

LABORATORY VALIDATION OF HELMETED AND NON-HELMETED WEARABLE SENSORS

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ABSTRACT

An estimated 3.8 million sports-related traumatic brain injuries (TBI's) occur annually in the United States. In recent years, there has been an increased focus on studying the mechanisms of mild traumatic brain injuries or concussions. Several wearable impact sensors have been marketed to athletes, parents, and researchers claiming to provide accurate measurement of head impact biomechanics. In the present study, we tested a helmet, Head Impact Telemetry System (HITS) (Simbex, Lebanon, NH) and a mouthguard, Prevent Biometrics Intelligent Mouthguard (IMG) (Edina, MN) based wearable systems. To test the laboratory performance of these wearable sensors, a setup was developed to impact a National Operating Committee on Standards for Athletic Equipment (NOCSAE) headform at multiple velocities and orientations in a guided free-fall. The headform was instrumented with a sensor package that consist of three triaxial accelerometers and three angular rate sensors and was used as a reference sensor. The headform was modified to fit a custom dentition capable of coupling with the IMG sensor. The headform was also outfitted with a large Riddell SpeedFlex helmet with a HITS sensor. The instrumented headform was dropped on a 45-degree anvil in frontal and lateral orientations at low (4 m/s) and high (6 m/s) velocities. Data was collected from the HIT and IMG sensors and compared to the reference sensor. The HIT sensor reported higher peak linear accelerations (PLA) for frontal and lateral orientations for high and low-velocity impacts compared to reference sensors whereas the IMG sensor reported lower PLA magnitudes. Both devices showed poor performance for measuring peak angular accelerations (PAA) in lateral orientation for high and low-velocity impacts. Further testing is needed to better understand the performance of these sensors at impact orientations and velocities. By acknowledging the limitation and measurement errors in these wearable sensors, deployment of these sensors in on-field setting can provide valuable biomechanics data in better understanding the onset of a concussion.

Keywords: HITS, Injury, Biomechanics, Football, Head Impact, Validation

INTRODUCTION

The Centers for Disease Control (CDC) estimates that approximately 3.8 million sports-related injuries occur in the United States each year [1]. According to CDC estimates, the number of sport and recreational Traumatic Brain Injuries (TBIs) among children and young adolescents has gone up from approximately 153,000 per year in 2001 to 248,000 in 2009 [2]. Epidemiological studies have shown a high rate of concussions among high school athletes in high contact and low or minimal contact sports such as football, ice hockey, and soccer [1], [3]. Similar trends have been reported in other studies for athletes at the collegiate level [4][5].

Despite the high rate of concussions in sports-related activities, the research into the role of head impact biomechanics to the onset of concussion remains incomplete. Recent studies have indicated that low magnitude subconcussive head impacts may play a role in the onset of concussion [6]–[8]. Low magnitude head impacts have been associated with cognitive decline, white matter changes and theorized to influence concussion tolerance [9]–[11].

In recent years, there has been a steady rise in the number of commercially available wearable devices that are marketed to provide head impact biomechanics data. These devices are available in various forms and mounting locations such as skin (xPatch, X2 Biosystems), ear-canal (MVTRAK), teeth