Quantifying variation in human cortical thickness in the tibia: Implications for fracture risk

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Computed tomography (CT) is a prevalent clinical instrument providing images that can be used to assess bone quality. Quantifying bone quality across various skeletal elements is important in understanding fracture risk, namely for the purpose of creating a more biofidelic finite element (FE) human body model. Considering the commonality of tibiae injuries in automotive crash scenarios, especially pedestrian impacts, it is of interest to investigate tibial variation to improve the accuracy of injury prediction.

Cortical thickness (Ct.Th) has been established as an important predictor of bone strength across the skeleton, however data are lacking in the variation present both along the diaphysis of the tibia and within a cross-section of the tibial cortex. It is also commonly assumed by commercially available computer analysis software programs that there are no differences in Ct.Th between volumes of interest (VOIs), with an average value reported to represent the entirety of the cross-section. Therefore, the purpose of this study is twofold: first, to quantify the variation in Ct.Th between segments (VOIs) of the tibia; and second, to quantify the variation of Ct.Th within a cross-section using manual measurements.

Sixty left ex-vivo tibiae were obtained from 30 male (63.6 ± 10.0 years) and 30 female (63.4 ± 15.8 years) post-mortem human subjects (PMHS) ranging from 45 to 89 years (mean 64.5 ± 13.1). Tibiae were scanned on a Philips Ingenuity 64-slice CT at 0.671mm slice thickness. Acquisition parameters were consistent, resulting in an in-plane resolution of 0.335mm. CT images were imported into commercially validated SkyScan (Bruker) software for segmentation into 38%, 50%, and 66% VOIs relative to the distal articular surface. Ct.Th averages of the entire VOI at each segment were automatically quantified. OsiriX MD (v.8.0.1) was used to similarly segment tibiae into 38%, 50%, and 66% regions of interest (ROI) for ImageJ (NIH) analysis. Manual measurements of Ct.Th were performed at 8 equidistant vectors from the centroid across each tibial cross-section in ImageJ.

An ANOVA revealed that the average SkyScan Ct.Th measurements demonstrated a significant difference between all segments in both males and females ($p<0.01$). Within the cross-section of each segment, an ANOVA test was performed twice: first to compare the Ct.Th at the 8 equidistant vectors for each site individually, and next to compare the individual vectors between the three segment sites. The within groups test confirmed there was significant Ct.Th variation around the cortex in males and females ($p<0.05$). The between groups test showed there was a significant difference between sites at the same vector ($p<0.05$) except at the most posterior location in females and at the medial location in males.

These results indicate that due to a significant amount of Ct.Th variation both within the cross-section at each segment as well as along the tibia, Ct.Th variation should be

accounted for when creating FE models so as to improve fracture assessment in car crash and other traumatic injury scenarios.