Title: MRI data fusion reveals acute and persistent brain changes in concussed female rugby players

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Introduction: The effects of concussion and subconcussive sport-related impacts involve a complex and longitudinal neuronal cascade. Multimodal MRI can provide a rich amount of data but the related changes over time can be difficult to interpret. Linked independent component analysis (LICA) can elegantly evaluate inter-subject variations across different image modalities and succinctly describe intricate neuronal sequela. We hypothesized that there would be multi-modal components that relate acute and prolonged co-varying functional and white matter microstructural brain changes post-concussion and that these components would be related to subject-specific clinical scores and concussion history.

Methods: We acquired diffusion and resting state functional MRI (RS-fMRI) from non-concussed rugby players throughout the in- and off-season and compared to concussed rugby players (n = 21) acutely (24-72 hours) and longitudinally (3-months and 6-months) after a diagnosed concussion. All data (n = 182) was merged and decomposed into 15 linked components using FSL software. Components with subject weights that had a significant main effect for group according to an ANOVA, or significantly correlated with clinical metrics were investigated. A repeated measures ANOVA was used to investigate longitudinal data from a subset of concussed players with complete data.

Results: We found two components that had a significant main effect for group ($p < 0.001$). Component 4 had significantly lower subject weights for acute post-concussion data and during the in-season compared to off-season data located inferiorly in a number of major white matter tracts indicating decreased mean and axial diffusivity. Component 5 had significantly higher subject weights 3- and 6-months post-concussion compared to in- and off-season data indicating diffusion abnormalities along the corpus callosum, and these subject weights correlated significantly with the total number of concussions reported ($r = 0.5$, $p < 0.0000001$). We observed consistent changes when looking at repeated measures analyses of concussed athletes.

Discussion: These linked components revealed distinct multi-modal imaging markers that relate to acute and prolonged structural abnormalities and spatially relevant functional connectivity changes. While some axonal disruption appears to normalize other areas continued to progress long-after clearance to return to play. Furthermore, some components were related to any presence of concussion history, however distal. The consequences of early brain injury for ongoing development and the risk of neural degenerative processes like chronic traumatic encephalopathy need to be elucidated.