Age- and gender-related differences in the geometric properties and biomechanical significance of intracortical porosity in the distal radius and tibia.

Abstract:
Cortical bone contributes the majority of overall bone mass and bears the bulk of axial loads in the peripheral skeleton. Bone metabolic disorders often are manifested by cortical microstructural changes via osteonal remodeling and endocortical trabecularization. The goal of this study was to characterize intracortical porosity in a cross-sectional patient cohort using novel quantitative computational methods applied to high-resolution peripheral quantitative computed tomography (HR-pQCT) images of the distal radius and tibia. The distal radius and tibia of 151 subjects (57 male, 94 female; 47 +/- 16 years of age, range 20 to 78 years) were imaged using HR-pQCT. Intracortical porosity (Ct.Po) was calculated as the pore volume normalized by the sum of the pore and cortical bone volume. Micro-finite element analysis (microFE) was used to simulate 1% uniaxial compression for two scenarios per data set: (1) the original structure and (2) the structure with intracortical porosity artificially occluded. Differential biomechanical indices for stiffness (Delta K), modulus (Delta E), failure load (Delta F), and cortical load fraction (Delta Ct.LF) were calculated as the difference between original and occluded values. Regression analysis revealed that cortical porosity, as depicted by HR-pQCT, exhibited moderate but significant age-related dependence for
both male and female cohorts (radius ρ = 0.7; tibia ρ = 0.5; p< .001). In contrast, standard cortical
metrics (Ct.Th, Ct.Ar, and Ct.vBMD) were more weakly correlated or not significantly correlated with
age in this population. Furthermore, differential microFE analysis revealed that the biomechanical
deficit (Delta K) associated with cortical porosity was significantly higher for postmenopausal women
than for premenopausal women (p< .001). Finally, porosity-related measures provided the only
significant decade-wise discrimination in the radius for females in their fifties versus females in their
sixties (p< .01). Several important conclusions can be drawn from these results. Age-related
differences in cortical porosity, as detected by HR-pQCT, are more pronounced than differences in
standard cortical metrics. The biomechanical significance of these structural differences increases
with age for men and women and provides discriminatory information for menopause-related bone
quality effects.