Mild traumatic brain injuries (mTBI), including concussions, are prevalent, affecting as many as 5.3 million people,[1] and costing approximately $75 billion in the United States annually.[6] Recent work from our group[3,4] and others[5] have found that even subconcussive blows to the head can have an effect on the brain. Contact sports-related injuries, although largely preventable, provide an ideal laboratory for the study of these injuries, due to their relatively high incidence in an otherwise healthy, homogenous population, free from common neurological comorbidities. Our previous work[3,4] has found changes in the neurometabolism of asymptomatic high school football players through the use of functional magnetic resonance imaging (fMRI), and that these changes are correlated with the number of blows the player experienced. This work further examines the nature of these changes.

### Participants

53 male football players (range=14-18 years) participated in the study. Subjects were recruited from two local high school football teams, over two seasons. Subjects who participated in more than one season were treated independently, resulting in 40 complete subject-seasons and 76 in-season scans.

### Head Collision Monitoring

Subjects wore helmets with Head Impact Telemetry System (HITS, Simbex, NH) that recorded head blows for every practice and game. Recorded hit events were grouped by helmet region. Subjects participated in the season without interruption or intervention.

### Magnetic Resonance Imaging

Subjects participated in pre-season, in-season, and post-season sessions. Two fMRI tasks were acquired (gradient echo epi, TR=1500ms, TE=26ms, flip angle=35°, 64x64x34 at 3.75mm isotropic). A T1-weighted SPGR was acquired for registration (1mm isotropic). Tasks were verbal and visual N-back (0-, 1-, and 2- back) working memory tasks.

### Image Processing

Imaging data were processed with AFNI[8] using an analysis stream adapted from afni_proc.py. Contrasts presented here are the 2-back vs 0-back task. Voxel-wise t-statistics from the general linear model were averaged over MarsBar[7] regions and further analyzed on a region-wise basis using MATLAB (Mathworks, MA).

### Results

**Figure 2**: Group means of pre- and post-season sessions for visual and verbal task (n=35). These results are in agreement with other studies utilizing similar tasks[9].

At the group level, fMRI activation patterns match expectations.[8] When these activations are compared to hit counts, there were significant correlations, as our group has reported in the past.[3,4] A Monte Carlo permutation method demonstrates that the number of regions that were correlated to hits at a naïve $p=0.05$ was greater than what would be expected by chance, and has an estimated significance of $p=0.001$ for the visual task (57/116 regions), and $p=0.013$ for the verbal task (46/116 regions).

**Figure 3**: Map of regions correlated with hits at a naïve significance of $p=0.05$.

**Figure 4**: Probability distributions of number of regions correlated to hits at a naïve significance of $p=0.05$. The combination of repeated measures and step-wise regression overestimates the significance of individual regions, but not enough to account for our results.

### Conclusions

In this study of high school football players, we have compared fMRI activity during two working memory tasks to history of blows to the head. We found widespread changes in brain activity that are correlated with hit history in the absence of a diagnosed concussion. When within-season activation changes are compared to number of recent blows, fMRI activation decreases in regions proximal to the blow, and increases in distal regions. It is hoped that this work will provide further insight into the nature of this injury which may inform treatment and prevention strategies.

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### References