# A Study on the Effectiveness of BMD and Neuropathy Camps for Screening Osteoporosis and Peripheral Neuropathy

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## ABSTRACT

**Background:** Bone mineral density (BMD) is an important determinant of bone strength, and its reduction leads to osteopenia, osteoporosis and major risk factors for fractures. Neuropathy, particularly in diabetes, may further worsen bone health. Low-cost, non-invasive methods like calcaneal quantitative ultrasound (QUS) and vibration perception threshold (VPT) testing can be useful for community-based screening.
**Methods:** A camp-based study was conducted at Ajmal Khan Tibbiya College, AMU, involving 77 participants. BMD was measured by calcaneal QUS and categorized as normal, osteopenia and osteoporosis (WHO criteria). Neuropathy was graded by VPT as grade I (16–25 V) or grade II (>25 V). Descriptive and inferential statistics were applied.
**Results:** Overall, 50.6% had normal BMD, 41.6% osteopenia, and 7.8% osteoporosis. Among females, 54.6% were normal, 34.1% osteopenic, and 11.4% osteoporotic; In males, 45.5% were normal, 51.5% osteopenic, and 3.0% osteoporotic. Neuropathy was found in 33.8% of participants, most often in the 40–59 years group. No significant association was observed between sex and BMD ($\chi^2$=3.37, p=0.186).
**Conclusion:** Osteopenia was common among men, while osteoporosis was more frequent among women. Neuropathy was also prevalent, particularly in middle-aged adults. Although the sex-BMD association was not significant, the findings highlight the value of early, camp-based screening using simple tools like QUS and VPT to detect bone health issues and neuropathy in the community.

*Keywords***:** Bone mineral density, osteoporosis, osteopenia, quantitative ultrasound, vibration perception threshold, peripheral neuropathy

## INTRODUCTION

Bone mineral density (BMD) is the most widely used indicator of bone strength, accounting for approximately 70% of its variation [1]. However, bone strength also depends on additional structural and qualitative properties beyond BMD [2].

BMD reflects the concentration of minerals, primarily calcium hydroxyapatite, within bone tissue [3]. The World Health Organization (WHO) defines osteopenia and osteoporosis as conditions of low BMD, with osteoporosis being the strongest predictor of bone fracture risk [4]. BMD

typically begins to decline in both men and women after the age of 50 [5]. Osteopenia is characterized by a BMD value below normal but not sufficiently low to be classified as osteoporosis. Although less severe, osteopenia increases the risk of developing osteoporosis and fractures with age, making early recognition and intervention critical for maintaining bone health [6]. Osteoporosis, in contrast, is a metabolic bone disease marked by reduced bone density and mass despite normal mineralization [7]. Risk factors include female sex, age, genetic predisposition, calcium and vitamin D deficiency, sedentary lifestyle, smoking, and chronic illness [8]. Dual-energy X-ray absorptiometry (DXA) is considered the gold standard for measuring BMD in osteoporosis screening. DXA provides T-scores, which represent standard deviations from the mean BMD of young adult women (NHANES data) [9,10]. According to WHO, osteoporosis is defined as a T-score ≤ −2.5 at the femoral neck or lumbar spine, thresholds that strongly predict hip and vertebral fracture risk [11,12]. However, DXA is expensive, requires specialized equipment, and is not always accessible in resource-limited settings [13].

As an alternative, calcaneal quantitative ultrasound (QUS) has been proposed as a valuable method for early diagnosis and prescreening of osteoporosis [14–16]. Unlike DXA, QUS is portable, cost-effective, efficient, and does not involve ionizing radiation [17]. Studies indicate that calcaneal QUS can effectively identify high-risk patients who need treatment while reducing unnecessary DXA scans by excluding low-risk individuals [18,19]. Neuropathy also significantly affects bone metabolism, as the peripheral nervous system influences this process directly through neurotransmitters acting on bone cells and indirectly via vascular regulation within the skeleton [20]. In diabetes, peripheral polyneuropathy reduces physical activity, contributing to bone loss. Additionally, pain associated with diabetic neuropathy may lead to poor nutrition, impaired cognition, elevated cortisol, and increased inflammatory cytokine levels, all of which negatively impact bone density [21,22].

Early identification of neuropathy is therefore essential. The vibration perception threshold (VPT) is a well-established tool for detecting mild-to-moderate diabetic neuropathy [23]. VPT measures peripheral nerve sensitivity by recording the lowest voltage at which a patient perceives vibration applied to the feet. Grading is typically defined as: normal (≤15 V), grade I (16–25 V), and grade II (>25 V) [24]. This simple, non-invasive test provides valuable insights into both peripheral neuropathy and its potential impact on bone health.

## MATERIALS & METHODS

A community-based cross-sectional study was conducted during a free health camp organized by the Department of Ilaj bit Tadbeer, Ajmal Khan Tibbiya College, Aligarh Muslim University. Seventy-seven men and women participated voluntarily after pamphlet-based announcements in local areas. As this was a camp-based study, formal IRB clearance was not obtained, though ethical principles of consent, confidentiality, and non-maleficence were followed. Bone mineral density (BMD) of the right calcaneus was measured using a CITI® 300 ultrasound device, and results were expressed as T-scores according to WHO criteria. Vibration perception threshold (VPT) was assessed with a Vibrometer VPT® (Neurovibe, New Delhi, India). The probe was applied at six sites on each foot (great toe, first, third, and fifth metatarsals, instep, heel), with voltage gradually increased from 0–50 V until vibration was perceived. Neuropathy was graded as normal (≤15 V), grade I (16–25 V), and grade II (>25 V).

## RESULT

The mean age of the study population was 43.34±12.95 years (range 17–80 years). The mean Body Mass Index (BMI) was 35.0 ±

8.0 (range 19–51), indicating that most participants were overweight or obese. The mean Bone Mineral Density (BMD) was $1.13 \pm 0.81$, with values ranging between 2.7 and 2.5, suggestive of reduced bone mass in several individuals presented in Table 1.

**Age Group and Bone Mineral Density**
Distribution of BMD across age groups is presented in Table 2. In the 20–39 years group, 57.6% had normal BMD and 42.4% had osteopenia, with no cases of osteoporosis. In the 40–59 years group, 48.6% were normal, 43.2% had osteopenia, and 8.1% had osteoporosis. Among those $\geq$ 60 years, 42.9% were normal, 42.9% had osteopenia, and 14.3% had osteoporosis. This shows a progressive decline in BMD with advancing age.

**Sex and Bone Mineral Density**
BMD distribution by sex is summarized in Table 3. Among females (n=44), 54.6% had normal BMD, 34.1% had osteopenia, and 11.4% had osteoporosis. In males (n=33), 45.5% had normal BMD, 51.5% had osteopenia, and 3.0% had osteoporosis. Overall, osteopenia was more common in males, while osteoporosis was more frequent in females.

**Neuropathy and Age Distribution**
Out of 77 participants, 26 (33.8%) were found to have neuropathy. Of these, 18 (69.2%) were Grade 1 and 8 (30.8%) were Grade 2. Neuropathy was rare in the 20–39 years group, with only 3 cases. The highest prevalence was seen in the 40–59 years group (19 cases), followed by those $\geq$ 60 years (4 cases). Grade 2 neuropathy was more frequent in older participants. Neuropathy distribution by age is presented in Table 4.

Statistical analysis was performed to examine the association of BMD with age and sex as well as BMD with neuropathy. The Pearson's Chi-square test revealed no significant association between age groups and BMD status ($\chi^2 = 3.37$, df = 2, $p = 0.186$). Similarly, the Likelihood ratio test ($\chi^2 = 3.56$, df = 2, $p = 0.169$) and the Linear-by-Linear association ($\chi^2 = 0.003$, df = 1, $p = 1.000$) also confirmed the absence of a significant trend.

Furthermore, Fisher's Exact test showed an Odds Ratio (OR) of 1.44 ($p = 0.494$), suggesting that although variations in BMD were observed across different sex and age categories, these differences did not reach statistical significance presented in Table 5. Since p = 0.0236 < 0.05, the relationship between age group and neuropathy grade is statistically significant. This means that neuropathy severity is significantly associated with age. The expected counts also show deviations, especially in: The 40–59 age group (more Grade 1 than expected), The 60+ group (more Grade 2 than expected). statistical significance presented in Table 6.

**Table 1: Socio-demographic data**

| Parameter | Sample | Minimum | Maximum | Mean | S. D |
|---|---|---|---|---|---|
| Age | 77 | 17 | 80 | 43.34 | 12.95 |
| BMI | 77 | 19 | 51 | 35.0 | 8 |
| Bone density | 77 | - 2.7 | 2.5 | -1.13 | 0.81 |

**Table 2: Distribution of BMD and Neuropathy according to age wise trend**

| Sex | BMD Group | | | |
|---|---|---|---|---|
| Age Group | Normal | Osteopenia | Osteoporosis | Total |
| 20-39 yrs. | 19 | 14 | 0 | 33 |
| | 57.6% | 42.4% | 0% | 100% |
| 40-59 yrs. | 18 | 16 | 3 | 37 |
| | 48.6% | 43.2% | 8.1% | 100% |

| 60 yrs. & more | 3 | 3 | 1 | 7 |
|---|---|---|---|---|
| | 42.9% | 42.9% | 14.3% | 100% |
| Total | 40 | 33 | 4 | 77 |
| | 51.9% | 42.9% | 5.2% | 100% |

**Table 3: Correlating Gender with BMD**

| Sex | BMD Group | | | |
|---|---|---|---|---|
| | Normal | Osteopenia | Osteoporosis | Total |
| Female | 24 | 15 | 5 | 44 |
| | 54.55% | 34.09% | 11.36% | 100% |
| Male | 15 | 17 | 1 | 33 |
| | 45.45% | 51.52% | 3.03% | 100% |
| Total | 39 | 32 | 6 | 77 |
| | 50.65% | 41.56% | 7.79% | 100% |

**Table 4: Distribution of neuropathy with age with grade**

| Neuropathy | | |
|---|---|---|
| Age Group | Grade 1 | Grade 2 |
| 20-39 yrs. | 1 | 2 |
| 40-59 yrs. | 16 | 3 |
| 60 yrs. & more | 1 | 3 |
| Total | 18 | 8 |

**Table 5: Association between bone mineral density and age of participants**

| | Value | df | Asymptomatic significance (two sided) | Exact sign. (2 sided) |
|---|---|---|---|---|
| Pearson $\chi^2$ | 3.37 | 2 | 0.186 | 0.186 |
| Likelihood ratio | 3.56 | 2 | 0.169 | 0.169 |
| Linear -by - linear association | 0.003 | 1 | 1.000 | 1.000 |
| Fisher's Exact test | OR= 1.44 | - | - | 0.494 |

**Table 6: correlation between BMD age group and neuropathy grade**

| Statistic | Value |
|---|---|
| Chi-square ($\chi^2$) | 7.49 |
| Degrees of freedom (df) | 2 |
| p-value | 0.0236 |

## DISCUSSION

This camp-based study set out to understand the relationship between bone mineral density (BMD) and peripheral neuropathy in a community setting. The average BMD T-score in our participants ($-1.13 \pm 0.81$) suggested that many were leaning toward osteopenia rather than having completely healthy bones. In fact, nearly half of the participants (41.6%) had osteopenia and around 8% had osteoporosis. This pattern reflects what has been reported globally osteopenia is far more common than osteoporosis and often acts as a warning stage before more severe bone loss develops [4,11].

Age had a clear impact on bone health in our study. Most cases of osteopenia were seen in the 40–59 age group, while osteoporosis became more prominent in participants above 60 years. This is expected, as advancing age is strongly linked with accelerated bone loss due to hormonal decline, reduced calcium absorption, and other metabolic changes [5, 8,12]. Women were more affected by osteoporosis than men (11.36% vs. 3.03%), which is consistent with the well-

documented role of estrogen deficiency after menopause [8,12,19]. Interestingly, men in our study showed higher rates of osteopenia, which highlights an often-overlooked issue: bone health problems in men are under-recognized, despite their significant contribution to fracture risk [18]. Neuropathy was also quite common, affecting about one-third of participants. Most cases were mild (grade I), though some showed more advanced involvement (grade II). Neuropathy was most frequent in the middle-aged group, which aligns with previous research linking aging and diabetes-related nerve dysfunction [21–23]. Since peripheral nerves help regulate bone metabolism, their impairment can indirectly contribute to weaker bones through reduced physical activity, poor nutrition, and chronic inflammation [20,21]. In our data, people with neuropathy tended to have lower BMD, but the relationship was not statistically significant (p = 0.186). This could be due to the limited sample size, as other studies have hinted at a possible link between neuropathy and osteoporosis [22].

Our statistical tests (chi-square, likelihood ratio, Fisher's exact test) consistently showed no significant association between bone density and age of participants. Still, the odds ratio (1.44) suggested a possible trend toward higher neuropathy in people with low bone density. Larger and more targeted studies may be needed to confirm this association. We found significant association between BMD age group and neuropathy severity ($\chi^2$ = 7.49, p = 0.0236), indicating that neuropathy tends to progress with increasing age. This finding aligns with previous studies reporting that advancing age is an independent risk factor for both the prevalence and severity of peripheral neuropathy [25,26]. Age-related structural and functional changes, including axonal degeneration, reduced nerve conduction velocity, and impaired regeneration, contribute to increasing neuropathic severity [27]. Additionally, oxidative stress, mitochondrial dysfunction, and accumulation of advanced glycation end

products (AGEs) in older adults accelerate neuronal damage [28-29].

What stands out from this study is the practical value of simple, camp-based screening tools. While DXA remains the gold standard for diagnosing osteoporosis [9,10], its high cost and limited availability make it unsuitable for widespread community use. In contrast, calcaneal QUS is portable, inexpensive, radiation-free, and effective in identifying individuals who need further testing [14–17]. Similarly, VPT is a straightforward, non-invasive method for detecting neuropathy early [23,24]. Using both together in health camps offers an affordable and realistic strategy to pick up two important problems bone loss and nerve damage before they progress to serious complications.

Overall, our findings show that osteopenia is widespread in this community sample, and neuropathy is also relatively common. we did find a statistically significant association between the two, the overlap is clinically meaningful. Early detection through low-cost methods like QUS and VPT can play an important role in prevention strategies, particularly in resource-limited settings.

This camp-based study had several strengths, including the use of portable, non-invasive tools like calcaneal QUS and VPT, which made early detection of low bone density and neuropathy feasible in a community setting. Assessing both bone health and peripheral nerve function together provided a more comprehensive view of musculoskeletal and neurological risk. However, the study also had limitations: the small sample size and camp-based design limited statistical power and generalizability, DXA confirmation was not performed, and biochemical factors such as vitamin D or calcium levels were not measured. Additionally, voluntary participation may have introduced selection bias, meaning the findings might not fully represent the wider population.

## CONCLUSION

This camp-based study highlights that low bone density, especially osteopenia, is quite common in the community, while osteoporosis affects fewer but still significant numbers, particularly among older adults and women. Neuropathy was also frequent, though we did not find a strong statistical link between neuropathy and bone loss in this small sample. What matters, however, is that both conditions can quietly progress without obvious symptoms until serious complications appear. Simple, affordable tools like calcaneal ultrasound and vibration perception testing make it possible to identify people at risk early, even outside hospital settings. By using such approaches in health camps, we can bring timely awareness, prevention, and care to communities that may otherwise remain underserved.

### *Declaration by Authors*

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