Correlation of Clinical Changes with Repetitive Head Impact Exposure in High School American Football Athletes: Preliminary Findings

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I. INTRODUCTION

It has been estimated that as many as 3.8 million sport-related concussions occur annually in the United States, with over 200,000 trips to the Emergency Department [1]. The symptomatology of sport-related concussion includes cognitive, emotional, and postural disturbances with a majority of patients becoming symptom free in seven days [2]. However, in some cases, chronic symptoms can persist and repeated concussions have been linked to life-long cognitive and emotional difficulties [3]. The accepted biomechanical mechanism for concussion includes a single head impact resulting in high magnitude head rotational accelerations that leads to diffuse injury within the tissues of the brain [4]. More recently, our studies in American football athletes have identified a possible second mechanism for concussion that involves repetitive subconcussive head impact exposure [5]. According to that mechanism, athletes would experience a more gradual onset of concussion associated with progressive changes in brain function resulting from the combination of a high number and severity of repetitive head impact exposure over a longer time period, as opposed to a single concussive event. Accordingly, this study was designed to measure repetitive head impact exposure over the course of an American football season and identify possible cognitive, postural, and physical disturbances in athletes without diagnosed concussion using repeated clinical assessments.

II. METHODS

The Institutional Review Board at the Medical College of Wisconsin approved study research methods. All participants provided informed consent, or parental consent with athlete assent, prior to initiation of data collection. Head impact accelerations were monitored during all contact activities using the Head Impact Telemetry (HIT) System (Riddell SRS, Riddell, Rosemont, IL, USA) for 13 high school American football athletes from three high schools in the Milwaukee, WI area during the 2018 fall season. The HIT System is a helmet-based impact monitoring system that continually monitors head accelerations using six uniaxial accelerometers. Only impacts with peak resultant linear acceleration greater than 10 g were included in the present analysis.

Baseline clinical assessments were performed prior to initiation of football-related contact activities. Athletes received identical clinical assessments approximately one month into the season (i.e., mid-season assessment) and a post-season assessment after the conclusion of the season. Clinical assessments consisted of the Sport Concussion Assessment Tool (SCAT3), the Balance Error Scoring System (BESS), the Standardized Assessment for Concussion (SAC), and the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) test battery.

Although each clinical assessment consisted of multiple individual assessments, the following values were compared between baseline and mid-season, and between baseline and post-season. SCAT Symptom Severity score was the cumulative score for all 22 symptom scores (0: none to 6: severe). BESS total score was the cumulative number of errors for all stance and surface conditions. SAC total score was the number correct across all orientation, memory, concentration and recall trials. ImPACT verbal memory, visual memory, and reaction time composite scores were analyzed separately. Using previously established reliable change index (RCI) cutoffs, athletes with significantly worse performance (80% confidence interval) from baseline to the mid-season and baseline to the post-season assessments were identified. Head impact exposure in the 'symptomatic' group for each of the ten assessments was then compared to the 'asymptomatic' group using

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Analysis of Variance (ANOVA). Head impact exposure was quantified as the total number of recorded head impacts and Risk-Weighted Exposure (RWE) [6] from the beginning of the season until the date of assessment for the mid- and post-season assessments.

III. INITIAL FINDINGS

All thirteen athletes received the mid-season assessment and 10/13 athletes received the post-season assessment, with 3 athletes dropping out of the study prior to the end of the season. Multiple athletes had significant worsening in clinical assessments at mid- and post-season time points when compared to baseline scores (Table 1). Significant worsening from baseline was more common at the mid-season assessment than the post-season assessment. At the mid-season timepoint, the following assessments demonstrated the greatest percentage of athletes with significant changes from baseline: SAC total score, SCAT symptom severity, and ImPACT visual memory. Fewer athletes demonstrated significant changes from baseline at the post-season assessment, with only SAC total score and ImPACT reaction time resulting in a higher percentage of athletes showing significant worsening than would be expected given estimated base rates (i.e., >10%). Biomechanical metrics were greater for athletes demonstrating significant SCAT symptom severity and SAC total scores at the mid-season assessment, although only RWE for the group with greater SCAT symptom severity at mid-season was significantly different ($p<0.01$). Similarly, the two athletes demonstrating decreased (worse) SAC total score at the post-season assessment sustained a greater number of head impacts for the season, although the difference was not statistically significant.

Table 1: Athletes demonstrating significant changes in clinical assessments (greater than 80% confidence interval (CI)) and corresponding head impact data (mean±stdev) for the group without (0) and with changes (1). Biomechanics are represented as the total number of head impacts from the start of the season until the date of the mid- and post-season assessments. Statistically significant group-wise differences in biomechanics ($p<0.05$) are represented in bold.

	Mid-Season Assessment			Post-Season Assessment		
Assessment	# > 80% CI	# Impacts	RWE	# > 80% CI	# Impacts	RWE
SCAT Symptom Severity	4/13 (31%)	0: 152±65 1: 209±68	**0: 0.23±0.28** **1: 0.73±0.19**	1/10 (10%)	0: 388±228 1: 297±0	0: 1.40±1.35 1: 1.76±0
BESS Total Score	1/13 (8%)	0: 170±72 1: 162±0	0: 0.40±0.35 1: 0.09±0	1/10 (10%)	0: 343±196 1: 704±0	**0: 1.10±0.78** **1: 4.43±0**
SAC Total Score	4/13 (31%)	0: 158±71 1: 194±64	0: 0.38±0.35 1: 0.39±0.37	2/10 (20%)	0: 360±204 1: 458±343	0: 1.58±1.41 1: 0.88±0.38
ImPACT Verbal Memory	1/13 (8%)	0: 170±72 1: 165±0	0: 0.41±0.34 1: 0.08±0	1/10 (10%)	0: 397±222 1: 215±0	0: 1.47±1.35 1: 1.14±0
ImPACT Visual Memory	3/13 (23%)	0: 176±76 1: 145±32	0: 0.41±0.35 1: 0.30±0.37	1/10 (10%)	0: 388±228 1: 297±0	0: 1.40±1.35 1: 1.76±0
ImPACT Reaction Time	2/13 (15%)	0: 175±72 1: 135±42	0: 0.44±0.34 1: 0.05±0.03	3/10 (30%)	0: 385±248 1: 341±155	0: 1.46±1.53 1: 1.37±0.56

IV. DISCUSSION

This study has provided evidence of clinical changes in some non-concussed American football athletes throughout the course of a single season, which is consistent with prior research [7]. Head impact burden was greater in athletes that demonstrated some clinical changes (i.e., SCAT and SAC). However, a novel aspect of the present study was the incorporation of a mid-season assessment. Interestingly, the percentage of athletes demonstrating significant clinical changes was greater at the mid-season than the post-season assessment. This may be attributable to higher head impact density (# impacts / time) often reported during preseason training camp than during the regular season. However, given the limited sample size, these data represent only preliminary findings and further validation of these findings are required.

V. REFERENCES

1. A Levy et al. J Neurotrauma 2009. 2. M McCrea et al. JAMA 2003. 3. M. McCrea et al. J Int Neuropsychol Soc 2013. 4. AK Ommaya et al. Science 1966. 5. BD Stemper et al. Ann Biomed Eng 2018. 6. J Urban et al. Ann Biomed Eng 2013. 7. TM Talavage et al. J Neurotrauma 2014.