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Age-Targeted Human Body Models Indicate Increased Thoracic Injury Risk with Aging

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Objective: The objective of this work is to generate age-targeted versions of the male and female Global Human Body Models Consortium (GHBMC) occupant human body models (HBMs), to validate each in frontal impacts and to assess predicted rib fractures of each.

Methods: Six age-targeted models were developed based on the GHBMC average male and small female occupant models (M50-O v.6.0 and F05-O v.6.0 respectively). All age-targeted models were modified to represent population means for height, weight, shape, and relevant material properties. Male age targets were: 24YO (74.5 kg, 1.75 m), 42YO (83.0 kg, 1.76 m) and 70YO (74.0 kg, 1.70 m). Female age targets were: 24YO (42.7 kg, 1.50 m), 42YO (47.9 kg, 1.51 m) and 70YO (44.4 kg, 1.49 m). The thin plate spline method was used to morph models, and material properties were modified using available literature. Validation focused on chest response. Models were evaluated in biomechanical frontal and oblique chest impacts (Kroell, 1974 & Viano, 1989). M50-O models were evaluated in a 40 km/h frontal sled test (Shaw, 2009) and F05-O models in a 30 km/h frontal sled test (Shaw, 2017). A total of 18 simulations were conducted (3 ages x 2 sexes x 3 cases).

Data Sources: The aged body habitus' were generated from statistical data generated on sex, BMI and height targets (Reed, 2020). Target heights for each model were based off the U.S. National Health and Nutrition Survey. BMI targets were generated from a global dataset (Di Cesare, 2016). Rib materials were aged using Katzenberger 2020 data. Rib shape was based on Weaver, 2014 in M50-O and Holcombe, 2017 in F05-O. Lung material properties were aged based on Lai-Fook, 2000. Costal cartilage calcification was based on Huang, 2019 and Holcombe 2017.

Results: Chest deflections and landmark kinematics matched the respective corridors in the M50-O and F05-O aged models. F05-O aged kinematics can be seen in Figure 1. Increasing fracture was observed through rib cortical bone element erosion by age in all cases, from 1 rib fracture in 24YO to 9 ribs fractured in 70YO in the M50-O frontal sled (Figure 2). The M50-O 70YO and F05-O 70YO models best matched the PMHS in number of rib fractures in classical biomechanics tests as these tests used older subjects (age 61±15).

Conclusions: Age-targeted HBMs indicate increased fracture with age when subjected to equivalent impacts. Gross model kinematics match PMHS data well but appear to show little difference between ages.

Significance: While human models of advanced age have been presented in the literature, this study aims to provide age-targeted models spanning the driving lifespan. We demonstrate that HBMs can be modified morphologically and material response-wise to meet this end. The findings indicate that such models capture trends of increased thoracic injury risk observed in experimental and field studies and suggest their potential use to target interventions for vulnerable driving populations, such as older adults.

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