Evaluation of Small Female Knee-Thigh-Hip Response in Frontal Collisions

Randolff Carpenter, Jason Forman

Objective

The current study is aimed at evaluating the effect of mass coupling in the knee-thigh-hip (KTH) complex on the peak forces observed in frontal collisions. The objective of the study includes identifying the sensitivity of loading as a function of impact velocity and mass coupled to the KTH complex.

Problem Outline

There is a lack of PMHS data that can separate and quantify the effects of sex and size at the KTH complex. Differences in femur geometry and alignment between sexes would suggest that there is a difference in the KTH response to loading, however the magnitude of this difference is unknown. In order to establish this, it is crucial to first analyze how loading is affected in female PMHS tests as a function of both the impacting velocity and mass coupled to the KTH complex.

Methodology

Four small female post-mortem human subjects (PMHS) were used in this study Subjects were placed onto a low friction surface and tested under bilateral KTH impact conditions. The impactor was driven using a pneumatically driven linear actuator that was controlled with active feedback. The impactor was padded with an energy absorbing polymer mounted onto multi-axis load cells that measured the impact forces applied to the knee. 10 tests were performed in a hierarchal fashion, varying the velocities at impact and the mass of the KTH system.

Included Data

The dataset provided in this study included force and/or acceleration data for portions of the KTH complex including the knee, femur, and pelvis. Velocities at impact included 2.5, 3.5, 4.9, and 7.2 m/s, which produced loading rates similar to those observed in automotive crash conditions. The subject conditions included whole body tests (WB), tests where the thigh flesh was removed (TFR), tests with an implantable femur load cell (TFR+LC), and tests where the torso was removed (ToR).

Summary of Results and Conclusions

The average (and standard deviation) peak forces at impact are as follows: TFR+LC and WB conditions were tested at 2.5 m/s with average peak forces of 1840.75±129.02N and 2205.69±207.39N, respectively; ToR, TFR, TFR+LC, and WB conditions were tested at 3.5 m/s with average peak forces of 2568.40±157.49N, 2646.28±193.34N, 2734.32±136.88N, and 3259.09±288.44N, respectively; ToR, TFR+LC, and WB were tested at 4.9 m/s with average peak forces of 3788.34±139.74N, 3938.9±235.34N, and 4674.92±479.45N, respectively; ToR was tested at 7.2 m/s with an average peak force of 5961.19±237.45N. Peak force was directly proportional to both effective mass of the KTH complex and impact velocity. Velocity trends were statistically significant ($p<0.001$). For each impact velocity, the peak forces observed in the WB condition were significantly different from all other cases ($p<0.05$). Despite this, adding a load cell and removing the torso did not show a significant difference with respect to removing the thigh flesh ($p>0.05$). These results show the same trends as Rupp 2008, which performed a similar investigation using male subjects. These results will ultimately be used to inform a one-dimensional multibody model of the KTH complex. Future tests should seek to compare these results with responses observed in small female ATDs.