MEG and Repetitive Head Impact Exposure in Youth Football Players

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Objective: The objective of the present analysis was to compare imaging variables between a control group and groups of players with the highest and lowest head acceleration scores throughout the season.

Materials and Methods: 72 youth football players (all male; average age = 12.2 y) and 17 non-contact sport controls (all male; average age=11.5y) were included in this study. Football players wore sensor-embedded helmets that measured head impacts throughout the season. From this data, rotational and linear risk-weighted exposure (RWE) measures were calculated per subject. Control participants were assumed to have a 0 RWE value. In addition to the control group, four groups of 17 football players each were created with this data: lowest rotational RWE (L-$RWE_{Rotational}$), lowest linear RWE (L-RWE_{Linear}), highest rotational RWE (H-$RWE_{Rotational}$), and highest linear RWE (H-RWE_{Linear}). DKI MRI and 8-minutes of eyes-open resting-state MEG data were acquired pre-season and post-season. MEG data underwent standard pre-processing, and the images were source localized to the structural T1w MRI in Brainstorm. The relative power per frequency band and mean kurtosis (MK) for each voxel were calculated and normalized to MNI space. Voxel-wise difference maps (post-season minus pre-season) were computed for each frequency band per subject. Voxel-wise z-scores were computed utilizing the control group's mean and standard deviation. Whole-brain z-score maps were thresholded at 2 standard deviations above the mean of the controls resulting in the number of abnormal voxels (AV) per imaging measure. To identify significant differences between groups and to pinpoint the imaging variable that could best differentiate the highest head impacts from the lowest and control groups, we conducted a two-step analysis consisting of a multivariate analysis of covariance (MANCOVA) followed by a linear discriminant analysis (LDA).

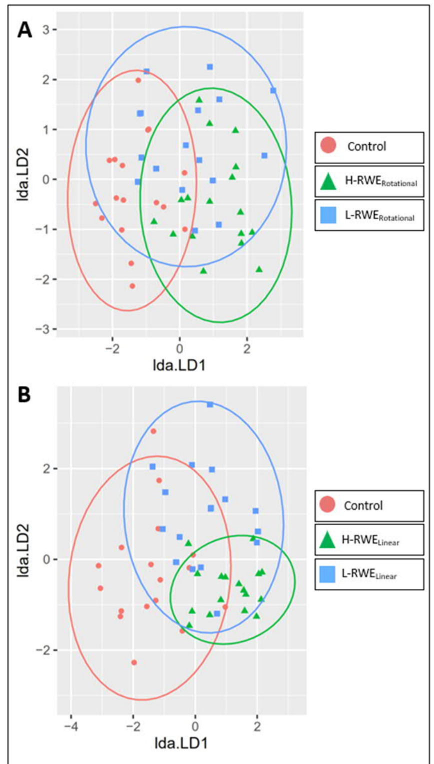

Figure 1. MANCOVA LDA Results. Subfigure A is reporting the result of the $RWE_{Rotational}$ data. LD1 accounted for 79.5% of the variance ratio while LD2 account for 20.5%. Subfigure B is reporting the results of the RWE_{Linear} data. LD1 accounted for 70.5% of the variance ratio while LD2 account for 29.5%.

Results and Discussion: When evaluating between football player (H-$RWE_{Rotational}$ and L- $RWE_{Rotational}$) and control groups, the MANCOVA model was significant ($p<0.05$) and the model's effect size was 0.27. A LDA analysis looks at Fisher's linear discriminants LD1 and LD2. Firstly, LD1 is representative of a linear function that achieves the maximum separation between groups and identifies the variable(s) responsible for this differentiation, while LD2 is a linear function orthogonal to LD1 that also identifies the variable(s) responsible for maximal differentiation between all three groups. The LD1 results demonstrated higher AV in theta and MK differentiated the H-$RWE_{Rotational}$ group from the other groups, while LD2 indicated lower theta values differentiated L- $RWE_{Rotational}$ football players and control groups. A lower AV in low gamma differentiated the controls from the other groups. When comparing the results between the football players (H-RWE_{Linear} and L-RWE_{Linear}) and control groups, the MANCOVA model was significant ($p<0.0001$) and the model's effect size was 0.42. The LD1 results demonstrated higher AV in MK differentiated all football players from the control group, while LD2 indicated that lower AV in theta differentiated H-RWE_{Linear} from L-RWE_{Linear} football players and controls.

Conclusions: In conclusion, our analysis indicated that MEG and DKI can be valuable tools for monitoring the progression of RSHI in pediatric populations. Specifically, we demonstrated that MK was able to distinguish controls from football players, while theta differentiated the high RSHI exposure group from the lowest RSHI exposure group and controls.