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

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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-five collegiate ice hockey players (14 males and 11 females, 20.6 ± 2.0 years; Table 1), all part of the Hockey Concussion Education Project (HCEP), underwent diffusion-weighted magnetic resonance imaging (dMRI) before and after the Canadian Interuniversity Sports (CIS) ice hockey season 2011-2012 and 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 (RH; Figure 1). In significant voxel clusters ($p<0.05$), decreases in FA (absolute difference pre- vs. postseason: 0.0268) and increases in MD (0.0002), 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.

		males	females	p-value
number of players		14	11	-
age (in years; (mean ± SD)		21.7 ± 1.3	19.2 ± 1.8	0.0005
handedness (right/left/ambidextrous)		10/3/1	10/1/0	0.6040
ImPACT score (preseason testing; mean ± SD)	verbal memory	90.9 ± 4.5	91.0 ± 8.6	0.3615
	visual memory	83.7 ± 8.6	85.4 ± 10.0	0.5358
	visual motor speed	44.1 ± 4.2	42.7 ± 3.7	0.3712
	reaction time	0.5 ± 0.1	0.6 ± 0.1	0.0862
ImPACT score (postseason testing; mean ± SD)	verbal memory	89.4 ± 7.7	94.7 ± 4.1	0.0608
	visual memory	81.8 ± 11.9	79.2 ± 9.9	0.4623
	visual motor speed	47.4 ± 5.3	42.9 ± 5.4	0.0344
	reaction time	0.5 ± 0.1	0.5 ± 0.1	0.4613

Table 1: Participant-related characteristics
ImPACT: Immediate Post-Concussion Assessment and Cognitive Test, SD: standard deviation.

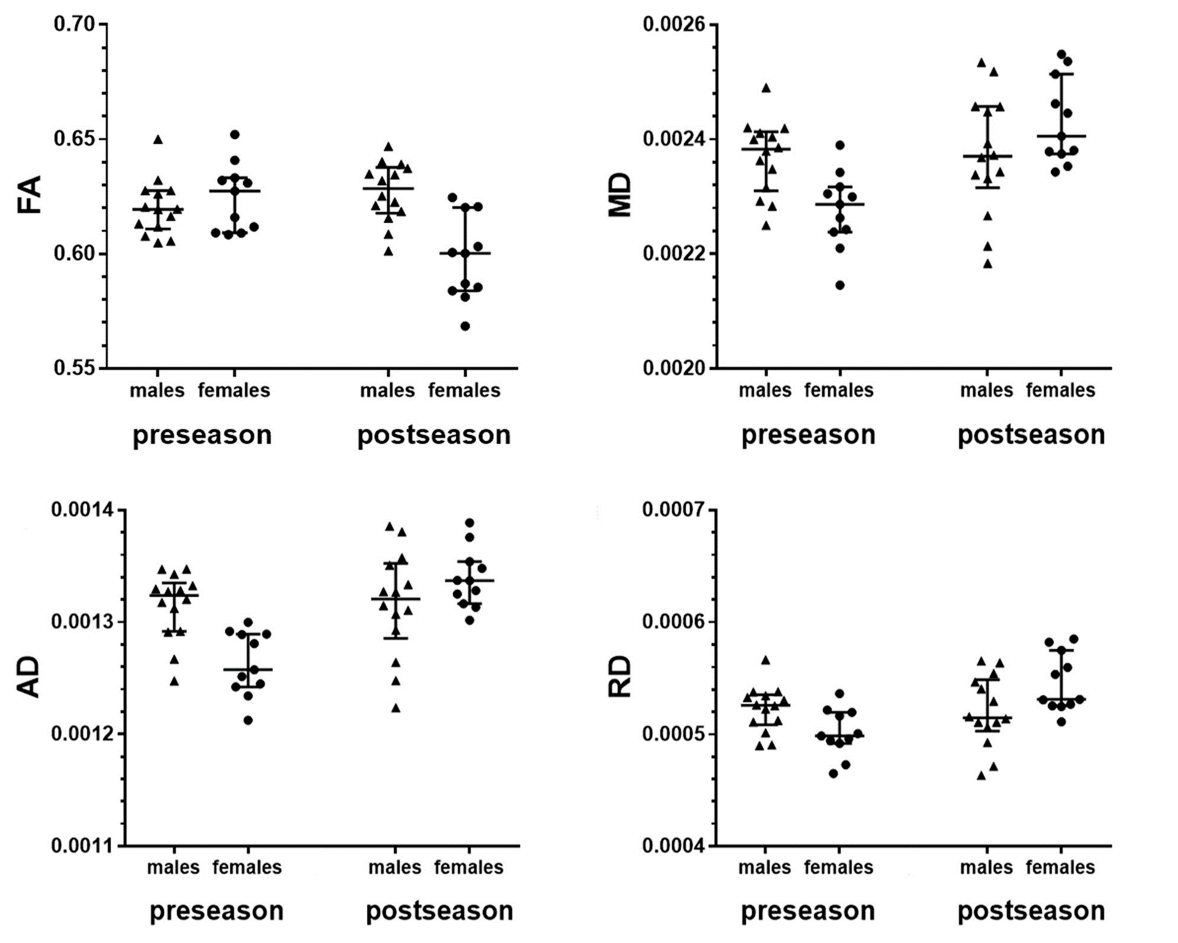

Figure 2: Results of the tract-based spatial statistics (TBSS) analysis II
This figure depicts scatter plots of average values in the voxel clusters with statistically significant group differences ($p<0.05$; Figure 1) for fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD). The values are shown for males vs. females and pre- vs. postseason data, respectively. There was a statistically significant difference between pre- and postseason FA, MD, AD, and RD in female participants ($p<0.05$). In contrast, no statistically significant changes were observed in males over the course of one season with respect to FA, MD, AD, and RD ($p>0.05$).

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.

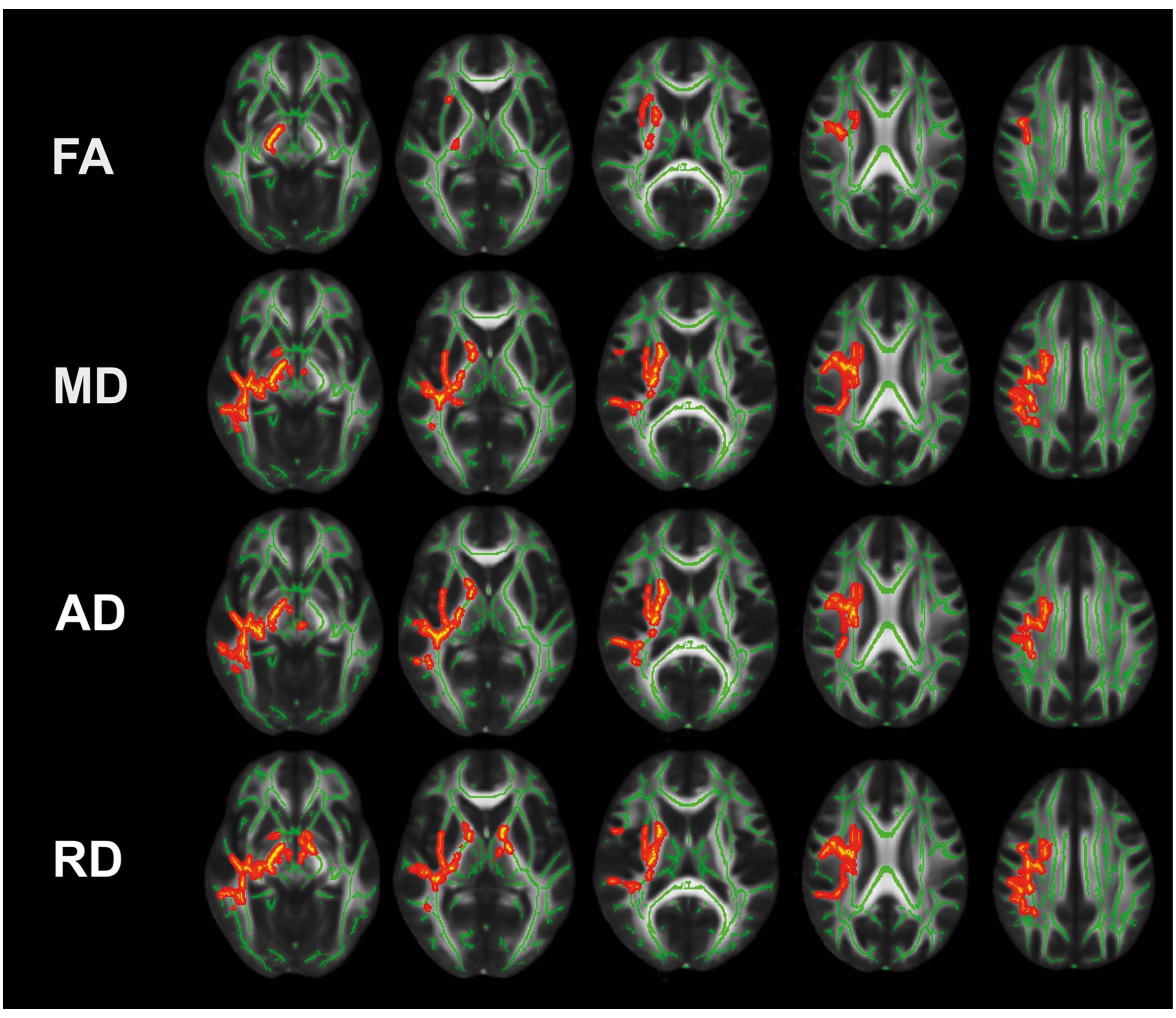

Figure 1: Results of the tract-based spatial statistics (TBSS) analysis I
This figure illustrates the results of the TBSS analysis (axial views). Voxel clusters with statistically significant differences ($p<0.05$) in change over time (postseason minus preseason datasets) between male and female participants are highlighted in red to yellow and primarily overlap with the superior longitudinal fasciculus (SLF), the internal capsule (IC), and the corona radiata (CR). The TBSS analysis was carried out for fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD). Voxels of the statistically significant clusters are thickened into local tracts on a standardized FA skeleton (FMRIB58_FA-skeleton; green) and a standardized diffusion-weighted image (FMRIB58_FA). The left side in each image corresponds to the right hemisphere (RH).