High Rate Behaviour of the Cervical Spine Segments

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ABSTRACT

Understanding the response of the cervical spine segments to high rate loading can help in predicting and preventing injuries in car crash scenarios. The objective of this study was to test the hypothesis that the cervical spine demonstrates increased stiffness in flexion and extension at higher rates of rotation. Recent ligament studies have demonstrated increased cervical spine ligament stiffness at higher strain rates [1]. The end goal of this research was to provide validation data in high speed flexion/extension, currently not available for detailed cervical spine models. Eight fresh frozen spines (five male, three female) were procured for testing. The spines were dissected into segments (four at each level from C2-C3 to C7-T1) consisting of two vertebrae with the associated ligaments and intervertebral disc intact. The vertebrae were placed into separate cups and set with resin. The inferior vertebra was mounted on a six axis load cell (Model 45E15A4 1000N, JR3, California, USA). The superior vertebra was attached to a specially designed fixed-axis rotating frame driven by a Danaher Motion servo motor (Electromate, Ontario, Canada). Each segment was preconditioned to a rotation of four degrees in both flexion and extension, for 10 load cycles, and then tested three times at rates of 1 degree and 500 degrees per second (up to eight degrees) in flexion and extension. Five hundred deg/s was chosen for the high rate since this was typical of the rotation rate observed during 15g and 22g frontal crash scenarios [2]. The moment-rotation relationship was recorded with LabView using a data acquisition card (National Instruments, Model 6216, 100Hz at 1 deg/s, 10 kHz at 500 deg/s). A paired difference test was used to evaluate the statistical significance between low and high rate testing. The test compared the average resultant moment of the low and high rate tests at the same rotational displacement in one degree intervals. At displacements of six degrees or less, the statistical analysis demonstrated no evidence of increased stiffness at the higher rotation rate. Above six degrees of rotation, the test found moderate ($p<0.05$) evidence of increased stiffness in flexion at the higher rotation rate for the C3-C4, C5-C6 and C6-C7 (Figure 1) segments and weak evidence ($p<0.10$) for the C2-C3 and C7-T1 segments. In extension, the C5-C6 and C6-C7 segments were the only ones to show moderate evidence of increased stiffness at more than six degrees of rotation.