Effect of Body Size on the Quantification of Bone Mineral Density from QCT Images Using a Novel Anthropomorphic Hip Phantom

Serena Bonaretti[1], Isra Saeed[1], Andrew J. Burghardt[1], Lifeng Yu[2], Michael Bruesewitz[2], Sundeep Khosla[2], Thomas F. Lang[1]

[1]Musculoskeletal Quantitative Imaging Research Group, Department of Radiology and Biomedical Imaging, University of California, San Francisco, CA, USA

[2]Division of Endocrinology, Metabolism and Nutrition, Department of Internal Medicine, College of Medicine, Mayo Clinic, Rocherster, MN, USA

BACKGROUND

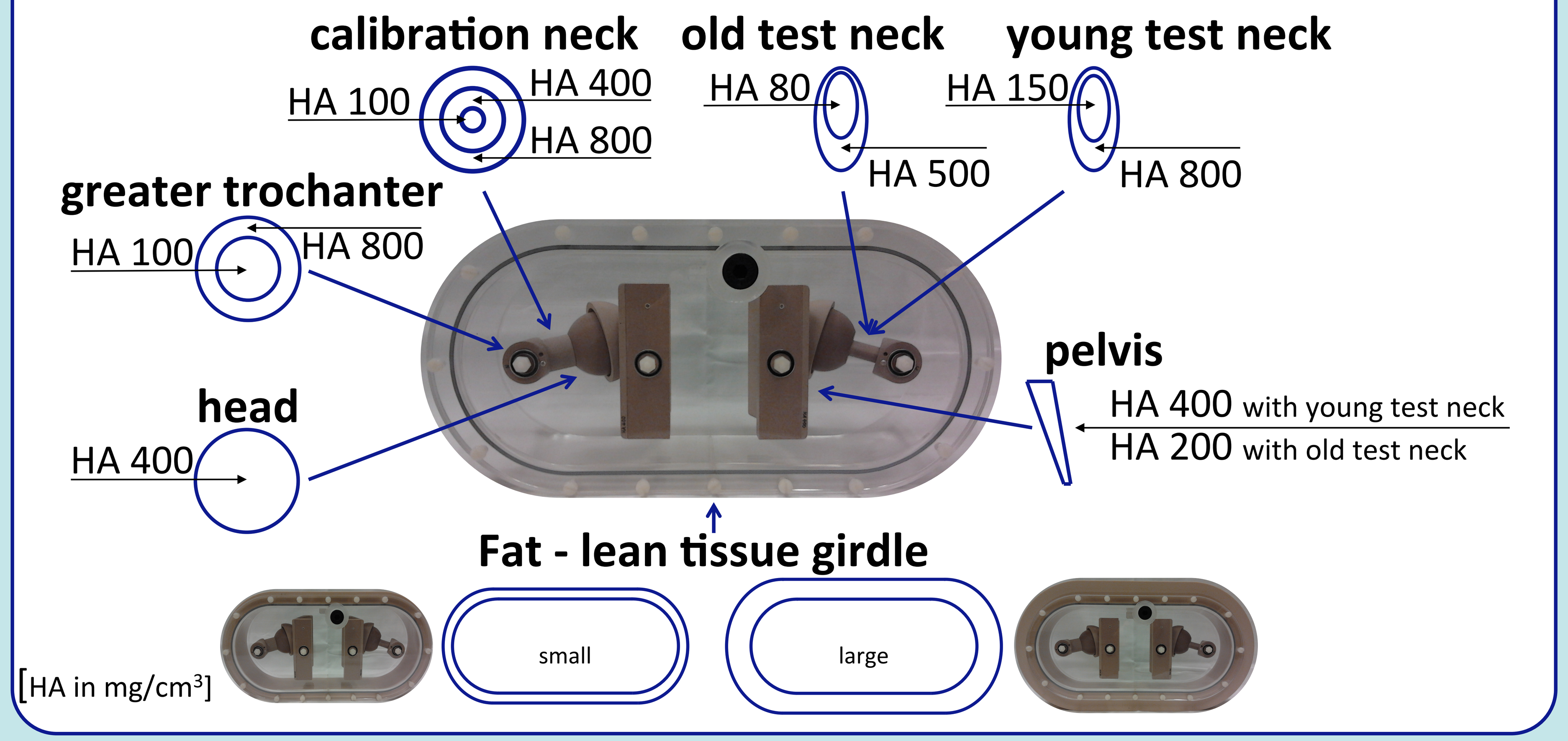
- Pharmaceutical and epidemiological studies often employ quantitative computed tomography (QCT) to estimate volumetric bone mineral density (BMD), bone geometry and strength [1-3].
- Variations in body size and shape, and in bone size and density, result in beam hardening errors that heterogeneously distort image intensities and BMD [4].
- Beam hardening effects may cause BMD measurement artifacts in people of different sizes, and contribute to degradation of data when scanners are changed.

AIM

- To investigate the effect variable body size and bone density on BMD measurements using a novel anthropomorphic hip phantom for different scanners

ANTHROPOMORPHIC HIP PHANTOM (AHP)

- The AHP is designed to study the effect of variable *body size* and *pelvic anatomy* on hip BMD measurements
- It contains a *calibration neck* to correct the measured BMD and a *test neck* to evaluate the correction

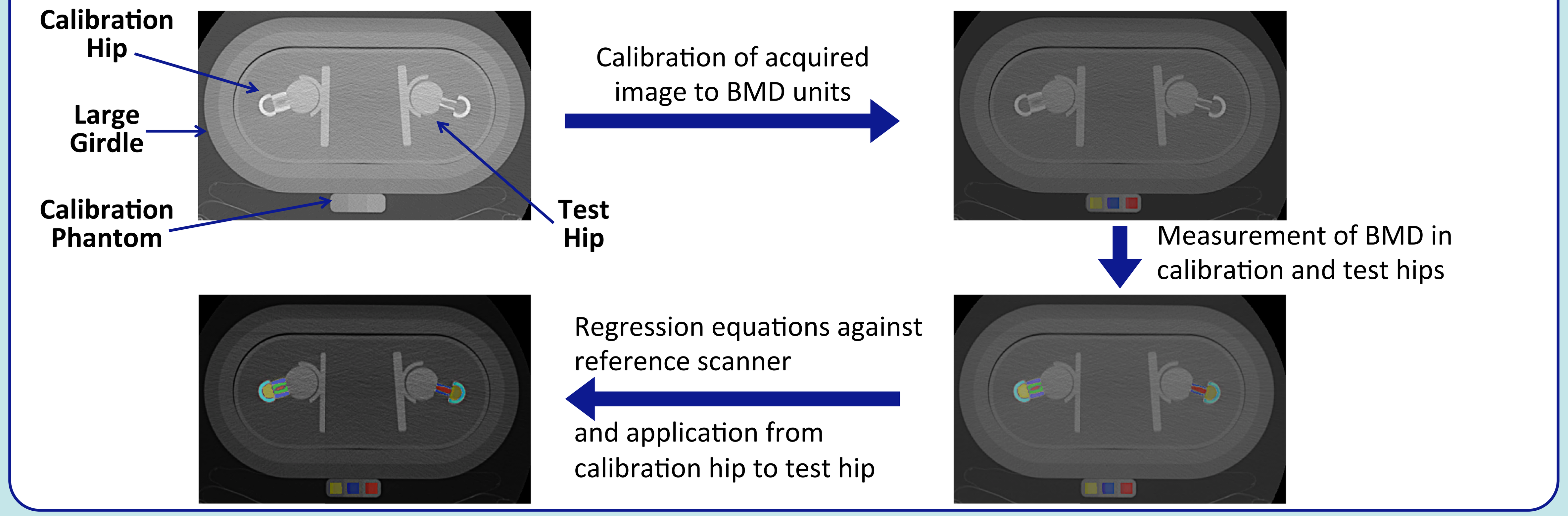


EXPERIMENT

- The AHP was scanned in 6 different variations, combining **age** (old/young test hip) and **body size** (no/small/large girdles).
- The scans were acquired on **2 GE VCT 64 systems**, **1 Siemens Biograph** and **1 Siemens Definition,** at UCSF and MAYO Clinic.
- The AHP was scanned with the **patient calibration phantom**, which is commonly used to calibrate subject images in QCT.

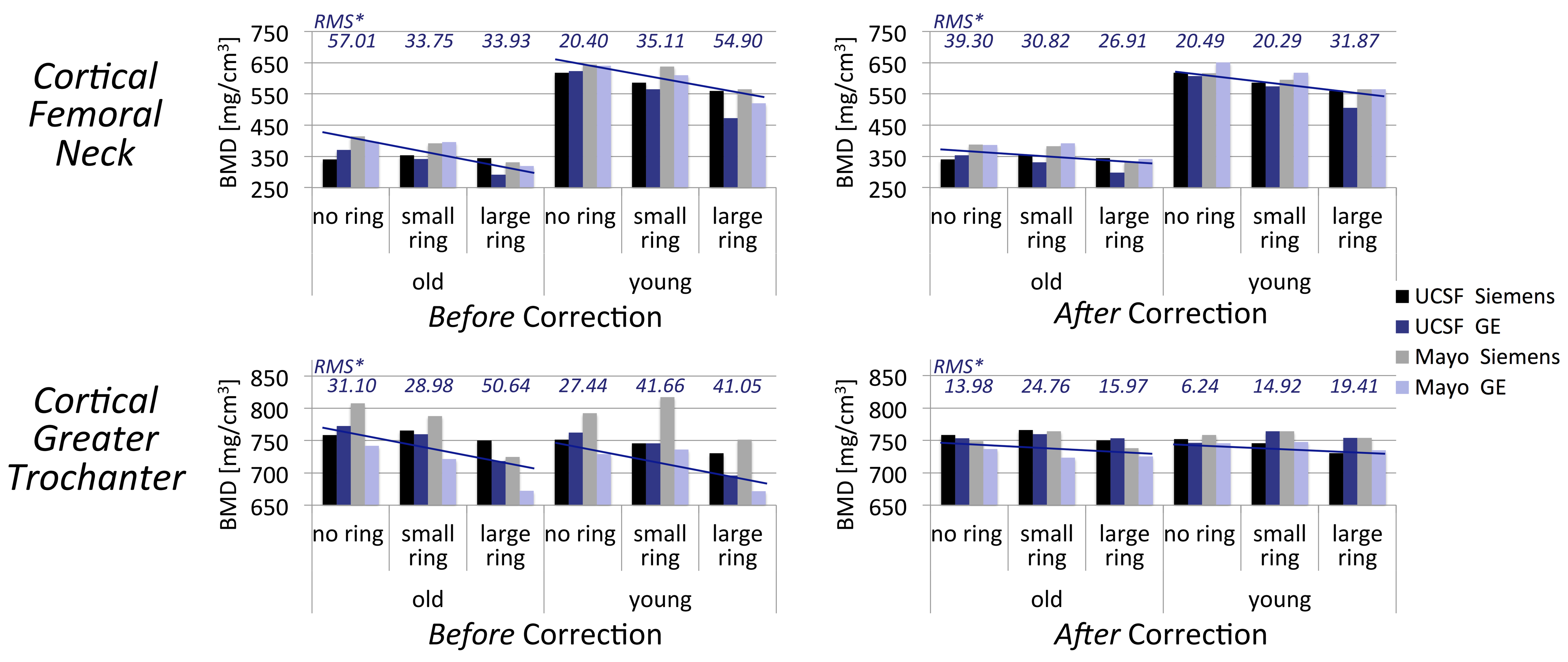
MEASUREMENT OF BMD FROM IMAGES

- We calibrated each image with the calibration phantom
- We calculated cortical, trabecular and integral BMD for calibration and test hips
- We chose the Siemens Biograph as reference for its less dependence to body size
- We computed regression equations of calibration hip BMD for each scanner against reference scanner
- We applied calibration hip regression to each image and compared pre- and post correction measurements



BMD OF TEST HIP BEFORE AND AFTER CORRECTION

- Larger BMD differences were found of the **cortical bone** of femoral neck and greater trochanter



*RMS** = root mean square of inter-scanner differences. For each ring configuration, inter-scanner differences were calculated between the reference scanner and the other scanners.
— = Trend of BMD with body size

DISCUSSION

In this study we analyzed the consequences of *variable body size* on *BMD measurements* using the AHP. We found that:

- Values of cortical BMD decrease dramatically with increasing body size
- Inter-scanner differences are body size dependent, especially for cortical BMD
- Body size dependence was more visible for the GE VCT 64 systems and the Siemens Definition
- Corrections based on calibration hip dramatically reduced inter-scanner errors

Implications:

- Artifactual reductions of BMD with increasing weight complicate measurements in obese patients and patients undergoing weight loss
- Special consideration is required for bone strength estimates. Elastic modulus estimates vary with ≈BMD^2, and cortical voxels are located farthest from neutral axis
- Results show poorer efficacy for correcting thin structures such as cortical femoral neck. We are carrying out studies to address potential interaction between spatial resolution and inter-scanner/body weight variations.
- Overall, initial results show promise for phantom-based corrections to reduce variations in BMD between scanners and patients

APPLICATION TO HUMAN SUBJECTS

- We are currently working on applying the inter-scanner corrections to human subjects, where the same subject was scanned on two different scanners
- Analyses of body size and inter-scanner corrections on bone strength are currently underway.

REFERENCES

1. Black D.M. et al. *Proximal femoral structure and the prediction of hip fracture in men: a large prospective study using QCT*. J Bone Miner Res. 2008. 23(8):1326-33
2. Keaveny T. et al. *Femoral and vertebral strength improvements in postmenopausal women with osteoporosis treated with denosumab*. J Bone Miner Res. 2013 Jun 21
3. Eastell R. et al. *Effect of once-yearly zoledronic acid on the spine and hip as measured by quantitative computed tomography: results of the HORIZON Pivotal Fracture Trial*. Osteoporos Int. 2010. 21(7):1277-85
4. Hsieh, Jiang. *Computed tomography*. Bellingham, Wash. SPIE, c2009

MORE INFORMATION

Information and technical details about this study are available at https://sites.google.com/site/serenabonaretti/asbmr2013

Acknowledgment

The project is funded by NIH/NIAMS 5R01AR060700

serena.bonaretti@ucsf.edu