

# Associations Between Subconcussive Impacts and Macrostructural Alterations in Collegiate Female Flag Football

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## BACKGROUND

**Subconcussive impacts** may not elicit immediate concussion symptoms, but can cumulatively increase the risk of developing neurological deficits overtime.<sup>1</sup>

**Repetitive subconcussive impacts (RSCI)** have been studied primarily in male athletes despite **females being more likely to experience a sports-related concussion** and report worse symptoms compared to their male counterparts.<sup>2</sup>

**Female flag football** has grown exponentially at the university, provincial, and national levels, though the risk of sustaining RSCI through the sport has yet to be identified.

MRtrix3's **fixel-based analysis (FBA)** provides enhanced measures of white matter integrity compared to other diffusion image processing software by mapping fiber populations per voxel, improving anatomical precision especially in areas of crossing fibers. FBA has rarely been utilized in RSCI studies.

## OBJECTIVES

1. Quantify subconcussive impact exposure in collegiate female flag football.
2. Utilize FBA to compare dMRI data between football and control athletes.
3. Correlate the number and severity of impacts with neuronal white matter changes identified within the football cohort.

## METHODS

**Mouthguards with instrumented accelerometers** were provided to 19 athletes from the Queen's University Women's Football team and worn for every practice and game of their 2025 season [Figure 1]. The main metrics of interest included **video validated impacts sustained above 2g**, and the **average peak linear acceleration (PLA)** and **peak angular acceleration (PAA) per impact**.



Figure 1. Prevent Biometrics Boil-and-Bite instrumented accelerometer mouthguards. Photo from Smith et al. (2025).<sup>3,4</sup>

Participants completed **diffusion-weighted magnetic resonance imaging (dMRI) before and immediately following their respective seasons**, including 16 control female varsity athletes of non-contact sports teams.

dMRI data was processed through FBA to identify clusters where **fiber density (FD)**, **fiber cross-section (logFC)**, and **fiber density and cross-section (FDC)** may have changed, analyzed using connectivity-based fixel enhancement.<sup>5</sup> **Groupwise comparisons** between football players and controls were carried out on FBA metrics with MRtrix3's nonparametric permutation testing to identify areas of difference.

**Total number of impacts, mean PLA, and mean PAA** per player were correlated with individual changes to FD, logFC, and FDC (computed as post minus pre) within the identified fixel cluster in the football cohort.

## RESULTS

**Table 1.** Recorded impact metrics across 18 practices and 11 games summarized by position. Includes all film-validated impacts over 2g.

Position (# Players)	Recorded Impacts	Average PLA (g)	Average PAA (rad/sec <sup>2</sup> )
Offensive Line (5)	75	9.58 +/- 4.85	859.4 +/- 615.2
Defensive Line (6)	44	9.44 +/- 7.11	961.9 +/- 828.4
Receivers (2)	54	8.18 +/- 4.5	1066.1 +/- 559.6
Linebackers (5)	25	8.22 +/- 3.54	445.8 +/- 294.1
Running Back (1)	11	6.83 +/- 3.8	588.9 +/- 569.6

A total of **209 impacts** above the 2g threshold were recorded and validated. No significant difference in impact exposure or magnitude was identified between positions [Table 1].

A **significant fixel cluster of decreased logFC** was found in the football cohort spanning regions within the **medial prefrontal cortex**, though no significant interactions between football players and controls were observed for any of the fixel metrics [Figure 2].

**Increased mean PAA was significantly correlated with decreased logFC** in the football cohort [Figure 3], though this correlation did not survive correction for multiple comparisons. No other correlations between impact count, mean PLA, and mean PAA and changes in FD, logFC, and FDC within the identified fixel cluster were significant.

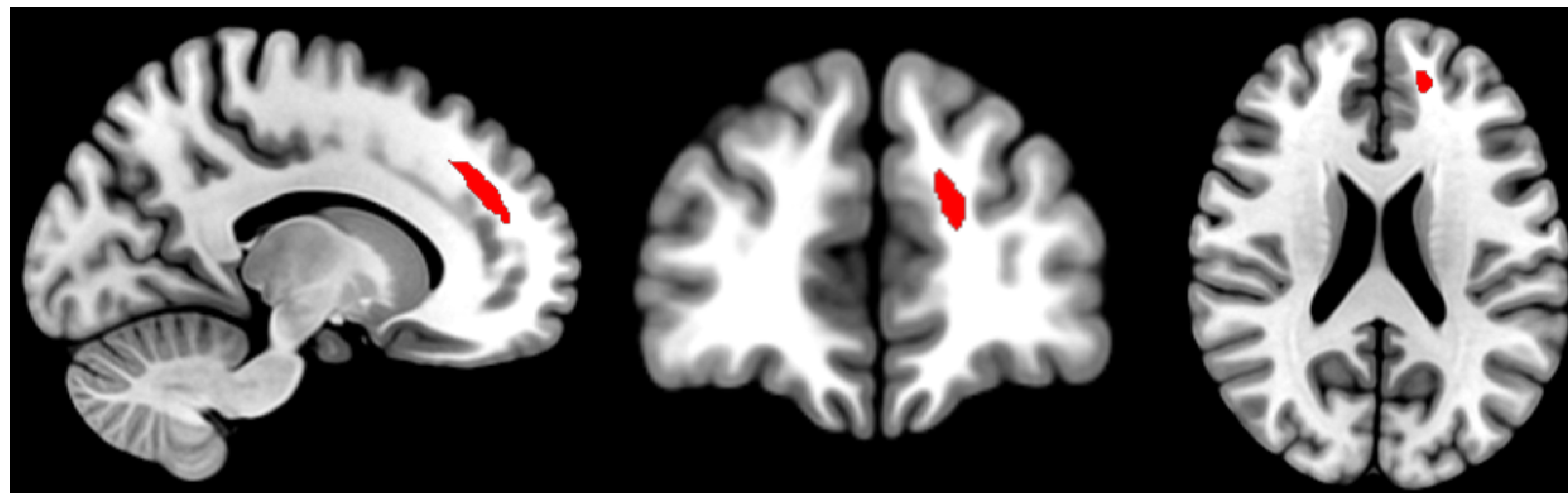


Figure 2. Sagittal, coronal, and axial view displaying a segment of the significant fixel cluster (red) representing a decrease in logFC in football players compared to controls (152 fixels, peak t-value -6.09, FWE  $p < 0.001$ ), overlapping primarily with the right cingulum frontal parahippocampal region, corpus callosum forceps minor, anterior thalamic radiation region, and anterior corticostriatal tract.

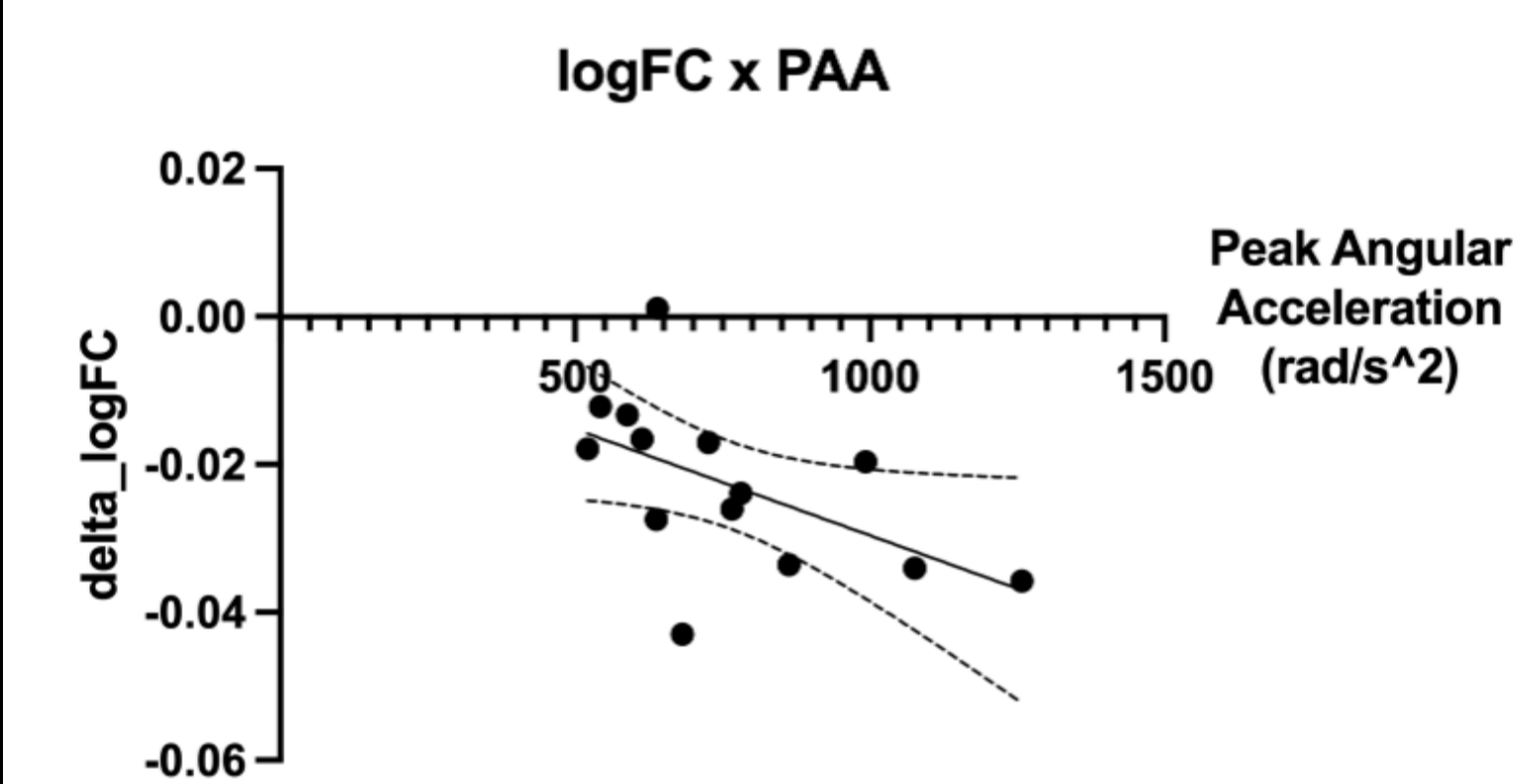


Figure 3. Increased mean PAA correlated with decreased logFC ( $p = 0.0475$ ) post season prior to FDR correction ( $p = 0.2138$ ) in the football cohort.

## CONCLUSIONS

Macrostructural white matter changes were observed in this cohort, indicating that flag football players may be sustaining enough RSCI to experience neurological alterations. Despite not surviving corrections, a relationship between increased PAA sustained and a decrease in logFC was observed. This study also shows that MRtrix3's FBA is a useful tool in identifying subtle changes to white matter integrity following RSCI. Continued research in under-studied female populations can improve our understanding of the female brain's response to injury to enhance prevention strategies and approaches to treatment.

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