Effects of Linear and Rotational Head Impact on White Matter Changes in High School Football Players

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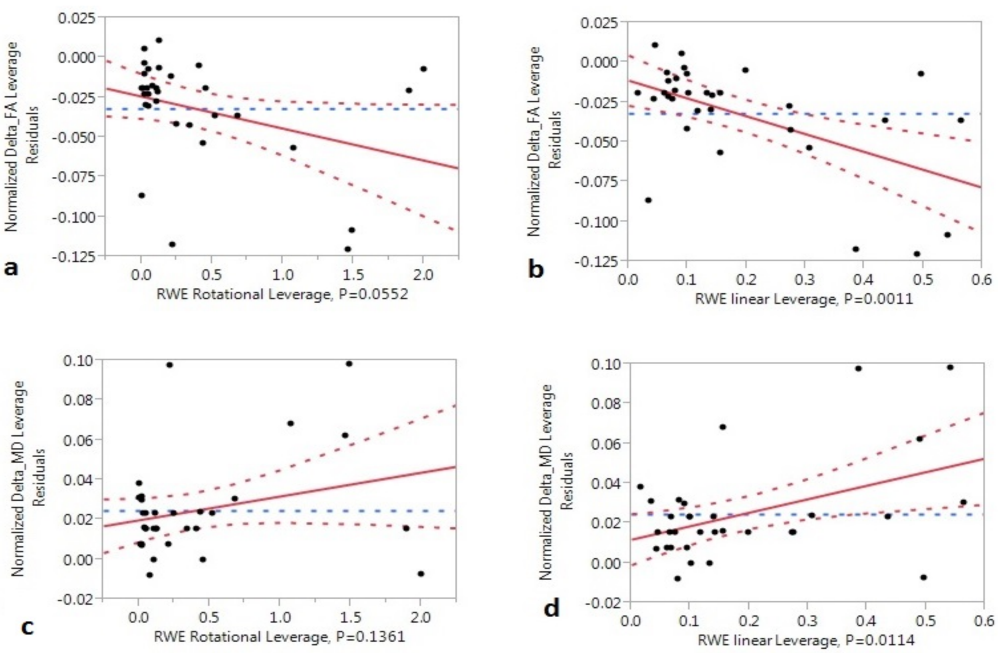
Target audience: Neurologists, radiologists, medical physicists, Physicians who practice sports medicine

Introduction: Sports-related concussion is the most common athletic head injury. Football has the highest rate of head injury among high school sports compared to other contact team sports. It is estimated that nearly 1.1 million students play high school football in the United States[1]. Previously, it has been shown that there are significant associations between risk weighted cumulative exposure and diffusion tensor imaging (DTI) metrics in the white matter[2]. Risk weighted cumulative exposure (RWE_{CP}) is a biomechanical metric that is used to measure cumulative head impacts and is a combined probability of rotational and linear accelerations. The purpose of this study was to investigate the individual effects of linear and rotational accelerations on white matter changes in high school football players using DTI.

Materials and Methods: Thirty two players from a local high school football team (age range=16-18) were instrumented with the Head Impact Telemetry System (HITs) during all practices and games. None of the players were diagnosed clinically with concussion during the season. All players received pre- and post-season MRI. DTI images were acquired using a 2D single-shot EPI sequence (TR=10.5 sec; TE=99 msec; FA=90 degrees; spatial resolution= 2.2x2.2 mm; slice thickness = 3 mm; 54 slices; 10 b = 0 volumes; 15 diffusion directions with b = 0 and 1000) on a 3T Siemens MRI. The biomechanical metric computed from the HITS data for this study was the risk weighted linear,and rotational exposures (RWE_L.and RWE_R,)[3]. Rotational acceleration conveys the idea that head is pivoting about the neck, whereas linear acceleration is the direct impact in a straight line through the center of head. A whole brain tract-based spatial statistics (TBSS) analysis was conducted using FSL. The Fractional anisotropy (FA) and mean diffusivity (MD) skeleton was calculated for each subject. The percent change of FA and MD was calculated based on the post-pre season differences in the mean of the skeleton. Linear regression analysis was conducted with SAS (SAS Institute Inc.; Cary, NC, USA) to establish the relationships between RWE (RWE_L, RWE_R, and RWE_{CP}) and normalized delta ({post-pre}/pre) for mean skeleton FA and MD. Age at pre-season, body mass index, and time between scans were used as covariates in the statistical analysis.



Results and Discussion: Linear regression analysis showed significant associations between the DTI metrics and RWE_L . (Figure 1 b and d) The relationship with RWE_R did not achieve statistical significance (Figures 1 a and c)

Figure1: Scatterplot showing relationship between DTI metrics and biomechanical values; a) depicts the relationship between FA with RWE_R (R^2 = 0.11,corrected p =0.055) and RWE_L (R^2 = 0.30 and corrected $p \leq 0.01$), c-d) depicts the relationship between MD with RWE_R (R^2 = 0.07 and corrected p = 0.13) and RWE_L (R^2 = 0.19 and corrected $p \leq 0.05$), respectively.

Conclusions: Our findings suggest changes in DTI metrics are associated significantly with the linear component of the risk-weighted cumulative exposure (RWE_L) in high school football players. The rotational component (RWE_R) did not show any significant association with the DTI metrics. Prior studies done with professional football players[4] have similarly suggested linear acceleration has a significant impact on the brain compared to rotational acceleration but other studies[4] have shown that rotational acceleration have greater impact on the brain. This topic is not well understood and is still a matter of debate. A future study with larger sample size is needed to explore the relationship of RWE_L and RWE_R and their effect on brain white matter.

References: [1] Jantzen et al.AJNR 25(5):738-745 (2004) [2] Davenport et al.J. Neurotrauma 31:1617–1624 (2014) [3] Urban et al.Annals of biomedical engineering (2013). [4] Pellman et al. Neurosurgery 53:799-812 (2003) [4] Broglio et al.J of Athletic Training 44: 342-349 (2009)