Validation of a Simplified Human Body Model for Predicting Occupant Kinematics during Autonomous Braking

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Research Question/Objective: Passive finite element Human Body Models (HBMs) without active musculature fail to accurately predict volunteer kinematics in various pre-crash scenarios, underscoring the need for active HBMs. The objective of this study is to develop and validate a simplified HBM with active musculature for simulating occupant response during autonomous braking, both with and without active restraint systems. The Global Human Body Models Consortium (GHBMC) average male simplified occupant model (M50-OS) was updated with active musculature (M50-OS+Active) as part of this study. The goal of this study was to validate the M50-OS+Active model's performance in autonomous braking scenarios.

Methods: A previously published autonomous braking event was simulated by applying an initial velocity of 70 km/h and braking acceleration pulse of 1.2g in the x-direction (direction of forward travel) in LS-DYNA (R. 9.1, LSTC, Livermore, CA). Two sets of simulations were carried out, one set with a pre-tensioner and one set without the pre-tensioner. The baseline M50-OS model was updated with one-dimensional beam elements representing all the major skeletal muscles. These beam elements were assigned an established Hill-Type muscle material. The updated model M50-OS+Active employs 32 proportional–integral–derivative (PID) controllers for maintaining the initial posture of the model, designed to capture the assumed behavior of the volunteers. The output of the PID controllers, along with initial activation was used for calculating muscle activation levels for each muscle using a firing rate of motor neurons sigmoid function from the literature.

Data Sources: Volunteer (n = 11) data from autonomous braking tests by Olafsdottir et. al. was used to simulate the events in LS-DYNA (R. 9.1, LSTC, Livermore, CA). The tests were conducted in a passenger car with an initial speed of 70 km/h and autonomous braking intervention to reduce the vehicle speed to 50 km/h. The data consists of occupant kinematics with subjects in passenger seat position. A generic frontal crash driver-side buck was used in this study. The braking pulse and seatbelt pre-tensioner loading pattern used in the simulations were taken from this published volunteer study.

Results: Preliminary results from volunteer simulations have shown a strong dependence of reaction loads and kinematics on muscle activation. The results from simulation without muscle activation were falling outside the experimental corridors. The head CG displacements in the x-direction are similar to the displacements observed in volunteer tests as shown in Figure 1, demonstrating the ability of the selected approach in capturing the active muscle response.

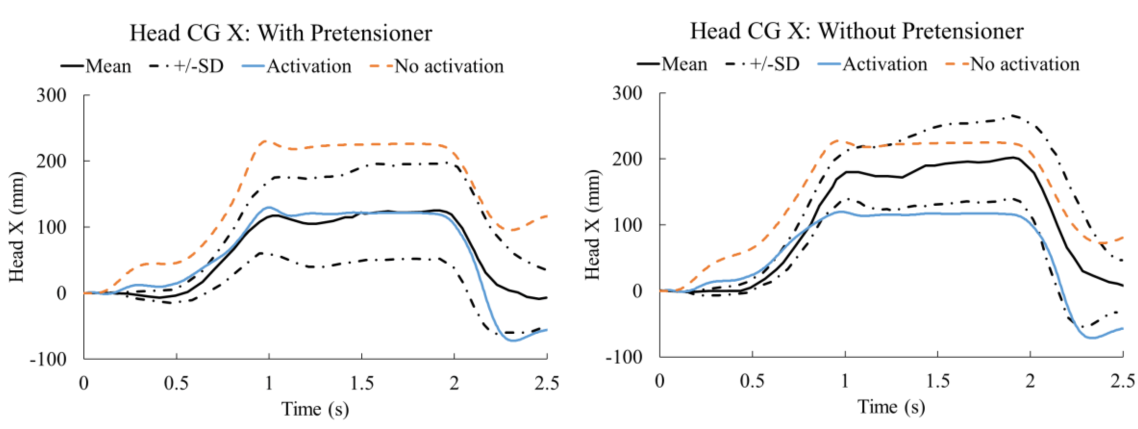

Figure 1: Head CG displacement in the x-direction (forward)

Conclusion: We demonstrate the effect of active muscles in simplified models to predict occupant kinematics during autonomous braking. An active muscle version of the GHBMC simplified occupant model was developed and validated for predicting occupant kinematics in autonomous braking.

References:

1. J. M. Olafsdottir, J. Östh, J. Davidsson, and K. Brolin, "Passenger kinematics and muscle responses in autonomous braking events with standard and reversible pre-tensioned restraints," in International Research Council on Biomechanics of Injury, Gothenburg, Sweden, 2013, no. IRC-13-70, pp. 602-617.