Influence of Age on Chest Injury in Simulated Table-top Loading Test with Double Diagonal Belt

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I. INTRODUCTION

In recent years, the proportion of elderly in traffic accident casualties has increased. It is reported that elderly people are more likely to sustain injuries to the chest [1-2]. Investigations using finite element (FE) models suggest that age-related factors affect rib fracture risk [3-4]. This study aims to elucidate the rib fracture mechanism of the elderly chest using human body FE models. The contribution of individual age-related factors to chest response was quantitatively evaluated.

II. METHODS

Age-related Human Body Model Preparation

Two torso FE models were used. One had a rib cage shape of a young adult, while the other had that of an elderly. Both models were generated by morphing THUMS-TUC. The process of model generation is described in the project report of the EC-funded project SENIORS [5]. Figure 1 shows the two rib cage models. The young adult model represents a 35yo 50th%ile male person, while the elderly model represents a 65yo+ person. In addition to the cage shape, the cortical bone thickness of the ribs and the elastic modulus of the costal cartilage were chosen as the age-related factors. The rib cortical area associated with age was reported by Stein *et al*. [6]. The thickness value was defined based on their data. The elastic modulus was defined based on the relationship between the age and the costal cartilage calcification [7], and the relationship between the calcification and the elastic modulus of the costal cartilage [8]. Table I summarises the age-related factors in ribs and their values used in this study.

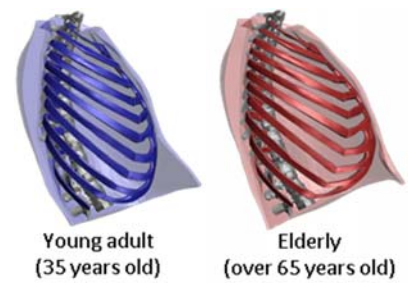

Fig. 1. Rib cage models for young adult and elderly.

TABLE I
AGE-RELATED FACTORS IN RIBS AND VALUES FOR EACH MODEL

	Young adult	Elderly
Cage shape	See Fig. 1	
Cortical bone thickness	0.82 [mm]	0.63 [mm]
Cartilage elastic modulus	21.94 [MPa]	69.38 [MPa]

Table-top Simulation

Figure 2 shows the table-top configuration with a double diagonal belt used in the tests carried out by Kent *et al*. [9]. The strain in the rib cortical bone was measured along with the chest deflection. The chest deflection was measured at a point on the chest surface located just under the belt intersection, and was divided by the initial depth to calculate the deflection ratio. An input was applied to displace the four ends of the belt in the vertical direction. Figure 3 shows the input time history reproducing the tests carried out by Kent *et al*. [3].

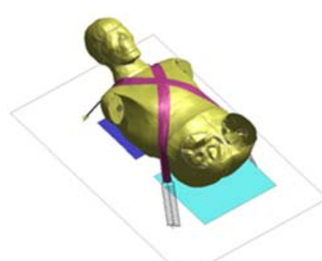

Fig. 2. Table-top configuration.

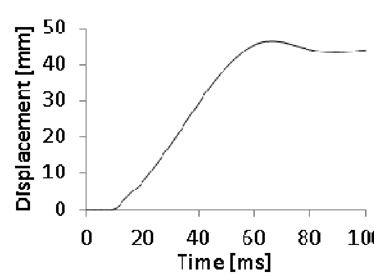

Fig. 3. Input time history.

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III. INITIAL FINDINGS

Figure 4 shows the force - deflection (ratio) curves calculated by the two models. The dotted curves indicate the test corridor. Both curves were found in the corridor. The maximum deflection ratio of the elderly model was smaller than that of the young adult. Figure 5 shows the strain contour of the elderly model at the timing of maximum strain. High strain value was noted on the lateral part of the fifth rib. In Figure 6, the maximum strain values of the left ribs in the two models are plotted. Although the maximum chest deflection ratio of the elderly model was smaller than that of the young adult, the strain values of the elderly model were higher than those of the young adult for most ribs. Table II summarises the chest response ratios of the elderly model to the young adult model for the age-related factors. A high ratio indicates a high contribution of the factor. The cage shape showed contributions for both chest deflection and strain. The cortical bone thickness showed a high contribution to the strain. The cartilage elastic modulus had little contribution. The ratios for the combination of all factors roughly matched the sum of the ratios for individual factors.

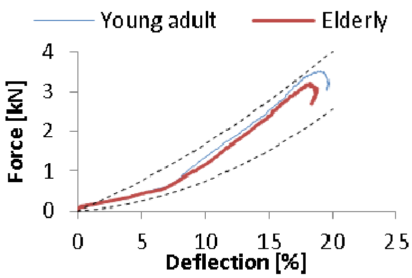

Fig. 4. Response curve of force deflection ratio.

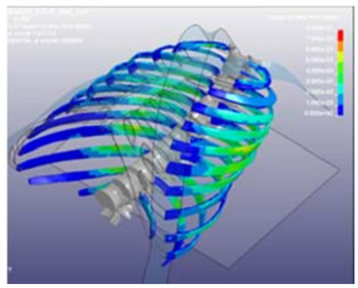

Fig. 5. Strain contour at maximum strain.

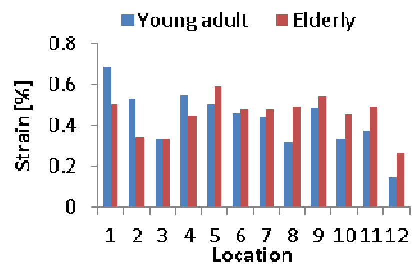

Fig. 6. Maximum strain values of left ribs in young adult and elderly.

TABLE II
CHEST RESPONSE RATIOS OF ELDERLY TO YOUNG ADULT

	Maximum deflection	Average for maximum strain
Combination of all three factors	-5%	15%
Cage shape	-6%	-3%
Cortical bone thickness	*	12–15 %
Cartilage elastic modulus	*	*

*Minor change by less than 2%.

IV. DISCUSSION

In this study, the same amount of anterior-posterior deflection was induced into the two chest models. The chest deflection ratio of the elderly model was smaller than that of the young adult because the initial depth of the chest was greater. The smaller chest deflection ratio resulted in the smaller rib strain of the elderly model. As for the influence of the age-related factors, the cortical bone thickness showed a higher contribution to the rib strain compared to that by cage shape. The results suggest that the cortical bone thickness is the dominant factor affecting the vulnerability to rib fracture due to aging.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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