Diffusion tensor imaging distinguishes between collegiate football players with and without concussion

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Target audience: Mild traumatic brain injuries (mTBIs) that represent about 80% of the 57 million annual TBIs[1] worldwide are considered a risk factor for development of long-term cognitive and psychiatric dysfunction[2]. Currently, clinical diagnosis and prognosis of mTBI severity are solely based on clinical judgment of the medical professionals due to a lack of mTBI diagnostic and prognostic neuroimaging markers.

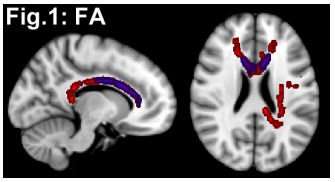
Purpose: To date, DTI findings in mTBI patients have been inconsistent. This inconsistency may be partially due to the heterogeneity of the populations studied. Here we imaged age and education matched groups of young males (athletic and not-athletic) to investigate sports-related concussion effects on white matter (WM) integrity. The Diffusion Tensor Imaging (DTI) technique has been shown to be sensitive to changes in microstructural properties of WM in mTBI subjects[3, 4]. It has been used in the past to detect the histologic effects of Diffuse Axonal Injury (DAI) in patients with traumatic brain injury by studying WM regions that appeared normal on other MR sequences[5]. Our aim is to investigate WM structural changes associated with sports-related concussion and the accumulation of head hits in young male athletes using several diffusion scalars derived from the tensor model, including fractional anisotropy (FA), mean diffusivity (MD), and directional diffusivity (axial (λ_1) and radial (λ_{23})). Analysis was performed during the acute and sub-acute injury phases. The concussed collegiate football players (AthCon) were compared with age-matched non-concussed football players (Ath), and age-matched control subjects with no history of concussion (HC) (non-athlete).

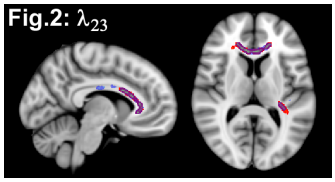
Methods: Nineteen AthCon (20.7±1.3 year; range: 19-23 years), 23 Ath (20.7±1.9 year; range: 19-27 years), and 10 HC subjects with no previous history of concussion (21.0±1.0 year; range: 18-25 years) participated in the study. The MR imaging data were acquired using a 3T scanner (GE MR750) with a 32-channel receive-only head array coil (Nova Medical). DTI was performed with 30 diffusion-encoding directions (TR/TE 8800/78.1 ms; acquisition matrix, 256 x 256; field of view, 25.6 x 25.6 cm; slice thickness 2 mm) with one b-value of 1000 sec/mm^2 image. All participants underwent an MRI investigation, psychological and neurocognitive tests. The AthCon group participated twice following injury; at 1-2 days (T1) and at one month (T3 for only 11 subjects). To investigate local changes in WM structure, voxel-wise analysis of the DTI indices was carried by TBSS part of the FMRIB Software Library (FSL). TBSS projects all subjects' DTI indices data onto a mean DTI indices tract skeleton. Between-group statistical analyses of the skeletonized data using FSL's randomize tool were conducted to measure voxel-wise differences in DTI derived metrics between concussed and control participants.

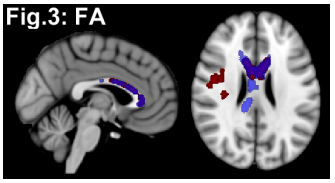
Results: Different WM areas, mainly in the genu of the corpus callosum (GCC), body of the corpus callosum (BCC), splenium of the corpus callosum (SCC), left posterior corona radiata (LPCR), and left superior corona radiata (LSCR) showed a significant FA increase and λ_{23} decrease in AthCon in the acute phase of injury (T1) compared to both HC and Ath ($p<0.05$). Moreover, similar relationships were found during the one-month follow-up. Figures 1 and 2 show differences in FA and λ_{23} between AthCon and HC, while Fig. 3 and 4 show differences in FA and λ_{23} between AthCon and Ath, both at T1 (depicted in blue) and one month (depicted in red) after injury, respectively. Increased FA and decreased λ_{23} in the acute phase may result from cytotoxic edema and localized inflammatory responses that do not disappear 30 days after concussion. Fig. 5 shows the differences in FA values in the GCC, BCC, SCC and LSCR between AthCon and controls in the acute phase. No significant difference was found in MD and λ_1 indices among these three groups. Correlations among psychiatric scales and DTI metrics were significant for the State-Trait Anxiety Inventory (Trait sub-scale) and FA values in the LSCR ($r=0.53$; $p=0.02$), between the Emotional Contagion Scale and λ_{23} values in the GCC ($r=0.50$; $p=0.04$), and between Hamilton Depression Scale (29 item score) and λ_{23} values in LPCR ($r=-0.48$; $p=0.05$).

Discussion: 10-20% of concussed athletes suffer long-term cognitive and psychiatric symptoms. These deficits may be related unresolved deficient WM integrity. Here we assess different DTI indices at multiple time-points during recovery in concussed collegiate football players to develop biomarkers of mTBI recovery. Results show significantly higher FA and lower λ_{23} values in concussed subjects than controls in various WM locations. Differences between the AthCon and Ath groups suggest that the present findings are specific to concussion rather than head hit totals.

Conclusion: Our finding shows that in the acute phase (T1) mTBI subjects had increased FA and decreased λ_{23} compared with the controls in different WM areas that correlate with some psychiatric symptoms. These differences remain and are enhanced one month after injury.







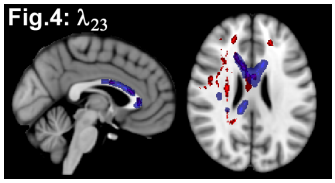


Fig. 1 & 2 Depict FA and λ_{23} differences between AthCon and HC while Fig. 3 & 4 Depict FA and λ_{23} differences between AthCon and Ath. Blue depicts differences days after injury and red depicts differences one-month after injury. Purple is the overlap of those time-points.

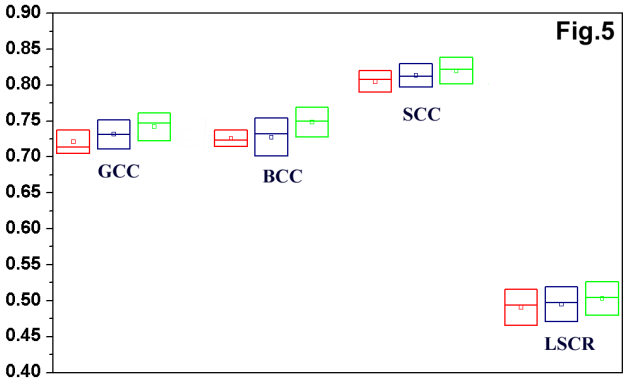


Fig.5: differences in FA values on GCC, BCC, SCC and LSCR between HC (red), Ath (blue) and AthCon (green) at T1.

Reference: 1.) Langlois, J.A., et al. J Head Trauma Rehabil, 2006. 21(5): p. 375-8; 2.) Iverson, G.L. Curr Opin Psychiatry, 2005. 18(3): p. 301-17; 3.) Bazarian, J.J., et al. Magn Reson Imaging, 2012. 30(2): p. 171-80; 4.) Caeyenberghs, K., et al. Neurorehabil Neural Repair, 2011. 25(6): p. 492-502; 5.) Inglese, M., et al.. J Neurosurg, 2005. 103(2): p. 298-303.