**EVIDENCE OF BRAIN INJURY IN CURRENT HIGH SCHOOL FOOTBALL PLAYERS  WITHOUT DIAGNOSED CONCUSSION**12019*Clinical Journal of Sports Medicine*
**Relative Head Impact Exposure and Brain White Matter Alterations After a Single Season of Competitive Football: A Pilot Comparison of Youth Versus High School Football.**
SETTING:

One season of YFB (grades 7 and 8) and varsity HS football (grades 10-12).S:

Twelve YFB (13.08 ± 0.64 years) and 21 HS (17.5 ± 0.78 years) athletes.

Participants completed 2 magnetic resonance imaging sessions: preseason and postseason. Head impact exposure was recorded during practice and games using a helmet-mounted accelerometer.

Tract-based spatial statistics were used to evaluate group differences in preseason to postseason changes in diffusion tensor imaging, including fractional anisotropy and mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD)

The HS group exhibited significant preseason to postseason reductions in Mean Diffusivity, Axial Diffusivity, and Radial Diffusivity (P < 0.05, corrected) in widespread White Matter areas of the brain.
Significant White Matter reductions for the Youth Football  group were only observed for Axial  Diifusivity  (P < 0.05, corrected), but was more limited in extent compared with High Schol.

Significant preseason to postseason Axial Diffusivity reduction was found in both Youth Football  and High School groups after one season of competitive play.
<https://www.ncbi.nlm.nih.gov/pubmed/31688173>

2. 2019 *Brain Imaging and Behavior***Dependence on Subconcussive Impacts of Brain Metabolism in Collision Sport Athletes: an MR Spectroscopic Study**“Neurometabolic alterations observed in football athletes during the second half of the season were found to be significantly associated with the average acceleration per head acceleration events, being best predicted by the accumulation of events exceeding 50 g. These marked deviations in neurometabolism, in the absence of overt symptoms, raise concern about the neural health of adolescent collision-sport athletes and suggest limiting exposure to head acceleration events may help to ameliorate the risk of subsequent cognitive impairment.”[http://bit.ly/3208s7G](https://www.google.com/url?q=http://bit.ly/3208s7G&sa=D&ust=1579812708223000)

3. 2019 Frontiers in Neurology
**Association of Increased Serum S100B Levels With High School Football Subconcussive Head Impacts**
The degree of acute S100B increases was correlated with subconcussive head impact exposure, suggesting that acute astrocyte damage may be induced in an impact-dependent manner.”
[http://bit.ly/2KJN4hu](https://www.google.com/url?q=http://bit.ly/2KJN4hu&sa=D&ust=1579812708223000)

4. 2018*American Journal of Neuroradiology***White Matter Changes Related to Subconcussive Impact Frequency during a Single Season of High School Football**
“The mean number of impacts over a 10-g threshold sustained was 414 ± 291...

Our (MRI) findings suggest that subclinical neurotrauma related to participation in American football may result in white matter injury and that alterations in white matter tracts within the limbic system may be detectable after only 1 season of play at the high school level.”[http://bit.ly/2XaHKWr](https://www.google.com/url?q=http://bit.ly/2XaHKWr&sa=D&ust=1579812708224000)

5. 2018 *Journal of the American Medical Association Opthamology***Oculomotor Response to Cumulative Subconcussive Head Impacts in US High School Football Players: A Pilot Longitudinal Study**
“The 12 included players were all boys, with a mean (SD) age of 16.4 (0.5) years. A total of 8009 head impacts, 177 907 g of peak linear acceleration, and 16 123 371 rad/s2 of peak rotational
acceleration was recorded from the players in a single football season.”
“This longitudinal case series study suggests that NPC (Near Point Convergence of the eyes) can be perturbed over the long term by subconcussive head impacts but may normalize over time. The oculomotor system may have an adaptational capacity to subclinical head impacts, yet the mechanism for such remains an open question and warrants further investigation.”
[http://bit.ly/2FDwJ9R](https://www.google.com/url?q=http://bit.ly/2FDwJ9R&sa=D&ust=1579812708225000)

6. 2018*Neurobiological Disorders*
**Microstructural Alterations of Cortical and Deep Gray Matter Over a Season of High School Football Revealed by Diffusion Kurtosis Imaging**“Significant microstructural changes, as reflected by DKI metrics, in cortical gray matter such as the rostral middle frontal cortices, and in deep gray matter such as the thalamus were observed in high school football players over the course of a single season without clinically diagnosed concussion. QSM showed no evidence of iron-related changes in the observed subconcussive brain injuries. The detected microstructural changes in cortical and deep gray matter correlated with frequency of subconcussive head impacts.” [http://bit.ly/2Jb5VyR](https://www.google.com/url?q=http://bit.ly/2Jb5VyR&sa=D&ust=1579812708225000)

7. 2018 *Journal of Neurosurgery*
**Elevated Markers of Brain Injury as a Result of Clinically Asymptomatic High-acceleration Head Impacts in High-School Football Athletes**

“In this pilot study on asymptomatic football athletes, an HHI ( High-velocity Head Impact) was associated with increased markers of neuronal (UCH-L1) and axonal (tau) injury when compared with values in control athletes. These same markers were also increased in nonconcussed athletes following the football season.” [https://t.co/MSbUwRPfrg?amp=1](https://www.google.com/url?q=https://t.co/MSbUwRPfrg?amp%3D1&sa=D&ust=1579812708226000)

8. 2016 *Journal of Neurotrauma*
**Abnormalities in Diffusional Kurtosis Metrics Related to Head Impact Exposure in a Season of High School Varsity Football**
"In summary, we demonstrate a single season of HIGH SCHOOL football can produce diffusional kurtosis imaging (DKI) measurable changes in the absence of clinically diagnosed concussion.”

[http://bit.ly/3226UKy](https://www.google.com/url?q=http://bit.ly/3226UKy&sa=D&ust=1579812708227000)

9. 2015 *Brain Connectivity***Alteration of Default Mode Network in High School Football Athletes Due to Repetitive Subconcussive Mild Traumatic Brain Injury: A Resting-State Functional Magnetic Resonance Imaging Study
“**Overall, football athletes had significantly different functional connectivity measures than controls for most of the year. The presence of this deviation of football athletes from their healthy peers even before the start of the season suggests a neurological change that has accumulated over the years of playing the sport. Football athletes also demonstrate short-term changes relative to their own baseline at the start of the season. Football athletes exhibited hyperconnectivity in the DMN compared to controls for most of the sessions, which indicates that, despite the absence of symptoms typically associated with concussion, the repetitive trauma accrued produced long-term brain changes compared to their healthy peers.”[http://bit.ly/2Jiut94](https://www.google.com/url?q=https://t.co/MQAGepf2oP?amp%3D1&sa=D&ust=1579812708227000)

10. 2015 *Developmental Neuropsychology*

**Sub-concussive Hit Characteristics Predict Deviant Brain Metabolism in Football Athletes**Magnetic resonance spectroscopy and helmet telemetry were used to monitor the neural metabolic response to repetitive head collisions in 25 high school American football athletes. Specific hit characteristics were determined highly predictive of metabolic alterations, suggesting that sub-concussive blows can produce biochemical changes and potentially lead to neurological problems.[http://bit.ly/2RGHxZX](https://www.google.com/url?q=http://bit.ly/2RGHxZX&sa=D&ust=1579812708228000) [11. 2015](https://www.google.com/url?q=https://t.co/G7ZMCWhAnX?amp%3D1&sa=D&ust=1579812708228000)[*Developmental Neuropsychology*](https://www.google.com/url?q=https://t.co/G7ZMCWhAnX?amp%3D1&sa=D&ust=1579812708229000)

[**Effects of Repetitive Sub-concussive Brain Injury on the Functional Connectivity of Default Mode Network in High School Football Athletes**.](https://www.google.com/url?q=https://t.co/G7ZMCWhAnX?amp%3D1&sa=D&ust=1579812708230000)

"Resting state functional MRI was used to prospectively study changes in Default Mode Network connectivity for clinically asymptomatic high school football athletes. Athletes exhibited short-term changes relative to baseline and across sessions." [(](https://www.google.com/url?q=https://t.co/WyYhpEdQ6T?amp%3D1&sa=D&ust=1579812708230000)[http://bit.ly/322AVcO](https://www.google.com/url?q=http://bit.ly/322AVcO&sa=D&ust=1579812708231000)[)](https://www.google.com/url?q=https://t.co/WyYhpEdQ6T?amp%3D1&sa=D&ust=1579812708231000)

12. 2015*Developmental Neuropsychology*

**FMRI of Visual Working Memory in High School Football Players.**

“This study uses a visual N-back working memory functional magnetic resonance imaging task to longitudinally assess asymptomatic football athletes for abnormal activity. Athletes were increasingly "flagged" as the season progressed.” [(http://bit.ly/2X5TZU8)](https://www.google.com/url?q=https://t.co/QhzXSmhfzJ?amp%3D1&sa=D&ust=1579812708232000)

13. 2015*Developmental Neuropsychology*

**Cerebrovascular Reactivity Alterations in Asymptomatic High School Football Players**
“Cerebrovascular reactivity (CVR) is impaired following brain injury, increasing susceptibility to subsequent injury. CVR was tracked in football and non-collision athletes throughout one season. CVR transiently decreased in football athletes during the first half of the season. Results indicate the brain adapts slowly to increases in loading, increasing risk for injury.”
[http://bit.ly/2KMSN6a](https://www.google.com/url?q=http://bit.ly/2KMSN6a&sa=D&ust=1579812708232000)

14.2015*Developmental Neuropsychology* **Post-Season Neurophysiological Deficits Assessed by ImPACT and fMRI in Athletes Competing in American Football**

"Neurocognitive assessment, functional magnetic resonance imaging, and head impact monitoring were used to evaluate neurological changes in high school football players throughout competitive seasons. A substantial number of asymptomatic athletes exhibited neurophysiological changes that persisted post-season, with abnormal measures significantly more common in athletes receiving 50 or more hits per week during the season.”
[http://bit.ly/2XbkF5G](https://www.google.com/url?q=http://bit.ly/2XbkF5G&sa=D&ust=1579812708233000)

15. 2015 *Developmental Neuropsychology***DTI Detection of Longitudinal WM Abnormalities Due to Accumulated Head Impacts**

"Longitudinal evaluation using diffusion-weighted imaging and collision event monitoring was performed on high school athletes who participate in American football. Observed changes in white matter health were suggestive of injury and found to be correlated with accumulation of head collision events during practices and games.” [http://bit.ly/2NmTjdh](https://www.google.com/url?q=http://bit.ly/2NmTjdh&sa=D&ust=1579812708234000)

16. 2014*Journal of Neurotrauma*

**Functionally-Detected Cognitive Impairment in High School Football Players Without Clinically-Diagnosed Concussion**“more players are suffering neurological injury than are currently being detected using traditional concussion-assessment tools. These individuals are unlikely to undergo clinical evaluation, and thus may continue to participate in football-related activities, even when changes in brain physiology (and potential brain damage) are present, which will increase the risk of future neurological injury.” [http://bit.ly/2NnMtnO](https://www.google.com/url?q=http://bit.ly/2NnMtnO&sa=D&ust=1579812708235000)

17. 2014 *Journal of Neurotrauma*
**Abnormal White Matter Integrity Related to Head Impact Exposure in a Season of High School Varsity Football**
“There was also a strong correlation between DTI ( Diffusion Tension Imaging) measures and change in Verbal Memory subscore of the ImPACT.  We demonstrate that a single season of football can produce brain MRI changes in the absence of clinical concussion. Similar brain MRI changes have been previously associated with mild traumatic brain injury.”
[http://bit.ly/2RN8Kdh](https://www.google.com/url?q=http://bit.ly/2RN8Kdh&sa=D&ust=1579812708236000)

18. 2012 *Journal of Biomechanics*

**Biomechanical Correlates of Symptomatic and Asymptomatic Neurophysiological Impairment in High School Football.**
"Our findings reinforce the hypothesis that the effects of repetitive blows to the head are cumulative and that repeated exposure to subconcussive blows is connected to pathologically altered neurophysiology. [http://bit.ly/2Lro1iO](https://www.google.com/url?q=https://t.co/5yEvPZuF6E?amp%3D1&sa=D&ust=1579812708237000)

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