Assessing Surface Geometry Changes in Quasi-Static Settling of HBMs

Seth H. Mischo, Alex Kalmar-Gonzalo, Tyler Roy, F. Scott Gayzik

I. INTRODUCTION

Human Body Models (HBMs) are extensively used in dynamic loading boundary conditions to assess injury likelihood, vehicle crashworthiness, and to evaluate novel countermeasure designs for occupant safety. While there is a large body of work which assesses and validates the biofidelity of dynamic HBMs in controlled impacts and sled simulations [1], there is very little validation of the quasi-static settling phase of simulations. In review of the literature, the PIPER Adult Comfort Model [2] is one of the few which has been validated in settling, although it is not widely used in dynamic simulations. It has been shown that the settling phase is an integral part of initial positioning of HBMs within their virtual environments, and that changes to the settling time can influence kinetics and kinematics in the dynamic phase of a simulation [3]. However, the referenced study only encompasses settling timing and does not address the changes in surface contours of the HBM itself when settled into a seat. Our group has studied changes in the body contour of healthy adult participants while seated (8M : 9F) and quantified differences in the hips and thighs between unloaded and loaded surface geometry (WFU IRB # 00109011). This study begins to address the gap in settling validation via assessment of surface geometry changes in two Global Human Body Model Consortium (GHBMC) models, the 50th Percentile Male Occupant, Simplified (M50-OS) and 5th Percentile Female Occupant, Simplified (F05-OS), providing insight into how accurately the models reflect the body's interaction with a seating environment.

II. METHODS

Human subjects were seated in a 90-90-90 posture using a wood and acrylic hard seat. Posture and anthropometric measures were measured using standard anthropometric techniques, and 3D surface data was collected using a Peel 3D Scanner (Quebec, Canada). A to-scale computer aided design of the seat from the experimental work was made using Fusion 360 (AutoDesk, San Francisco, CA), and meshed in LS-PrePost (LSTC, Livermore, CA), along with a footrest. The seat was given a rigid material except for the tabletop surface, which was assigned the properties of acrylic. The seat was fixed in space using a boundary single point constraint in all 6 degrees of freedom. Both M50-OS and F05-OS had a measure taken of buttock to knee length, as well as from the bottom of the leg to the heel of the foot. These two measures were used for: 1. Positioning of the models at 70% buttocks and leg coverage on the acrylic, and 2. Footrest positioning to allow for contact with the feet, Figure 1. Constraints were placed on the hands and knees to prevent lateral movement, as well as on the spine (C1-T12) in rotation to prevent slouching of the HBMs. The hands were not positioned laterally to match the human participants because the constraints on them did not allow contact with the rest of the body and had minimal oscillation. Finally, gravity was applied in the Z-direction and both boundary conditions were run for 350 ms until normal termination using LS-DYNA R12.2.1, using the Wake Forest School of Medicine High Performance Cluster on 64 cores with 96 GB of RAM. Three outcome measures were assessed on HBMs compared to their sex-specific experimental counterparts via comparison of initial state and the terminal end-state: the change in lateral hip breadth (ΔY_{hip}), change in superior-inferior distance at 50% the length of the leg (ΔX_{leg}) and the change in lateral distance at 50% the length of the leg (ΔY_{leg}). Measurements were collected in LS-PrePost at the start (t = 0 ms) and end (t = 350 ms) states of the simulations to assess deformation. For ΔY_{hip} the measure was taken from surface nodes at the greater trochanter

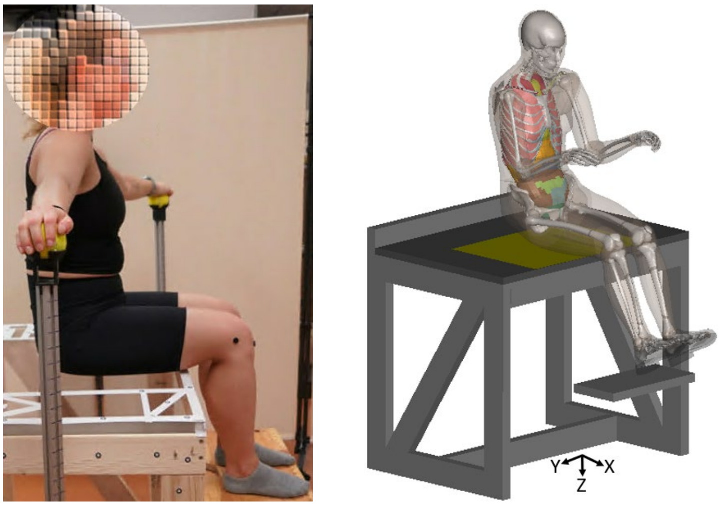

Fig. 1. Initial (t= 0 ms) position of F05-OS in the seat (right) compared to a female participant from the experimental study (left).

F. S. Gayzik (e-mail:sgayzik@wakehealth.edu; tel: 336-702-9177) is a Professor, S. Mischo is a PhD candidate in Biomedical Engineering, A. Kalmar-Gonzalo is a PhD student in Biomedical Engineering, T. Roy 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 HBMs.

on both sides. For ΔX_{leg} measures were taken from the superior and inferior most nodes of the right leg at 50% of the length of the leg. ΔY_{leg} was collected via the lateral and medial most points of the right leg at the same cross section. Leg length was determined based on half the distance of the buttocks-to-knee length of each model. These measures use the human body coordinate system in SAE J211.

III. INITIAL FINDINGS

Results are shown in Figure 2. In M50-OS, ΔY_{leg} was slightly below the mean but within the interquartile range. However, ΔX_{leg} and ΔY_{hip} were at the maximum and minimum, respectively, of the experimental data. The ΔX_{leg} was 23.6 mm, ΔY_{leg} was 16.2 mm, and ΔY_{hip} was 9.9 mm, as measured at the greater trochanter. The F05-OS HBM was on the low-end of the data for all measures, with an ΔX_{leg} of 10.8 mm, a ΔY_{leg} of 13.2 mm, and a ΔY_{hip} of 11.4 mm as measured at the greater trochanter.

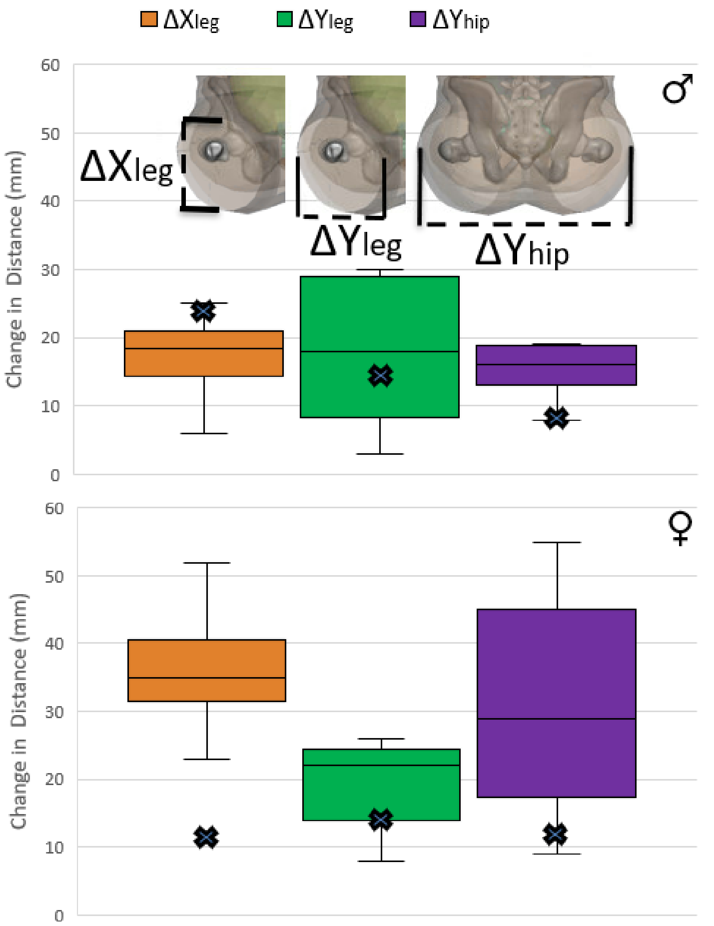

Fig. 2. Change in distance for ΔX_{leg} and ΔY_{leg} as well as ΔY_{hip} for males (top) and females (bottom). Human subject data is shown as box and whisker plots, with HBM results denoted with *X for M50-OS (male) and F05-OS (female).*

IV. DISCUSSION

These preliminary findings support the notion that further validation is necessary for dynamic HBMs in quasi-static settling simulations. It appears, based on this data, that M50-OS trends are stiffer in terms of lateral displacement of adipose as compared to the experimental work. This may be due to constitutive differences between the HBM and the human participants. In contrast, F05-OS had all three data points on the low end of the experimental data. This is expected, as a 5th percentile female would have less area to deform under load as compared to the general population. However, the ΔX_{leg} deformation was significantly below the box and whisker plot. This may be indicative that the superior-inferior change in the leg under load of F05-OS is lower than expected, and it is stiffer in superior-inferior displacement. Further investigation into settling characteristics of these models is warranted. A limited portion of collected human subject data is presented here. Our group utilised a multi-modality approach including 3D surface scan data, magnetic resonance imaging (MRI), and pressure mat data. Future work will focus on creating sex-and-subject-specific HBMs based on the M50-OS and F05-OS. These HBMs would then be used for a more comprehensive comparison of experimental data across measurements. Future work to implement up to date adipose tissue models may bring these results into greater alignment with the observed data [4]. No dynamic HBM, has been validated in settling, and with the advent of model certification for safety regulations this may be an important step in improving the overall utility of HBMs for the safety engineering community. By validating in a quasi-static settling mode, insight into the human-to-seat coupling of HBMs within a boundary condition will provide a more biofidelic and representative initial position, matching experimental conditions.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

[1] Blade, S., et *al*., IRCOBI 2025

[2] Liu, S., et *al*., Front. Bioeng. Biotechnol. 2023

[3] von Kleeck, B. W., et *al.,* Enhanc. Saf. Veh. ESV 2024.

[4]. Panzer, M., et *al*., IRCOBI 2024