Brain dynamic changes after mTBI and repetitive subconcussive head impacts

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Summary

This study investigated head impact exposure and brain dynamics in adolescent male rugby players. We used instrumented mouthguards and MRI to monitor brain changes over a season. Dynamic mode decomposition (DMD) analysis revealed that DMD-derived metrics correlated more strongly with strain changes than traditional cumulative measures. Our findings suggest that brain dynamics play a crucial role in the effects of head impacts, including mTBI, on adolescent athletes.

Introduction

Adolescent rugby players are at risk of head impacts, including mTBI and repetitive subconcussive impacts, with potential long-term consequences. This study examined the relationship between head impact exposure, brain dynamics, and strain patterns in adolescent male rugby players. By analyzing head acceleration events and brain changes using instrumented mouthguards, MRI, and DMD, we aimed to better understand the effects of head impacts on adolescent athletes and inform injury prevention strategies.

Methods

In a longitudinal study of 33 male rugby players (mean age 16.22 ± 0.94 years) [1], we monitored brain changes over a rugby season using MRI scans, including diffusion tensor imaging (DTI). Head acceleration events during games and practices were measured using instrumented mouthguards (HitIQ Nexus A9). These data were filtered to remove false positives, and cumulative linear and angular head accelerations were calculated to determine the total cumulative head impact for each player. Subject-specific finite element (FE) models were generated for 15 players (two with clinically diagnosed mTBI) using T1-weighted MRI and DTI, following a previously developed and validated pipeline [2,3]. T1-weighted images provided subject-specific brain shapes, while DTI provided location-dependent hyper-viscoelastic tissue properties. Other major tissue types, including the skull, cerebrospinal fluid (CSF), dura mater, and pia mater, were also incorporated. Sliding movement between the brain and skull was simulated using frictional contact (friction coefficient 0.3). With MRI scans acquired at pre-season, mid-season, and post-season, a total of 45 FE models (15 subjects x 3 time points) were generated. Dynamic impact simulations were conducted using a representative 300 ms impact profile of measured linear and angular accelerations, employing FEBio's explicit dynamic simulation software (www.febio.org). This approach allowed us to analyze changes in spatiotemporal patterns of brain dynamics during head acceleration events throughout the rugby season, using dynamic mode decomposition [4].

Results and Discussion

We tracked changes in the cumulative strain damage measure (CSDM) throughout the season. For players without mTBI but with repetitive subconcussive head impacts, the CSDM showed a weak correlation with the total amount of angular acceleration (r = 0.22). Further analysis of the player with mTBI revealed altered brain dynamic responses post-injury. Under the same impact scenario, both average and maximum brain strain increased over time, with drastic changes in their temporal dynamics (Fig. 1). We then used k-means clustering to group CSDM based on strain patterns, and damping ratio and mode energy derived from dynamic mode decomposition (DMD). Subsequent correlation analysis showed that DMD-derived metrics (mode energy and damping ratio) correlated more strongly with strain changes than CSDM (r = 0.72 and r = 0.74, respectively). These findings suggest that brain dynamics may play a crucial role in longitudinal changes in brain behavior following mTBI and repetitive subconcussive impacts.

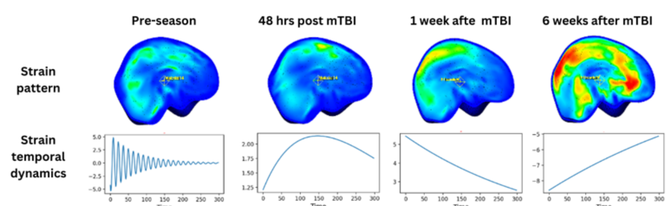

Figure 1: Strain pattern and temporal dynamics change after mTBI

Conclusions

This study highlights the importance of considering brain dynamics, alongside traditional cumulative measures, when assessing the impact of head acceleration events on adolescent athletes. Future research with larger cohorts and diverse populations is needed to further validate these findings and develop targeted interventions to mitigate the risks associated with head impacts in youth sports.

References

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