Follower Load Influences the Kinematics and Kinetics of Cervical Spine Buckling during Simulated Head-First Impact

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ABSTRACT

Biomechanical understanding of cervical spine injury is based on decades of quasi-static compression and head-first impact studies that suggest that, during head first impact, the cervical spine buckles as the head moves toward the more massive torso and further that buckling characteristics and injuries may be correlated [1]. Some impact studies describe cables tethered to cervical anatomy to simulate the role of neck musculature in controlling neck posture. However, these cables do not recreate lines of action of compressive follower loads that neck musculature supplies in vivo and that has been shown through recent modeling to significantly increase neck injury risk [2]. In quasi-static experiments, compressive follower loads have been shown to increase the compressive loads at which buckling occurs [3]. Therefore, we hypothesize that it is important to simulate in vivo compressive follower load in ex vivo impacts and that buckling in past ex vivo impact experiments [1] may be due to absence of follower loads. The objective of this work was to compare the kinematics and kinetics of buckling of isolated cervical head/neck complexes instrumented with follower load to those without. We simulated head-first impact of cervical spine-head complexes (n=12). Six complexes (Occ.-T1) were instrumented with follower load (FL group), while six were not (NFL group). The metrics reported here are: impact speed; time to neck buckle; and the total angular divergence at the levels at which the neck buckled. The criterion to determine buckling was failure of the neck to support compressive force while C7 continued to translate toward the head and opposite angular rotation across vertebral levels that was greater than 2 degrees. The mean impact speeds were 2.8 m/s (NFL) and 2.9 m/s (FL). Buckle time was significantly (p=0.009) lower in the FL group (avg. 2.5 ms) compared to the NFL (avg. 4.9 ms). All specimens exhibited hyperextension and 11/12 buckled across mid-cervical levels (C3-5) while one involved C2. When buckled, The FL specimens (avg. 5 degrees) had significantly smaller (p=0.002) rotations than NFL (avg. 20 degrees).