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

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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 $12.06 \pm 1.81$ g, and the maximum angular velocity was $6.94 \pm 0.61$ rad/s. The maximum resultant linear acceleration during co-contraction was $12.06 \pm 1.46$ g, and the maximum angular velocity was $6.56 \pm 0.68$ rad/s. The maximum resultant linear acceleration and angular velocity of the head decreased during the unilateral contraction to $10.69 \pm 1.68$ g and $6.16 \pm 0.61$ 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.