Development of an Automated Pipeline to Characterize Full Rib Cage Shape Variability

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Introduction: Thoracic injury remains a common injury outcome of motor vehicle crashes [1], but injury risk differs across populations [2, 3]. Such differences have been attributed to local and global geometric properties of the rib cage, which have been characterized via statistical shape models and morphological techniques [4-6]. However, past research primarily focuses on age-related changes, is limited in sample size when using the full rib cage and does not account for non-average geometries. The objective of the current study was to develop an automated pipeline to extract full rib cage measurements from a large population and produce distributions of these measurements to assess variability.

Methods: A retrospective study of clinical CT scans was approved under #IRB00006511. A ML-based segmentation tool [7] was used to obtain 3D reconstructions of the rib cage and sternum. MATLAB v2023a (The MathWorks Inc, Natick, Massachusetts) was used to standardize patient positioning via rotational adjustments. Ten measurements describing the full rib cage shape, including convex hull areas and volume, which have not been previously utilized in the study of rib cage morphology, were collected for each scan. The distribution of measurements was summarized in histograms and scatterplots vs BMI by sex (Figure 1). Students t-tests were performed to compare female and male measures. Lastly, multivariate multiple regression was performed to assess how demographic parameters predict the measurements.

Results: This preliminary sample size included 400 subjects. Females (n=200) had a mean stature, weight, and BMI of 1.64 ± 0.08 m, 80.0 ± 24.0 kg, and 29.7 ± 8.7 kg/m^2, respectively. Males (n = 200) had a mean stature, weight, and BMI of 1.78 ± 0.08 m, 88.0 ± 22.0 kg, and 27.5 ± 6.2 kg/m^2, respectively. Males had statistically larger measurements on average than females ($p < 0.0001$), except in angular measurements. Demographic predictors better explained the variance in convex hull area and volume measures, with average adjusted-R^2 values of 0.45 for females and 0.47 for males. The greatest R^2 value was seen in the axial area measure for both sexes, suggesting that demographic predictors may better capture the relationship between rib cage width and depth compared to analyzing these variables individually.

Conclusions: Like previous studies, the predictive model of rib cage shape is only able to account for 27-55% of the variance seen when using demographic predictors. However, the dataset of real-world rib cages developed in this work gives researchers access to a range of possible rib cage geometries meeting a specific demographic criterion and enables an understanding of this range within the whole dataset. This dataset enables researchers to utilize all possible geometries in thoracic injury studies instead of defaulting to an average geometry. The sample size from this study will be expanded in future work.

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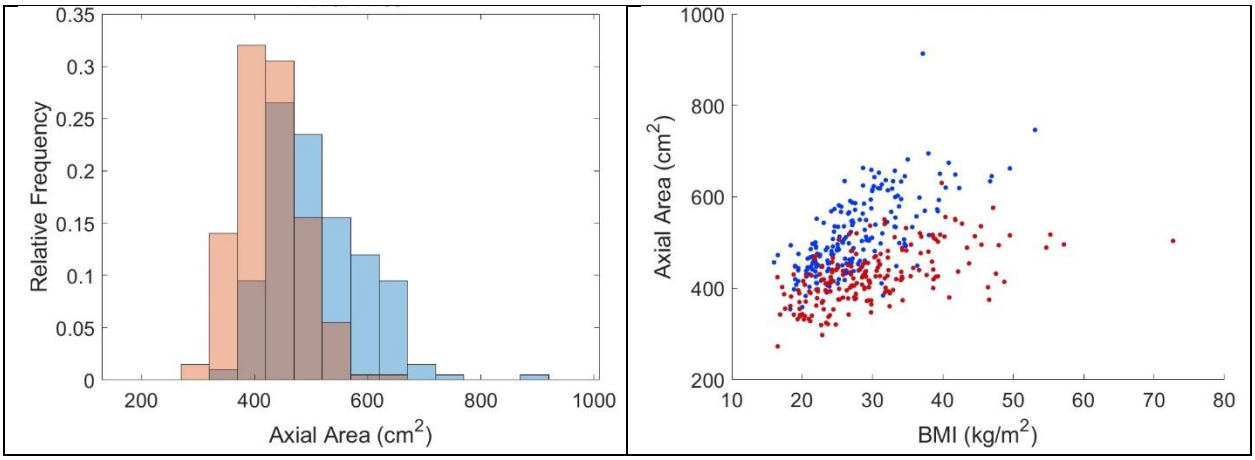

Figure 1: Histogram and Scatter plot of Axial Area measurement. Females in red and Males in blue.

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