AN APPROACH TO CALCULATING LINEAR HEAD ACCELERATIONS IS NOT AFFECTED BY ROTATIONAL HEAD ACCELERATIONS

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INTRODUCTION

Mild traumatic brain injury (MTBI), or concussion, is a growing health concern especially for young athletes. A critical piece in the puzzle for understanding MTBI is the link between the mechanical input (trauma) that causes injury and the clinical outcome. We hypothesize that head acceleration due to impact is predictive of the type and severity of concussion, and correlates to specific clinical measures of concussion. One major limiting factor in testing this hypothesis and the development of strategies to reduce MTBI is the lack of sufficient *in vivo* biomechanical head impact data. Previously, we developed and validated the Head Impact Telemetry (HIT) System as an approach to measure linear head acceleration of a helmeted athlete [1]. The purpose of this work was to determine if the theoretical accuracy of calculating linear head acceleration using this approach was affected in the presence of rotational accelerations.

METHODS

Theory. The HIT System consists of six linear accelerometers placed within the liner of a football helmet in close proximity and orthogonal to the skull. The system estimates the linear acceleration of the center of gravity of the head ($\vec{H}$) due to an impact, with its direction specified in spherical coordinates (azimuth θ and elevation α). The value of each accelerometer ($\vec{a}_i$), located at (θ_i, α_i), is used to minimize the least-square error,

$$\sum_{i=1}^{6}\left(\|\vec{H}\|\left(\cos\alpha_i \cos\alpha_H \cos\left(\theta_i - \theta_H\right) + \sin\alpha_i \sin\alpha_H\right) - \|\vec{a}_i\|\right)^2,$$

and to obtain an estimate of the magnitude of the linear head acceleration $\|\vec{H}\|$ and its impact location (θ_H, α_H). Rotational accelerations were estimated assuming a fixed rotation point 10 cm inferior to the center of gravity of the head.

Experiment. Laboratory experiments were performed using a Hybrid III headform, neck and torso fit with a commercially available football helmet that was impacted (n=48) with a weighted pendulum (8.2 kg) at various locations about the helmet and at 3 impact speeds (3, 5, and 7 m/s). The linear and rotational accelerations of the Hybrid III headform were computed using a standard 3-2-2-2 accelerometer package and established algorithms (Biokinetics, Ottawa, CA). These experimentally measured accelerations were used to predict the accelerations of each HIT system accelerometer, which were then feed back into the theoretical algorithm. The differences between the experimentally measured headform accelerations (linear and rotational, GSI, and HIC15) and those predicted from the theoretical algorithm were compared using root mean square error (RMSE)

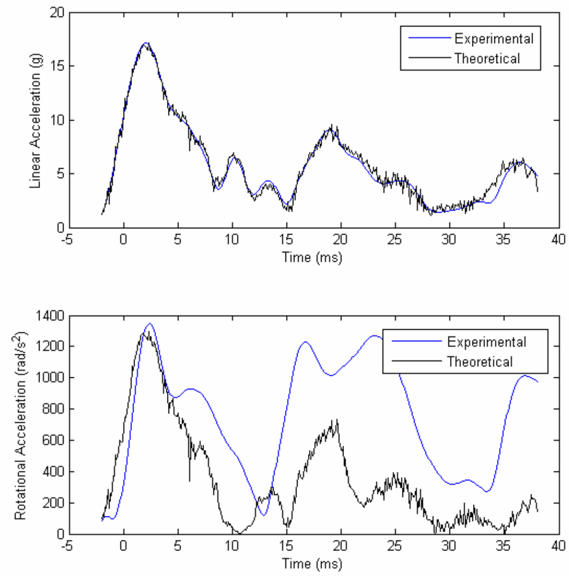

Figure 1: Typical acceleration-time curve.

RESULTS AND DISCUSSION

A typical theoretical linear acceleration-time curve was in excellent agreement with the experimental curve, but there was only limited agreement with the rotational acceleration-time curve (Fig. 1.). The RSME errors for the peak linear acceleration, peak rotational acceleration, GSI, and HIC15 were 2.9g [experimental range of values: 15–82 g], 31 GSI [6.6–294 GSI], 16 HIC15 [4–232 HIC 15], 757 rad/s^2 [1201–4555 rad/s^2], and the mean (1 s.d.) percent error was -4% (5), -17% (16), -10% (14), and -20% (32), respectively.

CONCLUSIONS

Using helmeted impacts within a laboratory setting we were able to demonstrate that our previously reported algorithm is quite robust and can accurately (RSME 3 g's) predict linear head acceleration even when these impacts are associated with a wide range of rotational accelerations. An algorithm for more accurately measuring rotational acceleration with this approach remains to be further developed.

REFERENCES

1. Crisco JJ, Chu JJ, Greenwald RM. An Algorithm for Estimating Acceleration Magnitude and Impact Using Multiple Non-Orthogonal Single-Axis Accelerometers, Journal Biomechanical Engineering, **In Press.**

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