Distribution of Rib Cross-sectional Area Affects Fracture Location in Side Impact for Small Stature Females

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I. INTRODUCTION

Aged small-stature females exhibit a higher incidence of injury and mortality than their young counterparts in car crash scenarios [1]. Thoracic injury is the leading cause of fatalities in the aged population in car crash scenarios [2], potentially due to the changes in geometry and material properties that occur with age [3]. Human Body Models (HBMs) offer the opportunity to investigate the effect of geometrical and material properties changes. The GHBMC F05 v6.0 is a HBM that represents a 26-year-old (26YO) small-stature female (F05). One geometrical feature that has been shown to affect the rib response in finite element (FE) models is the rib cross-sectional area [4]. The rib cross-sectional area has been quantified in population studies and shown to decrease with increasing age [5]. However, the effect of the cross-sectional area has not been investigated at the full-body level. The aim of this study was to quantify the effect of the changes in cross-sectional area due to increasing age using the detailed GHBMC F05 v6.0 model, evaluated in a simplified side impact.

II. METHODS

The cross-sectional area of the 2nd to 11th ribs in the F05 model were modified to follow the population average of the young subjects ($F05_{26CA}$) and the aged subjects ($F05_{75CA}$) from the International Center for Automotive Medicine (ICAM), University of Michigan. The cross-sectional area was scaled up or down according to the population data while preserving the original rib cross-sectional shape (Fig. 1). The mesh quality of the output models met the GHBMC mesh quality requirements. The F05, $F05_{26CA}$ and $F05_{75CA}$ models were evaluated in side-impact sled simulations (6.9 m/s). Rib fractures predicted in the models were compared (Fig. 1).

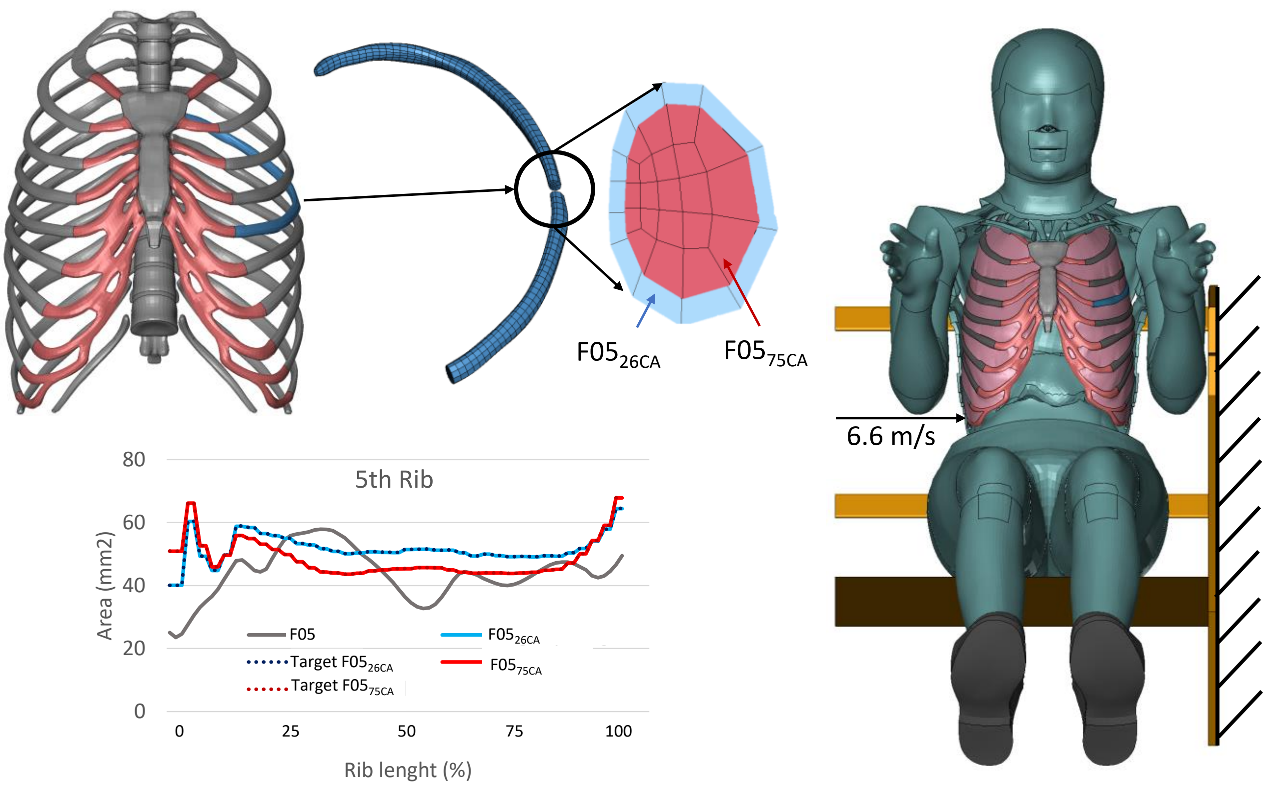

Fig. 1. Modification of the cross-sectional area preserving the cross-sectional shape following the average population data. In the right, the boundary conditions of the simplified side-impact sled.

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III. INITIAL FINDINGS

Compared to the population data, the F05 model generally had a lower cross-sectional area than the average for the 26YO population (Fig. 2). The aged population exhibited higher cross-sectional area in the posterior region and lower area in the mid-anterior region (Fig. 2). In side impact, the rib cross-sectional distribution and magnitude affected the fracture location and number of fractures. The $F05_{26CA}$ model predicted five rib fractures, the $F05_{75CA}$ predicted seven and the F05 predicted eight (Fig. 2).

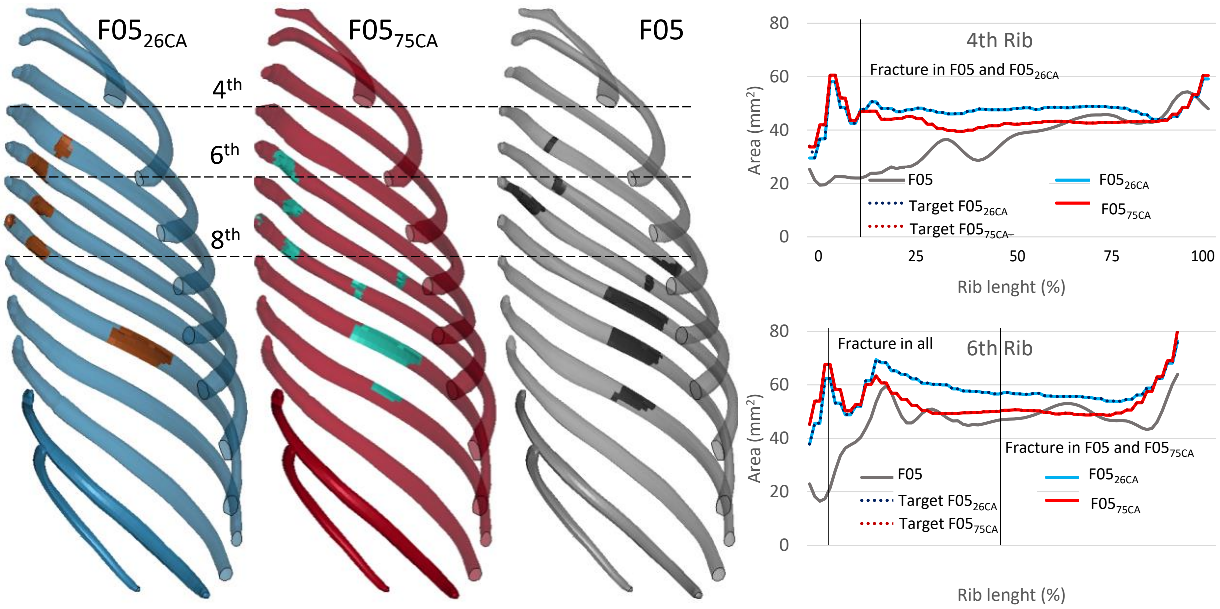

Fig. 2. Left: rib fracture prediction of the $F05_{26CA}$ (blue), $F05_{75CA}$ (red) and F05 (grey). Right: the cross-sectional area of the F05 and the target and output rib cross-sectional area for the $F05_{26CA}$ and $F05_{75CA}$ models.

IV. DISCUSSION

The present study quantified the effect of changing cross-sectional area with increasing age. Other factors such as material strength changes were not considered in this study. The rib cross-sectional area changes between young and aged affected the fracture location and led to a higher number of rib fractures. The $F05_{75CA}$ predicted multiple fractures in ribs six and seven. In contrast, the $F05_{26CA}$ model predicted simple rib fractures throughout the thorax. The distribution of the cross-sectional area (e.g. rib seven) affected the fracture location in side-impact simulations despite the magnitudes being similar between the F05 and $F05_{75CA}$ (Fig. 3). The results suggest that a correct representation of the rib cross-sectional area and distribution plays an important role in the fracture response of human ribs. The average changes with age in cross-sectional area were analysed; however, future work must assess the effect of variability with increasing age. Future work include the modification of the material properties to represent the aged population.

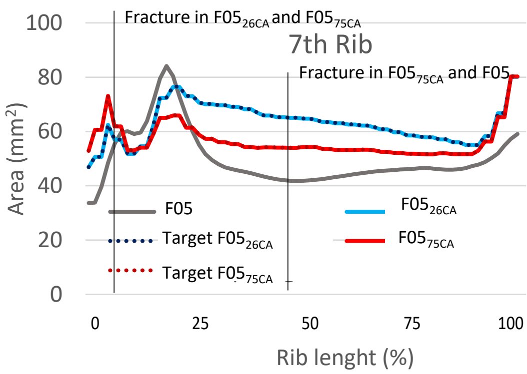

Fig. 3. The cross-sectional area of the F05, $F05_{26CA}$ and $F05_{75CA}$ models demonstrating the differences in the distribution of cross-sectional area.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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