

Load-Displacement Characteristics of the Cervical Spine During Shear Loading

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Introduction: The biomechanics of the cervical spine during shear loading are not well-established as compared to other loading regimes. This knowledge deficit is problematic as it has been demonstrated that shear loads may be implicated in fracture-dislocation injuries¹, which are the most common mode of traumatic spine injury leading to spinal cord injury². Thus, the objectives of this study are to determine the load-displacement characteristics including stiffness and 3D kinematics during the application of pure shear loads.

Methodology: Shear loads were applied to five fresh-frozen human cadaveric C6-C7 functional spine units. Loads were applied to each specimen up to 100N via an Instron materials testing machine and custom-designed apparatus. Three directions (anterior, posterior and lateral) were tested in each of three injury states: intact, with the posterior ligaments severed, and disc-only. Loads were measured using an 10kN Dynacell load cell. 3D kinematics were measured with Optotrak rigid body markers. Stiffnesses were calculated as a line of best fit between 0-20N and 20-100N for all tests. A Friedman test with a Wilcoxon signed rank post-hoc test was used to assess the effects of direction and injury state on stiffness and displacement.

Results: Anterior stiffness [CI] was found to decrease significantly from 185.5N/mm [97.2, 326.2] in the intact state to 105.0N/mm [77.7, 141.5] in the disc-only state ($p=0.043$) in the 20-100N load range. No significant differences were found between injury states in the lateral and posterior directions, nor in the initial stiffness between 0-20N in any direction or any injury condition. Posterior stiffness was found to have a non-significant decrease from 134.2N/mm [92.0, 182.2] to 118.6N/mm [82.5, 180.9].

Discussion: Results suggest that the posterior elements provide resistance in the presence of shearing loads in the anterior direction, but have a lesser effect in other directions. This was expected as the facet joints in the cervical spine are oriented such that they would tend to block anterior translation. Greater shear stiffness in the lateral direction could be explained by facet-lamina interactions and uncovertebral joint interactions, which would tend to impede lateral translation. These results compare well numerically to existing studies concerning the biomechanics of the cervical spine.

Conclusion: The shear stiffness of the cervical spine was characterized as a function of shearing direction and injury to the posterior elements. This information will be of use in improving the definition of and validation of existing finite element models of the human neck. It is hoped that increased biofidelity of such models may lead them closer to implementation in the automotive industry, thereby decreasing the risk of serious spine injury.

[1]Ivancic, P. C., Pearson, A. M., Tominaga, Y., Simpson, A. K., Yue, J. J., & Panjabi, M. M. (2008). Biomechanics of cervical facet dislocation. *Traffic injury prevention*, 9(6), 606-611.

[2]Sekhon, L. H., & Fehlings, M. G. (2001). Epidemiology, demographics, and pathophysiology of acute spinal cord injury. *Spine*, 26(24S), S2-S12.