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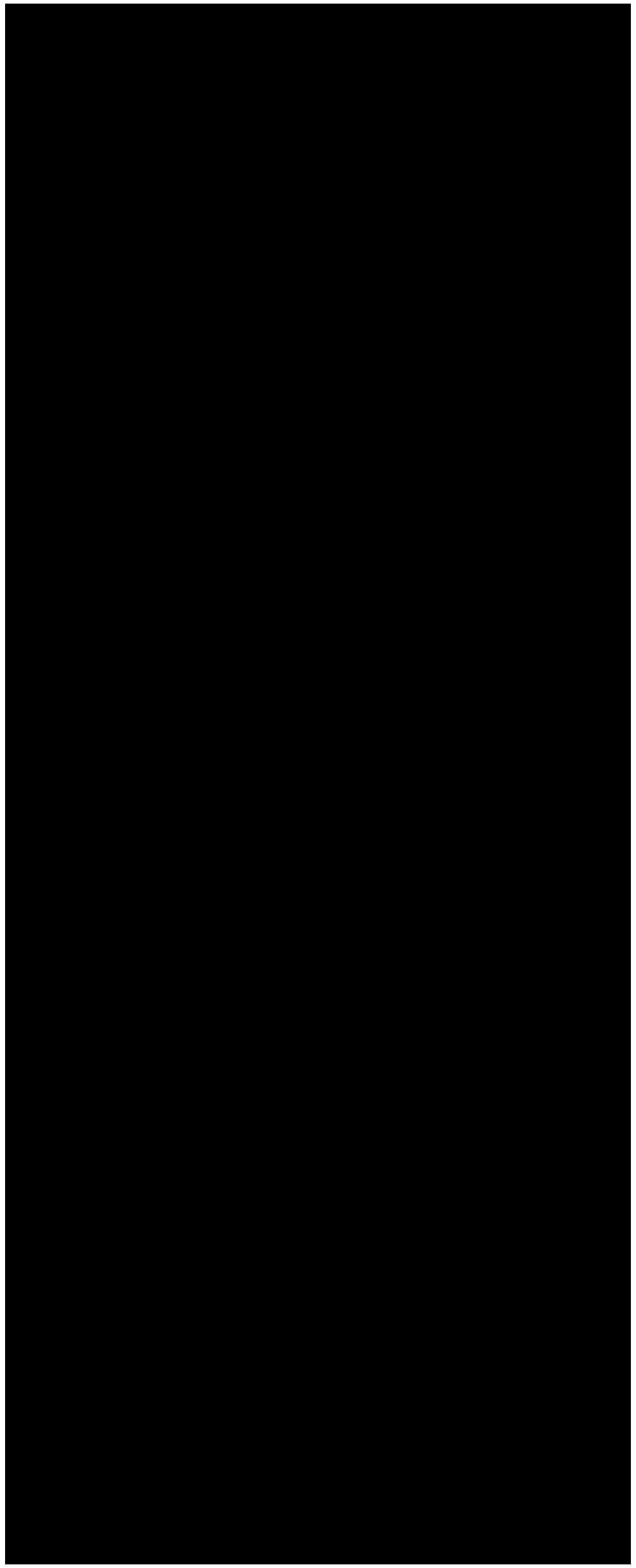
Concussion crash course



ARTICLES

CONCUSSION CRASH COURSE

J. Daniel Bireley

The prevalence of concussions and concern over head injury today has led to an explosion of interest about this subject matter. Athletic communities, war veterans, and parents alike are learning about the consequences of an impact to the head through news and media sources and are realizing the potential danger. This concern is well illustrated by the fact that the National Football League, an icon of popular culture in the United States, took action in 2010 and changed its rule book to include stipulations that disallow hits above the shoulders to "defenseless" players.[1] Kickoffs are shorter now as well, giving both teams less time to gain momentum and smash into each other at frightening velocities. Action by such an institution indicates the serious nature of the matter.

As much press as the NFL has gotten for the initiative it is taking on the medical front, the ailments of professional football players in the United States is not the focus of this discussion. Worldwide, awareness is spreading about the implications of traumatic brain injury. It is not severe head trauma and open head wounds, but rather mild traumatic brain injury (mTBI) and those impacts deemed "subconcussive" that are of interest here. These kinds of injuries are seen in settings ranging from a high school soccer game where the star player collides with an opponent while fighting for the ball, to war zones, where soldiers are enduring blast injuries and are returning home to deal with the lasting effects.

With improved medical technology and a growing number of patients, it is not surprising that mTBI has made its way to the front lines of international attention. I wish to address the array of physical and mental consequences that can result from mTBI as well as delve into current research, which presents concerning information about less intense impacts, considered "subconcussive."[2] It is important to differentiate between mild traumatic brain injury and a subconcussive impact, mTBI being an injury resulting in a concussion where the patient shows symptoms of concussion.[3] A subconcussive impact refers to a hit to the head that does not result in any physical injury to the brain or any noticeable symptoms.[4] Such trauma may intuitively seem less dangerous, but doctors and researchers are discovering an entirely new threat to physical health and cognitive function that those of the present generation and generations to come must confront.

First, we must establish a general understanding of a concussion. Additionally, there is clear need for a solution, or at least improvement upon our understanding of head injury, which has become a unique challenge in the present day. With technological advancement and a continual improvement in our understanding of cognitive and behavioral function, new techniques are emerging which offer further insight into the brain and opportunity for more precise diagnoses. Discussion of this issue is not meant to discourage activity or normal living for fear of head injury. Rather, awareness is necessary, especially when new information becomes available, and good health is a concern. With that being said, let us determine the constituents of a concussion, on physical, cognitive, and molecular levels, and explore the known repercussions of such trauma.

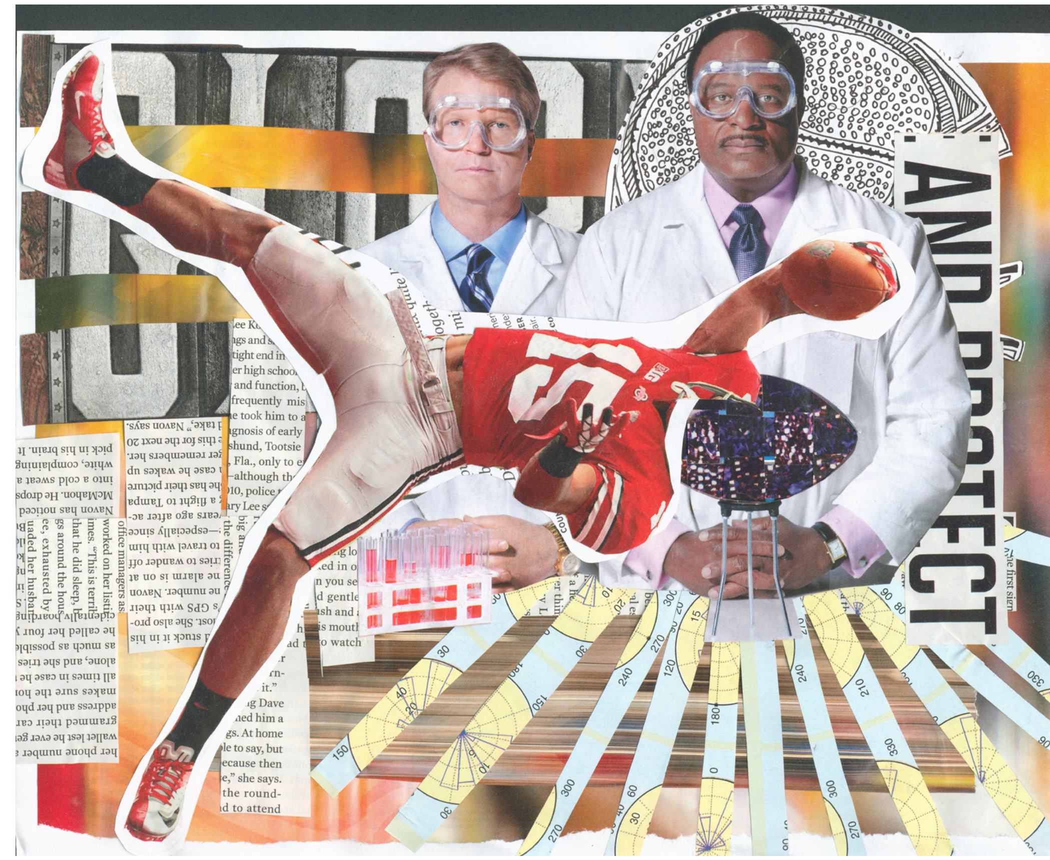
Concussion, or mild traumatic brain injury, is a common form of brain injury. It is estimated that approximately 1.7 million people are affected by traumatic brain injury (TBI) each year and 75% of the TBIs are classified as minor (mBTI).[5] It is possible that this is a gross underestimation of the overall occurrence of concussion as well because a patient displaying little to no symptoms, as is characteristic of mBTI, is less likely to seek medical attention. A concussion is generally defined as a brain injury caused by an impact to the head that forces the brain to collide with the skull or strains the brain's neural tissue.[6] Any acceleration of the brain into the surrounding protective structures has been shown to produce at least some microscopic neural damage to impacted tissue[7] (this issue will be explored in more detail later). One can determine the presence of concussion using diagnostic magnetic resonance imaging (MRI).[8] The use of the Glasgow Coma Scale (GCS) is a tool used to objectively diagnose the severity of brain trauma. This technique was developed in 1974 at the University of Glasgow to assess a patient's level of consciousness.[9] It utilizes measurements of physical and cognitive function, specifically eye opening, verbal response, and best motor response, to assign a number 3 through 15 to a patient as an indicator of level of brain injury (for our purposes, we are only interested in head injuries with scores between 13 and 15, as these scores indicate mTBI). This is a relatively quick and simple method. Physically, one must assess conditions when the eyes are open. This ranges from spontaneous eye opening and closing to a complete lack of opening, even at the onset of pain. Cognitively, one measures the ability to understand and produce language as well as motor response to a motivating stimulus such as pain. This technique, along with MRI, is non-invasive, but more precise methods will take into account the body's biological response to head injury as a means of measuring the amount of trauma that the brain has endured.

In the past twenty years researchers have developed a method of brain injury diagnosis that involves studying serum samples from patients who have suffered mTBI. Dr. Topolovec-Vranic and colleagues performed a study in the Trauma and Neurosurgery program at St. Michael's Hospital in Toronto, Canada, where they measured the dependability of biomarker sampling as an indicator of mTBI. No patients suffered brain trauma more than four hours prior to sample collection. The results of the study reveal that the serum samples from these patients often contained abnormally high levels of protein S-100b and neuron specific enolase (NSE).[10] Elevated levels of such biomarkers were predominantly present in subjects in need of more extensive medical attention, suggesting patients with more severe trauma were more likely to produce samples containing excess amounts of S-100b and NSE. Thus, this study proposes that serum biomarkers can be used in conjunction with other non-invasive techniques to determine the presence and severity of traumatic brain injury.

As previously mentioned, athletics is the front-runner when it comes to discussions about mTBI and head safety. Beginning in the 2011-2012 school year, Massachusetts' new concussion laws mandate that high schools and middle schools report all head injuries and concussions to the state's Department of Public Health. In the fall of 2011 over 300 head injuries were sustained on football and soccer teams across 26 different high schools.[11] The most interesting statistic was that girl's soccer teams sustained nearly twice the number of head injuries than varsity

football programs from these schools.[12] It is not all about football. These statistics are leading to concussion laws, which are becoming more popular nationwide, especially as people realize how common head injury is. With that being said, what is so scary about brain trauma? We must establish the common effects of mTBI to justify the reason for concern over such injury.

Concussion occurs when the soft tissue of the brain is accelerated and collides with the surrounding protective structures, effectively causing a strain on neural tissue and the vasculature of the brain.[13] Normal cellular function can be disrupted, which can last for varying amounts of time. The initial signs of mTBI include headache, neck pain, forgetfulness, dizziness, loss of balance, difficulty concentrating, nausea, vomiting, trouble sleeping, light and noise sensitivity, fatigue, moodiness, and literally "seeing stars."[14] These are merely the initial effects of brain trauma and may persist for an extended period but are likely to eventually dissipate.[15] It is the long-term, unforeseen danger of repeated or mistreated mTBI that is also of great concern and which carries serious implications for good health. Many areas of the brain are susceptible to brain injury including the outermost portions of the cortex known as the telencephalon where the frontal, parietal, and temporal lobes reside. Injury to each lobe has varying consequences for physical and cognitive function.



Artwork by Rachel Franklin

The frontal lobe is a known center of command for executive function, information processing, personality, and the ability to socially relate to others.[16] Over the long term, injury to this area of the brain can slow reaction time, change personality, and adversely affect motor planning and function.[17] Damage to areas that control personality and the more abstract human behaviors can also lead to depression or the onset of post-traumatic stress disorder.[18]

The temporal lobe contains centers largely concerned with memory formation and retrieval.[19] The hippocampus and surrounding structures of the medial temporal lobe are important for episodic memory as well as converting short-term memories to long-term memories. Injury to these areas of the brain often times result in various kinds of memory loss as well as temporal lobe seizures.[20] A study done by Dr. Erin Brigler and associates at Brigham Young University helped demonstrate the vulnerability of the temporal lobe to impact by studying the atrophy of this brain area over time.[21] To control for the general effects of aging, they compared the group that had suffered mTBI with a control group of age-matched adults. The results showed significantly more atrophy to white matter and the hippocampus in older adults who had experienced head trauma at some point in life. With the deterioration of brain structures that play a direct role in memory and brain connectivity, it is not surprising to observe such symptoms as memory loss in patients over time.[22] It has also been noted that similar brain injury can quicken the onset of Alzheimer disease (AD), Parkinson disease (PD) and other neurodegenerative disorders.[23,24] This is a frightening reality considering the debilitating effects of these illnesses. Lastly, repeated blows to the head can disrupt cellular function and cause cellular atrophy potentially initiating disorders such as Chronic Traumatic Encephalopathy (CTE).[25] CTE is one of the diseases found often post-mortem in athletes who have been subjected to repeated head impacts. The disease is characterized clinically by a progressive loss of memory, executive function, and potentially motor skills; eventual dementia, and also mood and behavioral shifts such as depression, apathy, aggressiveness, and suicidal thoughts.[26] Neuropathologically, there is extensive tissue atrophy and patients tend to live no more than 20 years after diagnosis.[27] As illustrated, there is a vast array of possible side effects that can develop through mTBI and permanently alter a life.

The sad reality of a situation where head trauma changed the course of a life is seen in the story of Dave Duerson, who played in the NFL for the Chicago Bears in the 1980s. On February 17, 2011, Dave died of self-inflicted gunshot wounds at the age of 50. Dave suffered at least ten concussions during his time in the NFL and was diagnosed as having CTE and extensive tissue atrophy when his brain was analyzed post mortem.[28] Now his family is in the midst of a wrongful death lawsuit against the league, as they believe the NFL has failed to educate its players about the risks associated with the sport.[29] More recently, Junior Seau, a well-known and respected football player in the 1990s and 2000s also lost his life in the same way Dave did and his brain is now being examined for the same disease from which Dave suffered. The scary reality of head injury certainly shows itself in stories such as these. With more knowledge about the issue, hopefully more can be done to prevent situations with circumstances like that of the Duerson and Seau families.

> **"The findings imply that the damage, no matter how small, created by these subconcussive impacts is also a threat to brain health."**

As research has continued on mild traumatic brain injury, there has been one discovery in particular that has the potential to further change the way we view head trauma. In 2010, a group of researchers from Purdue University studied the brains of a team of high school football players with the objective of developing better detection and characterization methods for brain trauma. Their most interesting finding was the discovery that players who had not received a "concussion" by the traditional definition still showed neurocognitive and neurophysiological deficits.[30] These young men were subjected to hits considered "subconcussive," predominantly to the top and front portions of the head. They were tested for the presence of a concussion using the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) program, Head Impact Telemetry (HIT) system, and functional magnetic resonance imaging (fMRI) to determine how impacts of various sizes affected these high school boys. The athletes had not technically received a concussion and did not display the classic physical symptoms of a concussed subject, yet still suffered from deficits with primary visual memory and dorsolateral prefrontal cortex (DLFPC) function, the DLFPC being involved in working memory and cognitive control.[31] The findings imply that the damage, no matter how small, created by these subconcussive impacts is also a threat to brain health and that the current criteria for traumatic brain injury may not be as reliable as once thought.

The data collected at Purdue University has helped to prompt further research into the danger of subconcussive hits and the compilation of these impacts to the brain. The recurrence of such impacts and the summation of tissue damage has led to progressive neurodegeneration, once termed dementia pugilistica.[32] The first instances of this syndrome were found in retired boxers who had been exposed to repeated hits not resulting in concussion. This condition is now referred to as the aforementioned Chronic Traumatic Encephalopathy (CTE). The accumulation of less intense impacts to the head over an extended period of time also threatens normal brain function and must be treated appropriately with the knowledge of this potential danger.

Now, since even the smallest brain injuries can be considered dangerous, more must be done to protect the brain. This includes prevention of impacts to the head and better identification of the presence of brain trauma, no matter how slight. Prevention is the more simple of the two. One must reduce the number of daily, weekly, or monthly situations where head injury is likely. For a football player, this may mean not as many practices in full pads. Better, more protective equipment could also be helpful. Developing new technology and remodeling the present day public understanding of head injury are just a couple of steps we can take toward preserving the sports we love, and keeping people safe.

In terms of identification, a correct diagnosis is imperative for proper treatment. As previously discussed, there are techniques like the Glasgow Coma Scale and the measurement of biomarkers that allow us to establish the presence of traumatic head injury. Unfortunately, these procedures tell us little about injury localization. MRI has served as a useful method for determining structural brain damage.[33] Another technique that has been used to better quantify and localize the area of injury is high definition fiber tracking (HDFT). HDFT has recently been developed to extend the ability of physicians to obtain detailed information about mTBI. Using this technique, one can visualize the specific area of axonal injury, as well as its severity, and then infer possible functional impairments based on the degree of damage to these cortical projections.[34] This kind of cutting edge technology offers new and improved methods for visualizing brain tissue and connectivity both in healthy subjects and those affected by mTBI. Researchers are still determining how concussion affects the brain in the long term, and people like John Beattie, a Scottish rugby star who promised to donate his brain to neuroscience after his death, give us further hope in discovering more and more about the adverse affects of this kind of injury.[35] With these growing resources, we hope that a fuller knowledge of the brain will emerge and improved treatment for brain injury will continue to develop.

There is a need for a general shift of mindset toward the issue of brain trauma. Family, friends and coaches alike need to be aware of the severe nature of this matter. Necessary precautions must be taken, injuries must be reported, and it must be acceptable in any situation for a person to acknowledge a brain injury and seek the appropriate medical attention. This is a grassroots issue that is not aimed at taking the fun out of sports, or confining people to their homes, for fear of a hit to the head. Rather, the goal is to preserve the institutions we have developed and to make sure that a problem like unnecessary brain trauma does not destroy our pastimes. Hopefully this discussion has clarified misconceptions about head injury, ushered in more awareness about the common risks involved with mTBI, and displayed the strides science and technology are making to discover and explain the many fascinating aspects of human behavior. Don't let a hit to the head let you lose what you have learned here.

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