Human Body Model Morphing for Biofidelic Predictions of Kinematics and Rib Fracture Risk for a Diverse Population of Occupants

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Background

Female, obese and elderly occupants are at greater risk of injury in vehicle accidents. In order to develop vehicle safety systems that provides protection for all vehicle occupants, understanding the influence of occupant characteristics, i.e. sex, age, stature and weight, on injury risk is necessary. With recent developments in Human Body Model (HBM) morphing methods, HBMs anthropometrically representing a wide range of statures, weights and ages for both males and females can be created. Morphed HBMs have the potential to be applicable tools for such investigations. The aim of this study is to evaluate the capability of morphed HBMs to predict the kinematics and rib fracture risk observed in individual PMHS tests.

Methodology

Twenty-two published whole-body PMHS impact tests were included in this study. The tests included seven female and twelve male PMHS with a wide range of ages (34-87YR), statures (152-189cm) and weights (39-124kg). Impact directions included lateral near-side, frontal oblique, frontal and far-side oblique. The tests were re-created in finite element simulations with the SAFER HBM as occupant substitute. The HBM was morphed to the sex, age, stature and body mass of the PMHS in each test. Material properties were not modified. The HBM simulation results were compared to the corresponding results from the PMHS tests. For objective rating of HBM predictions, magnitude weighted CORrelation and Analysis cross correlation method (CORA) rating was used. A kinematics CORA rating ≥0.65 was considered biofidelic. The HBM predicted risk of fractured ribs was compared to the number of fractured ribs in the tests.

Results and Discussion

In frontal, near and far-side oblique cases the average CORA rating for predicted kinematics was 0.74. Highest and lowest rating were 0.83 and 0.66. The morphed HBMs underpredicted the maximum pelvis forwards excursion in eight of nine tests. In the thirteen lateral impact tests, the morphed HBMs obtained an average, maximum and minimum kinematics CORA rating of 0.73, 0.89 and 0.65, respectively. The morphed HBMs overpredicted impact force magnitudes and underpredicted lateral chest and abdominal deflection magnitudes. The morphed HBMs predicted a high risk (>50%) of two or more ribs fractured (NFR2+) in four out of 17 tests with NFR2+.

The morphed HBMs predicted the PMHS kinematics for a wide range of anthropometries as judged by a CORA rating ≥0.65. More research is needed to identify biofidelity requirements for HBMs with respect to individual PMHS test results. The underprediction of excursion and chest deflection magnitudes indicated that the HBM was too stiff regardless of test condition and which anthropometry it was morphed to. Future work will update the tissue modeling in the HBM to mitigate the exaggerated stiffness and further improve kinematic and rib fracture risk predictions of morphed HBMs.

Conclusions

HBM morphing allows for biofidelic predictions of individual PMHS kinematics (CORA ≥ 0.65). Morphed HBMs predicted a low risk (<50%) of NFR2+ in thirteen tests with NFR2+.