Sex differences in white matter alterations following repetitive subconcussive head impacts in collegiate ice hockey players

Sollmann, N. 3,5,7; Eichlin, P. S.; Schultz, V. 2,5; Lin, A. R. 5,7; Shenton, M. E. 2,6; Koerte, I. K. 2,3

1 Department of Diagnostic and Interventional Neuroradiology, Klinikum rechts der Isar, Technische Universität München, Munich, Germany.
2 Psychiatry Neuroradiology Laboratory, Brigham and Women’s Hospital, Harvard Medical School, Boston, MA, USA.
3 Harvard Neuroimaging Center, Klinikum rechts der Isar, Technische Universität München, Munich, Germany.
4 Department of Child and Adolescent Psychiatry, Psychosomatic and Psychotherapy, Ludwig-Maximilians-Universität, Munich, Germany.
5 Department of Radiology, Brigham and Women’s Hospital, Harvard Medical School, Boston, MA, USA.
6 Center for Clinical Spectroscopy, Brigham and Women’s Hospital, Harvard Medical School, Boston, MA, USA.
7 MVA Boston Healthcare System, Brookline Division, Brookline, MA, USA.

Purpose
Repetitive subconcussive head impacts (RSHI) may lead to structural, functional, and metabolic alterations of the brain. While differences between males and females have already been suggested following a concussion, whether there are sex differences following exposure to RSHI remains largely unknown. The aim of this study was to identify and to characterize sex differences following exposure to RSHI.

Methods
Twenty collegiate ice hockey players (14 males and 11 females, 20.6 ± 2 years; Table 1), all part of the Hockey Concussion Education Project (HCEP), underwent diffusion-weighted magnetic resonance imaging (dMRI). Thereafter, the games from the 2011-2012 season and after the Canadian Interuniversity Sports (CIS) ice hockey season 2011-2012 did not experience a concussion during the season. Whole-brain tract-based spatial statistics (TBSS) were used to compare pre- and postseason imaging in both sexes for fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD). Pre- and postseason neurocognitive performance were assessed by the Immediate Post-Concussion Assessment and Cognitive Test (imPACT).

Results
Significant differences between the sexes were primarily located within the superior longitudinal fasciculus (SLF), the internal capsule (IC), and the corona radiata (CR) of the right hemisphere (Figure 1). In significant voxel clusters (Table 1), decreases in FA (absolute difference pre- vs. postseason: 0.0268) and increases in MD (0.00002), AD (0.00008), and RD (0.00005) were observed in females whereas males showed no significant changes (Figure 2). There was no significant correlation between changes in diffusion scalar measures over the course of the season and neurocognitive performance as evidenced from postseason imPACT scores.

Conclusion
Previous research has shown that exposure to RSHI during a single varsity ice hockey season can result in significant alterations in white matter diffusivity. The results of this study further suggest sex differences in diffusivity following exposure to RSHI. The underlying mechanisms remain to be elucidated but may include an increased vulnerability of the female brain to RSHI.

Table 1: Participant characteristics.

<table>
<thead>
<tr>
<th></th>
<th>males</th>
<th>females</th>
<th>gender</th>
<th>number of players</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>11</td>
<td>62</td>
<td>25</td>
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</tbody>
</table>

Figure 1: Results of the tract-based spatial statistics (TBSS) analysis.

This figure illustrates the number of the TBSS analysis (axial view). Voxel clusters with statistically significant differences (p<0.05) change in time (postseason minus preseason, distance values are shown for males vs. females and pre- vs. postseason data, respectively. There was a statistically significant difference between pre- and postseason FA, MF, AD, and RD in female participants (p<0.05). Contrast, no statistically significant changes were observed in males over the course of a season with respect to FA, MF, AD, and RD (p>0.05).

Figure 2: Results of the tract-based spatial statistics (TBSS) analysis.

This figure depicts scatter plots of averages in the visual clusters with significantly group-differences (p<0.05). Figure 1: for fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD) values are shown for males vs. females and pre- vs. postseason data, respectively. There was a statistically significant difference between pre- and postseason FA, MF, AD, and RD in female participants (p<0.05). Contrast, no statistically significant changes were observed in males over the course of a season with respect to FA, MF, AD, and RD (p>0.05).