Determination of Post Mortem Human Subject Response to 15G Vertical Drop Tower Testing and Initial Application for Total Human Model For Safety Finite Element Model Validation

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Background – Ejection from high-performance aircraft during emergency events can expose pilots to upwards of 18 times the force of gravity (Gs) in vertical acceleration. Current methods for evaluating the potential for injury related to these events rely on instrumented anthropometric test devices (ATDs) and seats in a controlled laboratory environment. However, current lumbar criteria rely solely on recorded seat accelerations for injury prediction. A series of tests using Post Mortem Human Subjects (PMHS) was conducted to establish new criteria for evaluating spinal injury relating to vertical loading through direct estimation of lumbar loads. Finite element (FE) human body models such as the Total Human Model for Safety (THUMS) have the potential to supplement experimental testing with computer simulations to expedite potential injury risk evaluations. However, minimal work has been done to validate these FE models in vertical loading scenarios, which is a critical step to ensure validity in results prior to their implementation as tools for aircraft safety analysis.

Objective – The objective of this study is to evaluate the THUMS v6.1 FE human body model response to 15G peak vertical acceleration utilizing a novel male PMHS data set collected during vertical drop tower testing.

Methods – Drop tower testing was conducted using 50th percentile male PMHS at 15G peak acceleration in a rigid seat, with a seatpan-to-seatback angle of 90°. Subjects were instrumented with 6DX motion blocks at T1, T4, T12, L3, and S1 to capture detailed vertebral body kinematics. Pressure sensors were also placed throughout the lumbar spine to estimate force in the intervertebral discs from S1-L2. PMHS were restrained using a pilot torso harness attached to the seat at the shoulders and lap belt, both pretensioned to 90 N. Reaction forces were measured in the seat using six-axis loads under the seatpan. Final positioning of the occupant was documented using a FARO arm point probe and laser scanner. To recreate the experimental setup, CAD models of the experimental fixture were meshed using a commercial FE modeling software (Hypermesh) and imported into LS-Dyna for incorporation with the THUMS model. The belt routing tool in LS-PrePost v4.9.12 was used to develop the torso harness and shoulder and lap belts. Pre-simulation was performed to position the THUMS model in accordance with recorded FARO data, and the experimentally recorded seat vertical acceleration was assigned using boundary-prescribed motion. Finally, instrumentation locations were duplicated within the THUMS model to match the PMHS experimental setup.

Results – The THUMS model showed similar head kinematics compared to experiment going first into extension, followed by flexion during the primary pulse. The torso of the model however, experienced an increased flexion/compression response compared to PMHS. Peak reaction force in the simulated seat load cells measured 13.03 kN, which was within one standard deviation of the average value (average = 14.8 kN, standard deviation = 3.0 kN). Average load in the lumbar spine in the model was found to be 3.8 kN, which was within one standard deviation of the experimental values (average = 5.2 kN, standard deviation = 1.9 kN).