Thoracic Biomechanical Responses of Small Female PMHS in a Simplified Side Impact Condition

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Introduction: Biomechanical response targets for the thorax have largely focused on the 50th percentile male, limiting their relevance for smaller females. Previous studies have provided side impact female PMHS data from either oversimplified boundary conditions for thoracic response (Agnew et al., 2024) or extremely realistic boundary conditions (Bolte et al., 2023) that are slightly less repeatable and make interpretations complicated.

Objective: This study aimed to compare thoracic biomechanical responses of small female PMHS between two input energy conditions in a realistic but simplified side impact experiment.

Methodology: Twelve small female PMHS (aged 46-86 years) were included in this study. The PMHS were positioned on a simplified seat that included FMVSS No.213a seat foam on a rigid frame with seat pan and back angles of 15° from horizontal and 18° from vertical, respectively. The left thorax of each PMHS was impacted once with either a 14.0kg ("low-energy input group") or 23.7kg ("high-energy input group") pneumatic impactor at a target velocity of 4.5m/s to replicate a near-side impact to a driver. A rectangular impactor face (22.9x25.4cm) covered with 6.35cm thick FMVSS No.213a armrest foam was used to simulate an intruding door panel, maximize the thoracic load distribution, and engage only the rib cage (the upper extremity was positioned out of the load path). Thoracic deflections were measured with a chestband centered at the impact location. The impactor load cell axial force was inertially compensated using the effective mass (i.e., mass between the center of the load cell and impacting surface) and an accelerometer mounted directly behind the impactor face. Six-degree of freedom motion blocks were mounted on the spine to measure spinal kinematics. PMHS anthropometry and thoracic biomechanical responses were statistically compared between energy groups using Two-Sample T-tests.

Results: PMHS anthropometry, including age, weight, seated height, BMI, and aBMD, were similar between groups. Compared with the low-energy condition, the high-energy group exhibited significantly higher peak forces (2.5 vs 1.9 kN, p=0.0001), greater thoracic deflections (41.0 vs 33.9 mm, p=0.016), and increased deformation energy (91.6 vs 61.0 J, p=0.0001). However, effective stiffness did not differ significantly between groups (p=0.734). Energy dissipation increased with impact severity, as reflected by a significantly higher percent energy loss (66.2 vs 56.7%, p=0.020). Thoracic kinematic responses also increased with input energy. Peak y-accelerations were significantly higher at T4 (25.4 vs 18.2 g, p=0.022) and T8 (35.7 vs 23.1 g, p=0.004). Additionally, T12 exhibited significantly greater peak x-angular velocities in the high-energy group (733 vs 309 deg/s, p=0.013).

Conclusions: This study provides essential thoracic biomechanical response data for small female PMHS under repeatable, simplified, yet realistic side impact conditions. Increased impact energy produced substantially higher thoracic forces, deflections, deformation energy, and energy dissipation in the small female PMHS with similar anthropometry between groups. Furthermore, kinematic responses increased significantly with impact severity. These findings establish an important baseline in developing new

realistic and repeatable testing conditions, ultimately facilitating the robust evaluation and improvement of female HBMs and ATDs in side impact scenarios.