Quantifying and Comparing the Intersegmental Kinematics of the Pediatric Whole Cervical Spine to Individual Motion Segment Kinematics in a Six-Year-Old PMHS

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Mitigating both neck and head injuries in the pediatric population relies heavily on improving our understanding of the underlying biomechanics of the pediatric cervical spine. To-date, there are few studies characterizing the biomechanical response of the pediatric cervical spine. The tensile response for individual motion segments and the whole cervical spine has been reported, but there is no data characterizing the intersegmental kinematics of pediatric whole spines under axial loading conditions. The structural response of motion segments and whole cervical spines provide valuable data for the design and validation of biofidelic physical and computational models for the pediatric population. However, the use of motion segment data to construct whole spine response or the use of whole spine axial stiffness to accurately characterize intersegmental response presents limitations to modeling the pediatric cervical spine response. In this secondary analysis of the work of Luck et al. (2013), a six-year-old postmortem human surrogate (PMHS) cervical spine was tested under multiple modes of loading. In the original test setup, the whole spine was tested in tension where the head was rigidly attached with the Frankfort plane horizontal, normal cervical lordosis and T1 cast in PMMA in a fixed condition allowing only axial translation. The whole cervical spine (WCS) was loaded to approximately 10% of the estimated failure load as calculated by scaling the adult tensile failure load (178 N). After the tensile test, the individual motion segments (O-C2, C4-C5, and C6-C7) were dissected from the WCS and tested in a fixed-fixed configuration. The individual motion segments were also tested under load-control and loaded to the same maximum load as the whole spine test. High-speed video (100 samples/sec) of these non-failure tests were obtained and intersegmental axial displacements were measured by tracking the vertebral bodies and analyzing the vertical displacement. Intersegmental axial displacements observed in the WCS tension tests for O-C2, C3-C4, C6-C7, and C7-T1 indicated a tensile behavior, stretching 3.44mm (76% of total WCS axial displacement), 0.11mm (2.4%), 0.64mm (14%), and 1.98mm (32.8%), respectively. C2-C3 and C5-C6 indicated a compressive response of 0.13mm (2.9%) and 0.16mm (3.4%). C4-C5 did not experience any appreciable changes in the axial-direction. Compared to the individual motion segments, O-C2 experienced a larger axial displacement in the WCS test (3.44 vs. 2.80mm) while C4-C5 and C6-C7 experienced a reduced axial displacement when compared to the WCS test (0.01 vs. 0.86mm and 0.64 vs. 0.93mm; respectively). Future analysis will incorporate shear and rotation of the intersegmental kinematics observed in the WCS test – a current limitation of this analysis. Preliminary analysis suggests that C2, C3, C4, and C5 exhibited a flexion motion while C6 and C7 exhibited an extension motion during WCS tensile loading. Additionally, the difference in orientation of the motion segments in the whole spine test and during the individual motion segment tests will be investigated. These findings will be a valuable addition to our understanding of pediatric neck biomechanics and contribute to the development and validation of existing and future physical and computational models of the pediatric cervical spine.