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The six degrees of freedom motion of the human head, spine, and pelvis in a frontal impact

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Abstract-

Objective:
The goal of this study is to characterize the in situ 6-degree-of-freedom kinematics of the head, 3 vertebrae (T1, T8, and L2), and the pelvis in a 40 km/h frontal impact.
Methods:
Three postmortem human surrogates (PMHS) were exposed to a deceleration of 15 g over 125 ms and the motion of selected anatomical structures (head, T1, T8, L2, and pelvis) was tracked at 1000 Hz using an optoelectric stereophotogrammetric system. Displacements of the analyzed structures are reported in the sagittal and the transverse planes. Rotations of the structures are described using the finite helical axis of the motion.
Results:
Anterior displacements were 530.5 ± 39.4 mm (head), 434.7 ± 20.0 mm (T1), 353.3 ± 29.6 mm (T8), 219.9 ± 19.3 mm (L2), and 78.9 ± 22.1 mm (pelvis). The ratio between peak anterior and lateral displacement was up to 19 percent (T1) and 26 percent (head). Magnitudes of the rotation of the head (69.9 ± 1.5°), lumbar (66.5 ± 9.1°), and pelvis (63.8 ± 11.8°) were greater than that of the thoracic vertebrae (T1: 49.1 ± 7.8°; T8: 47.7 ± 6.3°). Thoracic vertebrae exhibited a complex rotation behavior caused by the asymmetric loading of the shoulder belt. Rotation of the lumbar vertebra and pelvis occurred primarily within the sagittal plane (flexion).
Conclusion:
Despite the predominance of the sagittal motion of the occupant in a pure (12 o’clock) frontal impact, the asymmetry of belt loading induced other relevant displacements and rotations of the head and thoracic spine. Attempts to model occupant kinematics in a frontal impact should consider these results to biofidelically describe the interaction of the torso with the belt.

Index Terms- frontal impact, spine, kinematics, helical axis

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