Abnormal White Matter Microstructure and Cognitions in Adolescent Athletes with Concussion History

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Introduction

- Every year, ~1,000,000 athletes in the US play American football competition at the high school level. Despite wearing helmets, their heads remain vulnerable to subconcussive impacts, which may lead to concussions. Previous concussion(s) may impair athletes’ cognition, but the neurobiological basis remains unclear.
- Diffusion-weighted magnetic resonance imaging can quantitatively assess white matter (WM) microstructure and water diffusion in brain.
  - Fractional anisotropy (FA) is sensitive to size, density, and myelination of axons;
  - Mean diffusivity (MD) reflects the magnitude of water diffusion.
- We investigated the WM microstructure and cognitive performances of local adolescent male football athletes (FB) and non-contact sports athletes (CON), with or without history of concussion (HOC+ & HOC-) over one competition season. We hypothesized: Compared to HOC- athletes, HOC+ athletes demonstrated greater WM microstructural deficits and cognitive impairments.

Methods

- Participants (Table 1):
  - 23 FB compl. 3 MRI sessions: 1 scan approx. 1 mo. before contact practices, 2 scans in the 1st and 2nd 6-wk periods of the season.
  - 15 CON compl. 2 MRI sessions bw. ~5-18 wks.
  - Immediate Post-concussion Assessment and Cognitive Test (ImPACT) was assessed in each session.
- Data were processed using FSL:
  - Fractional anisotropy (FA) and medial diffusivity (MD) were estimated for each individual.
  - Mean FA and MD skeletons were created from tract-based spatial statistics.
- Data analyses:
  - One-way analysis of covariance with age as covariate was performed in both FB and CON to study the effects of concussion history on DWI measures.
  - Spearman’s correlation was used to explore assoc. b/w ImPACT scores & DWI measures.
  - All statistics were corrected with false discovery rate for multiple comparisons.

Table 1: Demographics and ImPACT scores [mean ± SD]

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>HOC- (n=15)</th>
<th>HOC+ (n=8)</th>
<th>CON (n=15)</th>
<th>HOC+ (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
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<tr>
<td>Age</td>
<td>16.3 ± 0.9</td>
<td>16.9 ± 1.0</td>
<td>16.2 ± 1.1</td>
<td>16.6 ± 1.3</td>
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<tr>
<td>Years of high-school experience</td>
<td>2.0 ± 0.9</td>
<td>2.2 ± 0.8</td>
<td>1.8 ± 1.1</td>
<td>2.3 ± 1.1</td>
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<tr>
<td>Number of concussion(s)</td>
<td>2.2 ± 1.1</td>
<td>1.9 ± 1.1</td>
<td></td>
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<tr>
<td>Verbal memory composite</td>
<td>89 ± 10.3</td>
<td>89 ± 6.4</td>
<td>91.7 ± 7.3</td>
<td>89.9 ± 12.7</td>
</tr>
<tr>
<td>Visual memory composite</td>
<td>78.2 ± 11.1</td>
<td>82.8 ± 11.8</td>
<td>84.1 ± 12.5</td>
<td>84.9 ± 14.8</td>
</tr>
<tr>
<td>Motor speed composite</td>
<td>43.2 ± 5.3</td>
<td>45.7 ± 4.8</td>
<td>43.3 ± 6.8</td>
<td>45.1 ± 12.5</td>
</tr>
<tr>
<td>Reaction time composite</td>
<td>0.5 ± 0.1</td>
<td>0.5 ± 0.1</td>
<td>0.5 ± 0.0</td>
<td>0.5 ± 0.0</td>
</tr>
<tr>
<td>Impulse control composite</td>
<td>5.9 ± 6.5</td>
<td>7.1 ± 6.6</td>
<td>5.1 ± 2.1</td>
<td>5.8 ± 4.0</td>
</tr>
<tr>
<td>Total symptom score</td>
<td>1.9 ± 3.0</td>
<td>5.3 ± 9.4</td>
<td>1.1 ± 2.8</td>
<td>3.9 ± 3.8</td>
</tr>
</tbody>
</table>

Results

- HOC+ athletes demonstrated various regional WM microstructural abnormalities vs. HOC- athletes:
  - For FB (Fig. 2A), sig. higher MD in right fornix/stria terminalis (0.98 × 10^-3 ± 0.03 × 10^-3 vs. 0.96 × 10^-3 ± 0.03 × 10^-3, p = 0.004, Fig. 1 top left);
  - sig. lower FA in the right posterior thalamic radiation (0.63 ± 0.03 vs. 0.65 ± 0.03, p = 0.019, Fig. 1 top right);
  - For CON (Fig. 2B), sig. higher MD in the right superior fronto-occipital fasciculus (0.73 × 10^-3 ± 0.01 × 10^-3 vs. 0.71 × 10^-3 ± 0.02 × 10^-3, p = 0.012, Fig. 1 bottom left) and the left anterior limb of internal capsule (0.87 × 10^-3 ± 0.02 × 10^-3 vs. 0.84 × 10^-3 ± 0.02 × 10^-3, p = 0.001, Fig. 1 bottom right).
- In FB, 8 HOC+ exhibited faster visual motor speed asso. with higher FA in the right posterior thalamic radiation (Fig. 3).

Conclusions

- Our study showed an effect of concussion history on regional WM microstructure within thalamocortical tracts in FB and projection fibres in CON.
- The regions found in FB and CON vary, likely due to differences in systematic (FB) vs. accidental (CON) nature of collision exposure in these sports.
- Altered WM microstructure correlated with several cognitive measures, suggesting HOC+ athletes may experience greater cognitive impairments with repeated collision exposure events.

Fig. 1: Highlighted WM tracts in FB (red) & CON (blue)

Fig. 2: Regional DWI differences b/w HOC+ & HOC- athletes

Fig. 3: Assoc. b/w ImPACT scores & FA, HOC+ Football Athletes (n=8)

REFERENCES:

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