VALIDATING FE HYBRID III, THOR, AND GHBMC M50-OS FOR FUTURE SPACEFLIGHT CONFIGURATION TESTING

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INTRODUCTION

Injury assessment reference values (IARVs) use post-mortem human subjects postured in specific configurations to determine injury risks to occupants. While historically used in both automotive and military research, these testing configurations may not translate directly to spaceflight. Namely, there are differences in the loading directions, postures, and restraint systems in spaceflight.

This study begins to addresses these differences by validating Finite Element (FE) models of Anthropomorphic Test Devices (ATDs) and FE Human Body Models (HBMs) against physical dummies and human volunteers in various loading directions. This step is crucial for future in spaceflight seat design, in which the occupants are subjected to various loading directions and magnitudes.

METHODS

Between 1976 and 2013, a combination of Hybrid III, THOR, and human volunteer tests were conducted using both the Horizontal Impulse Accelerator (HIA) and Vertical Deceleration Tower (VDT) at Wright-Patterson Air Force Base and USAF Armstrong Laboratory [1-3]. These tests formed a matrix for FE validation. All tests used a 5-point belt restraint system in a flat pan seat with a vertical back [1]. The 275 tests selected comprised 49 physical test configurations with accelerations in the frontal (X-), rear (X+), lateral (Y), and vertical (Z+) directions. The acceleration magnitudes varied from 3-20 G and had pulse duration ranges from 20-110 ms.

Simulations were performed using the Humanetics 50th percentile male Hybrid III, NHTSA THOR 50th Male, and the Global Human Body Models Consortium (GHBMC) 50th male simplified occupant (M50-OS) models in LS_DYNA [4-6]. All simulations consisted of a 150 ms period of gravitational settling and belt pretensioning followed by the acceleration pulse taken from the physical test of interest.

Analysis consisted of both a visual comparison of kinematics as well as a quantitative analysis. Simulation signals in the head, neck, thorax, and pelvis were compared to matched physical signals using the Gehre et al. method (CORrelation and Analysis, or CORA, size phase, and shape) [7].

RESULTS

Visual inspection for the 49 test configuration simulations showed agreement with the physical test cases in regards to the excursion magnitude and direction of the thorax and the head. An example comparison of the THOR model shows agreement in neck flexion, translation of the back relative to the seat back, hand position relative to the knees, and feet position relative to the chair legs. An example head acceleration between the physical and FE THOR model was analyzed. In this example, the size, shape, and phase scores were 0.717, 0.871, and 0.297 respectively on a scale from 0 to 1, with 1 being a perfect score.

DISCUSSION

Initial validation of ATD and human body models against physical test data is essential for building confidence in future applications of those models. Overall the physical and simulation results were comparable, ensuring confidence in FE model performance in the validated regime. The results of this study are highly applicable to both government and commercial spaceflight and provide confidence in FE simulation for future design.

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