Evaluating Passive Human Body Models against Non-injurious Lateral Head Impacts Measured in Volunteers

Sayak Mukherjee, Kristen A. Reynier, Benjamin J. Igo, Shubham P. Kulkarni,
Kalle Chastain, Matthew B. Panzer

I. INTRODUCTION

The human body modelling (HBM) community is focused on enhancing existing models with active muscle response to make them more biofidelic in impact scenarios. Any human volunteer data involving impact, from simple loading cases to complex sled tests, provide a valuable opportunity to identify current limitations and guide future improvements. The present study evaluates the passive response of three HBMs when experiencing a lateral impact to the head, and the response is compared to human volunteer data with the same impact conditions with variations in neck muscle activation [1]. In the volunteer study, 20 male subjects were impacted at the side of the head with a sphere of mass 3.7 kg at a linear velocity of 2 m/s. During the impacts, both the impactor and volunteer head were covered with foam padding, and the same foam was mechanically characterized to develop a constitutive model for implementing into simulation. The results of this study provide an insight into the utility of the HBMs in predicting response under low-severity impacts.

II. METHODS

Padding Material Characterization

In the volunteer tests, the impactor was covered with 6.35 mm polyurethane foam. The volunteer also had a padding of 19.05 mm polyurethane foam at the location of impact. Material characterization was done to obtain the material parameters to be used in the FE simulations. Compression and stress relaxation tests were done on the impactor and head padding samples. A quasilinear viscoelastic model with the characterization of $g\,(t) = G_\infty + \sum_{i=1}^{n} G_i\, e^{-\beta_i t}$ was used for the foams with five reduced shear terms [2].

Computational Modelling Setup

Three commonly used 50th percentile male seated occupant HBMs – GHBMC v6.0 detailed, GHBMC v2.3 simplified, and THUMS v6.1 – were used in this study (LS DYNA mpp R12.0.0). The HBMs were validated with lateral sled test data [3-5] and other automotive loading environments [6-9]. All three HBMs were positioned in the test setup with the neck upright (Fig. 1), and no activation was applied to the HBM muscles. The impactor was assigned an initial velocity of 2 m/s in the lateral direction, with the other two directions constrained. The steel ball (rigid, 3.7 kg) and HBM head were modelled with the attached foam consistent with the experiment (Fig. 1). Simulated head kinematics were filtered using SAE CFC 300 Hz filter before comparing it to the head kinematics from the passive and unilaterally contracted muscle activation states as these cases bounded the volunteer data. In the volunteer tests, the average peak acceleration and peak angular velocity in the unilateral activation condition was found to be lower than the passive condition [1].

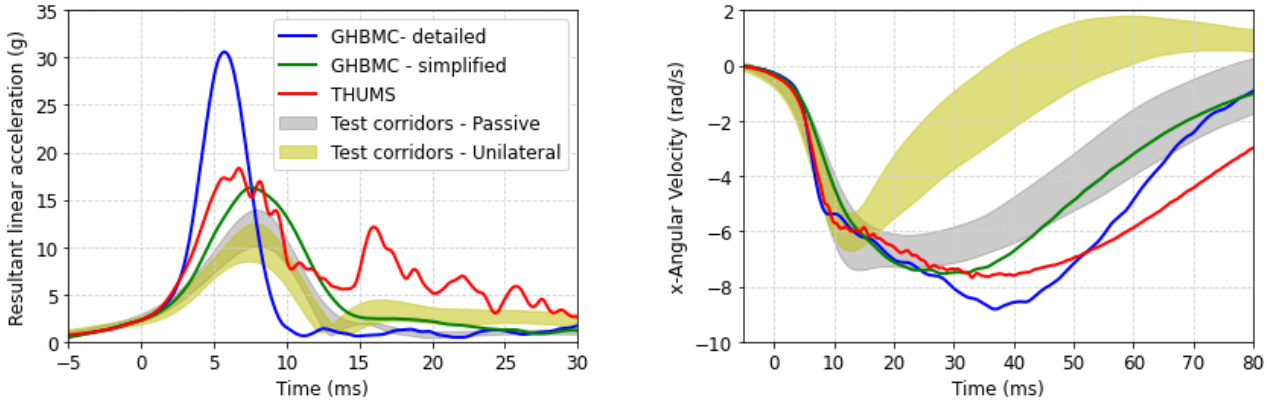
(a) (b)

Fig. 1. Model setup for the head impact. (a) HBM with impactor and head padding, (b) isometric view of the impact.

S. Mukherjee and K. Reynier are PhD students, and M. Panzer (e-mail: panzer@virginia.edu; tel: +1 434.297.8062) is an Associate Professor at the Center for Applied Biomechanics in the Department of Mechanical and Aerospace Engineering, University of Virginia. B. Igo, S. Kulkarni and K. Chastain graduated with MS from Department of Mechanical and Aerospace Engineering, University of Virginia.

III. INITIAL FINDINGS

The simulation data were adjusted such that the magnitude of head linear acceleration was 2 g at 0 ms to be consistent with the timing of the experimental data. The results obtained from the head impact simulations were compared with the response corridors for passive and unilaterally contracted volunteer tests [1] and simulated resultant head linear acceleration and coronal angular velocity demonstrated differences between all three models in this non-injurious loading condition (Fig. 2).



(a) (b)

Fig. 2. Head kinematics response: (a) Resultant linear acceleration, (b) coronal angular velocity.

Preliminary analysis of the simulation data suggests that the simplified GHBMC HBM has the most biofidelic response to the lateral impact among the three models under study, and the magnitude of head acceleration and angular velocity were slightly higher than the passive volunteer corridor. The resultant head acceleration peak in the detailed GHBMC was twice in magnitude to the peaks observed in the passive tests, and substantially higher in angular velocity. The THUMS model had a response that was in between the two GHBMC models, however the linear and rotational response were outside the test corridors during the unloading phase of the simulation. Both detailed HBMs had issues with matching the temporal characteristics of the volunteer data.

IV. DISCUSSION

The current study quantified the response of passive HBMs under non-injurious lateral impacts relative to two neck muscle activation schemes in a group of 20 male human volunteers. The differences in response of the HBMs compared to the test data highlight current challenges in HBM development for multiple regimes of loading, as most of the historical validation data are based on cadaveric, injurious loading. Many factors associated with the soft tissue properties of the HBMs may contribute to the differences observed in this study, and further investigation is required to understand and evaluate the effect of each component on the overall response of the HBM head and neck. It is understandable why passive HBMs cannot capture the complete time-history of volunteer response, as involuntary muscle contraction is likely influencing the post-peak head kinematics in these low-severity impacts. Further analysis is needed to study the effect of muscle activations on the HBM head kinematics in these volunteer head impacts. This data, along with other human volunteer data collected in the field, should help guide and refine progress towards better muscle activation models for HBM simulation and lead to more biofidelic models across a broader range of loading conditions.

V. REFERENCES

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