Assessment of Ear- and Tooth-Mounted Accelerometers as Representative of Human Head Response

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Introduction

Due to widespread use of improvised explosive devices (IEDs) and subsequent blast-related injuries including traumatic brain injury (TBI) in the current military conflicts, a significant effort has been made to record head accelerations through various helmet-mounted systems. By collecting and accurately measuring head accelerations and correlating with injury outcomes, injury criteria can be developed which will expedite diagnosis and treatment of TBI. While size and power requirements of accelerometers continue to be an obstacle to widespread monitoring of the general population, there has been significant progress in the size, power requirements, and suitable mounting locations for these monitoring devices. Previous studies have assessed various mounting locations including the ear. This study investigates if a tooth-mounted sensor can decouple from the head.

Methods

Three PMHS heads were selected for this study: one 24 year old female, one 72 year old male, and one 66 year old male. The specimens were prepared by removing the mandible as well as the cervical spine from the occipital condyle in order to rigidly mount the skull to both a drop tower fixture and a vertical hydraulic shaker. An 3-axis accelerometer array was placed in the ear canal using a stiff syntactic foam, similar to previous studies. A 3-axis array was also mounted to a rear molar with cyanoacrylate adhesive. A uniaxial accelerometer was fixed to the epidermis on the forehead. A rigidly mounted reference cube was mounted on the left side of the skull in line with the Frankfort plane, which was used as the reference head Frankfort plane.

Each specimen was loaded in the SAE X-, Y-, and Z-direction on both the drop tower and shaker.

Primary data was collected to assess the performance of accelerating response in the ear and tooth mounting locations including the ear. The degree of coupling with the head depends on the direction of the load. SAE-X loading direction yielded the most compliance with the ear and tooth arrays, while SAE-Z and Y showed similar coupling patterns.

Results

• For the low frequency input, the tooth and ear arrays followed similar trends of the reference, but showed more compliance and high frequency peaks in the data.
• Coordinates for the tooth and ear arrays were determined from CT analysis and a coordinate transformation was done to transform them to the reference array.
• The degree of coupling with the head depends on the direction of the load. SAE-X loading direction yielded the most compliance with the ear and tooth arrays, while SAE-Z and Y showed similar coupling patterns.
• There was close agreement between the skin-mounted forehead sensor and the reference array.

Discussion

• Overall goal of monitoring and recording head accelerations is to further understand and predict TBI.
• In previous studies, helmet mounted sensors can decouple from the head.
• The goal of this study was to investigate a new mounting location for an accelerometer array.
• There are many instances where monitoring head accelerations is important: elderly living alone with the potential of exposure to combat conditions.
• The monitoring sensors must be passive to the wearer and must be able to communicate actively with medical personnel.
• The information collected must be interpreted as head accelerations so that it can be compared to the best available injury criteria.

Future Work

• Include rigidly attached angular rate sensors to quantify the amount of rigid body skull flexion that can be linked to concussions.
• Investigate the magnitude and distribution of skull flexion under uniform high-g loading. Evidence from this study suggests that there are skull deformations, but the locations and magnitude are unknown.
• Using ARAMIS, a 3D optical system will track skull deformation and determine the rate at which the skull locally deforms and rotates so that the results can be compared to established metrics for rotation rates that contribute to concussion.
• By having a better understanding of the possible local mechanisms that may contribute to mTBI, better safety systems, including helmet padding can be designed to better protect the wearer and prevent the harmful skull deformations.

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References