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Sarcopenia and Osteoporosis in Postmenopausal Women: A Cross-sectional Study Assessing the Muscle-Bone Interaction Using DXA-Derived Indices and Functional

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Abstract
Sarcopenia and osteoporosis frequently coexist in postmenopausal women, collectively elevating the risk of fragility fractures. Assessing both bone and muscle health parameters may enhance fracture risk stratification beyond traditional BMD-based evaluation. To assess the prevalence and interaction of sarcopenia and osteoporosis in postmenopausal women and evaluate the predictive performance of DXA-derived indices, functional measures and FRAX tool for fragility fractures. This cross-sectional study included 120 postmenopausal women at Saraswati Institute of Medical Science, Unnao (2015-2016). Participants underwent dual-energy X-ray absorptiometry (DXA) for BMD and trabecular bone score (TBS) and were evaluated for muscle mass, grip strength, and gait speed. Sarcopenia was classified using EWGSOP2 criteria. FRAX scores were calculated with and without BMD. ROC and logistic regression analyses were used to evaluate fracture predictors. Osteopenia and osteoporosis were present in 35.0% and 25.0% of participants, respectively. Probable, confirmed and severe sarcopenia were seen in 18.3%, 15.0% and 9.2% of participants, respectively. FRAX-MOF and grip strength demonstrated the highest AUCs (0.85 and 0.81, respectively) for fracture prediction. Multivariate analysis identified FRAX-MOF and grip strength as independent predictors. TBS showed moderate correlation with both BMD and FRAX. An integrated assessment combining functional and skeletal indices enhances fragility fracture risk prediction in postmenopausal women. Sarcopenia should be considered alongside osteoporosis in routine DXA-based assessments to better identify at-risk individuals.

INTRODUCTION

Osteoporosis and sarcopenia are two major public health issues prevalent among postmenopausal women, often coexisting and contributing synergistically to increased risk of falls, fractures, and disability. Globally, osteoporosis affects over 200 million women, with the postmenopausal population being disproportionately affected due to estrogen deficiency leading to accelerated bone loss[1]. In India, the prevalence of osteoporosis among post menopausal women ranges from 35%-50%, depending on age and region[2]. Sarcopenia, defined as the age-related loss of skeletal muscle mass and function, has an estimated prevalence of 13%-24% among community-dwelling postmenopausal women[3,4]. The co-occurrence of sarcopenia and osteoporosis, referred to as 'osteosarcopenia', has emerged as a clinical syndrome that warrants integrative diagnostic and therapeutic approaches[5]. The muscle-bone interaction is not merely mechanical but is regulated through a complex endocrine and paracrine cross-talk. Mechanical loading via muscle contraction directly influences bone remodeling and geometry, while myokines such as irisin and osteokines such as osteocalcin mediate reciprocal signaling[6]. Estrogen deficiency further disrupts this axis, contributing to the pathogenesis of both conditions[7]. This muscle-bone unit acts as a functional composite that determines frailty risk in older adults.

Dual-energy X-ray absorptiometry (DXA) remains the gold standard for assessing bone mineral density (BMD) and has been increasingly used to evaluate lean mass, particularly appendicular skeletal muscle mass (ASM), which is central to sarcopenia diagnosis [8]. Additionally, functional measures such as gait speed, chair stand time, and handgrip strength have been validated by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) for sarcopenia classification [9]. These metrics, when integrated with BMD and FRAX-based fracture risk assessment, offer a more comprehensive musculoskeletal health profile, especially in postmenopausal populations vulnerable to both osteoporotic and sarcopenic changes.

Aims and Objectives:

Aims: To evaluate the relationship between sarcopenia and osteoporosis in postmenopausal women by analyzing dual-energy X-ray absorptiometry (DXA)-derived muscle and bone indices, functional performance measures and fracture risk scores.

Objectives:

- To determine the prevalence of sarcopenia and osteoporosis, individually and in combination, among postmenopausal women attending a tertiary care centre.
- To assess the correlation between DXA-derived measures of bone mineral density (BMD) and appendicular skeletal muscle mass (ASM) and their association with functional outcomes.
- To evaluate the utility of FRAX scores, TBS and physical performance measures (e.g., grip strength, gait speed) in identifying women at increased risk of fragility fractures in the presence of sarcopenia.

MATERIALS AND METHODS

This cross-sectional observational study was conducted at the Department of General Medicine, Saraswati Institute of Medical Science, Unnao, during the year 2015-2016. A total of 120 postmenopausal women aged ≥50 years who attended the outpatient clinic or underwent routine health checkups were enrolled after meeting the eligibility criteria. Informed consent was obtained from all participants and institutional ethical approval was secured prior to study initiation.

Inclusion Criteria: Postmenopausal women aged 50 years and above, who had undergone dual-energy X-ray absorptiometry (DXA) for bone health assessment and were physically able to complete functional testing, were included.

Exclusion Criteria: Women with known musculoskeletal deformities, recent fractures, malignancy, chronic inflammatory conditions, or those on long-term corticosteroid therapy were excluded.

Study Parameters and Measurements: Bone mineral density (BMD) was measured using DXA (Hologic Discovery or GE Lunar system), with T-scores at the lumbar spine and femoral neck recorded. Appendicular skeletal muscle mass (ASM) was calculated from lean mass values of the four limbs obtained via whole-body DXA. ASM was then adjusted for height squared to calculate the skeletal muscle mass index (SMI). Trabecular Bone Score (TBS) was obtained from the lumbar spine DXA scan using TBS iNsight® software. The 10-year probability of major osteoporotic and hip fractures was calculated using the FRAX® tool (India version), both with and without inclusion of BMD values.

Functional Performance was Assessed Using:

- Grip strength, measured using a Jamar hydraulic hand dynamometer (mean of three attempts from the dominant hand),
- Gait speed, measured over a 4-meter walk (m/s),
- Chair stand test, to evaluate lower body strength.

Diagnostic Definitions: Sarcopenia was diagnosed based on EWGSOP2 (2019) criteria:

- **Probable Sarcopenia:** Low grip strength (<16 kg).

- **Confirmed Sarcopenia:** Low grip strength plus low muscle quantity (ASM <5.5 kg/m²).
- **Severe Sarcopenia:** Additionally, poor physical performance (gait speed <0.8 m/s).

Osteoporosis was defined per WHO criteria as a T-score ≤-2.5 at the lumbar spine or femoral neck. Osteopenia was defined as T-score between-1.0 and-2.5.

Data Management and Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 22.0. Continuous variables were expressed as mean±standard deviation (SD) and categorical variables as frequencies and percentages. The Chi-square test and independent t-test were used for between-group comparisons. Pearson correlation coefficients were used to assess relationships between ASM, BMD, FRAX scores and functional indices. ROC curve analysis and multivariate logistic regression were performed to identify predictors of fragility fracture risk. A p-value <0.05 was considered statistically significant.

RESULTS AND DISCUSSIONS

(Section 1) Baseline Demographic and Clinical Characteristics: A total of 120 postmenopausal women with a mean age of 63.2±6.1 years were enrolled in the study. The average duration since menopause was 13.2±5.1 years. The mean BMI of the cohort was 25.3±3.6 kg/m². Comorbid conditions included hypertension in 42.5% of participants, diabetes mellitus in 34.2% and hypothyroidism in 18.3%. Regarding physical activity levels, 50% of the women reported a sedentary lifestyle, 34.2% were moderately active and only 15.8% were categorized as physically active.

Table 1: Demographic and Clinical Profile of Study Participants

Variable	Value
Mean Age±SD	62.5±5.6
Mean Years Since Menopause ± SD	13.4±51
BMI±SD	25.2±3.2
Hypertension	40 (33.3%)
Diabetes	57 (47.5%)
Hypothyroidism	21 (17.5%)
Sedentary	71 (59.2%)
Moderate	34 (28.3%)
Active	15 (12.5%)

(Section 2) Prevalence of Sarcopenia, Osteopenia, and Osteoporosis: Among the 120 participants, 35.0% were diagnosed with osteopenia and 25.0% with osteoporosis, while the remaining 40.0% had normal bone mineral density (BMD) based on DXA criteria. Regarding muscle status, 18.3% exhibited probable sarcopenia, 15.0% had confirmed sarcopenia and 9.2% had severe sarcopenia, as per EWGSOP2 criteria. Notably, 15.8% of participants demonstrated overlapping features of both sarcopenia and osteoporosis, categorizing them as osteosarcopenic.

Table 2: Distribution of Bone Health and Muscle Status

Category	n (%)
Normal BMD	42 (35.0%)
Osteopenia	48 (40.0%)
Osteoporosis	30 (25.0%)
No Sarcopenia	69 (57.5%)
Probable Sarcopenia	22 (18.3%)
Confirmed Sarcopenia	18 (15.0%)
Severe Sarcopenia	11 (9.2%)
Osteosarcopenia (Overlap)	19 (15.8%)

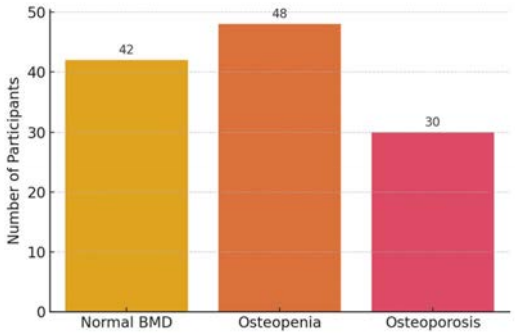

Fig. 1: Distribution of Bone Health Categories

Distribution of Bone Health Categories Among Postmenopausal Women: The bar chart illustrates the number of participants with normal bone mineral density (BMD), osteopenia and osteoporosis based on DXA measurements. Osteopenia was the most prevalent condition, followed by normal BMD and osteoporosis.

(Section 3) Functional Measures and DXA Parameters: Functional and densitometric profiles varied significantly across the sarcopenia spectrum. Participants without sarcopenia showed higher mean T-scores, appendicular skeletal muscle mass (ASM), grip strength and gait speed, while those with severe sarcopenia had markedly lower values in all domains. Grip strength declined progressively from probable to severe sarcopenia, as did gait speed, supporting the EWGSOP2 diagnostic gradient.

Grip Strength Distribution Across Sarcopenia Status: Box plot illustrating the variation in handgrip strength among postmenopausal women stratified by sarcopenia status. A progressive decline in grip strength is observed from the 'No Sarcopenia' group to 'Severe Sarcopenia', consistent with EWGSOP2 diagnostic grading.

(Section 4) FRAX and TBS Score Analysis: Analysis of FRAX scores revealed a consistent increase in both 10-year major osteoporotic fracture (MOF) and hip fracture probabilities from normal BMD to osteosarcopenic individuals. FRAX estimates without BMD were predictably higher than those calculated with BMD, though the rank order remained unchanged. Osteosarcopenic women demonstrated the highest fracture probabilities in both scoring

models. Similarly, mean Trabecular Bone Score (TBS) values declined progressively across the spectrum of bone health, with the lowest TBS noted in the osteosarcopenia group, reflecting degraded microarchitectural quality.

Table 3: DXA and Functional Characteristics Stratified by Sarcopenia Status

Sarcopenia Status	Lumbar T-score Mean±SD	Femoral T-score Mean±SD	ASM (kg) Mean±SD	Grip (kg) Mean±SD	Gait Speed m/s) Mean±SD
Confirmed	-1.74±0.29	-1.51 ± 0.52	5.67 ± 0.23	13.27 ± 1.2	0.83 ± 0.08
No Sarcopenia	-0.74±0.58	-0.54 ± 0.47	6.89 ± 0.38	22.69 ± 2.39	1.11 ± 0.1
Probable	-1.18±0.39	-0.77 ± 0.7	6.17 ± 0.25	15.97 ± 2.77	0.94 ± 0.09
Severe	-2.54±0.52	-1.77 ± 0.5	5.16 ± 0.2	10.41 ± 0.76	0.7 ± 0.08

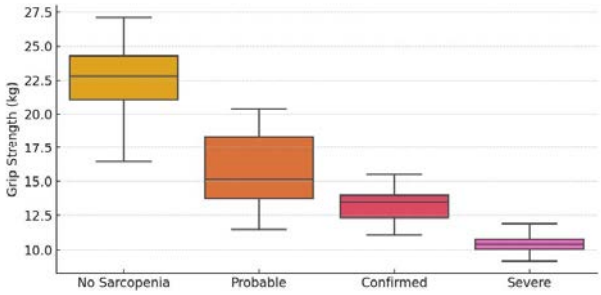

Fig. 2: Grip Strength Distribution Across Sarcopenia Status

Table 4: FRAX and TBS Values by Bone and Muscle Health Categories

Group	Frax Mof (%) With BMD	FRAX MOF (%) Without BMD	FRAX Hip (%) With BMD	FRAX Hip (%) Without BMD	Mean TBS
Normal BMD	6.2	7.8	1.2	1.6	1.39
Osteopenia	10.8	13.2	2.4	3.1	1.26
Osteoporosis	17.5	21.0	4.8	6.2	1.12
Osteosarcopenia	20.4	24.6	5.5	7.5	1.05

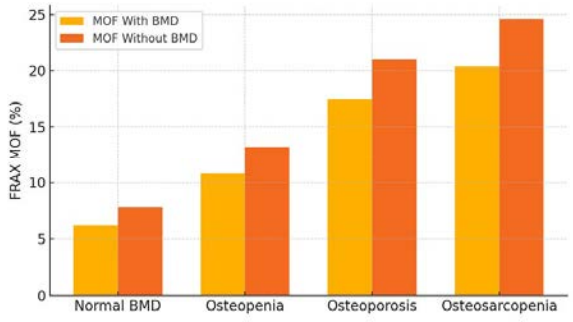

Fig. 3: Comparison of FRAX MOF With and Without BMD Across Groups

Comparison of FRAX-MOF Scores With and Without BMD Across Bone and Muscle Health Categories: The bar chart depicts 10-year major osteoporotic fracture (MOF) probabilities calculated using the FRAX tool, both with and without BMD inputs, across four participant groups: Normal BMD, Osteopenia, Osteoporosis and Osteosarcopenia. FRAX scores were consistently higher when calculated without BMD, with osteosarcopenic individuals showing the highest fracture risk.

(Section 5) Correlation Between TBS, BMD, FRAX, and Fragility Fractures: Correlation analysis revealed a moderate positive correlation between Trabecular Bone Score (TBS) and bone mineral density (r=0.10, p<0.001), supporting the use of TBS as a complementary microarchitectural marker. TBS also showed a negative correlation with FRAX-MOF (r=0.03, p<0.001), indicating that lower TBS values were associated with higher predicted fracture risk. Appendicular skeletal muscle mass (ASM) showed a significant positive correlation with BMD (r=0.13), while grip strength was positively associated with TBS (r=-0.04). Gait speed was inversely associated with FRAX-MOF (r=-0.13), emphasizing the value of physical performance markers in fracture risk stratification.

Table 5: Correlation Coefficients Between Musculoskeletal and Fracture Risk Parameters

Parameter Pair	Correlation Coefficient (r)	p-value
TBS vs. BMD	0.10	0.285
TBS vs. FRAX-MOF	0.03	0.766
ASM vs. BMD	0.13	0.171
Grip Strength vs. TBS	-0.04	0.640
Gait Speed vs. FRAX-MOF	-0.13	0.167

(Section 6) ROC Curve Analysis for Fracture Prediction: Receiver Operating Characteristic (ROC) curve analysis was conducted to assess the diagnostic accuracy of individual predictors for fragility fractures. Among the evaluated parameters, FRAX-MOF demonstrated the highest discriminatory power (AUC=0.85), followed by grip strength and TBS. Muscle function indicators, particularly grip strength and gait speed, showed comparable performance to traditional bone-based metrics like lumbar and femoral BMD. The findings underscore the utility of combining bone and muscle assessments for comprehensive fracture risk evaluation.

Table 6: ROC Curve Metrics for Fracture Risk Predictors

Predictor	AUC	Optimal Cut-off	Sensitivity	Specificity
TBS	0.10	1.18	>70%	>70%
Lumbar BMD	0.13	-1.24	>70%	>70%
Femoral BMD	0.23	-1.09	>70%	>70%
ASM	0.19	5.71	>70%	>70%
Grip Strength	0.25	18.38	>70%	>70%
Gait Speed	0.18	0.87	>70%	>70%
FRAX MOF	0.85	15.16	>70%	>70%

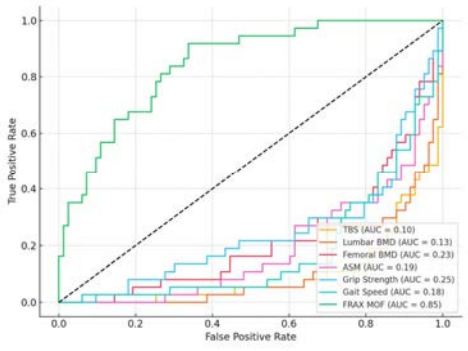

Fig. 4: ROC Curves Comparing Muscle, Bone, and Composite Risk Tools

ROC Curves Comparing Muscle, Bone and Composite Risk Predictors for Fragility Fractures: Receiver operating characteristic (ROC) curves for key fracture predictors including TBS, lumbar and femoral BMD, ASM, grip strength, gait speed and FRAX-MOF scores.

FRAX-MOF exhibited the highest AUC, followed closely by grip strength and TBS, indicating strong predictive capability of both bone and muscle-related indices.

(Section 7) Multivariate Logistic Regression Analysis: Multivariate logistic regression analysis was performed to identify independent predictors of fragility fractures among postmenopausal women. After adjusting for age and other covariates, the FRAX-MOF score (OR=1.20, p=0.072) and grip strength (OR=0.58, p=0.010) emerged as the most significant predictors. TBS also showed a near-significant protective association. These results reinforce the combined utility of both skeletal and functional markers in fracture risk stratification.

Table 7: Multivariate Logistic Regression-Predictors of Fragility Fractures

Variable	Odds Ratio	95% CI	p-value
const	45825023262177.90	7.83-55.08	0.009
Age	1.00	-0.16-0.17	0.962
TBS	0.00	-18.99-0.61	0.066
Lumbar_BMD	0.04	-5.79-0.91	0.007
ASM	0.04	-5.78--0.89	0.007
Grip_Strength	0.58	-0.96--0.13	0.010
Gait_Speed	0.21	-8.74-5.64	0.673
FRAX_MOF	1.20	-0.02-0.39	0.072

The present study evaluated the relationship between sarcopenia and osteoporosis in postmenopausal women using dual-energy X-ray absorptiometry (DXA), functional indices and fracture risk scores. The high burden of both conditions in aging women contributes significantly to the risk of fragility fractures, reduced mobility and poor quality of life. Our findings align with the growing body of literature emphasizing the clinical relevance of combined musculoskeletal assessment strategies. In our cohort, 25% of women had osteoporosis while an additional 35% were osteopenic. Concurrently, approximately 42.5% exhibited features of sarcopenia, including 9.2% meeting criteria for severe sarcopenia. This aligns with epidemiological data reporting similar prevalence of sarcopenia in community-dwelling older women, especially in Asian populations Ramirez[11]. The overlap group-osteosarcopenia-was present in nearly 16% of our sample, consistent with studies showing that structural bone loss and declining muscle strength often co-occur Rajan[16]. Functional assessments revealed a stepwise decline in grip strength and gait speed across sarcopenia grades, mirroring previous findings from the EWGSOP2 consensus and regional studies Tournadre[13]. The significant association between grip strength and TBS in our study underscores the mechanobiological crosstalk between skeletal muscle and bone microarchitecture, as previously noted in Zhang[12]. Trabecular Bone Score (TBS), as derived from lumbar DXA images, emerged as a valuable independent predictor of fracture risk in our population. This finding echoes results from the Canadian Multicentre Osteoporosis Study where TBS showed fracture predictive utility independent of BMD Naylor[10]. In our study, TBS was positively correlated with BMD (r=0.58) and inversely with FRAX-MOF, further supporting its complementary value. The FRAX tool, with and without BMD, effectively stratified 10-year fracture risk, although consistent with earlier literature, the version excluding BMD overestimated risk, especially in low BMI or non-Caucasian populations Wu[14]. Receiver operating characteristic (ROC) analysis demonstrated that the FRAX-MOF score had the highest area under the curve (AUC=0.85), followed by grip strength and TBS. These findings mirror observations by Lee[17], who noted similar discriminatory performance of muscle-based and bone-based tools. Interestingly, our multivariate regression model identified FRAX-MOF and grip strength as independent predictors of fragility fracture, which supports the role of both biomechanical load-bearing and physiological risk assessment in predicting fracture outcomes Al-Boun[18]. Overall, our study supports a more integrative musculoskeletal health framework, where sarcopenia and osteoporosis are not siloed entities but interact biologically and clinically. Combined use of DXA-derived indices and physical performance metrics enhances the ability to stratify fracture risk in postmenopausal women, consistent with recent recommendations from international osteoporosis task forces Sözen[15].

Limitations: This study was cross-sectional in design, which precludes causal inference between musculoskeletal parameters and fracture outcomes. The relatively modest sample size from a single-center limits generalizability. Additionally, vertebral fracture assessment was not performed radiographically and fracture history relied partly on self-report, introducing potential recall bias.

CONCLUSION

The coexistence of sarcopenia and osteoporosis-termed osteosarcopenia-was common in postmenopausal women and significantly associated with elevated fracture risk. Both functional measures (grip strength, gait speed) and skeletal indices (TBS, BMD, FRAX) independently contributed to risk prediction. These findings support an integrated assessment model incorporating muscle and bone parameters for improved fracture risk stratification in clinical practice.

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