Bio-fidelity Evaluation of GHBMC M50-OS against Laboratory Sled Tests

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Introduction

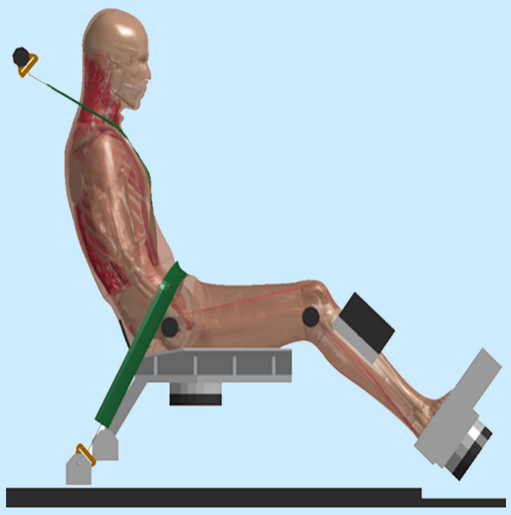
- Recent automotive safety research has focused on oblique frontal collisions to understand the occupant response and countermeasure efficacy for a frequent real-world crash mode.
- Human body models are injury prediction tools that can investigate the biomechanical response of the human body in this crash condition.
- In order to have confidence in the capabilities of the human body model to predict injury, they must be evaluated against experimental to demonstrate they are accurate (biofidelity).

Objective

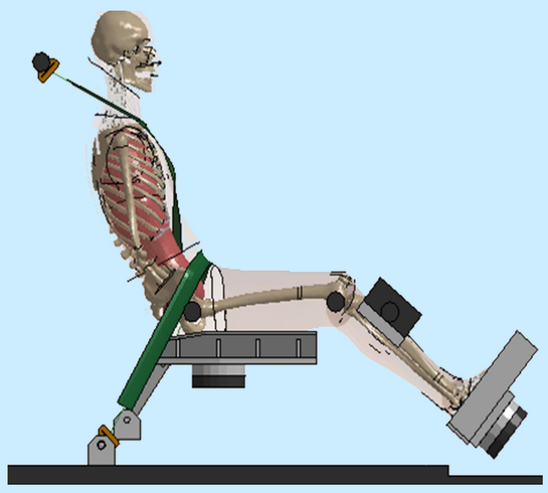
1. Assess the bio-fidelity of the Global Human Body Model Consortium (GHBMC) owned 50th percentile male detailed occupant model (GHBMC M50-O) and simplified occupant model (GHBMC M50-OS) using post-mortem human subject (PMHS) sled test data in a near-side oblique crash conditions.

Methods

GHBMC M50-O integration with GS3 setup



GHBMC M50-OS integration with GS3 setup



Sled Conditions

- The Gold Standard 3 (GS3) test is a 30km/h, 30° near-side oblique frontal impact test using a custom 3KN force-limited shoulder-belt and a modified seat. [1]

PMHS Characteristics

- N=3; Sex: Male; Mean data: 67.3 years, 173.7 cm, 69.6 kg

Model Set-up

- Each model was positioned to match the thorax, pelvis, and lower extremity positons in the PMHS tests
- The models were allowed to settle into the seat
- A seatbelt was fit across the thorax at the mid-sternum and mid-clavicle similar to the PMHS test set-up
- Instrumentation was added to each model to correspond to the PMHS test set-up

Quantitative Assessment of the Model

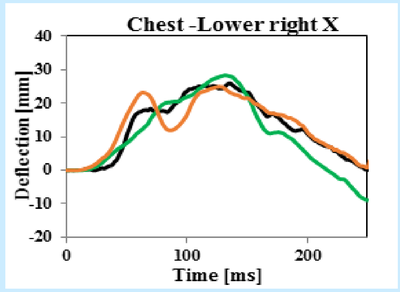
- The assessment was performed using CORA
- Weighting: Corridor: 0.4; Phase: 0.2; Magnitude: 0.2; Slope: 0.2

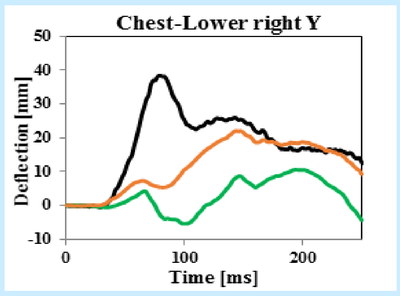
Injury Evaluation

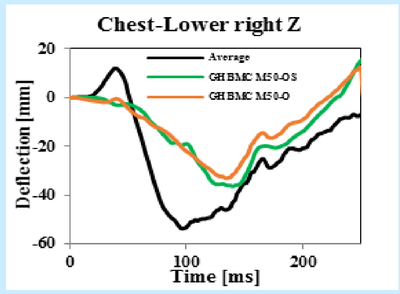
- GHBMC M50-OS
  - Not intended to predict crash induced injuries based on tissue-level criterion.
  - Obtain kinematics from accelerometers or deflection sensors.
- GHBMC M50-O
  - Deterministic method
    - Predict fracture injuries for clavicle, sternum and ribs via element erosion
    - Failure set to an effective plastic strain tolerance of 1.78%.
  - Probabilistic method
    - Predict the risk of rib fracture based on maximum principle strain response without element erosion.
    - Utilize a strain-based injury risk function accounting for tolerance variations in the population. [2]

Results

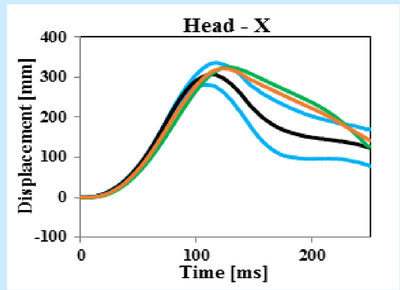
Lower right chest deflection relative to T8

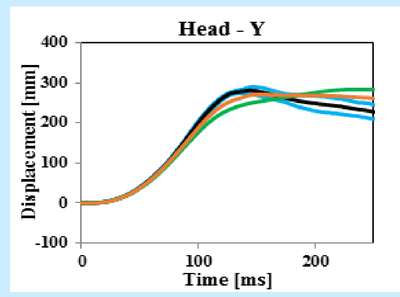


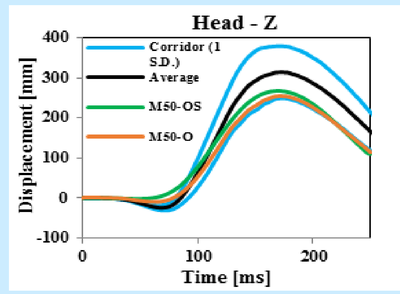




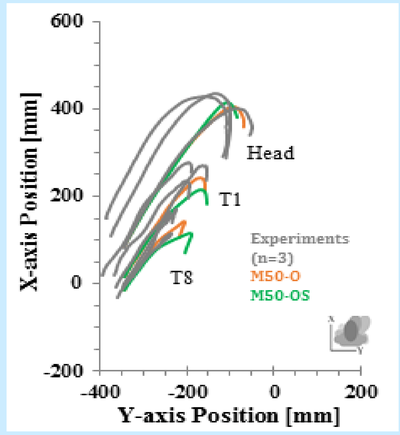
Head displacement relative to the sled

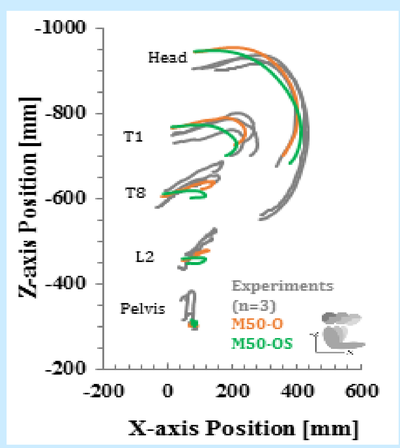




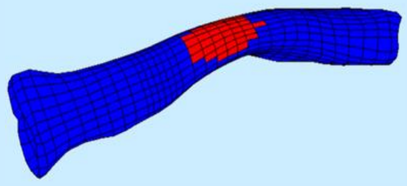


Spine trajectory

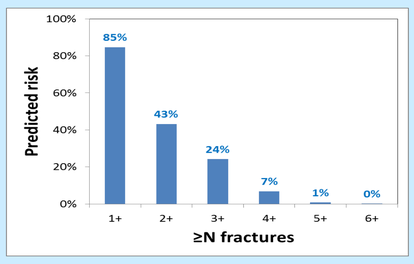




Injury evaluation



Right **clavicle bone fracture** (red) are those that exceeded the strain failure threshold.



Rib fracture risk based on rib strain response using an age-adjusted threshold targeting a 60 year old.

Discussion

- GHBMC M50-O and GHBMC M50-OS were able to reproduce most PMHS occupant motions with reasonable accuracy.
- Average CORA score across all 54 channels of data was 0.54 for M50-OS (range: 0.39-0.70) and 0.60 for M50-O (range: 0.38-0.80).
- Spine lateral displacement between the models and PMHS indicate that the thoracolumbar spine is an area for future model improvement.
- Model ability to predict rib fracture in this condition was satisfactory. However, the model was not able to predict cervical spine fracture.
- Summary of injuries predicted by M50-O

Experiments (n=3)	*M50-O*	*Prediction Method*
Clavicle fracture (33%)	Clavicle fx	Post-processing (EPS > 1.78%)
Cervical fracture	None	Post-processing (EPS > 1.78%)
Sternum fracture (33%)	None	Post-processing (EPS > 1.78%)
Rib Fracture (≥ 1) (66 %)	Rib Fracture (≥ 1) (85 %)	Strain-based fracture risk prediction [1]
Rib Fracture (≥ 6) (66 %)	Rib Fracture (≥ 6) (0 %)	Strain-based fracture risk prediction [1]

Conclusions

1. Validity of the responses of GHBMC M50-O and GHBMC M50-OS were evaluated by simulating each model in the GS3 sled test condition and compared to PMHS data.
2. Both models were compared favorably to the PMHS responses but local differences in occupant kinematics were observed.
3. Injury prediction for GHBMC M50-O was found to be satisfactory despite a tendency for under-predicting rib fractures.

[1] Acosta, S. M., et al. (2016). Comparison of Whole Body Response in Oblique and Full Frontal Sled Tests. In IRCOBI Conference Proceedings.
[2] Forman, J.L., et al. (2012). Predicting rib fracture risk with whole-body finite element models: development and preliminary evaluation of a probabilistic analytical framework. Annals of Advances in Automotive Medicine 56:109-124

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