Evaluating the effect of muscle activation on head motion during non-injurious impact in human volunteers

Kristen A. Reynier[1], Ahmed Alshareef[2], Daniel Shedd[2], Erin Sanchez[3], Jim Funk[3], Matthew B. Panzer[1]

[1]University of Virginia, Center for Applied Biomechanics, Department of Mechanical and Aerospace Engineering, Charlottesville, VA

[2]University of Virginia, Center for Applied Biomechanics, Department of Biomedical Engineering, Charlottesville, VA

[3]Biocore LLC, Charlottesville, VA

Concussion due to blunt impact is a major problem in contact sports, automotive impacts, and recreational activities. It is suggested in the literature that bracing of the neck muscles increases the effective mass of the head and can protect against a concussion. A larger effective mass results in less momentum transfer to the head and can potentially lower head acceleration and risk of injury. The goal of this study is to determine the effect of active muscle tension on the head kinematics of a human volunteer in response to a direct impact to the head.

The testing methodology was developed and validated using impacts to the head of an anthropomorphic testing device (ATD). The head was impacted laterally using a biflament pendulum with a padded 3.7 kg steel ball instrumented with a six degree-of-freedom sensor. Impacts were delivered to the padded head at varying speeds (1, 1.5, 2, 2.5, and 3 m/s) to the head center of gravity (CG) to determine the linear acceleration, angular velocity, and angular acceleration experienced by the head.

Based on the ATD testing, the 2 m/s lateral impact to the CG was determined to be safe and resulted in a target maximum linear acceleration (10–15 g) and impact duration (15–20 ms). The volunteer study, approved by the University of Virginia Institutional Review Board, was completed using twenty male volunteers. Each subject completed a series of baseline tests, including magnetic resonance imaging (MRI) and neuro-cognitive assessments. Each subject experienced three non-injurious impacts delivered by the padded spherical impact at 2 m/s to the side of the head at the CG. The subjects were instructed to provide different levels of neck muscle activation for each test (passive, maximum co-contraction, and maximum unilateral isometric contraction). Muscle activation was recorded using surface electromyography sensors on the sternocleidomastoid and the upper trapezius muscles, and subjects wore a custom-fit mouth piece instrumented with a six degree-of-freedom sensor to measure head kinematics. Follow-up MRI imaging and neuro-cognitive assessments were completed to ensure no injury was induced.

During passive activation, the maximum resultant linear head acceleration was 12.06 ± 1.81 g, and the maximum angular velocity was 6.94 ± 0.61 rad/s. The maximum resultant linear acceleration during co-contraction was 12.06 ± 1.46 g, and the maximum angular velocity was 6.56 ± 0.68 rad/s. The maximum resultant linear acceleration and angular velocity of the head decreased during the unilateral contraction to 10.69 ± 1.68 g and 6.16 ± 0.61 rad/s. Statistical significance was determined using a paired t-test for equal means ($p < 0.05$). The change in both peak linear acceleration and angular velocity between passive activation and maximum unilateral contraction were statistically significant.

Maximum muscle contraction during the unilateral tensing resulted in a decrease in linear acceleration and angular velocity. This data could be used to make important conclusions about techniques to reduce injury in higher impact scenarios. This study was the first to investigate the effect of active muscle tension in human subjects during a direct impact to the head.