Mechanical Response of the Cervical Spine under Compression Loading

Carolyn Roberts, Jason Kerrigan

University of Virginia, Charlottesville, VA

Abstract

Given the frequency and severity of cervical spine injuries resulting from rollover crashes, it is critical to analyze the mechanism of cervical spine injury in this loading condition. A velocity condition of 3.2 m/s upon impact has been used as an injury threshold for the cervical spine in axial compression loading. Most of the research that supports this injury threshold is based on component-level studies that have assumed the magnitude of the effective mass of the body that compresses the spine. Clearly, this velocity criterion is heavily dependent on the effective mass of the body acting. For example, if the assumed magnitude of the effective mass is too great, injury would occur at a much lower velocity. Few tests have analyzed the entire body during an inverted head impact; therefore, little is known regarding the effective mass of the torso and how mass is recruited following the impact. Also, some of those component-level studies have made simplifying assumptions about the boundary conditions at the lower part of the spine that may have affected the results of the test. The objective of this study is to use whole body test s determine how torso mass causes injury to the cervical spine, what the boundary conditions are between the cervical and thoracic spines, specifically how much of the torso mass effectively acts on the neck during an inverted head impact.

Five post-mortem human surrogates (PMHS) were suspended upside-down in the standard seating position, and were then dropped from three heights to achieve different velocities at impact. The subjects were dropped on a padded five-axis load plate in order to determine the force experienced following initial contact. Subjects were dropped with a combination of impact velocities at levels of 2 m/s and 4.4 m/s. Each PMHS was instrumented with a three blocks mounted along the thoracic spine and two blocks on the head. Every block contained three accelerometers and there angular rate sensors. His-speed X-ray was taken to visualize the kinematics of the vertebrae. Forces at the occipital condyle were calculated using inverse dynamical analysis with the assumption of the skull acting as a rigid body.

Data show that rotational velocities at T1 occur throughout the impact, suggesting that boundary conditions that fix T1 to move only in a vertical direction might not accurately depict the kinematics of the spine in vivo. The force from the load cell followed the same characteristic double peak shape as seen in other studies. Typically, the first peak is assumed to be associated with the mass of the head acting on the load cell and the second peak is thought to be the effect of the torso mass. However, acceleration timing of the T1, T4 and T8 blocks suggest that part of the torso mass acts on the force plate within the first peak of the loading. Analysis of these data

show how much of the torso mass effectively acts on the neck during an inverted head impact, kinematics of the cervical and thoracic spine following an applied axial load, and patterns of bony fracture generated by different velocity conditions.