A Five-year Longitudinal Study Assessing Age- And Sex-related Bone Changes - A Comparison Of DXA And HR-pQCT

Lauren A. Burt¹, Anne-Laure Ménard², Heather M. Macdonald³, David A. Hanley⁴, Steven K. Boyd⁵.
¹McCai Institute for Bone and Joint Health, Department of Radiology, University of Calgary, Calgary, AB, Canada, ²Department of Mechanical Engineering, École Polytechnique de Montréal, Montréal, QC, Canada, ³Department of Orthopaedics, Child & Family Research Institute, University of British Columbia, Vancouver, BC, Canada, ⁴Departments of Medicine, Community Health Sciences, and Oncology, University of Calgary, Calgary, AB, Canada.

Disclosures:
L.A. Burt: None. A. Ménard: None. H.M. Macdonald: None. D.A. Hanley: 2; Amgen. 3B; Amgen, Eli Lilly, Merck. 3C; Eli Lilly. 5; Amgen, Eli Lilly, Merc. S.K. Boyd: 2; Merck. 3B; Amgen, Merc. 3C; Amgen, Pure North S’Energy Foundation. 5; Merck.

Introduction:
Dual X-ray absorptiometry (DXA) is the current gold standard for measuring and assessing bone changes, in particular bone loss associated with ageing. The increase in bone loss resulting in osteoporosis and fragility fractures currently affects one in three women and one in five men, costing the health care system over two billion dollars annually [1]. With the ageing population the number of people affected by diseases associated with bone loss, and the cost of such diseases will increase. Based on DXA assessment techniques, age-related bone loss (excluding the time around menopause) occurs at a rate of 1% per year [2,3] and is similar between women and men; however, the age at which bone loss occurs varies across skeletal sites. High-resolution peripheral quantitative computed tomography (HR-pQCT) is a newer three-dimensional imaging modality currently being used as a research tool to assess bone health. Whereas DXA measures areal bone mineral density (aBMD) at the hip and spine, HR-pQCT is able to assess volumetric BMD in addition to geometric and microstructural bone properties, at the tibia and radius. We hypothesized longitudinally assessed age-related bone changes in BMD will differ between HR-pQCT and DXA measurements. In our population-based cohort we aimed to compare subject-specific longitudinal age-related bone changes in different skeletal sites using two imaging modalities. In addition we aimed to determine if these changes are similar between women and men.

Methods:
Women (n=113) and men (n=43) 60 to 85 years from the Calgary cohort of the Canadian Multicentre Osteoporosis Study (CaMos) participated in a 5-year follow-up study. In brief, CaMos is an ongoing population-based study consisting of both adult (25 years and older) and youth (16 to 24 years) cohorts at nine locations across Canada. Participants in this study were assessed using two different imaging modalities: DXA and HR-pQCT. Areal bone mineral density (aBMD) at the lumbar spine (LS), femoral neck (FN) and total hip (TH) were obtained from DXA (Hologic, USA) scans of L1-L4 and the left hip. The non-dominant radius and left tibia were scanned using HR-pQCT (Scanco Medical, Switzerland). Total volumetric BMD (Tt.BMD), cortical BMD (Ct.BMD), trabecular BMD (Tb.BMD), total area (Tt.Ar) and cortical porosity (Ct.Po) were assessed using standard and automated segmentation methods. In addition, finite element analysis (FEA) estimated apparent bone strength at both the radius and tibia. Repeated measures ANOVA assessed age-related bone change over time. T-tests compared differences between skeletal sites, imaging modalities and sex. Data were analyzed using SPSS and significance was set at p <0.05.

Results:
Age-related bone changes are expressed as the percentage change per year. DXA-derived aBMD in women decreased between 0.8% (FN) and 1.0% (TH) whereas HR-pQCT-derived Tt.BMD declined between 0.5% (tibia) and 1.5% (radius) (p<0.05). At the radius in women, Tb.BMD decreased 1.2% and Ct.BMD 0.6% per year (p<0.01). However, at the tibia Tb.BMD did not change among women (p>0.05) and Ct.BMD decreased by 0.9% (p<0.01). Bone size (Tt.Ar) did not change at the radius or tibia over study duration for women (p>0.05). The greatest age-related change in women was Ct.Po; Ct.Po increased by 10.7% at the radius and 6.8% at the tibia per year (p<0.01). Furthermore, in women FEA results revealed an annual loss in radial apparent bone strength of 0.9% (p<0.05).

In men, there was no change in aBMD at the FN; TH decreased 0.5% per year, Tb.BMD decreased 0.9% at the radius and 0.4% at the tibia per year (p<0.05). In men, Tb.BMD decreased 0.3% at the radius and 0.2% at the tibia whereas Ct.BMD decreased 1.0% at the radius and 0.7% at the tibia (p<0.05). In alignment with women, Tt.Ar did not change at the radius or tibia (p>0.05) and Ct.Po increased dramatically in men, increasing 8.6% at the radius and 3.6% at the tibia per year (p<0.01). Preliminary FEA results for men indicated no significant change in bone strength (p>0.05).

Comparisons between skeletal sites indicated that age-related changes in Tt.BMD were larger at the radius than tibia for both women and men (p<0.05), and Ct.Po changes were larger at the radius than tibia for women (p<0.05). Similarly, age-related aBMD changes were greater at the TH than LS for both women and men (p<0.01).

Discussion:
Our 5-year population-based cohort study demonstrated age-related skeletal changes in women and men over 60 years of age. Age-related changes differed according to imaging modality (DXA vs HR-pQCT), skeletal site and sex. Comparable results were observed for density measures across the two imaging modalities and are in line with previously reported bone loss, changing between 0.5 to 1.5% per year [4,5]. However, Ct.Po changed at a much higher rate than density, increasing 4 to 11% per year depending on skeletal site and sex. In general more age-related bone changes occurred at the radius than tibia and among women than men, particularly in terms of Ct.Po at the tibia.

Our future research will determine if these age-related changes are due to the sensitivity and differences in scanning modalities (DXA: two-dimensional and aBMD; HR-pQCT: three dimensional, volumetric BMD, geometric and microstructural parameters), or if these changes are due to scanning different skeletal sites and the site-specific differences observed within and between sexes. Further understanding of age-related changes in bone quality will enhance our ability to assess bone health with HR-pQCT.

**Significance:**
DXA is the gold standard for assessing and monitoring bone loss and osteoporosis; however, it is limited in its ability to predict fractures, which is the primary concern, not low bone density. The microarchitectural changes detected over five years, particularly cortical porosity, may be more indicative of changes in bone strength and hence fracture risk. Thus, using techniques such as FEA in combination with longitudinal measurements of bone microarchitecture by HR-pQCT may be better able to distinguish normal from abnormal bone loss, and therefore more accurately isolate those at risk of fracture.

**Acknowledgments:**
We would like to thank all the volunteers who participated in the study, Jane Allan, Bernice Love and Michelle Kan for their assistance with participant recruitment, interviews and scanning.

**References:**