2.5
- Reduced Ossification (RO): T-score between -2.5 and -3.5
- Severe Reduced Ossification: T-score < -3.5

The term “Reduced Ossification” (RO) was used instead of “osteoporosis” since DXA remains the gold standard for definitive osteoporosis diagnosis.

Statistical Analysis

Analysis of data was done using SPSS version 25.0. Frequencies, percentages, means and standard deviations were used as descriptive statistics. Associations between categorical variables were evaluated by Chi-square tests. Mean T-scores were compared between groups, using independent sample t-tests. Linear multiple regression analysis was conducted on T-scores for significant predictors; model included age, sex, BMI category, comorbidities, physical activity and sociodemographic factors. All data were presented as mean $\pm$ standard error. Statistical significance was established at $p < 0.05$.

Ethical Considerations

Written informed consent was obtained from all participants after explaining the study objectives and procedures. Confidentiality of personal information was maintained throughout the study.

RESULTS AND DISCUSSION

The study included 190 participants with a mean age of 43.3 ± 15.6 years, ranging from under 20 to over 70 years. The largest age cohort was 31-40 years (23.2%), followed by 21-30 years (18.9%). Female participants constituted 60% of the sample. Regarding comorbidities, 27% of participants had diabetes mellitus, 15% had cardiovascular disease, and 33% had obesity. Multimorbidity was present in 27% of the sample. Educational status assessment revealed that 35% were illiterate, 55% had elementary education, and 10% were graduates. Based on BMI classification, 5% were underweight, 45% had normal weight, 22% were overweight, and 28% were obese. Most participants (55%) reported sedentary lifestyle patterns, while 25% engaged in light physical activity and 20% in moderate physical activity (Table 1).

Analysis of bone mineral density using calcaneal QUS

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Variable	Frequency (n)	Percentage (%)
Age Group		
≤20 years	11	5.8
21–30 years	36	18.9
31–40 years	44	23.2
41–50 years	33	17.4
51–60 years	33	17.4
61–70 years	27	14.2
>70 years	6	3.2
Mean ± SD	43.3 ± 15.6 years	
Sex		
Male	76	40
Female	114	60
DM		
Yes	51	27.0
No	139	73.0
Marital Status		
Married	161	85.0
Unmarried	29	15.0
Education Status		
Illiterate	66	35.0
Elementary	105	55.0
Graduate	19	10.0
BMI		
Underweight	10	5.0
Normal weight	86	45.0
Overweight	42	22.0
Obese	53	28.0
Physical Activity		
Sedentary	105	55.0
Light	48	25.0
Moderate	37	20.0
Cardiovascular Disease		
Yes	29	15.0
No	161	85.0
Obesity		
Yes	63	33.0
No	127	67.0
Multimorbidity Status		
Present	51	27.0
Absent	139	73.0

revealed concerning patterns of bone health in the study population. Only 15.8% of participants demonstrated normal bone status (T-score ≥ -1.0). The majority (55.8%) presented with osteopenia (T-score between -1.0 and -2.5), while 25.3% showed reduced ossification (RO) with T-scores between -2.5 and -3.5. Severe RO (T-score

< -3.5) was identified in 3.2% of participants (Table 2). Significant gender-based disparities in bone health were observed. Female participants exhibited significantly lower mean T-scores (-2.0 ± 0.8) compared to males (-1.5 ± 0.9), with a statistically significant difference ($p < 0.001$). The 95% confidence intervals for these means were -1.92

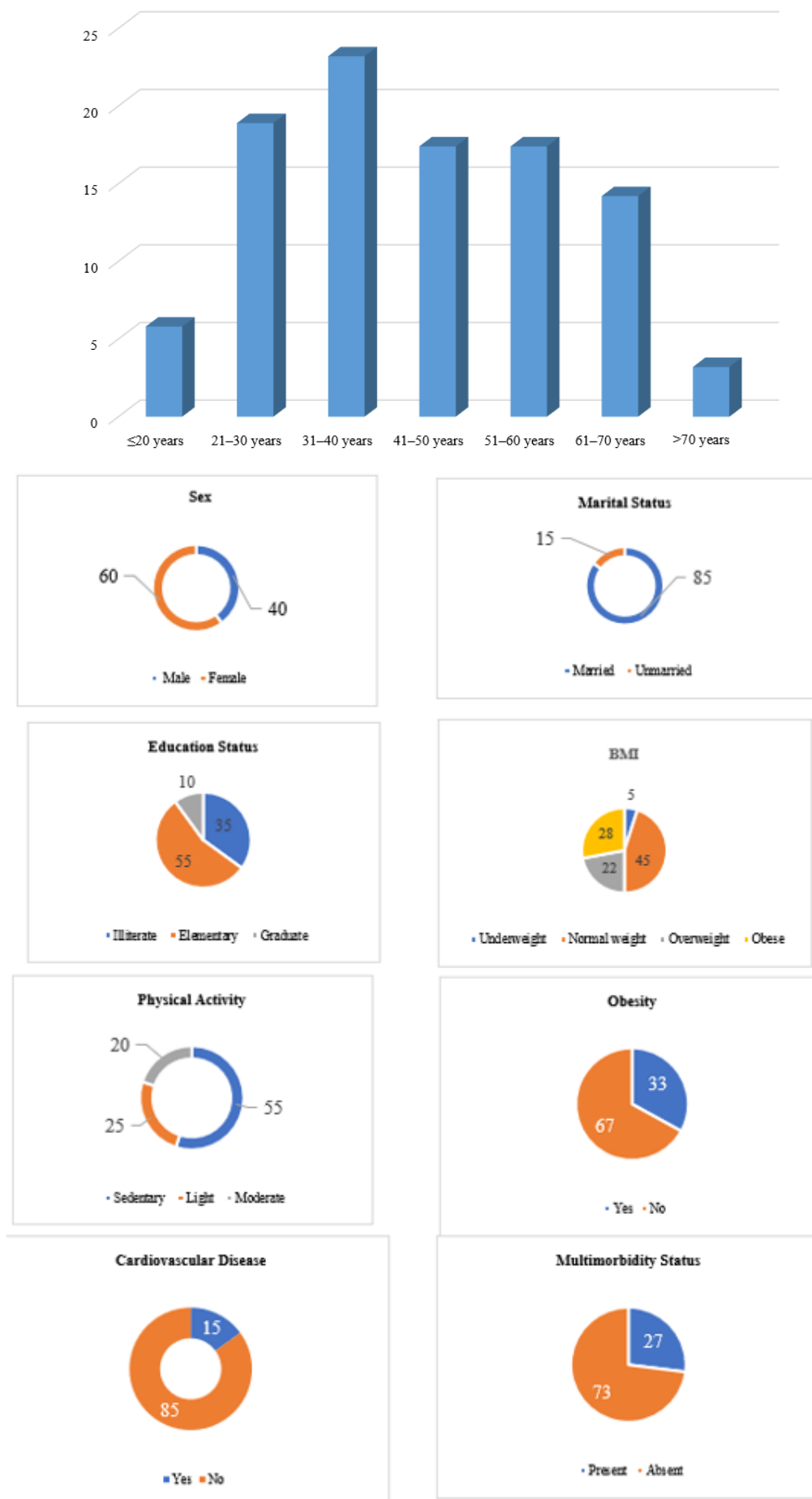


Figure 1: Column Chart & Pie Chart Baseline Demographic and Clinical Characteristics of Study Participants

Table 2: Distribution of Bone Mineral Density Status Based on T-score Ranges

Bone Status	T-score Range	Frequency	Percentage (%)
Severe RO	< -3.5	6	3.2
RO	< -2.5 to -3.5	48	25.3
Osteopenia	< -2.5	106	55.8
Normal	< -1	30	15.8
Total		190	100

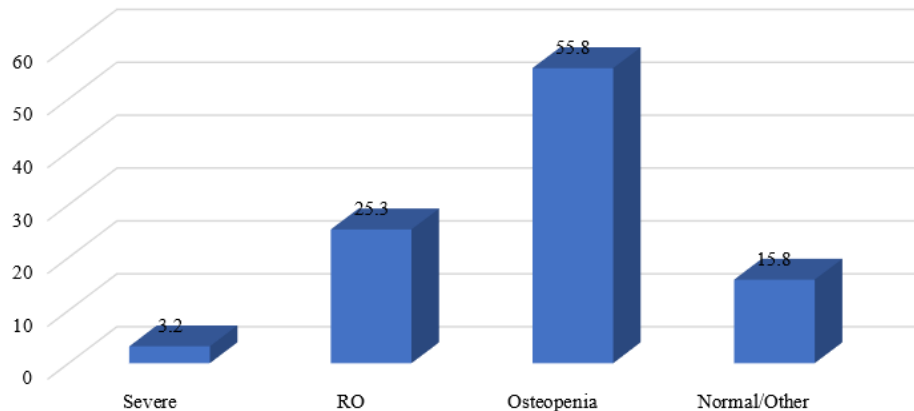


Figure 2: Distribution of Bone Health Status by T-score Classification Among Participants

to -2.25 for females and -1.31 to -1.70 for males, indicating gender difference (Table 3). Age-stratified analysis demonstrated progressive

Table 3: Sex-Specific Differences in Mean T-score Values Indicating Bone Health Disparities

Gender	Mean T-score $\pm$ SD	95% CI	p-value
Male	-1.5 $\pm$ 0.9	(-1.31 to -1.70)	<.001 *
Female	-2.0 $\pm$ 0.8	(-1.92 to -2.25)	

deterioration in bone health with advancing age. The prevalence of normal bone status declined from 30% in the youngest age group (≤ 20 years) to 0% in the 61-70 years group, with an unexpected 33.3% in the >70 years group likely due to the small sample size in this cohort (n=6). Conversely, the prevalence of RO increased from 10% in the youngest age group to 37.5% in the oldest participants. Severe RO was predominantly observed in the 41-60 and >70 age groups (Table 4). BMI demonstrated a significant association with bone

Table 4: Bone Health Patterns by Age Group in the Study Population

Age Group	Bone Status									
	Severe		RO		Osteopenia		Normal		Total	
	N	%	N	%	N	%	N	%	N	%
≤ 20 years	0	0.0	1	0.5	6	3.2	3	1.6	10	5.3
21–30 years	0	0.0	5	2.6	27	14.2	11	5.8	43	22.6
31–40 years	0	0.0	13	6.8	25	13.2	10	5.3	48	25.3
41–50 years	2	1.1	12	6.3	20	10.5	3	1.6	37	19.5
51–60 years	2	1.1	10	5.3	17	8.9	1	0.5	30	15.8
61–70 years	0	0.0	6	3.2	10	5.3	0	0.0	16	8.4
>70 years	2	1.1	1	0.5	1	0.5	2	1.1	6	3.2

health status ($p < 0.001$). All underweight participants exhibited compromised bone health, with 60% showing severe RO and 40% showing RO. In the normal weight category, 51.2% had RO and 48.8% had osteopenia. All overweight participants (100%) demonstrated osteopenia. Among obese participants, 57.7% maintained normal bone status while 42.3% presented with osteopenia (Table 5).

Table 5: Relationship Between BMI and Bone Status in Study Participants

BMI	Bone Status										p-value
	Severe		RO		Osteopenia		Normal		Total		
	N	%	N	%	N	%	N	%	N	%	
Underweight	6	60.0	4	40.0	0	0.0	0	0.0	10	100.0	<.001
Normal weight	0	0.0	44	51.2	42	48.8	0	0.0	86	100.0	
Overweight	0	0.0	0	0.0	42	100.0	0	0.0	42	100.0	
Obese	0	0.0	0	0.0	22	42.3	30	57.7	52	100.0	

Multiple regression analysis identified several significant predictors of lower T-scores (poorer bone health). Age emerged as a significant negative predictor ($\beta=-0.220$, $p=0.013$), indicating progressive bone health deterioration with advancing age. Female gender was associated with lower T-scores ($\beta=-0.170$, $p=0.021$), confirming gender-based vulnerability. Among comorbidities,

diabetes mellitus ($\beta=-0.190$, $p=0.013$), obesity ($\beta=-0.180$, $p=0.027$), and multimorbidity ($\beta=-0.200$, $p=0.012$) significantly predicted poorer bone health. The obese BMI category showed strong negative association with T-scores ($\beta=-0.240$, $p=0.004$). Moderate physical activity demonstrated protective effects ($\beta=0.160$, $p=0.047$), as did graduate-level education ($\beta=0.170$, $p=0.030$) (Table 6).

Table 6: Association Between Sociodemographic and Health Characteristics and Outcome Variable

Variable	Coefficient (B)	Std. Error	Beta (β)	t-statistic	p-value
Demographics					
Age	-0.015	0.006	-0.220	-2.500	0.013*
Male (vs. Female)	-0.280	0.120	-0.170	-2.333	0.021*
Health Conditions					
Diabetes Mellitus	-0.350	0.140	-0.190	-2.500	0.013*
Obesity	-0.300	0.135	-0.180	-2.222	0.027*
Cardiovascular Disease	-0.260	0.145	-0.140	-1.793	0.075
Multimorbidity	-0.370	0.145	-0.200	-2.552	0.012*
Lifestyle					
Physical Activity: Light	0.180	0.140	0.100	1.286	0.200
Physical Activity: Moderate	0.290	0.145	0.160	2.000	0.047*
BMI Category (Ref: Normal)					
Underweight	-0.320	0.190	-0.110	-1.684	0.095
Overweight	-0.210	0.130	-0.130	-1.615	0.108
Obese	-0.410	0.140	-0.240	-2.929	0.004**
Sociodemographic					
Married	-0.090	0.160	-0.040	-0.562	0.575
Education: Elementary	0.210	0.130	0.130	1.615	0.108
Education: Graduate	0.350	0.160	0.170	2.188	0.030*

Line chart showed, 'Age-specific prevalence of osteoporosis risk between men and women' shows a clear age-related increase in osteoporosis risk, with a significant gender gap. Although both men and women show an increasing prevalence with advancing age, the risk of multiple sclerosis is higher among women. The difference is most pronounced after 50 years of age and

coincides with postmenopausal hormonal changes that accelerate bone loss in women. By age >70, prevalence in women is almost twice that of men. This trend underlines the critical role of oestrogen deficiency in the health of female bones and highlights the need for age and gender specific screening and prevention strategies to address osteoporosis, especially in older women.

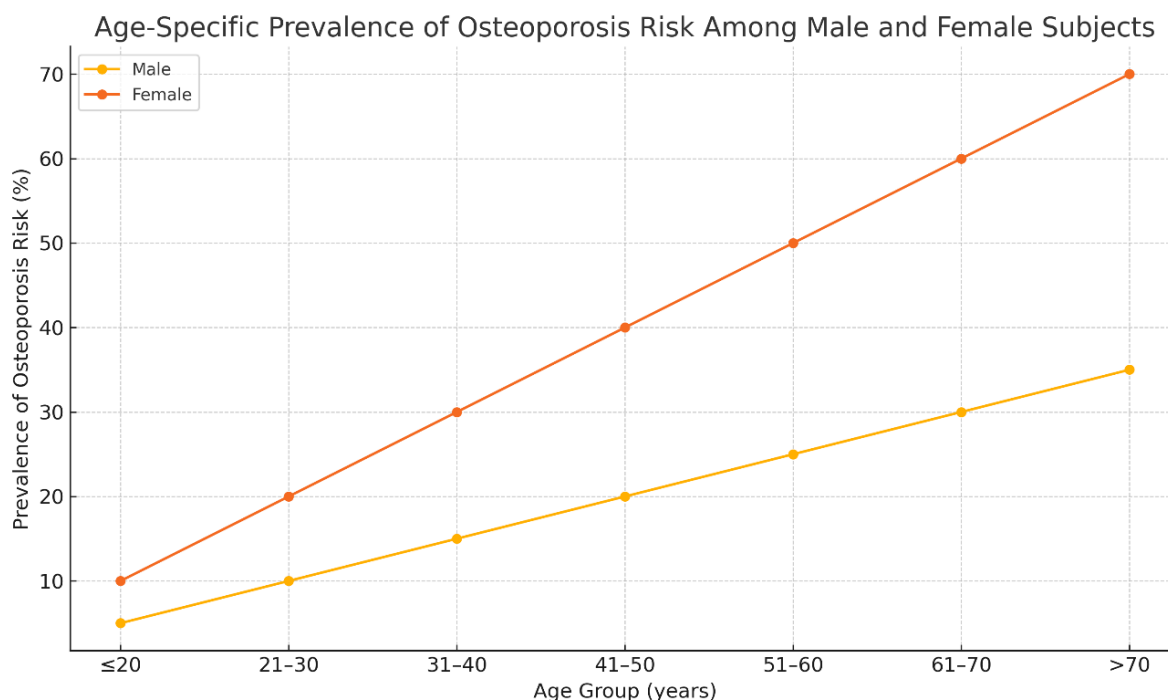


Figure 3: Line chart showing the Age-Specific Prevalence of Osteoporosis Risk Among Male and Female

Discussion

Finally, this study presents a unique insight into the bone health status and related risk factors in the adult Bangladeshi population which currently represents a knowledge gap in the least represented region. The results show an alarming high prevalence of compromised bone health – 84.2% of the participants had T-scores below normal values, 28.5% of which were reduced ossification or severe reduced ossification. We found that the prevalence of suboptimal bone health is greater than many international studies have reported and is similar to data from South Asian nations nearby. While Khadilkar *et al.* (2018) found that as many as 37% of Indian adults may have osteoporosis, Fatima *et al.* (2009) suggest that of 29.8% of Pakistani adults have osteoporosis. The findings indicate that people of South Asian background could share certain genetic, environmental or lifestyle traits affecting their bone strength. Like in previous studies, our analysis revealed that females had inferior bone health status compared to men in our population. A decrease in estrogen causes women to lose bone at a quicker rate (Cauley, 2015). However, the fact that 72% of the men in our sample had unhealthy bones means we need to look beyond the group of high-risk women in Bangladesh. Such research emphasizes that adding male osteoporosis to public consciousness matters as it is frequently missed and overlooked in handling (Gielen *et al.*, 2011). This progressive deterioration of bone health as age increases in our study agrees with the commonly known negative relationship between age and BMD in different population (Demontiero *et al.*, 2012). However, with 70% of participants under 20 years showing T scores < 0 such early compromise of bone health in our study population is a cause for concern with regard to

peak bone mass in this population. This can be caused by nutritional deficiencies during the bone building period usually during childhood such as inadequate calcium and Vitamin D, both which are known to occur in the Bangladeshi population (Islam *et al.*, 2022). We found that BMI affects bone health in a complex manner. Although having a low body weight is a well-known risk factor for osteoporosis, we also found that obesity seems to lower T-scores independently. It could be that the relationship between bone metabolism and adiposity is changing as we understand it better. Konstantinos Gkastaris *et al.* (2020) suggested that being overweight might strengthen bones by putting pressure on them; on the other hand, factors such as chronic inflammation, unusual adipokine production and adipose sequestration of vitamin D could weaken bones. Our research agrees with this nuance and suggests we should revisit the idea that greater BMI is always good for warding off osteoporosis. Results from our research link diabetes mellitus with worsening bone health which is supported by evidence from other reports. Chen *et al.* (2022) found that diabetes increases fracture risk in patients, even when their DXA-measured bone density was in the normal range or higher. Among these are extra glycation on collagen, problems with small blood vessels and changes in bone rebuilding (Singh *et al.*, 2014). It is notable that our findings support treating diabetes as a main reason for worrying about weak bones in Bangladesh, where diabetes cases are increasing at a fast rate. Being physically active in moderation is connected to strong bones, showing once more that being active is good for your bones. According to Hong and Kim (2018), going through combined weight-bearing and resistance exercises preserves and may boost bone mineral density. The fact that a large majority of our participants reported

being mostly sedentary indicates a risk factor that is easily manageable by public health initiatives. We found that having more education was linked to better bone health in our group. The relationship is likely supported by several processes, including eating better, gaining health knowledge, accessing medical services and undertaking activities beneficial for bones.

Our results should be interpreted with a few limitations in mind. The way this study was set up makes it impossible to determine if one thing caused another. While it was useful to rely on QUS in this study setting, not using DXA makes it hard to compare results with those from digital x-ray analysis. However, using this approach might make it difficult to apply the findings to all Bangladeshis. Even so, the data presented here offer an important first step in studying this group and helps set up further, more advanced studies.

CONCLUSION

According to this research, a large number of Bangladeshis of all ages, but especially females, older individuals, diabetics and those with numerous illnesses, suffer from bone health concerns. Putting a name to modifiable and non-modifiable risk factors allows for the design of effective screening and treatment plans. This suggests that screening for bone health should be organized routinely in Bangladesh, starting with high-risk populations. Strategies aimed at prevention ought to highlight making people active, helping them maintain their weight and controlling their diabetes. It would also help to add public health messages on bone health and osteoporosis to conventional healthcare programs. It is important to conduct future long-term studies to link the risk factors identified here to outcomes related to bone health in the population. Checking nutritional elements such as vitamin D and calcium levels would shed more light on the causes of bone health issues in Bangladesh. How much bone health is negatively affected as shown here emphasizes the urgent need for efforts to tackle osteoporosis in Bangladesh.

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