Primary, Secondary, and Translational Motions of the Craniocervical Junction: A Biomechanical Investigation

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Introduction:

The C0-C2 junction is a highly mobile region of the spine. The occipito-atlantal (OA) joint primarily permits flexion-extension angular motion and the atlanto-axial joint (AA) permits axial rotation angular motion[1,2], however the amount of coupled motion is rarely discussed. A cadaveric study was used to identify range of motion patterns during primary bending, the secondary contribution of off-axis rotations during primary bending, and the translational component of the OA and AA joint complexes.

Methods:

Intervertebral motions were tested in seven cadavers from C0-C3 on a spine simulator. Primary bending moments of 2.5 N-m were applied to create flexion-extension (FE), lateral bending (LB), and axial rotation (AR) at a rate of 1.5°/s. Primary (applied) rotations, secondary (coupled) rotations, and translations (anterior-posterior (AP), cranial-caudal (CC), and medial-lateral (ML) planes) were recorded. Markers were placed on C0, C1, and C2 and relative changes were calculated using Optotrak Certus (NDI, Waterloo, Canada).

Results:

Applied moments resulted in multiple rotations simultaneously (Figure 1). During applied FE, the OA joint accounted for 16°, 4°, and 3° in FE, LB, and AR, respectively. The AA joint accounted for 10°, 3°, and 14° in FE, LB, and AR, respectively. During applied LB, the OA joint accounted for 5°, 5°, and 4° in FE, LB, and AR, respectively. The AA joint accounted for 4°, 4°, and 18° in FE, LB, and AR, respectively. The coupled motion of OA joint performing FE and AA joint performing AR combined to achieve maximum LB. During applied AR, the OA joint accounted for 12°, 6°, and 9° in FE, LB, and AR, respectively. The AA joint accounted for 12°, 12°, and 69° in FE, LB, and AR, respectively.

Conclusions:

Occipito-atlantal and atlanto-axial movements are not just pure rotations, but highly complex coupled motions with concurrent translations. The C0-C1 joint primarily performs flexion-extension. The C1-C2 joint primarily performs axial rotation, during which cranial-caudal translation can occur more often then other primary motion. Secondary motions may exceed primary motions at both joints. Although it was not noted in previous studies, this study found that the dominant motion patterns of each joint combine as coupled motion to perform lateral bending at the craniocervical junction.

Results Cont'd:

Applied motion also resulted in multi-planar translations (Figure 2). AP and ML translations were the principal translations at the OA joint, with CC translations mainly at AA joint during applied FE. All translation planes played a role during LB. Overall, the AA joint contributes to the highest amount of translation with AP being the greatest and ML being the least during applied AR.

References

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2. Roozmon P, Gracovetsky SA, Gouw GJ, Newman N. Examining motion in the cervical spine. II: Characterization of coupled joint motion using an opto-electronic device to track skin markers. Journal of biomedical engineering 1993;15:13-22.

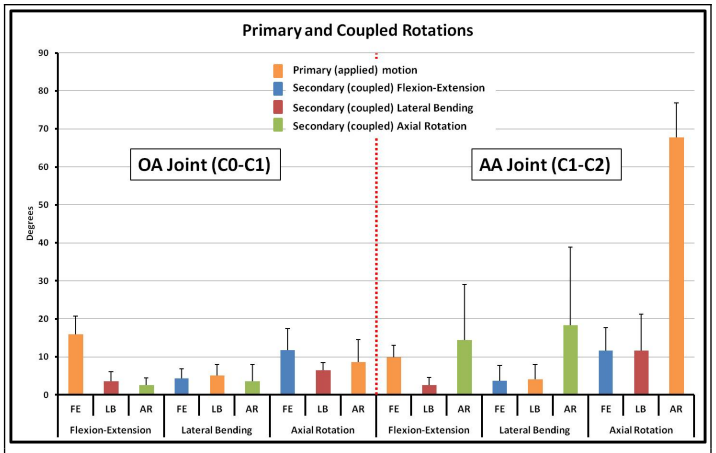

Figure 1: The applied motions (orange) with its secondary motions are shown in this figure. Each segment has some coupled motion during primary bending.

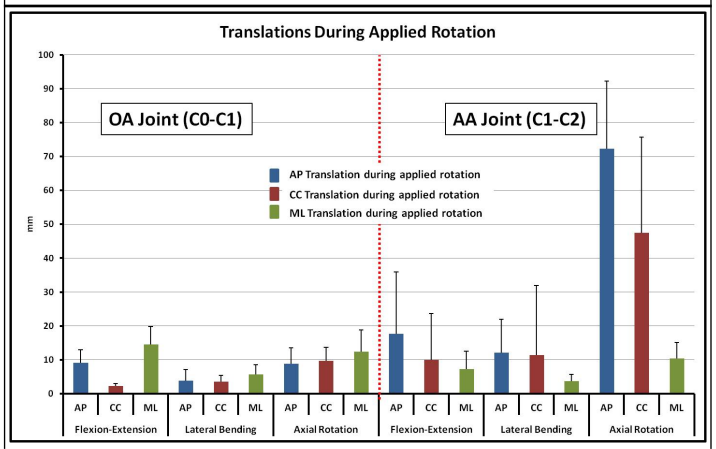

Figure 2: The AP, CC, and ML translation for each joint is shown.