Lateral Impact Validation Study Using a Probabilistic Statistical Shape Finite Element Model of the Head and Neck

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Abstract

Injury prediction and mitigation are common overarching goals of modern biomechanics research. This research is fundamental to preventing and mitigating injuries sustained by those exposed to dangerous conditions including but not limited to occupational hazards, warfighter risks, automotive accidents, etc. Unlike traditional mechanical system research, biological systems are difficult and costly to test resulting in a need for robust and accurate numerical simulations.

As part of a hierarchical validation and verification (V&V) methodology, lateral impact cadaveric cervical spine experiments were compared to a high fidelity statistical shape finite element model (SSFEM) of the cervical spine and head. Specimens were mounted to a sled and accelerated using a pendulum impact with 1, 2, and 3 m/s impact velocities. A Vicon motion capture system was used to record all relevant kinematics. Sled accelerations were used as input boundary conditions for the probabilistic study using the SSFEM. Head and vertebrae rotations between the experimental and model responses were then compared.

A latin hypercube probabilistic analysis was performed for each impact velocity to determine the probabilistic response of each rotation metric. A quantitative validation metric based on the cumulative distribution functions (CDF) of the experiment and model responses was used to compare both the average and variation. Our results showed a very good match between the model and experiment at the higher impact velocities and a slightly stiffer response at lower rates. These results are consistent with previous validation studies performed with this SSFEM.

By expanding the validation data set with lateral impact loading, greater confidence of model performance is obtained. This confidence allows the model to be used for probability of injury predictions as well as to identify important system variables in preventing injuries. Providing rapid and cost effective assessment of hazardous loading conditions and safety equipment compared to experimental testing.