HEAD AND NECK KINEMATICS DURING HORIZONTAL AND COMBINED HORIZONTAL/VERTICAL LOW VELOCITY WHIPLASH-LIKE PERTURBATIONS

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INTRODUCTION

Whiplash is a mechanism of injury that is commonly associated with rear-impact vehicle collisions. There is a large degree of variation in severity of symptoms between individuals for seemingly similar collisions. Rear-end collisions are responsible for most whiplash injuries (Berglund *et al.*, 2003).Some literature has reported vertical accelerations of both the occupant and vehicle during horizontal whiplash-like perturbations (Severy *et al.*, 1955) but no detailed studies of this phenomenon have been conducted. The purpose of this investigation was to compare the head accelerations and displacements, as well as sternocleidomastoid (SCM) activation (EMG), to horizontal acceleration whiplash-like perturbations and combined horizontal/vertical accelerations.

METHODS AND PROCEDURES

Permission for this study was obtained from the University of Guelph Research Ethics Board and written consent was obtained from all subjects. Twelve precisely controlled low-velocity rear impact whiplash-like perturbations were delivered to 8 subjects, 4 male and 4 female with an average age of 28.9±7.7 years, using a robotic platform (PRSCO, NH, USA). Perturbations had a peak horizontal acceleration of either 9.7± 0.5m/s² (High) or 5.6 ±0.2m/s² (Low). Rate of change of acceleration, or jerk; was 270m/s³ (Mild) or 380 m/s³ (Severe). Perturbations were either strictly in the horizontal direction; or had an additional element of upward or downward acceleration which was half the magnitude of horizontal acceleration. Subjects were seated in a fully functional 1991 Honda Accord front passenger car seat mounted to the robot's platform. Subjects were instructed to adopt a comfortable seated posture facing forward and resting their forearms on their laps. A triaxial accelerometer (Crossbow CSL04LP3 ±4g) was mounted on the robotic platform to determine the initial onset of the platform movement, which was defined zero time for the EMG onsets. Kinematic data of the head and thorax was collected using 3D motion capture (NDI Optotrak 3020), similarly to other researchers (Siegmund *et al.*, 2004). Surface electromyography was used to measure activity from the Sternocleidomastoid (SCM), Upper Trapezius (TRP), and Splenius Capitis (SCAP) muscles bilaterally. Resting bias and maximal contractions were collected for normalization of the EMG channels. EMG onsets were determined by visual inspection of the raw EMG data; EMG RMS amplitudes were quantified in adjacent 25 ms time windows.

RESULTS

Overall, high acceleration profiles caused significantly greater peak accelerations, displacements and EMG amplitudes than the low acceleration profiles. Perturbations that contained a vertical acceleration component caused different head kinematics than the strictly horizontal perturbations (Figure 1). For example, there was a statistically significant interaction between acceleration and perturbation direction. Follow-up tests revealed statistically significant differences between the vertical head accelerations for the high and low acceleration conditions in the horizontal as well as the horizontal-up perturbation directions. (Figure 1). This trend was maintained in the horizontal-down perturbation direction, though it was not statistically significant.

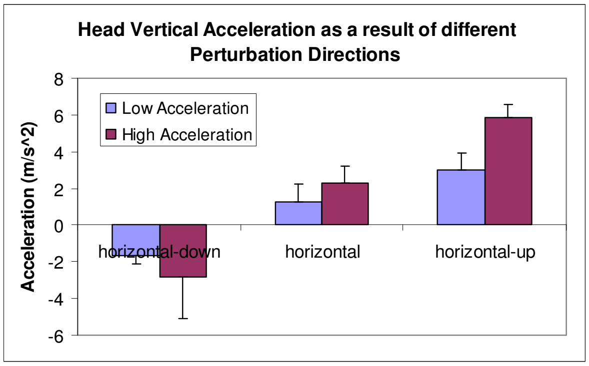

Figure 1. Vertical head acceleration for high and low accleration during each perturbation direction (Horizontal-down, Horizontal only, Horizontal-up).

DISCUSSION

Our results provide some biomechanical rationale for the epidemiological association between bumper height mismatch and patterns of injury. Researchers have shown increased severity of injuries in front-end collisions when bumpers vertical offsets (Siegel *et al.*, 2001). We believe that this may be caused by the vehicles having a downward component of the resulting perturbation pulse, similar to the horizontal-downward perturbation direction used in this study. Interestingly vertical components of acceleration have also been observed in collisions between test vehicles (Severy *et al.*, 1955), which are likely due to the vehicle suspensions.

SUMMARY

Although modelling studies are essential for investigating whiplash mechanisms of injury in automobile collisions, human studies are required to provide biologically relevant data. This study, enabled by the unique multi-directional capabilities of our robotic platform, illustrate that there appear to be systematic differences in head acceleration and muscle activation patterns between strict horizontal perturbations, and perturbations that include both horizontal and vertical accelerations. The differences that we observe shed light on the differences in patterns of injury that are observed in collisions between vehicles with offsets in bumper height, and illustrate that research studies that use sleds may not be capturing the meaningful vertical accelerations that occur in real vehicle collisions.

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