Low-Level Validation of an In-Ear Sensor for Measuring Head Impact Exposure in American Football

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Introduction

• Mild traumatic brain injury (mTBI) from sports affects between 1.6 and 3.8 million Americans each year.1
• American football has been associated with a higher incidence of concussion when compared to other sports among adolescents.2
• Measuring Head Impact Exposure (HIE) may serve to:
  - predict injury following an impact(s).
  - protect an injured participant from subsequent post-injury impacts.
  - improve diagnostic procedures for mTBI/concussion.
• Head impact exposure metrics can be quantified using head kinematics, but capturing in vivo head exposure presents challenges.
• Wearable sensors for measuring head kinematics have been developed, but robust device validation is needed to assess the fidelity of the measurements to the actual kinematics of the skull.

Experimental Methodology

• Three previously fresh frozen (unfixed) human cadaver heads.
• Reference sensor (6DX Pro, DTS) was fixed to the skull via a mounting plate and negative molds were 3D printed.
• A transparent silicone (Biopor AB, 70 Shore, Dreve) was cast into the negative mold, into which the 9 degrees of freedom in-ear sensor (DASHR) was inserted.
• A Riddell SpeedFlex football helmet (L, XL) was fitted for each specimen.

Testing Setup

• A linear impactor (Cadex) with a steel spherical impactor impacted each head at low (4.2 m/s), medium (6.4 m/s), and high (7.8 m/s) velocities at three impact locations (front, rear, and right side).
• Each combination was repeated three times.
• Secondary impacts between the specimen and the enclosure were analyzed in this study.

Data Processing

• Reference and DASHR linear acceleration were filtered using an 8th order 400 Hz, phaseless, lowpass Butterworth filter.
• Time aligned with the maximum cross-correlation.
• Reference linear acceleration at each DASHR location was calculated using rigid body kinematics (Eq. 1).
• Secondary impacts were isolated from resultant linear acceleration:
  - Peak width constrained to between 3 ms and 20 ms.
  - At least 5g in PLA.
  - At least 5g in signal prominence.
  - Up to one occurrence per trial.
• Impacts were excluded, where:
  - The DASHR was broken.
  - Peak finding identified non-impacts.
  - DASHR was decoupled with the ear.
• 209 secondary impacts were identified.

Results

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References