Estimating Bone Mineral Density and Muscle Mass from EOS Low Dose X-ray Imaging System

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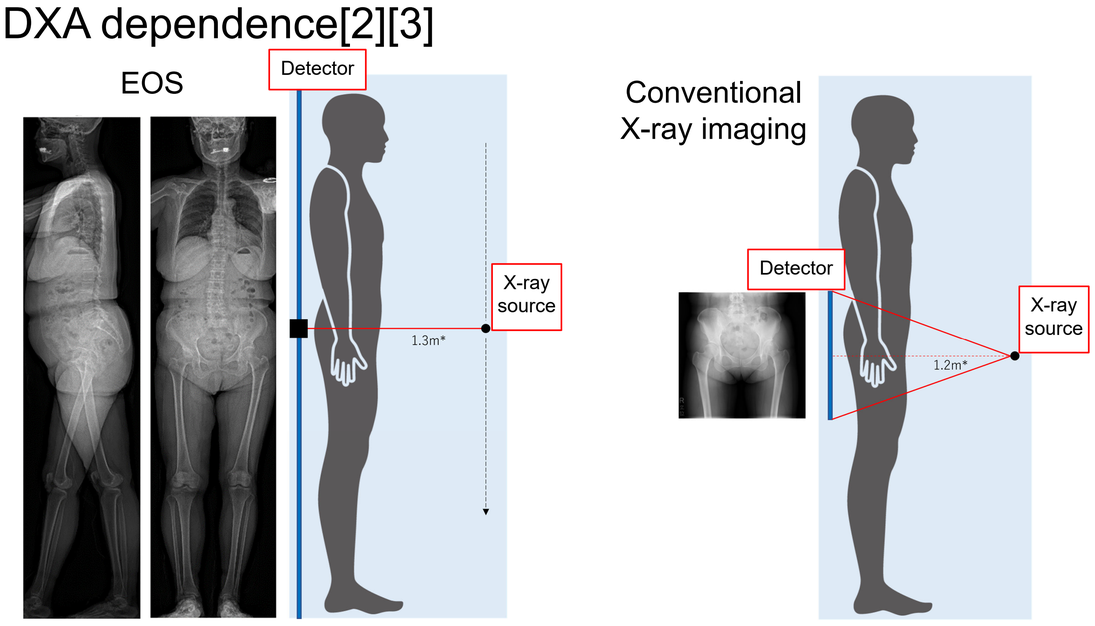
Introduction

- Low-dose EOS imaging enables full-body, biplanar X-rays for precise skeletal alignment and implant positioning in THA patients[1]
- Osteoporosis and sarcopenia risk quality of life, requiring early detection of bone mineral density and muscle mass
- Deep learning offers cost-effective BMD and muscle mass estimation from plain radiographs, reducing CT and DXA dependence[2][3]

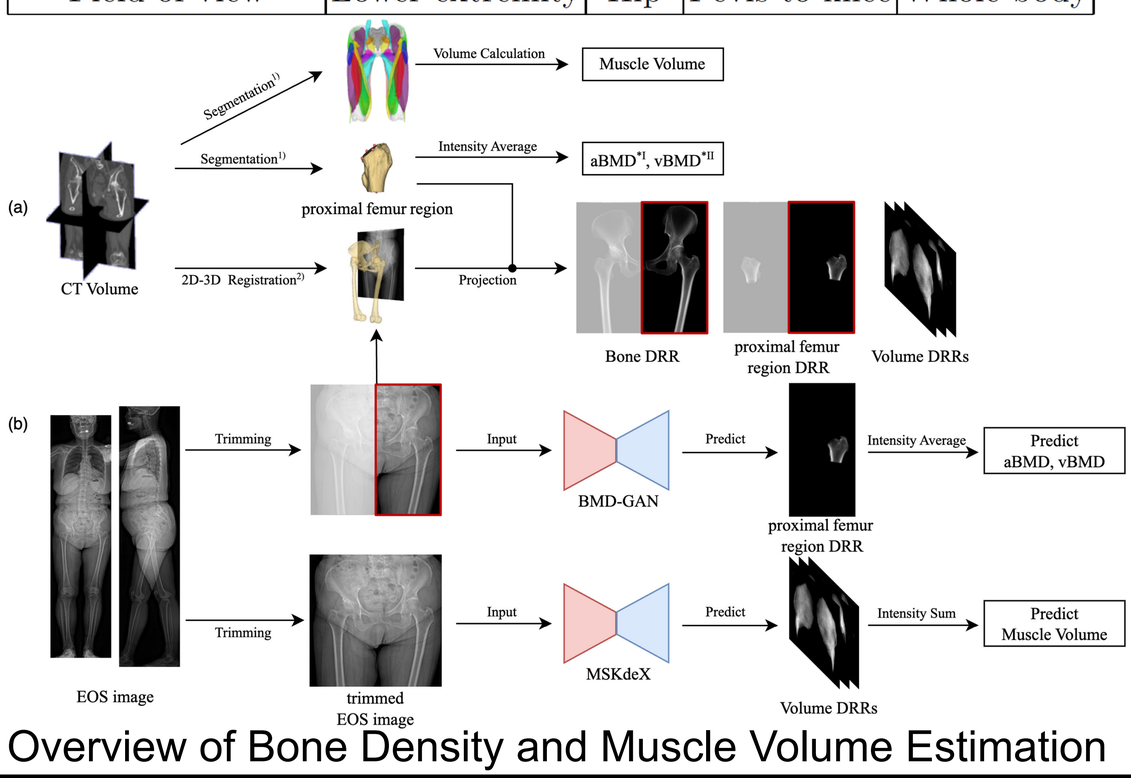


Methods

- Dataset included 600 CT and X-ray images for pre-training and 77 EOS–CT pairs for fine-tuning evaluation
- Ground truth BMD and muscle mass derived from CT using segmentation, 2D–3D registration, and DRR generation
- EOS images processed with BMD-GAN[2] and MSKdeX[3] models, fine-tuned to predict bone density and muscle volume

Details of the dataset used in this study

Acquired institution	Institution 1		Institution 2	
Purpose	pre-training		fine-tuning and testing	
Modality	CT	X-ray	CT	EOS
Data dimension	3D	2D	3D	2D
# of patients	600	600	77	77
# of images	600	2461[a]	77	77
Field of view	Lower extremity	Hip	Pevis to knee	Whole body

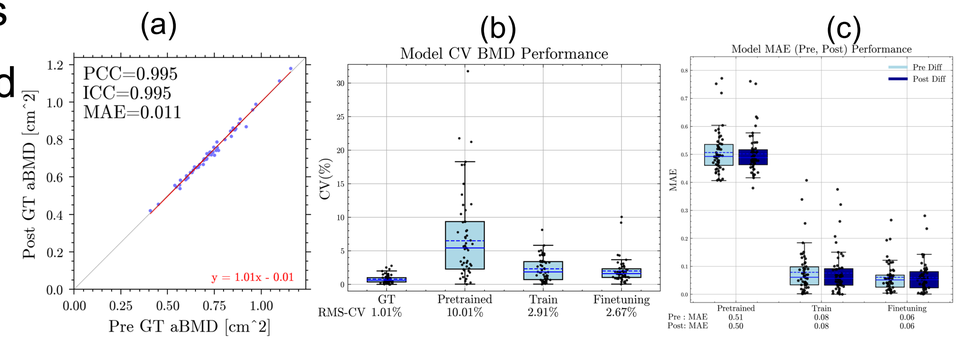


Overview of Bone Density and Muscle Volume Estimation

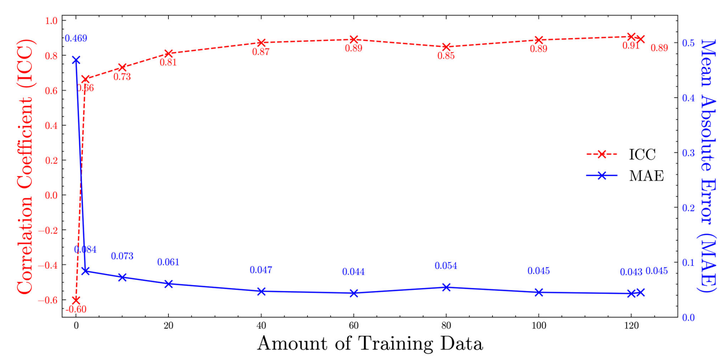
Results

- Fine-tuned model achieved the highest BMD prediction accuracy (PCC 0.916, ICC 0.894), surpassing pre-trained and scratch models
- Muscle mass estimation improved significantly with fine-tuning, especially for the iliopsoas muscle, showing higher ICC consistency
- Reliable pre-/postoperative BMD predictions with minimal error; performance stable even with only 40 paired EOS–CT images

BMD estimated from pre- and post-operative CT and EOS images.



Impact of training data size on prediction accuracy



BMD and Muscle Mass Estimation Results

Model type	BMD estimation	Muscle mass estimation Glu. max	Glu. med.	Glu. min.	Iliacus	Obt. ext.
PCC						
Train	0.791	0.705	0.753	0.63	0.792	0.701
Pre-trained	0.874	**0.821**	0.839	0.692	0.823	0.766
Linear calibration	0.869	0.798	0.832	0.670	0.805	0.740
Fine-tuning	**0.916**	0.795	**0.840**	**0.746**	**0.843**	**0.798**
ICC						
Train	0.710	0.483	0.655	0.596	0.721	0.647
Pre-trained	-0.604	0.344	0.568	0.579	-0.218	0.698
Linear calibration	0.861	**0.784**	**0.821**	0.629	**0.795**	0.719
Fine-tuning	**0.894**	0.631	0.772	**0.729**	0.763	**0.762**

Discussion

- Transfer learning from X-ray to EOS enables robust BMD and muscle mass estimation using limited training data
- Method maintains accuracy pre- and post-operatively, demonstrating feasibility for frequent low-dose monitoring in THA patients
- Future work includes multi-institutional data, domain adaptation, and longitudinal tracking to enhance generalizability and clinical impact

References

[1] Brage, K., Mussmann, B., Geijer, M., Larsen, P., Jensen, J.: Clinical application of EOS imaging system: a scoping review protocol. JBI evidence synthesis 21(5), 1009–1015 (2023).
[2] Gu, Y., Otake, Y., Uemura, K., Soufi, M., Takao, M., Talbot, H., Okada, S., Sugano, N., Sato, Y.: Bone mineral density estimation from a plain x-ray image by learning decomposition into projections of bone-segmented computed tomography. Medical Image Analysis 90, 102970 (2023).
[3] Gu, Y., Otake, Y., Uemura, K., Takao, M., Soufi, M., Hiasa, Y., Talbot, H., Okada, S., Sugano, N., Sato, Y.: MSKdeX: musculoskeletal (MSK) decomposition from an X-ray image for fine-grained estimation of lean muscle mass and muscle volume. In: International Conference on Medical Image Computing and Computer-Assisted Intervention. pp. 497–507. Springer (2023).

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