Development of an Omnidirectional Surrogate Neck

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Introduction

Head and neck injuries are among the most severe consequences of automotive collisions and extreme sports. Anthropomorphic test devices (ATDs) allow researchers to design and evaluate safety technologies which substantially reduce the frequency and severity of these injuries. It is crucial for ATDs to have a biofidelic response to impact, but no ATD neck mimics the neck's response to impact in multiple loading directions. To better conduct safety testing and research, a more representative neck model must be created that can replicate important kinematic and kinetic features of the cervical spine. This testing aimed to assess two of the most fundamental measures of neck response in the preliminary surrogate neck prototype; head motion following a direct sagittal-plane impact and cervical spine 3D flexibility characteristics.

Methodology

The surrogate neck included representations of four elements of the cervical spine: intervertebral discs, ligaments, musculature, and vertebral geometry. Vertebrae were segmented from a healthy cervical spine CT scan and 3D printed out of nylon with added muscle attachment points. Nylon muscle cables were fixed at the head-neck mounting plate and were tensioned and fixed at the lower-neck mounting plate. Ligament straps and discs were cast in a two-part polyurethane rubber and attached to the vertebrae with screw eyes and adhesive, respectively.

Kinematic tests were conducted by mounting a Hybrid-III headform to the surrogate, which was then impacted at the forehead with a linear impactor at 0.5 m/s, 3.25 m/s and 6 m/s. Sagittal plane vertebral and head displacements were measured using a high-speed camera. The maximum head deflection for each impact was found.

Kinetic testing was conducted using a custom spinal moment machine (Goertzen, 2004), which applied pure moments in the coronal, sagittal, and transverse planes of motion at a rate of 1.5 degrees per second. Muscle cables were removed from the surrogate to represent the "osteoligamentous" cervical spine, and intervertebral discs were adhered superiorly and inferiorly. Two full sets of ligament straps (two posterior, two anterior) were created in flexible neoprene rubber and semi-rigid polyethylene, which were tested in multiple configurations. The 3D motion of each vertebra was collected via an Optotrak along with the angular displacement of the motor arm and the applied torque on the model. From this, Euler angles of each vertebra relative to its inferior vertebra were identified, then plotted against the applied moments of the motor arm.

Results and Discussion

Kinematic testing head deflection values in particular were found to be substantially higher than actual head deflection of comparative volunteer data in similar forehead impact tests. This indicated that the neck lacked stiffness, which informed further iterations of the surrogate.

Data analysis is still ongoing for kinetic testing, which aims to compare the full-neck and vertebral-level ranges of motion with two different ligament strap materials. This analysis will provide insight on which ligament strap material is more representative of cervical spine ligaments, which in turn will be used on our model in future testing.