Predicting Small Stature Young Female Rib Response and Fracture Location with an Isolated Rib Finite Element Model

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Introduction: Thorax injury remains one of the leading contributors to mortality in car crash scenarios [1] with different incidence rate between sex and age groups. Finite Element (FE) Human Body Models (HBMs) have been used as tools to aid the understanding of the biomechanics of injury and the efficacy of safety systems. Importantly, sex and age-specific models can be developed to understand the differences in injury outcomes under similar car-crash conditions between groups [2]. It has been reported that small stature females demonstrate increased thoracic injury risk relative to males [1]; however, in isolated rib anterior-posterior loading, FE models have struggled to predict the overall rib response and the fracture location observed in the population data, and have not been assessed against age and sex-specific experimental data.

In this study, an isolated 6th rib finite element model was enhanced with improved constitutive models using material and geometric population data, targeting a 26-year-old (YO) subject.

Objective: To quantify the effect on rib response and fracture location of enhanced material models, age and sex specific population data used for material properties, cortical bone thickness, and cross-sectional area.

Methodology: The 6th rib was extracted from the GHBMC small stature female HBM (F05-O v-6.0). Then, the constitutive models for trabecular and cortical bone were replaced with the recently developed CFraC [3] and OrthoT [4] material models. The material orientation was aligned along the longitudinal axis of the rib, roughly corresponding to the osteon direction, at each element. The material properties were taken from age-specific experimental data for the cortical [5] and trabecular [6] bone, targeting a 26YO subject. Then, the rib mesh was morphed to match the cross-sectional area population data [7] of a small stature young (26YO) female. Finally, the cortical bone thickness distribution from population data targeting a small stature young (26YO) female [8] was mapped to the rib model cortical bone thickness along the rib length and around the rib circumference. The models were then evaluated in an anterior-posterior loading configuration following previous experimental and computational work [9,10]. The force-displacement response and fracture location were monitored and compared to small stature young females experimental data [10].

Data to be included: The results of this study will include the force-displacement curves of the developed models and the predicted fracture location compared to age and sex specific population experimental data.

Preliminary Results and current conclusions: The rib cross-sectional area and cortical bone thickness was successfully morphed to match the population data. Preliminary results demonstrate that the enhanced material models with age-specific material properties improved the force-displacement response compared to the experimental data. Importantly, the cortical bone thickness distribution had the biggest

effect on the rib fracture location. While the cross-sectional area had a modest effect on the overall rib stiffness. The enhanced model demonstrates the factors that are important for sex and age-specific isolated rib response and fracture location prediction and will be implemented in a full body model in future work.

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APPENDIX

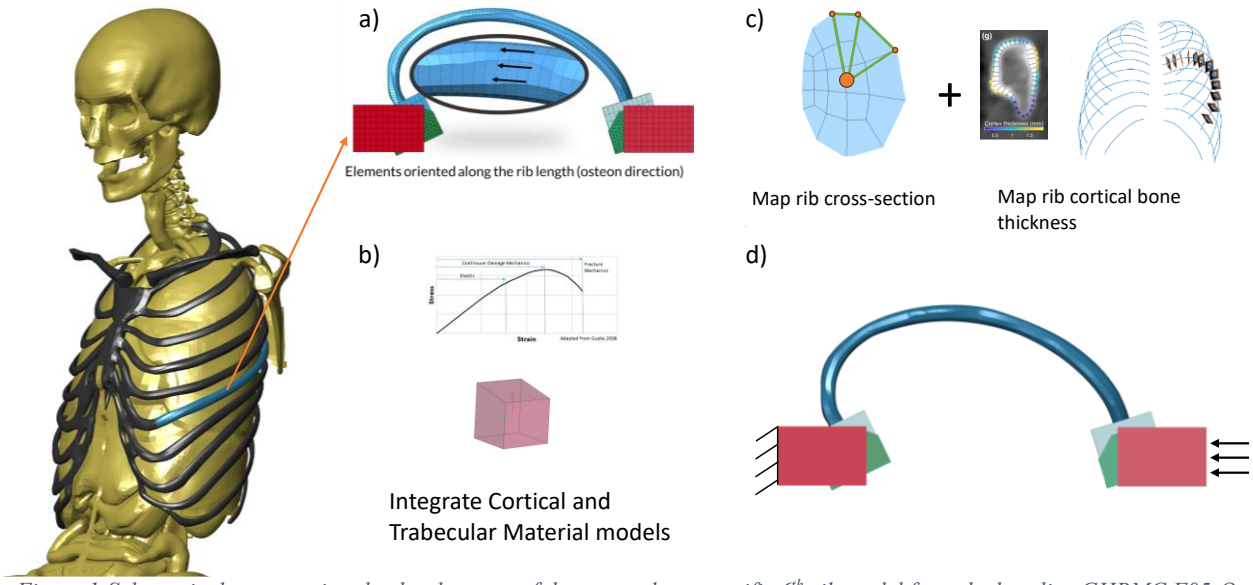

Figure 1:Schematic demonstrating the development of the age and sex-specific 6th rib model from the baseline GHBMC F05-O v6.0. a) Element orientation along the osteon direction, b) enhancement of the cortical and trabecular constitutive models populated with age-specific material properties, c) morphing towards age and sex-specific population cross-sectional area and cortical bone thickness distribution along the rib length and around the rib circumference and d) evaluation of the developed rib models in an anterior-posterior configuration.