Default-mode network functional connectivity progression in the days following a single sports concussion

Victoria L Morgan[1], Andrew J Gregory[2], and Allen K Sills[3]
[1]Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States, [2]Ortho-Sports Medicine, Vnderbilt University, Nashville, TN, United States, [3]Neurosurgery, Vanderbilt University, Nashville, TN, United States

Target audience: This work is relevant to those interested in the detection and monitoring of mild traumatic brain injury.

Purpose: Concussion is a complex pathophysiological brain injury induced by biomechanical head impact [1], and is associated with a wide range of symptoms and severities. Many neuroimaging studies have investigated the changes in functional connectivity at different times following the injury [2-3], but very little is known about the initial changes occurring in the first six days following a single concussive impact when post-concussive symptoms may still persist. The purpose of this work is to quantify the functional network changes across the brain in college student-athletes within one week of a single sports concussion.

Methods: We enrolled seven college student-athletes (4M/3F, 18-20 yrs) 3-6 days after suffering a sports concussion diagnosed by the certified athletic trainer (concussion group); and eleven healthy (5M/6F, 18-23 yrs) college students who have never suffered a concussion (healthy group). Three concussion subjects returned for same MRI protocol at least 4 months later. Structural (three dimensional, T1-weighted, 1x1x1 mm), and resting functional imaging (80x80, FOV = 240 mm, 34 axial slices, TE = 35 ms, TR = 2 sec, slice thickness = 3.5 mm/ 0.5 mm gap, 300 volumes) were performed on a 3T MRI scanner using a 32 channel head coil. A total of 18 regions of interest (ROIs) were identified in three networks across the brain using the WFUPickAtlas aal labels: Default-Mode Network (7 ROIs, DMN), Frontal–Parietal Control Network (5 ROIs, FPC), and Dorsal Attention Network (4 ROIs, DAN) and the left and right thalamus. Functional connectivity (FC) was calculated between all pairs of ROIs using partial correlation of time series after standard preprocessing including physiological noise correction with RETROICOR [4] and low pass filtering at 0.1 Hz. The motion and white matter time series were used as confounds. Two-sample t-tests were used to compare the FC in each ROI pair between the groups. The average within network connectivity across all pairs of ROIS in each network was computed and compared between groups using two sample t-tests. FC in all paths and networks were correlated with days after injury using Pearson's correlation.

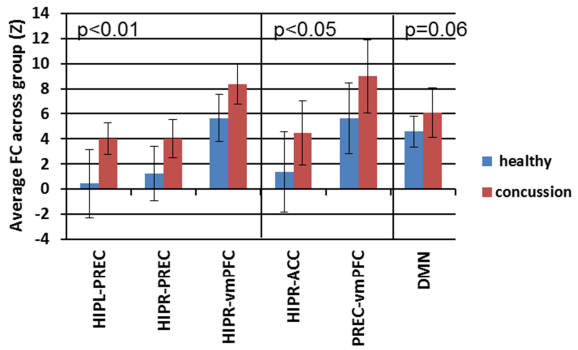

Figure 1. FC increases in concussed college athletes compared to healthy controls

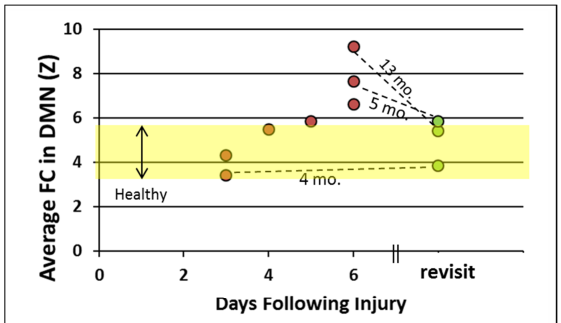

Figure 2. Average FC across the DMN in concussed athletes increases linearly with days following injury (p=0.005), but at the revisit is at the level of the healthy group. red = concussion, green = concussion revisit. Dashed lines link the same subject. Healthy mean ± stdev is indicated by arrow and yellow shading.

Results: Three paths including four ROIs within the DMN (left hippocampus HIPL, precuneus PREC, right hippocampus HIPR, and ventromedial prefrontal cortex vmPFC) were significantly increased in the concussion group compared to the healthy group ($p<0.01$, Figure 1). Two other paths including three of those four ROIs and the anterior cingulate (ACC) in the FPC also showed increases in the concussed group ($p<0.05$, Figure 1). None of these individual paths were linearly correlated with days after injury The average of all of paths in the DMN showed a trend of increased FC in the concussed group ($p=0.06$, Figure 1) that correlated positively with days after injury ($p=0.005$, Figure 2). The DMN FC of the each of the three concussed patients that returned is also shown in Figure 2. No difference between the groups was detected in the FPC or DAN. No significant decreases in FC were detected in the concussion group.

Discussion and Conclusion: Our results show that within days of a single sports concussion there were focal increases in FC in parts of the DMN including the bilateral hippocampus, precuneus and ventromedial prefrontal cortex. These initial increases may have implications for understanding post-concussive symptoms and behavior. When considering the DMN as a whole, there was a gradual increase in FC over the first week. Interestingly, this FC appeared to normalize (decrease) to the healthy level in those with initial increases (imaged initially at 6 days), but remain constant in the concussed patient with an initial measure in the healthy range (imaged initially at 3 days). Taken together these results hint at a progression of DMN FC over time where the paths in Figure 1 are first affected, followed in the first week by the rest of the DMN, with an eventual recovery of unknown duration. However, this hypothesis must be confirmed and fully characterized with more data.

References: [1] McCrory P et al., British Journal of Sports Medicine 2012;47, 250-258. [2] Johnson B et al. NeuroImage 2012; 59:511. [3] Mayer AR, et al. Human Brain Mapping 2011;32(11):1825.[4] Glover GH, et al. Magn Reson Med 2000;44:162. This work was supported in part by the Vanderbilt CTSA grant UL1 TR000445 from NCRR/NIH