Post-concussive mTBI in Student Athletes Detected by MRI: An AI/Radiomics Driven Analysis

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PURPOSE

3.8 million people suffer Sports-related concussions (SRC), a subset of Mild Traumatic Brain Injuries (mTBI) annually[1,2]. Unless clinical symptoms are present, imaging is typically utilized only for patients whose symptoms fail to resolve as expected[3]. Magnetic Resonance Imaging (MRI) of symptomatic post-concussive subjects are routinely negative with conventional MRI pulse sequences[3-5]. Here, we used radiomics and AI to create a Concussion Index able to identify mTBI in young athletes with post-concussive symptoms by analyzing clinical MRI data including DTI.

MATERIALS AND METHODS

101 subjects (55M, 46F) with history of one or more concussions and persistent post-concussive symptoms and 27 control subjects (15M, 12F) with no prior brain injury were imaged on a single 3T Siemens Skyra using a standardized protocol which included 3D MP RAGE and DTI data. Fractional anisotropy (FA) and apparent diffusion coefficients (ADCs) were computed from the DTI acquisition. All images were automatically segmented using Montreal Brain Atlas 152c, classifying gray/white matter and 8 anatomical subregions, and further quantified for 314 features per subject, including pattern, signal, texture; assessed volumetrically. Measurements were adjusted for age, height, and gender. AI/Machine Learning was trained on the subset of recently injured subjects older than 15y (<45 days, n=37) and control subjects (n=27). The case/control data was divided into a training set (95%) and testing set (5%). AI/ML discovered the highest performing variables to identify case/controls. This train-test cross-validation process was randomly repeated 300 times, yielding ~15 assessments per subject; each subjects' final assessment was the median of the 15 assessments. The final Concussion Index was computed using 100% of the training set, and then computed for all subjects.

Study Population	
Cases	Controls
N=101, 55M/46F	N=27, 15M/12F
9Y – 29Y, Median =17Y	19Y – 28Y, Median=21Y

Fig. 1 – Study Demographics

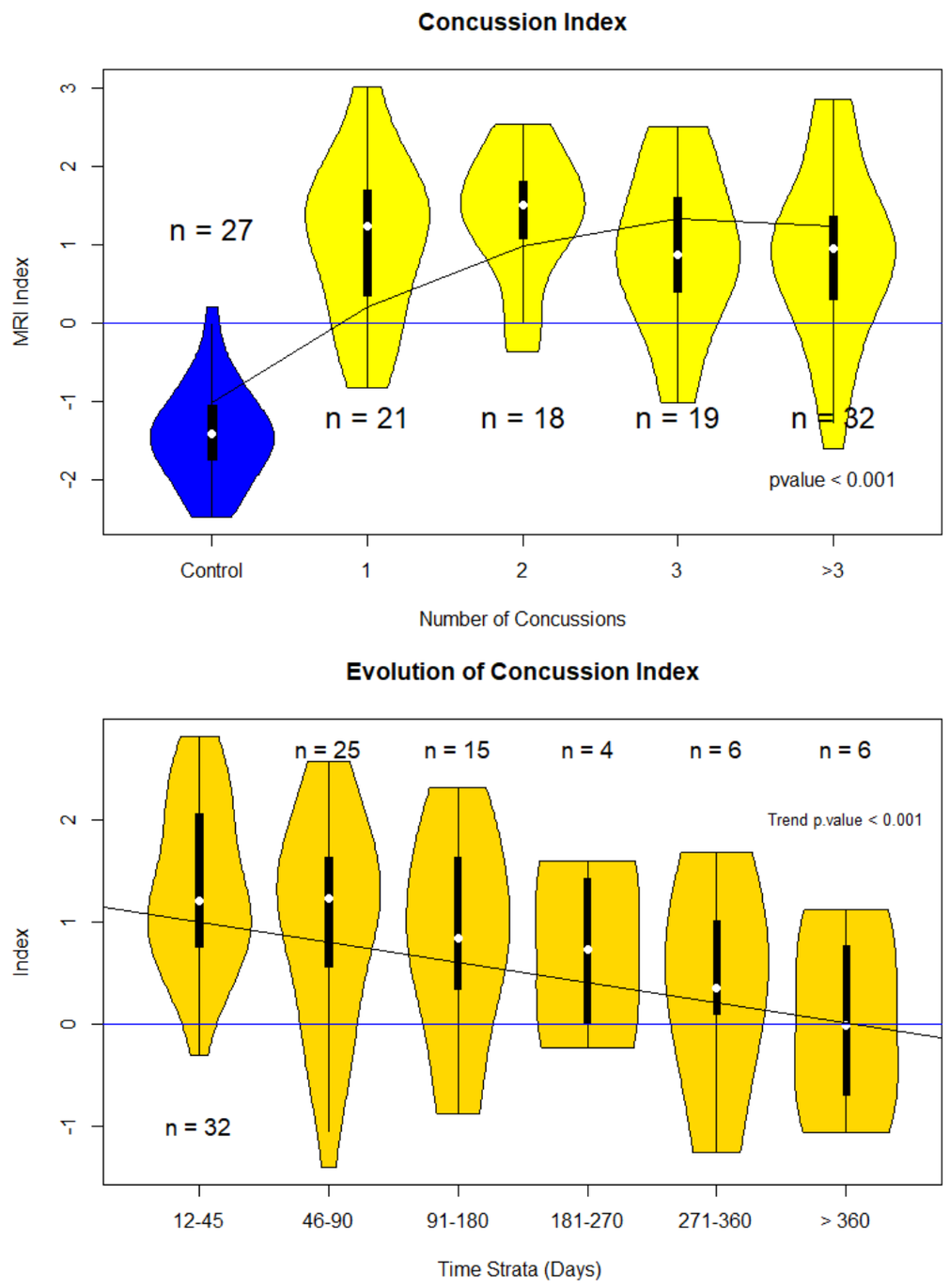

Fig. 2 – Relationship of Concussion Index to Number of Concussions (above) and Time from Injury (Below)

RESULTS

Figure 1 shows demographic characteristics of study population. Figure 2 shows the relationship of the Concussion Index to the number of concussions and the relationship of the Concussion Index to the time interval between injury and MR Exam. The Concussion Index was able to discriminate concussed subjects from healthy controls with a Sensitivity = 0.76, Specificity = 0.81 and Accuracy of 78%. The Concussion Index was positively associated with the number of concussions (p=0.000000015) and negatively associated with the time interval from injury (p=0.0000015).

CONCLUSION

This study's strengths include a robust set of similar subjects with and without concussion, all imaged on the same scanner. The radiomics and AI/ML techniques were able to yield a Concussion Index that showed statistically significant differences between young athletes with post-concussive syndrome and healthy controls. Further, the Concussion Index was able to differentiate among patients based on the number of prior concussions, suggesting a residual effect of SRC/mTBI. Finally, the time from injury analysis suggests that the abnormalities identified by the Concussion Index may persist for weeks or months. The study was limited by the lack of precise data regarding injury location and magnitude, preventing correlation with sub-regional injury predictions. The performance of the Concussion Index should be validated on independent data collected from other scanners. The results of this study show that the Concussion Index can provide a clinically-feasible, objective MRI assessment of post-concussion severity, potential time to recovery and return to play.

References

1: Centers for Disease Control Data statistics (2019), CDC Website

2: Langlois, J.A., Rutland-Brown, W., Wald, M.M., 2006. The epidemiology and impact of traumatic brain injury: a brief overview. J. Head. Trauma Rehabil. 21 (5), 375–378.

3: Eierud C, Craddock RC, Fletcher S, Aulakh M, King-Casas B, Kuehl D, LaConte SM. Neuroimaging after mild traumatic brain injury: review and meta-analysis. Neuroimage Clin. 2014 Jan 4;4:283-94. doi: 10.1016/j.nicl.2013.12.009. eCollection 2014. Review. PubMed PMID: 25061565; PubMed Central PMCID: PMC4107372.

4: Bitonte R, Tribuzio B, Hecht K and DeSanto D. Mild traumatic brain injuries were previously undiagnosable, and therefore treatment uncertain and damages speculative. International Brain Injury Association, https://www.internationalbrain.org/mild-traumatic-brain-injuries-were-prev-undiagnosable-therefore-treatment-uncertain-and-damages/

5: Greenberg JK, Jeffe DB, Carpenter CR, Yan Y, Pineda JA, Lumba-Brown A, Keller MS, Berger D, Bollo RJ, Ravindra VM, Naftel RP, Dewan MC, Shah MN, Burns EC, O'Neill BR, Hankinson TC, Whitehead WE, Adelson PD, Tamber MS, McDonald PJ, Ahn ES, Titsworth W, West AN, Brownson RC, Limbrick DD. North American survey on the post-neuroimaging management of children with mild head injuries. J Neurosurg Pediatr. 2018 Oct 26;23(2):227-235. doi: 10.3171/2018.7.PEDS18263. PubMed PMID: 30485194.