QCT for Biomechanical Scaling

Rhylee DeCrane, Maria Ortiz, Jason Kait, Hattie Cutcliffe, Cameron R 'Dale' Bass

Background

Over a human lifetime, Bone Mineral Density(BMD) changes in the lumbar spine. leading to changes in bone failure stress. One valuable, yet uncertain, relationship between BMD changes and age, especially in the context of cadaver testing, scaling and normalization to various populations of interest. Since most cadavers are older than the average population demographics, region specific population average BMD values across ages are valuable to provide age scaling and normalization to develop accurate models for bone failure risk. Our purpose for this paper is to first use QCT data on lumbar spines to find a scaling factor across age, then apply that factor to yield stress.

Methods

Using QCT on male cadaver lumbar spines, we found the BMD for all subjects in our dataset (n=185). A calibration phantom that had a mineralization density across a range of trabecular and cortical bone densities was placed vertically in proximity to the spine during scanning and was used to determine BMD from the raw medical images Comparison data from on lumbar spine volumetric BMC from Yoganandu (2006) and Riggs (2004) were used to determine age scaling coefficients across age using a breakpoint bilinear best fit. A published yield stress to failure from Kopperdahl et al. (2002) was used to determine the desired scaling of yield stress by age and can be used with normalization of scaling of injury risk functions, either by cadaveric BMD or by cadaver demographics.

Results and Discussion

Using an initial linear fit for the age vs BMD we find BMD = -1.1317 Age+215.25. An additional breakpoint regression was found with qualitatively better fit with a breakpoint at 47.5 years (insert equations here). This corresponds to typical male physiological bone evolution with age. For this, there is a slow decline in bone density until the late 40s or 50s changing to a more rapid decline in later years. This breakpoint regression is used with a yield stress correlation to determine age normalization or scaling across populations.

Conclusion

The population based scaling/normalization between age and BMD developed in this study is useful for the development of biomechanical risk functions that are appropriate to different populations. Knowing the scaling between populations, we are better able to scale cadaver data between ages or between demographics with differing bony strength will allow us to better the results from testing our often elderly cadavers.