Differences in Resting State Connectivity and White Matter Integrity in Adolescents with Sports-Related Concussion

Murdaugh, D.L.[1], Sun, B.[1], Jones, R.[1], King, T.Z.[2], Reisner, A.[1], & Burns, T.G.[1]
[1]Children's Healthcare of Atlanta; [2]Georgia State University
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BACKGROUND

Sports Related Concussion (SRC) has been shown to primarily affect brain function rather than structure.[1] Neuropsychological testing has consistently found that individuals who have sustained a SRC have decreased performance on measures of working memory, attention and concentration, verbal memory, and problem-solving.[2] However, the underlying neural mechanisms involved in SRC has only recently begun to be investigated. Studies that have assessed this using quantitative neuroimaging measures, such as fMRI and DTI, have found that neurological alterations can persist after cognitive symptoms have subsided.[3]

OBJECTIVES

In the present study, we evaluated neurological differences in concussed and non-concussed youth athletes using resting-state fMRI (rs-fMRI) and diffusion tensor imaging (DTI) both acutely (<1 week) and 21 days post-concussion. The specific aim of our study was to assess trajectory of recovery from concussion using neural markers and to determine whether changes in neuroimaging results correlate with neurocognitive results on traditional SRC outcome measures.

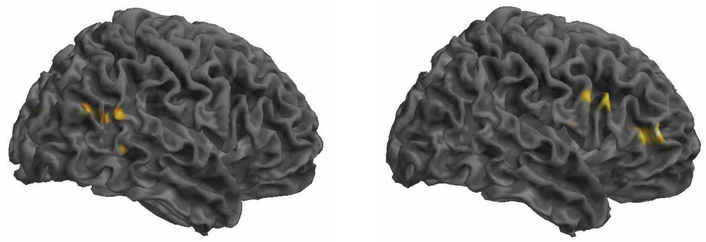
PARTICIPANTS

- Participants were recruited from the Sports Medicine Department at Children's Healthcare of Atlanta (CHOA), and included 15 male football players with a SRC and 14 age- and sport-matched male controls (ages 14-18) who had never sustained a concussion.
- Both groups were scanned twice (21 days apart) with the same imaging sequences. For the concussed group, the first scan was done within 7 days of the concussion.
- Two of the control participants had incidental findings on their neuroimaging scans and were excluded from the study. One participant from the concussed group did not return to the second neuroimaging session, and so was excluded from the analyses comparing session 1 and session 2.

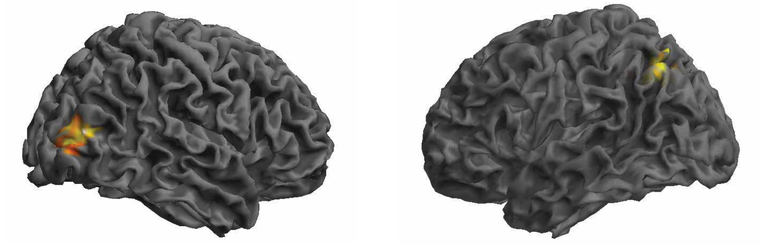
METHODS

- Data were acquired using a 3 Tesla Siemens Trio scanner. Session included anatomical T1 MPRAGE, rs-fMRI, pCASL and Diffusion-weighted Imaging (DWI) scans. Primary imaging parameters for the fMRI: TR=2130ms, TE=30ms, FA=90°, resolution=3x3x3 mm3.
- Resting state (rs-fMRI) data were pre-processed using SPM12. Slice timing correction was applied to the data. Images were motion-corrected, spatially normalized to standard MNI brain space, and spatially smoothed using a three-dimensional Gaussian kernel of 8 mm FWHM.
- Independent Components Analysis (ICA) was carried out using the Group ICA of fMRI Toolbox (GIFT) for MATLAB. The components were sorted based on spatial correlation with an anatomical mask of the default mode network. Components were transformed to z-scores using GIFT, and then exported to SPM12 where statistical analyses were performed. Multiple regression with neurocognitive scores on the Immediate Post-Concussive Assessment and Cognitive Testing (ImPACT) battery were also conducted to determine the extent to which imaging findings correlate with neurocognitive data.
- DWI data were preprocessed using FSL. Data was converted from dicom to nifti format and B values and B vectors were extracted from dicom header. Data was then corrected for motion and eddy currents. Fiber tractography was performed using quantitative anisotropy (QA)-based generalized deterministic tracking algorithm and connectometry analysis using the Diffusion Spectrum Imaging (DSI) Studio toolbox.

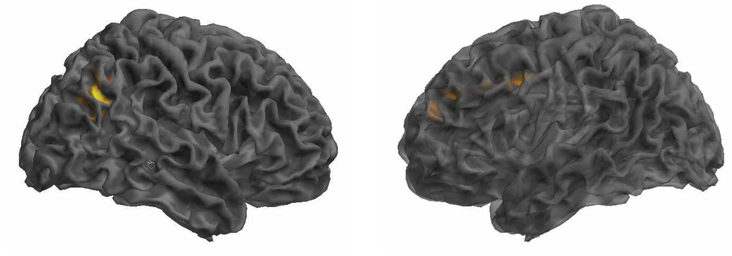
- Between group results revealed greater activation at session 1 in the control group in the right inferior frontal gyrus, middle frontal gyrus, middle temporal gyrus, and precuneus.



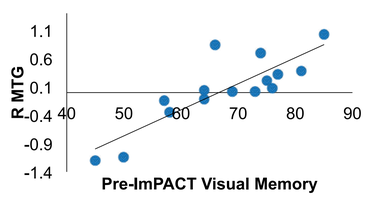
- Between group results revealed greater activation at session 1 in the concussed group (acute phase of SRC) in the left precuneus, left cerebellum (not shown), and right middle occipital cortex than the control group.

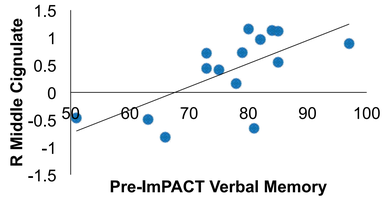


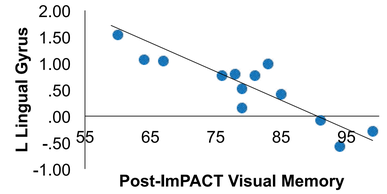
- Specific to the concussion group, results revealed greater activation in the acute phase of SRC in the left middle frontal gyrus, left middle cingulate, and right angular gyrus There were no regions that showed greater activation in the 21 days post-SRC session.



rs-fMRI CORRELATION WITH ImPACT SCORES

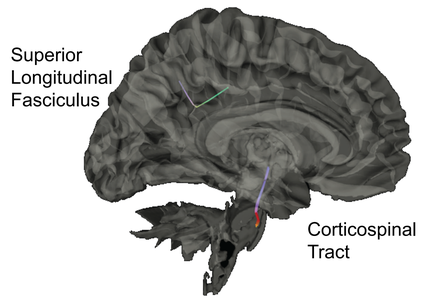






CONNECTOMETRY RESULTS

- Results from the connectometry analysis revealed greater white matter integrity in the control group compared to the concussed group at session 1 in the superior longitudinal fasciculus and the corticospinal tract. There were no differences between the control group or the concussed group at session 1 and 2.



DISCUSSION

This study lends support to a growing body of research that rs-fMRI and DWI may be sensitive measures to detect subtle changes in brain functioning following concussion that also correlate with neurocognitive measures used to assess recovery from SRC. While other studies have reported being able to detect subtle changes using neuroimaging up to two months post concussion[4], our study fits with the body of literature that suggests symptoms of concussion usually fully resolve within two weeks[5]. In the acute phase of SRC, we found significantly decreased connections within areas of the brain implicated in executive functioning in the concussed group. Overall, our results indicate both compensatory mechanisms and disruptions that appear to resolve over time, informing our understanding of underlying neural mechanisms in SRC.

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