Small Female Frontal Crash Mode ATD Analogous Human Body Models

Seth H. Mischo, Wade von Kleeck, F. Scott Gayzik

I. INTRODUCTION

In the study of injury biomechanics, a modeling approach typically focuses on either computational models of anthropomorphic test devices (ATDs) or human body models (HBMs) that represent a subset of a population, such as a 50th percent average male. It is well established that a single HBM is not representative of the vast anthropometric variation present in humans, but the anthropometric correspondence between a standard HBM and a given ATD has not been well studied. With the rise of the use of HBMs in regulatory and consumer testing, there is a potential role for HBMs that share anthropometry with ATDs to augment what can be physically tested while removing a clear confounding factor of differences in body habitus. Development of models that can be used in conjunction with ATDs may provide further insight into different injury criteria that result from an impact. The Global Human Body Model Consortium (GHBMC) model suite includes a computationally efficient simplified 50th percentile male HBM (M50-OS) and a 5th percentile female HBM (F05-OS) [1-2]. The anthropometry of these HBMs is based on medical imaging and surface scan data of subjects recruited to match specific measures of their respective target population [2-3]. These models have been run in a variety of validation cases compared to PMHS, including oblique and thoracic hub impacts, an abdominal bar test, and a sled tests [4]. To remove a confounding factor in the comparison of HBMs and ATDs, we developed ATD Analogous HBMs from the GHBMC 5th Percentile Female simplified occupant model (F05-OS) for F05 Hybrid III and THOR. This approach has been applied for the male M50-OS model, but has not yet been applied to the F05-OS [5]. Model performance is compared using component load case simulations and frontal sled simulations.

II. METHODS

Model development leveraged data from University of Michigan Transportation Research Institute (UMTRI)'s parametric human shape models. Measurements for anthropometry for various components of the model were taken via data from ANSUR I and measured manually in LS-PrePost. Seven anthropometric measurements from ANSUR I were obtained on the ATDs themselves in LS-PrePost. A Radial Basis Function Thin Plate Spline Morph was performed to target ATD anthropometry using nodes from GHBMC F05-Occupant Simplified (OS). Segment-based density adjustment was performed on the morphed models to obtain body segments within a 2% tolerance of their respective ATDs, the LSTC F05 Hybrid III v 190217 and the University of Virginia F-05 THOR v 02. Nine component load case simulations were simulated based on data from the respective ATD manuals, four simulations for Hybrid III and five simulations for Thor. A frontal belted 56 km/h sled test was also performed.

Fig. 1. Comparison of F05 HAN-OS (colour mapped, translucent) vs. F05 Hybrid III (black) in which we can see that the leg length and seated height are similar. The legs of F05 HAN-OS are slightly offset for visualisation purposes.

F. S. Gayzik (e-mail: sgayzik@wakehealth.edu; tel: 336-716-6643) is a professor, S. H. Mischo is a PhD student in Biomedical Engineering and W. von Kleeck is a Research Engineer, all at Wake Forest School of Medicine (WF-SOM) in Winston-Salem, NC, USA. **Disclosure:** F. S. Gayzik is a member of Elemance, LLC, which provides academic and commercial licenses for GHBMC-owned human body models.

III. INITIAL FINDINGS

We present 5th Percentile Female (F05-) Hybrid III and Thor Analogous Occupant Simplified models, HAN-OS and THAN-OS, respectively. Due to space limitations, we are showing only F05 HAN-OS images and data (Fig. 1). Morphing did not compromise model stability, and 2% tolerance benchmarks were met for segment-based density adjustment. Component load case simulations of the ATD analogous models did not yield significant differences from the baseline F05-OS model. Constitutive differences between HBMs and ATDs result in disparities in response data (Fig. 2). However, kinematics from the frontal sled simulation indicated that the F05 HAN-OS sagittal plane head trajectory demonstrated a trajectory more like F05 Hybrid III, exhibiting less hysteresis than F05-OS. This also presented itself in the h-point kinematics, where the F05 HAN-OS model exhibited less excursion compared to the baseline F05-OS, with the least excursion present in F05 Hybrid III. Interestingly, the T12 kinematics for F05 HAN-OS and F05-OS were quite different, and F05 HAN-OS excursion was more like F05 Hybrid III (Fig. 3).

IV. DISCUSSION

We expand upon previous work on the development of ATD-analogous models for the average male body habitus [5] by presenting the development of two 5th percentile female analogous models. This work seeks to further "bridge the gap" between ATDs and HBMs by providing an intermediary model that can be used in conjunction with its respective ATD. The ATD-analogous female models may serve several important roles in forthcoming computational biomechanics studies. First, they may prove useful for identifying occupant kinematics and kinetics in scenarios for which conventional ATDs are not intended. This includes low speed, long duration crash avoidance manoeuvres (driver or vehicle initiated), which are of contemporary interest to the safety community. HBMs that are based on the anthropometry of ATDs may also serve to homogenize or standardize sizes of HBMs for future regulatory testing protocols. Efforts are currently underway to develop virtual testing protocols, and not only the biomechanics, but also the anthropometry of nominally sized HBMs has been the subject of some debate. Two different HBMs that are nominally 5th percentile females may be quite different in terms of key anthropometric measures like seated height, and these differences can lead to different predicted outcomes. ATD-like models therefore offer a potential means to standardize HBM sizes in test protocols to a body habitus that is already widely used.

V. REFERENCES

[1] Schwartz, *et al.*, *Traffic Inj Prev*, 2015. [2] Davis, *et al.*, *Stapp Car Crash J*, 2016. [3] Gayzik, *et al.*, *Ann Biomed Eng*, 2011. [4] Decker, *et al.*, IRCOBI, 2018. [5] Mischo, *et al.*, *Accid Anal Prev*, 2021.

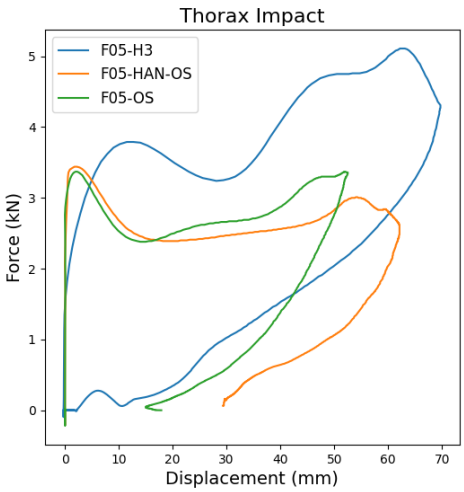

Fig. 2. Thoracic impact force vs. deflection data for the three presented of models. F05 HAN-OS had a higher peak force and peak displacement than F05-OS, putting its values more like that of F05 Hybrid III.

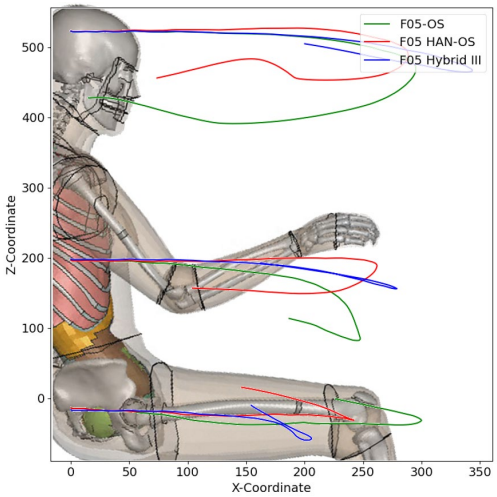

Fig. 3. Kinematics for the three models in the 56 km/h frontal sled test. F05-OS and F05 HAN-OS had similar excursion in x, however F05 HAN-OS had less excursion in z in the head, T12, and H-Point, closer matching F05 Hybrid III compared to 05-OS. All traces are normalised to start at x = 0, so they do not line up exactly to the given anatomical positions.