Epidemiology and Regional Variability in Knee Bone Mineral Density: Application of a CT-based Classification

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INTRODUCTION Prospective research by Huang et al. has found significant associations between BMD and both postoperative pain and functional recovery following total knee arthroplasty (TKA) using pre-operative dual-energy absorptiometry (DXA) and postoperative MicroCT imaging and compression testing.[1] The actual prevalence of regional knee osteoporosis and variability across knee regions remains unclear, as local knee DXA is not part of general bone health assessment.[2] This study aimed to assess (1) overall epidemiology of bone mineral density (BMD) classification among patients 50 years of age and older, and (2) consistency between knee regions and BMD classification categories.

METHODS: A search was performed from 2008-2025 for patients with non-contrast phantomless CT including the knee using a study database. 306 patients were included (mean age 66.9, SD 9.0; 157 females, 149 males) with similar age distribution by sex (p=0.308). Individuals under age 50, with history of femoral or tibial fractures or knee surgeries, CT non-inclusive of the entire knee, CT not acquired at 120kV, or known metabolic bone disease other than osteopenia and osteoporosis were excluded. The majority (99.3%) of CT was obtained for robotic-assisted hip or knee arthroplasty. Mean Hounsfield Units (HU) were measured using 15mm of trabecular bone on axial CT. Prior research has found good diagnostic accuracy for BMD assessment for knee CT HU vs. DXA, with area under the curve >0.8, for six regions.[3] Regions measured in this study matched these six regions: entire distal femur epiphysis (DFE), medial femoral condyle (MFC), lateral femoral condyle (LFC), entire proximal tibia epiphysis (PTE), medial tibial plateau (MTP), and lateral tibial plateau (LTP). BMD was classified separately for each region using previously reported HU reference values.[3] Data were checked for normal distribution (Shapiro-Wilk test). Associations between variables were assessed using Pearson's or Spearman's correlation coefficient, and pairwise comparison performed with one-way ANOVA or Kruskal Wallis tests, depending on data normality. A p-value <0.05 was considered statistically significant.

RESULTS: Analysis was performed on 306 patients (mean age 66.9±9.0; 51.3% females). Overall, based on most severe BMD classification identified across all knee regions, osteoporosis was present in 42.5%, osteopenia in 36.9%, and normal BMD in 20.6% (**Table 1, Fig. 1**). Knee BMD classification was variable across regions in 58.2% and consistent in 41.8%. Osteoporosis prevalence was significantly higher among hip arthroplasty patients vs. knee arthroplasty patients (54.5% vs. 38.0%; p=0.008). Females had higher osteoporosis prevalence vs. males (57.3% vs. 26.8%, respectively, p<0.001) and lower mean HU vs. males for all regions (p<0.001). Prevalence of each BMD classification was significantly different when stratified by age (<65 and ≥65) for all categories (p<0.05) except osteopenia (all p>0.05), and significantly different when stratified by sex for all categories (p<0.05) except osteopenia <65 (all p=0.821); (**Fig. 2**). Regional analysis revealed overall osteoporosis prevalence of 35.9% in DFE, 30.1% MFC, 36.3% LFC, 26.8% PTE, 24.2% MTP, and 23.5% LTP. Regional HU values were positively correlated with bodyweight (e.g., PTE: r=0.363, p<0.001).

DISCUSSION: High knee osteoporosis prevalence was found among a predominately knee and hip arthroplasty population, 42.5% overall, with osteoporosis present in at least one knee region. Variation in BMD classification across knee regions was found in 58.2% of patients.

SIGNIFICANCE/CLINICAL RELEVANCE: Knowledge of compartmental knee BMD can be helpful for surgical planning and fracture risk prediction.

REFERENCES:

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Table 1. Overall BMD classification stratified by age and sex.

Results	Age	Overall N (%)	Females N (%)	Males N (%)	Females vs. Males
		N=306	N=157	N=149	p-value[†]
Impaired BMD*	Overall	243 (79.4)	142 (90.4)	101 (67.8)	**<0.001**
Osteoporosis*	Overall	130 (42.5)	90 (57.3)	40 (26.8)	**<0.001**
Osteopenia*	Overall	113 (36.9)	52 (33.1)	61 (40.9)	0.157
Normal BMD*	Overall	63 (20.6)	15 (9.6)	48 (32.2)	**<0.001**
		N=132	N=62	N=70	
Impaired BMD*	<65	94 (71.2)	53 (85.5)	41 (58.6)	**<0.001**
Osteoporosis*	<65	40 (30.3)	27 (43.5)	13 (18.6)	**0.002**
Osteopenia*	<65	54 (40.9)	26 (41.9)	28 (40.0)	0.821
Normal BMD*	<65	38 (28.8)	9 (14.5)	29 (41.4)	**<0.001**
		N=174	N=95	N=79	
Impaired BMD*	≥65	149 (85.6)	89 (93.7)	60 (75.9)	**<0.001**
Osteoporosis*	≥65	90 (51.7)	63 (66.3)	27 (34.2)	**<0.001**
Osteopenia*	≥65	59 (33.9)	26 (27.4)	33 (41.8)	**0.046**
Normal BMD*	≥65	25 (14.4)	6 (6.3)	19 (24.1)	**<0.001**

[†]*Chi-squared test.*
Impaired BMD=osteopenia or osteoporosis. Bold=highest prevalence category.
e classification across all knee regions.

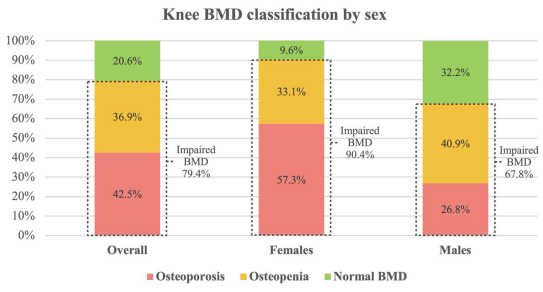

Fig 1. Bone mineral density classification results for the overall cohort, females and males.

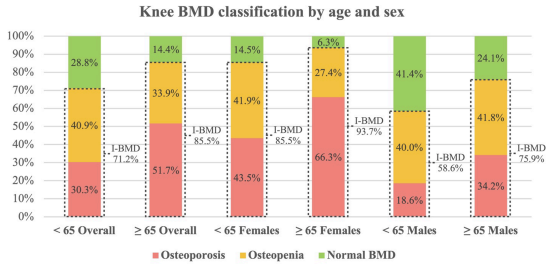

Fig 2. Bone mineral density classification results stratified by age for the overall cohort, females and males; I-BMD=impaired BMD.