

Fat Fraction and Bone Mineral Density in the Proximal Femur: A Localized Assessment of their Relationship in Fragility Fractures

Julio Carballido-Gamio¹, Dimitrios C Karampinos^{1,2}, Andrew Lai¹, Sonia Lee¹, and Roland Krug¹

¹Department of Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, CA, United States, ²Department of Diagnostic and Interventional Radiology, Technical University of Munich, Munich, Germany

Introduction. Bone strength is yielded by bone mineral density (BMD) and by bone quality. In osteoporosis, bone strength is decreased, and consequently there is a higher risk of fracture. Areal BMD (aBMD) measured by dual-energy x-ray absorptiometry is the standard clinical parameter for the diagnosis of osteoporosis. However, the different factors that are commonly addressed as bone quality (architecture, turnover, damage accumulation, mineralization) account for ~30% of bone strength, and are therefore also of clinical relevance. Previous studies have suggested that bone fat content can partly explain bone strength independently of BMD, and that bone fat content and BMD are negatively correlated. Both single-voxel magnetic resonance (MR) spectroscopy and MR water-fat imaging approaches have been used for fat quantification [1, 2]; however, previous studies have been based on predefined regions of interest (ROI) and aBMD. In this study, we used 1) a water-fat imaging-based fat quantification technique, which enables the generation of 3D fat-fraction (FF) maps; 2) quantitative computed tomography (QCT), which enables the generation of 3D BMD maps; and 3) Computational Anatomy, which enables the generation of 3D statistical atlases of features and ROI-free analyses: 1) to assess the local relationship of fat content and volumetric BMD (vBMD) in the proximal femur of normal postmenopausal women, and 2) to assess the spatial variation of fat content and vBMD in postmenopausal women with fragility fractures.

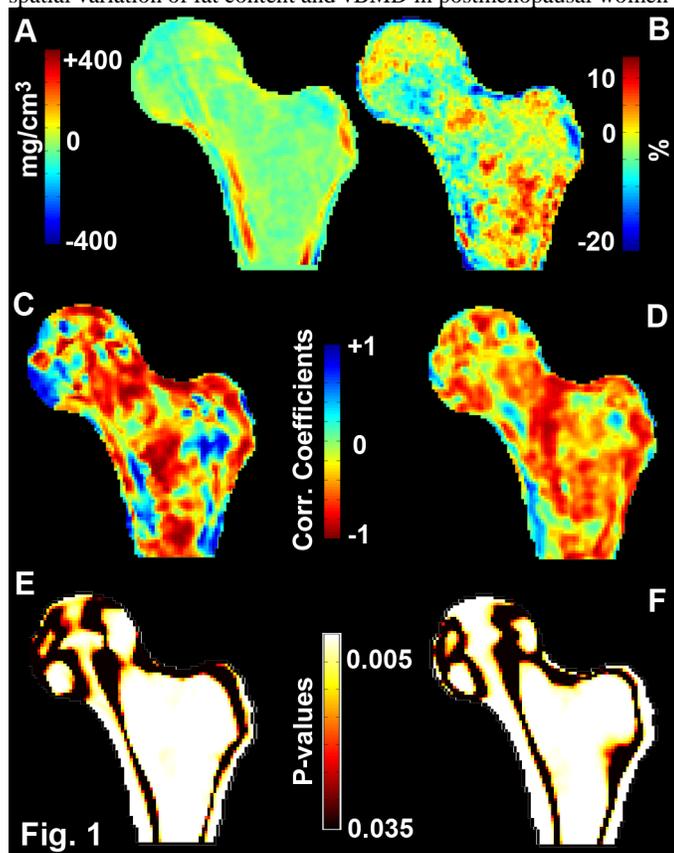


Fig. 1 Cases, respectively. Figures 1E (Controls) and 1F (Cases) indicate regions where correlations of vBMD and FF values were significant after FDR correction ($P < 0.035$).

Discussion. In this study, we have used MRI, QCT and Computational Anatomy to assess the spatial relationship between vBMD and FF in the proximal femur of normal postmenopausal women, and women with fragility fractures. Results showed positive and negative vBMD differences between Cases and Controls, and higher FF values in the neck and in the intertrochanteric region in Cases. As it was expected based on previous studies, vBMD and FF were mostly negatively correlated, however, small regions with positive correlations were also observed. Although regions with significant correlations between vBMD and FF were similar between Controls and Cases, Cases showed a distinct pattern. Unfortunately, the main limitation of this study is the small sample size, which is a potential explanation of the variability of the vBMD difference maps, and a reason to avoid any strong conclusions. We are currently recruiting more subjects to investigate if the observed patterns in the correlation map of women with fragility fractures are due to changes in vBMD alone, FF alone, or both, and to apply techniques such as voxel-based morphometry for further analysis.

References. [1] D.K. Yeung et al. JMIR 2005. [2] Wehrli et al. Radiology 2000. [3] Karampinos et al. MRM 2011. [4] Reeder et al. MRM 2005. [5] Yu et al. MRM 2008. [6] Carballido-Gamio et al. MRM 2011. **Acknowledgements.** This work was funded by NIH R01AR057336.

Methods. Fifteen postmenopausal women, 6 without fracture (Controls; age=62.4±8years), and 9 with fragility fractures (Cases; age=62.8±9 years) were included in this study. Coronal-oblique images of the proximal femur were acquired with a 3 Tesla MR750 scanner (GE Medical Systems) using an 8-channel cardiac phased-array coil. Scans included a 3D spoiled gradient echo pulse sequence with 6 echoes for chemical shift-based water-fat separation. A small flip angle was used to reduce the T1-bias effect [3], and acquisitions were reconstructed online using the IDEAL algorithm [4] combined with a multi-peak model for the fat spectrum and single T2* correction [5]. Eddy current effects were also corrected using a hybrid (complex/magnitude)-based approach. Scans were acquired with a spatial resolution of 0.468 x 0.468 x 2 mm³. QCT scans of both hip joints were obtained using a multi-detector CT scanner (Light Speed; GE Medical Systems) along with a calibration phantom (Mindways Inc.), enabling the conversion of Hounsfield units to equivalent concentrations of aqueous K₂HPO₄ (vBMD maps). Scans were obtained with a voxel size of 0.937 x 0.937 x 1.25 mm³. FF and vBMD maps were resampled to 1mm³, and registered to an atlas [6] using femoral segmentations and affine and non-linear registrations to establish local anatomic correspondence for all scans in the study. FF- and vBMD-difference maps (Cases minus Controls), and FF-vBMD Pearson correlation coefficient maps (Controls vs Controls, and Cases vs Cases) were generated. Due to the small sample size, and that small vBMD and FF differences were expected between Controls and Cases, significance of the difference maps was not evaluated. Significance of the Pearson correlation coefficient maps was evaluated based on paired t-tests, and false-discovery rate (FDR) correction was used to correct for multiple comparisons.

Results. Figure 1 summarizes the results of this study. Figures 1A and 1B depict coronal cross-sections of the vBMD and FF difference maps (Cases minus Controls), respectively. Figures 1C and 1D show the Pearson correlation coefficient maps of vBMD and FF values for Controls and