

EFFECT OF FILTERING KINEMATICS ON FINITE ELEMENT SIMULATIONS OF HEAD IMPACTS IN HIGH SCHOOL FEMALE LACROSSE

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ABSTRACT

The recent Consensus Head Acceleration Measurement Practices (CHAMP) Conference recommends the reporting of filter characteristics for head impact sensors, but CHAMP did not prescribe a specific filter and/or cut-off frequency as selection depends on device and application. A previous study reported 14 video-verified impacts to the face/jaw region of 8 high school female lacrosse players recorded by custom-fitted Stanford Instrumented Mouthguard (MiG) sensors. The raw kinematics data were originally filtered at 160 Hz using a 4th order Butterworth filter as specified by Stanford. The current study separately filtered the kinematics data at previously reported cut-off frequencies of 50, 100 and 200 Hz, and the peak kinematics were compared. In addition, the filtered kinematics were used to simulate the impacts using a finite element (FE) human head model and 95th percentile stresses and strains within the brain were compared. Lowering the cut-off frequency of the low-pass filter substantially reduced peak linear and angular accelerations, whereas peak angular velocity was less affected. In addition, a flow-on effect was observed as lowering the filtering cut-off frequency reduced 95th percentile stresses and strains within the brain. While low-pass filtering is a common approach to remove high-frequency noise from kinematics signals, information regarding the actual signal may be lost from over-filtering. Future studies using instrumented mouthguard data to investigate acceleration-based injury metrics, or drive FE human head models, should carefully consider filtering methods.

Keywords: female lacrosse, finite element, head acceleration event, instrumented mouthguard, youth sport

INTRODUCTION

Instrumented equipment worn by players during sports participation allow for the opportunity to quantitatively measure head impact exposure *in vivo*. Mouthguards are mandated in USA Lacrosse competitions [1]. Therefore, instrumented mouthguards are an ideal approach to record head acceleration events (HAEs) in lacrosse. Several studies have focused on quantifying the magnitude of HAEs in female lacrosse; however, most of these studies used instrumented skin patches [2-5] or headbands [6-7]. Laboratory studies have demonstrated that such sensor systems record the kinematics of the head less accurately than those that fix to the dentition (i.e., instrumented mouthguards and mouthpieces) [8-9]. In a human volunteer study of soccer ball heading, Wu et al. [10] compared the kinematics recorded by an instrumented mouthguard, skin patch and skull cap. The instrumented skin patch and skull cap were found to overestimate peak linear and angular accelerations, which was attributed to differences in sensor-skull coupling.

Only one study has monitored the head acceleration events of female lacrosse players using instrumented mouthguards. Patton et al. [11] used rigorous video review methods to verify true-positive HAEs recorded by instrumented mouthguards worn by high school female lacrosse players. Impact site (i.e., face/ jaw, forehead, crown, side or rear) was coded during the video review and impacts to the face/jaw region were found to have significantly ($p < 0.05$) greater peak kinematics than impacts to other regions of the head, which was suggested to be a result of interaction between the impacting surface, or the lower jaw, and the instrumented mouthguard.