PREDICTING BRAIN STRAIN IN RUGBY HEAD IMPACT SIMULATIONS: IDENTIFYING KEY FEATURES

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Introduction

Head impact exposure in rugby has been implicated in a plethora of negative health outcomes. Despite extensive research on head impact metrics in American football and ice hockey, rugby's unique gameplay style and biomechanics demand separate investigation. Combining head impact data with brain strain simulation tools offers the potential to identify potentially injurious gameplay situations. This study aimed to use laboratory drop test data and a pre-trained convolutional neural network (CNN), in conjunction with machine learning feature importance algorithms, to understand the specific kinematic features most closely associated with regional brain strains resulting from a head impact.

Methods

A pre-trained CNN model [1] was used (Figure 1) to estimate voxel-wise maximal principal strains (MPS) from 1,806 laboratory drop test head impacts using a Hybrid III (50th percentile male) headform and neck. Peak MPS was extracted from the corpus callosum (CC), brainstem, cerebellum, and left and right cerebellar hemispheres for each impact. A dataset was generated from the linear and rotational acceleration and velocity data of each impact, comprising 73 features. Data were split into training (70%) and testing (30%) sets and fit with two non-linear regression algorithms, decision tree and random forest, both with a maximum depth of 5. These algorithms were chosen due to the presence of both high valued features and features with a high degree of collinearity in the dataset. Linear models were excluded as the relationship between each of the features and peak regional MPS was non-linear. Permutation feature importance was applied on each algorithm to identify the features most important in predicting peak regional MPS for each algorithm. The R^2 value between the predicted and actual testing data was used to determine the validity of the importance results and the optimal number of important features. Hyperparameters were not tuned as the purpose of the study was only to assess potentially dangerous gameplay kinematics.

Results

Both decision tree and random forest algorithms provided consistent feature importance results with high R^2 values using only 4 – 5 features (0.89 – 0.95 for random forest and 0.85 – 0.94 for decision tree). The x-direction change in rotational velocity and the y-direction peak linear acceleration were found to be the strongest predictors of peak MPS in the CC, followed by the peak resultant and x-direction rotational velocity. This suggests impacts to the side of the head may promote greater strains within this region of the brain. The resultant peak rotational velocity (PRV), followed by its log transform, and the x-direction rotational velocity were identified as the strongest predictors of peak MPS in the brainstem. Again implicating impacts to the side of the head as potentially more damaging. It should be noted, the x-direction rotational velocity held lower importance in predicting peak MPS in the brainstem than in the CC. Similarly, peak MPS in the cerebellum was best predicted by the PRV and its log transform, followed by the change in linear velocity and y-directional peak linear acceleration. On the other hand, the z-direction change in rotational velocity was deemed one of the most important features for predicting peak MPS in the cerebellar hemispheres, preceded only by the PRV and its log transform. This suggests that motion acting to rotate the head about the axis of the neck may influence the strain in this region of the brain. These results require further verification with data from on-field gameplay to draw more definitive conclusions.

Figures

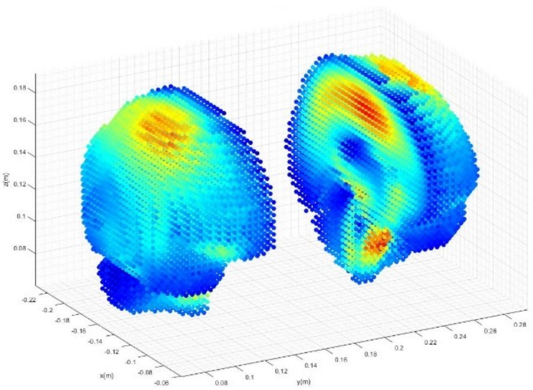

Figure 1: Voxel-wise MPS predicted by the CNN from a forehead impact. Segments were separated along the sagittal plane with high strains seen above the CC in the cerebral hemispheres and the front of the brainstem.

References

1. Shaoju Wu et al, Sci Rep 9, 2019.

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