Original Article

DOI: 10.7860/JCDR/2026/82606.23353

Radiology Section

Relationship between CT-derived Muscle Parameters and Bone Attenuation in the Indian Population: A Retrospective Observational Study

DEEPA REBECCA KORULA[1], VAMSI KRISHNA MADDINENI[2], P ROSELIN[3]

ABSTRACT

Introduction: Psoas muscle area and attenuation provide a practical, reproducible marker for overall skeletal muscle health and can be readily measured on routine abdominal Computed Tomography (CT). CT-derived femoral neck and lumbar vertebral attenuation have been proven as quantitative, reproducible imaging biomarkers of bone quality, which help in the detection and screening of osteoporosis. Thus, the combined assessment of CT-derived muscle parameters and bone attenuation may assist radiologists and clinicians in characterising the muscle-bone unit, and improving risk stratification for fractures, frailty, and adverse clinical outcomes.

Aim: To measure the psoas muscle area and attenuation, femoral neck attenuation, and lumbar vertebral attenuation across various age groups on plain CT abdomen scans and to assess the correlation between these parameters, age, and gender in the Indian population.

Materials and Methods: This retrospective observational study was conducted in the Radiology Department at Madha Medical College and Research Institute, Chennai, Tamil Nadu, India from January 2025 to June 2025. Analysis was done from July 2025 to August 2025. The study included consecutive CT abdomen studies of 796 patients (467 males and 329 females) in the age range of 11-90 years. The variables that were measured included the psoas area, psoas attenuation, Hounsfield Unit Average Calculation (HUAC), vertebral attenuation, and femoral neck attenuation. The association between age and outcome variables was assessed by Pearson's correlation coefficient at a 95% confidence interval.

Results: The overall mean age was 43.8±16.176 years. All the variables showed a decrease with increasing age, with a statistically significant decline (p-value <0.01) noted in the psoas muscle area and attenuation, femoral neck attenuation, and vertebral attenuation (particularly L3 and L4 vertebrae). Males exhibited significantly higher attenuation values at all vertebral levels (L1-L4), with a mean lumbar HU of 192.88±49.43 compared to 169.09±61.69 in females (p-value <0.001). Males showed a significantly larger psoas cross-sectional area (8.41±2.75 cm^2) compared to females (4.32±1.42 cm^2, p-value <0.001). The strongest correlation was found between the lumbar attenuation and the femur attenuation (r=0.690) and between the psoas attenuation and the HUAC (r=0.668). Weak correlation was found between the psoas area and the HUAC (r=0.095), all statistically significant (p-value <0.01).

Conclusion: The muscle and bone parameters measured on CT in the present study showed good correlation and these simple measurements on CT scans can be used in the future as prognostic indicators for osteosarcopenia, which may significantly assist in the treatment plan and prognostication of patients, especially in areas where Dual-energy X-Ray Absorptiometry (DXA) scan is unavailable.

Keywords: Bone mass, Computed tomography, Muscle, Osteosarcopenia

INTRODUCTION

Osteoporosis is a metabolic bone disease characterised by decreased bone mass leading to bone fragility and fracture susceptibility [1]. Based on the international consensus on osteopenia/osteoporosis by the World Health Organisation (WHO), osteoporosis can be defined as having a T-score ≤-2.5 Standard Deviation (SD) lower than the mean BMD of the same-gender reference population [2].

Sarcopenia is a condition characterised by progressive and generalised loss of skeletal mass, strength and function [3]. The Global Conceptual definition of sarcopenia comprises of both reduced muscle mass and strength as well as muscle-specific strength [4].

Early diagnosis of osteosarcopenia is important as both osteoporosis and sarcopenia are amenable to therapeutic interventions which include lifestyle interventions (adequate protein intake, exercise, vitamin D replacement) and novel pharmacotherapy agents [5].

Dual-energy X-ray Absorptiometry (DXA) is currently the gold standard recommended for the diagnosis of osteoporosis and sarcopenia however, it is not available at all centres.

With the widespread use of CT, several studies have shown a strong correlation between CT HU of different regions of interest in the lumbar spine and bone marrow density [6-10] stating that HU measurements on CT is a reliable, more convenient and cheaper method to predict osteoporosis. Psoas muscle area and density have also been described as prognostic indicators for sarcopenia [11]. The correlation between muscle attenuation (HU), muscle area and bone attenuation (femoral and vertebral HU) on CT has not been described, particularly in the Indian population, and that is the novelty of the current study. These simple measurements on CT can be used as prognostic indicators routinely and will significantly assist in the treatment plan and prognostication of patients with various chronic illnesses as well as those patients undergoing operative procedures especially in areas where a DXA scan is not available.

MATERIALS AND METHODS

This retrospective observational study was conducted in the Radiology Department at Madha Medical College and Research Institute, Chennai, Tamil Nadu, India, from January 2025 to June

2025. Analysis was done from July 2025 to August 2025. The study was approved by the Institutional Review Board (No: 2024/036)

Inclusion and Exclusion criteria: All patients aged >10 years who underwent non contrast CT abdomen scans in the department of Radiology, Madha Medical College, over the preceding two years were included in the study. Patients with lumbar vertebral or femoral neck fractures were excluded from the study. Patients with psoas haematoma or lesions were also excluded from the study.

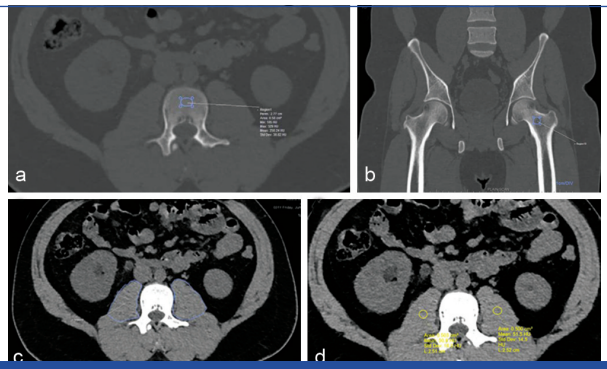
Study Procedure

All the CT abdomen scans were performed on a 32 slice Siemens machine and the study variables were measured as mentioned in [Table/Fig-1]. The scan type is a helical scan type with 2 mm acquisition at 0.75 mm reconstruction with pitch factor 0.938:1, rotation time 0.5 sec, 120 kV/200 mAs, detector coverage 24 mm, coverage speed 45 mm/sec, total exposure time 5 - 8 sec and a large Scan Field of View (SFOV).

[Table/Fig-2a-d] Illustrate how the variables were measured.

Study variables	CT
Psoas muscle area - measurement of the psoas muscle mass area at the level of the L3 vertebra.	Axial section
Psoas muscle attenuation - measurement of the average HU of the mid portion of the psoas muscle at the level of the L3 vertebra.	Axial section
Hounsfield Unit Average Calculation (HUAC)- measured by the formula (right area * density) + (left area * density)/ total area	NA
Vertebral HU - measurement of the average HU in the midportion of the L1-L4 vertebrae.	Axial section
Femoral neck HU - measurement of the average HU at the level of the femoral neck	Coronal section

[Table/Fig-1]: Study variables measured on CT.



[Table/Fig-2]: a) CT axial sections bone window shows measurement of the lumbar vertebra HU; b) CT coronal sections bone window shows the measurement of the femoral neck HU; c) CT axial sections soft-tissue window shows the measurement of the psoas area at the level of the L3 vertebra; d) CT axial sections soft-tissue window shows the measurement of the mid psoas HU at the level of the L3 vertebra.

All the measurements were obtained and interpreted by two radiologists with five- and eight-years experience. Each parameter was measured thrice and the average was entered. Psoas muscle area, psoas muscle attenuation, HUAC, vertebral attenuation and femoral neck attenuation were considered as outcome variables. Age and gender were considered as explanatory variables.

STATISTICAL ANALYSIS

Continuous variables were expressed as mean±SD, and categorical variables as frequencies and percentages. Right and left psoas values were averaged to obtain average psoas area and average psoas attenuation; lumbar vertebral levels (L1-L4) were averaged to calculate Average Lumbar Attenuation (ALA). Pearson's correlation coefficients evaluated associations among HUAC, ALA, femur HU, average psoas measurements, vertebral HU values, and age, with statistical significance set at p-value <0.01. Univariate linear regression assessed the relationship between age and individual imaging parameters, while multivariable regression identified predictors of HUAC, including age, gender, ALA, and femur neck HU. Differences between males and females were analysed using independent-samples t-tests, and right–left psoas comparisons used paired-samples t-tests. A two-tailed p-value<0.05 was considered statistically significant for all analyses except correlations. Statistical Pacakge for Social Sciences (SPSS) version 24.0 software was used for statistical analysis.

RESULTS

A total of 796 patients were included in the study out of which 467 were male (58%) and 329 were female (41 %) The overall mean age was 43.8±16.176 years.

The mean values of the femoral neck attenuation and average lumbar vertebra attenuation were 108.16±75.13 and 183.11±55.9, respectively [Table/Fig-3]. The mean of the psoas area was found to be slightly higher on the left-side as compared to the right however, this was not statistically significant (p-value=0.290). The mean of the psoas attenuation was found to be slightly higher on the right-side as compared to the left; however, this also was not statistically significant (p-value=0.113).

Variables	Mean±SD	Range
Right psoas area	6.73±3.07	0.6-13
Left psoas area	6.89±3.074	0.75-13
Right psoas attenuation	47.10±7.275	32.5-62
Left psoas attenuation	46.52±7.342	32-61
Femoral neck attenuation	108.16±75.13	-42-258
Average Lumbar Attenuation (ALA)	183.11±55.9	71-294
HUAC	47±9.2	28.6-65.4

[Table/Fig-3]: Descriptive statistics of outcome variables in the study population (N=796).

Increasing age was found to be associated with significant reduction in CT-derived muscle mass, muscle quality, and bone attenuation [Table/Fig-4].

Parameters	11-30 years (n=188)	31-50 years (n=320)	51-70 years (n=247)	71-90 years (n=41)	p-value
Average Psoas area	8.19±3.27	7.22±2.92	5.54±2.3	4.86±2.51	<0.001
Average Psoas attenuation	51.7±4.15	47.26± 5.37	43.73± 6.34	38.63± 10.01	<0.001
Femoral neck attenuation	143.44± 63.3	119.4± 55.85	64.65± 37.71	48.16± 28.99	<0.001
Lumbar attenuation	224.39± 37.84	201.2± 40.19	140.32± 45.38	105.51± 49.35	<0.001
HUAC	52.66± 13.13	47.25± 5.35	43.6±6.45	38.45 ±10.4	<0.001

[Table/Fig-4]: Descriptive statistics of muscle and bone attenuation parameters across age groups (N=796).
t-test was used

The HUAC demonstrated a moderate positive correlation with average lumbar vertebral attenuation, indicating that higher vertebral bone attenuation is associated with better muscle composition [Table/Fig-5].

Males showed a significantly larger psoas cross-sectional area (8.41±2.75 cm^2) compared to females (4.32±1.42 cm^2, p-value <0.001), reflecting greater muscle mass [Table/Fig-6].

Variables	Correlation coefficient (95% CI)	p-value
Average psoas area	-1.548 (-1.860 - -1.236)	<0.001
Average psoas attenuation	-0.935 (-1.066 - -0.805)	<0.001
Femur attenuation	-0.04 (-0.054 - -0.026)	<0.001
Average Lumbar Attenuation (ALA)	-0.026	>0.05
HUAC	0.616	<0.001

[Table/Fig-5]: Correlation between age and outcome variables.

Variables	Male	Female	t	p-value
Average Lumbar Attenuation (ALA) (L1–L4 mean HU)	192.88±49.43	169.09±61.69	6.027	<0.001
Femur (HU)	110.57±73.78	105.06±77.29	1.017	0.309
Hounsfield Unit Average Calculation (HUAC)	46.89±7.07	47.12±11.62	-0.341	0.733
Average psoas area	8.41±2.75	4.32±1.42	24.794	<0.001
Average psoas attenuation	47.3±7.48	46.81±7.01	0.929	0.353

[Table/Fig-6]: Comparison of variables measured on CT between male (n=467) and female (n=329).

The strongest correlation was found between the lumbar attenuation (HU) and the femur attenuation (HU) (r=0.690) and between the Psoas attenuation and the HUAC (r=0.668). Moderate correlation was found between the Psoas attenuation and the Lumbar attenuation (r=0.412). Weak correlation was found between the psoas area and the HUAC (r=0.095), but all are statistically significant (p-value <0.01) [Table/Fig-7].

Attenuation values of the lumbar vertebrae (L1-L4) and femoral neck showed expected patterns, with males exhibiting significantly higher HU values at all vertebral levels (p-value <0.001), indicative of greater bone mineral density. These findings are in line with literature documenting higher bone density in males [24,25], possibly due to greater mechanical loading and hormonal factors, and a higher prevalence of osteopenia/osteoporosis in females, especially postmenopausal. One study by Jang S et al., however, reported women had a higher mean L1 attenuation compared with men (p-value <0.008) until menopause, after which both groups had similar values [26].

Interestingly, despite the gender differences in vertebral HU, we found the HUAC values were not significantly different between males and females. Yoo T et al., in his study also described similar findings [23]. This may suggest that the HUAC, being a composite measure, may normalise interindividual variation and better reflect overall tissue density than isolated metrics.

Variables	Psoas area		Psoas attenuation		HUAC		Average Lumbar Attenuation (ALA)		Femur HU	
Psoas area	NA	NA	0.131	<0.01	0.095	<0.01	0.348	<0.01	0.236	<0.01
Psoas attenuation	0.131	<0.01	NA	NA	0.668	<0.01	0.412	<0.01	0.303	<0.01
Hounsfield Unit Average Calculation (HUAC)	0.095	<0.01	0.668	<0.01	NA	NA	0.359	<0.01	0.265	<0.01
Average Lumbar Attenuation (ALA)	0.348	<0.01	0.412	<0.01	0.359	<0.01	NA	NA	0.69	<0.01
Femur HU	0.236	<0.01	0.303	<0.01	0.265	<0.01	0.69	<0.01	NA	NA

[Table/Fig-7]: Correlation between outcome variables.

DISCUSSION

The present study evaluated the radiologic and morphometric parameters related to muscle and bone density in a large cohort of 796 patients using CT-based measurements. The findings provide valuable insight into the relationship between psoas muscle area and attenuation, vertebral bone density, femoral neck attenuation, and a composite metric- HUAC- as they relate to age and gender.

There was a statistically significant decline in the psoas area and attenuation, femoral HU, and lumbar vertebral HU with advancing age, in keeping with prior studies [12-17]. Murata Y et al., and Sasaki T et al., revealed that age ≥ 50 years was a risk factor for a decrease in psoas major area [12,18] while another cross-sectional study examining the influence of age and whole-body skeletal muscle mass in 468 participants using magnetic resonance imaging found that the skeletal muscle mass gradually increased until individuals were in their 30s and started to decrease around the ages of 45-50 years [19].

Kim Y et al., described a distinct decrease in vertebral attenuation with age, and that while attenuation values declined consistently with age in men, they declined abruptly in women aged >42 years [17]. Similar results have been described with regard to the proximal femoral neck attenuation, with Christensen DL et al., demonstrating that the proximal femoral HU measurement provided moderate-to-good correlations with DXA results [20].

Gender-based comparisons revealed significantly greater psoas muscle area in males as compared to females (8.41 cm^2 vs 4.32 cm^2, p-value<0.001), consistent with previous studies highlighting greater muscle mass in males due to hormonal and physiological differences [19,21,22]. No significant differences in psoas attenuation were observed between genders, suggesting comparable muscle quality, even though males possess larger muscle mass in keeping with several prior studies [21,23]. Lawlor MA et al., reported in a study on 193 patients that the Psoas Muscle Index (PMI) for males was 5.9±1.7 cm/m^2 and Psoas Muscle Density (PMD) was 48.4±5.5 HU and for females the PMI was 5.4±1.4 cm/m^2 and PMD was 48.18±5.5 HU [21]. This distinction may be important, as muscle attenuation (rather than size) is more closely associated with muscle function and frailty risk.

The current study was unique in the fact that the authors were able to demonstrate a good correlation between parameters measured on plain CT scans which can be used to assess for osteosarcopenia and may prove to be simple, reliable and more cost effective, especially in areas where DXA scan is unavailable.

Limitation(s)

Functional outcomes (e.g., physical performance, fracture history) were not assessed, limiting clinical correlation as this was a retrospective study. The inclusion of only radiologic parameters omits biochemical or hormonal factors that influence bone and muscle health. Future larger prospective studies may be necessary to consolidate the current study results.

CONCLUSION(S)

The present study highlights important age- and gender-related patterns in CT-based musculoskeletal metrics. While men have larger muscle mass and denser vertebrae, muscle quality (attenuation) appears similar across genders. HUAC correlates strongly with both muscle and bone parameters and holds promise as a simple, non invasive marker of body composition and health risk. These parameters measured on plain CT scans showed good correlation and will help in the future diagnosis, prognostication, and treatment of patients with sarcopenia and osteoporosis.

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PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Radiology, Madha Medical College, Chennai, Tamil Nadu, India.
2. Senior Resident, Department of Orthopaedics, SRM Medical College, Chennai, Tamil Nadu, India.
3. Associate Professor, Department of Radiology, Madha Medical College, Chennai, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Vamsi Krishna Maddineni,
Senior Resident, Department of Orthopaedics, SRM Medical College and Hospital, Chennai-603203, Tamil Nadu, India.
E-mail: boomshi.mbbs@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Aug 31, 2025
- Manual Googling: Dec 27, 2025
- iThenticate Software: Dec 31, 2025 (1%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Aug 08, 2025**
Date of Peer Review: **Dec 04, 2025**
Date of Acceptance: **Jan 03, 2026**
Date of Publishing: **May 01, 2026**