To what extent do concussions in youth sports lead to adverse long term health effects and what is the best approach to preventing these health impacts?

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Abstract: Concussions in youth sports cause extensive problems to an athlete's health. Athletes who suffer from concussions face both short term effects, long term effects, and even death. This paper analyzes how concussions affect student-athletes during the recovery period of a concussion, the potential for the development of neurodegenerative diseases such as Chronic Traumatic Encephalopathy, and methods to prevent tragedies such as Second Impact Syndrome. Research reveals how concussions lead to CTE and other cognitive impairments later in life. However, the lack of longitudinal studies into the prolonged effects of concussions makes it difficult to determine the full extent of the damage concussions cause. Nevertheless, prevention methods should be taken to avoid death and the academic struggle student-athletes face as a result of concussions.

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Part I-Introduction

At 6’1 and 255 pounds, the Pittsburgh Steelers’ Center Mike Webster forged himself into the powerhouse known as “Iron Mike ". He was unpassable as a center which awarded him with six All-Pro Selections, 1974 All-Rookie Team Member, four Superbowl titles, nine Pro Bowl selections, and Hall of Fame Class of 1997 ("Pro-Football Hall of Fame”). After his stellar career, at the age of fifty, Mike Webster spiraled downward onto an autopsy table under the knife of Bennet Omalu and ultimately became the first former NFL player to be diagnosed with Chronic Traumatic Encephalopathy (CTE). How could a Hall of Famer who made millions at the sport degrade into a shell of who he once was? What could make a person with no real history of mental illness super glue their teeth back into their gums, use a taser on themselves forty times a day just to concentrate, or not even remember their home address? The answer, Omalu determined, was the repeated impacts on Webster’s head throughout his football career. It turns out Webster was not an isolated incident. Soon the brains of more and more players exhibited signs of CTE due to impacts to the head (Omalu, et. al). CTE is not the only issue that concussions bring: Post-Concussion Syndrome (PCS), where people who have suffered concussions still report symptoms far past the average recovery time.

There are also short term effects of concussions, especially in students who exhibit falling grades and struggling comprehension on tests. In an effort to prevent sports-related concussions (SRC) many programs such as Heads-Up, created by the Centers for Disease Control and Prevention (CDC), have cropped up in order to prevent the short term and long term repercussions that concussions bring. However, there is still more that must be done in order to

avoid these effects: concussions lead to long term cognitive impacts and impairments. In order to prevent serious damage to the brain, youth sports associations must mandate precautions such as athletic trainers at every game and mandatory standard concussion protocols for head injuries.

Part II- Background Information

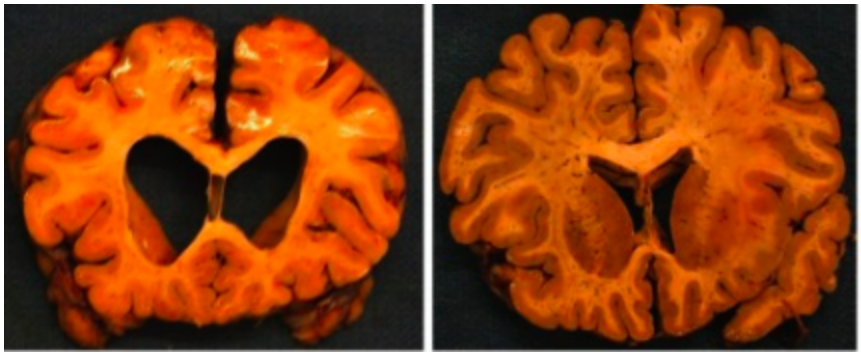
The Committee of Head Injury Nomenclature under the Congress of Neurological Surgeons in America defines concussions as "a clinical syndrome characterized by immediate and transient post-traumatic impairment of neural functions, such as alteration of consciousness, disturbance of vision, or equilibrium due to brain stem involvement" (167). Simply put a concussion is a short term (transient) brain injury created by trauma through an impact on the brain. The impairment of neural functions can be seen as physical and cognitive symptoms such as headaches, dizziness, poor memory, balance issues, and other short term damages. When a concussion occurs, the brain the forces from the impact cause disruption in how the brain balances glucose with blood flow. A blow to the head can also cause damage to the neurons disrupting the neurotransmitters and normal functions of the brain. This creates a snowball effect where the brain releases an excess of potassium, sodium, and calcium ions as well as increases its glycolysis rate in order to fix the disturbance. This snowball effect leads to the symptoms that athletes may experience as a result of a concussion (Theye and Muller).

A study by Joshua Kamins et al. examined the recovery period of concussions and discovered the period varies from person to person as well as the severity of the injury. The range of recovery can be between 7 to 45 days. (Kamins et al.). The recovery period is a massive issue for student-athletes with SRC's due to the chance of missing school with the potential of falling

grades. The length of the recovery period has the potential to lead to long term damages such as PCS. Instead of a transient brain injury, PCS is long term with concussion-like symptoms lasting for months or even years (Hiploylee, et al).

Concussions occur predominantly from impact to the head and neck area. This impact results in whiplash which knocks the brain into the skull causing damage to the tissue (Theye and Muller). When the brain is hammering about the skull, the small microtubule-associated protein (tau) which binds the microtubules (complex structure that forms the structure of a cell. They are a fundamental part of brain function) is altered and over time tangle creating neurofibrillary tangles (proteins that “clump” together) in the brain (Kanaan, et al.).Tau isn’t the only kind of tangle that found in neurodegenerative diseases. Other proteins such as beta-amyloid deposits that are plaques that “clog " the brain (Rodrigue, et al.). Not only does CTE and AD have plaque and neurofibrillary tangles, but the lateral ventricles are also expanded beyond a normal degree.

Appendix A



Diagnosed CTE **No CTE**

(Photo from Hazrati, et al.)

Essentially expanded ventricles mean that there is less brain matter and so the "wiring" of the brain is interrupted. These tangles are generally found in CTE, Alzheimer's Disease (AD), and other neurodegenerative diseases. CTE is a neurodegenerative disease that is generally associated with repeated head trauma. Generally, clinical symptoms of CTE include but are not limited to cognitive impairments such as difficulty concentrating and memory issues (short term memory loss and getting lost), unstable emotions, failure of executive functions (planning and carrying out tasks, word-finding), and other impairments (Mayo Clinic). CTE is the disease that is currently researched in association with concussions in former athletes. It is physiologically similar to AD. However, its pathology can be found in younger brains that have no reason to degenerate in the way AD does to older brains.

Part III- Research and Analysis

Section A: Short Term Effects

Concussions as earlier described can impair an athlete's focus and memory recall (Narayana et al.). While the effects of these symptoms are not long-lasting as concussions are transient, concussions still impair a student-athlete and can ultimately lead to long term effects later in life. Despite the short time (7-45 days) that athletes may suffer from these symptoms, they might still struggle academically and possibly behaviorally for that brief period of time, which can affect how they will bounce back at school and in relationships.

A known consensus amongst most research is that youth and in this instance, youth

athletes, take longer to recover from concussions (Moser et al.). This brings a whole host of problems, including students ignoring symptoms (which can cause more injury), experiencing memory challenges, and struggling to keep grades up. Focusing on the latter two problems, student-athletes with recent concussions and a history of concussions could end up doing worse in school (Moser et al.). Moser and her fellow researchers analyzed 223 high school athletes and assigned them to different categories regarding recent concussions and concussion history. In the study, 37% of the athletes didn't experience a concussion, 25% had a history of concussions, 20% had a concussion in the past six months and 18% had a recent concussion during the study (Moser et al.). The study assesses these athletes in the hopes of finding the neurological effects of concussion on high school athletes. Moser and her colleagues came to the conclusion that: "Scores on standardized educational achievement test did not reveal between-group differences, but academic GPA was observed to be significantly lower for youth athletes with multiple previous concussions, which would suggest that these cumulative effects may extend to general academic performance" (303). The evidence suggests that as high school athletes (relevant to this study) accumulate more concussions, the worse they will do in school. Performing poorly in school obviously has long term repercussions such as extra challenges when applying to higher education as well as continuing current education. The evidence found in this study is further backed by research done by Shalini Narayana et al. who analyzed different technology to monitor and diagnose concussions. While the topic of research had its differences (Narayana studied the technology that analyzes concussions. While Moser studied high school athletes and the effects concussions had on them), the conclusions are similar. The results from the Narayana et al. study found that memory impairments and difficulties in concentration could last up to over

a year after the injury (Narayana et al.).

Furthermore, Moser and her colleagues found that:

> Recently concussed athletes performed similarly to youth athletes with a history of two or more previous concussions may provide further support for the vulnerability of the young brain. Concussions sustained during critical developmental stages in the brain, staged marked by a period of increased brain plasticity, may ultimately impair this plasticity. (Moser et.al)

The deterioration of neuroplasticity in young brains can ultimately lead to lasting impacts that continue later in life. These impacts tend to include but are not limited to neurodegenerative diseases such as AD, CTE, and other diseases.

Section B: Long Term Effects

As Omalu dissected Webster's brain, he found something odd; Webster's brain had neurofibrillary tangles and amyloid plaques. This does not make sense seeing as he had no family history of AD and had no physiological evidence of Lewy body Dementia. Omalu determined that Webster showed evidence of CTE which could be caused by his long career in the NFL (Omalu, et al.). As a center, Webster constantly had to collide heads with some of the biggest and strongest athletes there are. This repeated impact to his head would have jarred his brain, breaking the microtubule bindings creating the neurofibrillary tangles that ultimately destroyed his brain.

As discussed earlier CTE is one of the more famous neurodegenerative diseases researched today in connection with concussions. Even more important is the research done on

former high school athletes and the prevalence of CTE. In a study by McKee, et al. the researchers analyzed 85 brains from various sports and military backgrounds, as well as a control group. Results in the study showed a large number of the brains had evidence of CTE:

> We analyzed the brains of 85 individuals with a history of repetitive mild traumatic brain injury and found evidence of CTE in 80%; all males, ranging in age from 17 to 98 years (mean = 59.5 years), including 64 athletes, 21 military veterans (most of whom were also athletes) and one individual who engaged in self-injurious head-banging behavior. (Mckee, et al.)

All of the athletes diagnosed with CTE displayed the defined clinical and physical symptoms and fifty of those athletes diagnosed with CTE were football players with six of them only playing high school football (Mckee et al.) This study clearly shows that prolonged head impacts will severely damage the brain. Furthermore, 12% of the brains of athletes who played football did not continue to play after high school yet still developed CTE. Granted 12% is not a large metric compared to the 66% that played in the NFL, however, this should be expected as the NFL players would have spent an upwards of a ten-year pro career with multiple mild traumatic brain injuries (concussions fall under this category). This career would be on top of both a seven to eight-year combined high school and college career, so the NFL players likely have eighteen to twenty-five years of repeated head injuries not including any middle school and youth football. This leaves the possibility that participation in at least high school football (as per this study) leads to diseases like CTE as the 12% of diagnosed football players did not play past high school and all the rest did play in high school. A study looking at the brains of solely high school and college athletes' brains can lead to more conclusive results on the impact of youth contact sports

particularly football as a whole. This relatively large scale study backs up the initial findings of Bennet Omalu's autopsy of Mike Webster and other NFL football players. In the first and second part of Omalu's research into CTE in NFL players, Omalu found that both causes displayed similar clinical and physiological symptoms: "Both manifested Major Depressive Disorder after retirement. Amyloid plaques were present in the first case and completely absent in the second case. Both cases exhibited neurofibrillary tangles, neuropil threads, and coronary atherosclerotic disease" (Omalu, et al.). The clinical and physiological symptoms that define CTE are present in both the cases that Omalu had and the subjects of the study by Mckee et al. This original research proves that concussions lead to long term health impacts. Other research such as systematic reviews of multiple forms of original research such as "A Systematic Review of Potential Long-Term Effects of Sport-Related Concussion" cite that there is evidence of prolonged health effects due to concussions (Manley, et al.).

However, this systematic review and others like it note the challenges and room for improvement in the field of research. For instance, conclusions within the article suggest the need for more research into sub-concussive blows, which does not have a consensus on a definition. Currently sub-concussive blows are defined as any kind of impact that does not result in a concussion. Another conclusion found that the limitations of concussion studies found that studies with negative findings tend to not be published, so there is difficulty in finding well-rounded conclusions (Manley, et al.). The next important critique from a systematic review called "What is the Evidence for Chronic Concussion-Related Changes in Retired Athletes: Behavioural, Pathological and Clinical Outcomes?" notes that the studies analyzed did not mention previous mental health or disease history (McCory, et al.). However, this appears to not

be true as all of the studies done by Omalu, Mckee, and others do, in fact, mention the health history of the patients. One study in particular "Absence of Chronic Traumatic Encephalopathy in Retired Football Players with Multiple Concussions and Neurological Symptomatology" clearly notes the medical history of the subjects. The authors state that not all athletes who sustain multiple concussions develop CTE. In other studies, not all subjects who suffer from multiple concussions develop CTE, however, a majority do. The flaw of the study: "Absence of Chronic Traumatic Encephalopathy in Retired Football Players with Multiple Concussions and Neurological Symptomatology" is mainly the number of subjects (six brains); of those six brains half had CTE and all had evidence of other neurodegenerative diseases (Hazrati, et al.). A reason why the authors hesitate to say concussions cause CTE may be because of the family medical history of the subjects which could muddle results. The majority of the subjects in the study had some form of neurodegenerative disease in their family history (Hazrati, et al.), however, with such a small sample size it's hard to determine if all CTE patients have other factors in their family history that would trigger the disease. While there is evidence that suggests concussions cause CTE there are other long term effects such as Post-Concussion Syndrome.

Those with PCS still suffer from symptoms of a concussion for weeks or even years after the injury. The most common clinical symptoms of PCS are headaches (most common), difficulty concentrating, fatigue, fogginess (the feeling that something isn't right), pressure in the head, sensitivity to light, and memory problems (Hiploylee, et al.). In the study "Longitudinal Study of Postconcussion Syndrome: Not Everyone Recovers" by Hiploylee, et al., researchers discovered that 73% of the subjects with PCS did not recover. In fact, if a patient has suffered from PCS for more than three years evidence from the study shows that the patient will not

recover. The recovery period for a patient with PCS seems to be longer if more symptoms are present, according to the study (Hiploylee, et al.). Those who suffer from PCS experience concussion symptoms long after a reasonable recovery period. Concussions already provide immense difficulty for students in particular, so PCS is a constant long term challenge. Further study of PCS and whether it could lead to neurodegenerative diseases needs to be done as well as a physiological study through autopsy.

In short, there are a vast number of long term effects concussions bring that can ultimately destroy sufferers' lives. In order to prevent these long term effects, certain precautionary measures must be taken.

Section C: Prevention

Concussions present a real danger to the brain and must be prevented. In order to do effectively do so, a national standard must be set for every sports association to follow. There are programs such as the CDC's "Heads Up" which teaches parents, coaches, and officials how to identify a concussion and what to do if a player has one (CDC). While this is a good way to teach about concussions and how to identify them, the program is not always followed and there is no nationwide protocol to follow (Beatty). However, having programs for awareness is better than no awareness or protocol. Before research into the effects of concussions became popular to the public there was no standard in place to take care of young athletes.

Before proper protocol, there was a potential for athletes to return to play without going through any type of protocol (Reilly). Returning to play too soon after a concussion not only increases the chance of getting another concussion (CDC), but it puts players at risk for

Second-Impact Syndrome (SIS). SIS happens due to a second hit to the head; true SIS is deadly and athletes die within minutes after impact (Bey and Ostick). In 2004 a Grandview High School freshman suffered from a concussion and returned to play without seeking treatment. He took a normal hit in a game and lost consciousness. Jake Snakenberg, a fourteen year old boy, never woke up (Brain Injury Alliance Colorado).

In response to that danger, many states created legislation in order to prevent further injury to athletes. For instance, in 2012 Colorado signed the Jake Snakenberg Youth Sports Concussion Act into law. The Act requires "Any athlete who exhibits signs, symptoms, or behaviors consistent with a concussion (such as loss of consciousness, headache, dizziness, confusion, or balance problems) shall be immediately removed from participation and shall not return to play until cleared by a licensed healthcare practitioner" (Colorado High School Athlete Association). The idea of this protocol would make it impossible for a high school athlete to return to play without clearance. Of course, athletes may be able to slip through the cracks if they can convince a coach they can return to play. That is why an amendment to the rule must be made to require athletic trainers at every game to test athletes for concussions. Athletic trainers whose job is to assess the injuries of all athletes on the field would provide an expert opinion on whether or not a player is fit to return to play. Another amendment that must be made is to require club sports to require the same type of protocol.

Despite, many states having legislation to prevent concussions or SIS, there is still no national standard, but in 2011 the US House of Representatives introduced:

> Protecting Student Athletes from Concussions Act of 2011, was introduced on January 26, 2011 Recognizing states' efforts to protect against and treat youth concussions, H.R.

> 469 was proposed, in part, to "promote minimum State requirements for the prevention and treatment of concussions caused by participation in school sports . . . ." The bill would require every school district in each state to establish "a standard plan for concussion safety and management," which must include: (1) education for parents, students, and school personnel; (2) support for post-concussion recovery; and (3) a standard safety protocol for the treatment and management of concussions. H.R. 469 is more specific than ConTACT (concussion guidelines) in terms of its prevention and education requirements, yet broader in terms of treatment and management, encompassing suspected concussions and requiring return-to-play approval from an outside health care professional. (Reilly)

However, the act was never passed. If put in place the act would have served many student-athletes at the high school level. It could have prevented tragedies like SIS and/or neurodegenerative diseases.

New bills have been introduced to the 116th House of Representatives to prevent further injury from concussions. The “Concussion Awareness and Education Act of 2019” introduces methods to educate parents and coaches about the dangers of concussions (Beatty). Another bill, the “Protecting Student Athletes from Concussions Act of 2019” ensures that youth athletes from elementary school and up would follow similar protocols that Colorado has in place on a nationwide scale (Durbin). Having a bill that ensures all states and youth sports associations protect athletes by using cautionary methods, such as requiring clearance from a healthcare professional, would be game-changing. An even lower risk of death from SIS is desirable for any parent, however, there are still changes to the mentality of athletes that need to be addressed.

In order to ensure that protocol is followed successfully youth athletes need to understand why it's in place. This can be done through education programs such as "Heads Up." However, even if athletes understand the dangers of concussions they may still find ways to avoid protocol. The reason behind athletes avoiding protocol isn't because they don't care about their brains, but because they don't want to be removed from the field (Theye et al,). Sports are extremely competitive and players train daily to win a starting spot. Injuries require time away from training and coach evaluations making it hard for an athlete to always return to a starting role. Concussions are not like a broken bone that can be obvious to everyone, the injury is inconspicuous and requires additional training to recognize the signs and symptoms and self-reporting to confirm it. It's easier to hide a concussion from a coach, thus the player never loses time on the field. Not only do nationwide protocols need to be implemented, but the culture surrounding concussions amongst athletes must change.

Part IV- Discussion

The results of this research show that there is evidence that multiple concussions lead to Chronic Traumatic Encephalopathy. Other evidence suggests that other long term health effects are a direct result of concussions, namely Post-Concussion Syndrome. The research into PCS shows that a majority of the subjects did not recover (Hiploylee, et al.), showing just one of the adverse health effects concussions bring. Furthermore, some student-athletes can die as a result of Second Impact Syndrome, an easily avoidable tragedy through better prevention methods.

Prevention methods outlined by the Jake Snakenberg Youth Sports Concussion Act ensures that youth athletes seek a medical professional if their coach suspects a concussion,

however, coaches are not perfect. The best way to ensure a student athlete is checked out for concussions is to have athletic trainers at every youth sports contest. This way coaches and players can't play off injury as there would be an unbiased party assessing the player. Also, an athletic trainer can assist in other injuries better than a coach can, so having a trainer on the field is ultimately beneficial for all parties. Another idea to keep in mind for trainers and coaches is the concept of "when in doubt sit them out." This concept ensures that in the result of any type of impact to the head and the player displays even a few symptoms, that they sit out until they are cleared. While it is a more cautious tactic it leaves no room for error as a player will be checked out regardless if they report that they feel fine. In short, using athletic trainers to assist with identifying concussions will ultimately help keep athletes safe.

In order to further prove the need to better protect the brains of young athletes, more longitudinal studies into the prolonged effects of concussions must be done. Despite the mounting evidence of the links between CTE and concussions, there is still debate on the prolonged effects of concussions. There are studies that suggest that there are no clinical symptoms that are related to concussions in early adulthood (Bohr, et al.), however the only clinical symptoms in the assesment include depression and thoughts of suicide which is a prevelant symtom, but not the only one in cases of CTE and PCS. Still the spectrum of the disease has yet to be fully determined, while the study by McKee et al. found that a majority of the subjects had signs of CTE or AD, there were some with no symptoms of either. The implications of no neurophysiological signs of a neurodegenerative disease calls for the need for more research into what triggers neurodegenerative diseases in most individuals, but not all.

Further research also must be done on defining what sub-concussive blows are and how

they are measured. Once these parameters are set, how these blows are linked to brain damage can be further researched. It's not easy to measure seeing as there's no way to diagnose what a sub-concussive blow is. If the force of an impact is dispersed throughout the body including the head; that leaves the question: is every impact the body takes sub-concussive? If so, how can athletes be protected from these kinds of hits, if at all?

Imaging of the brain has advanced significantly from when it began, however it still has its limitations. For example, a brain scan cannot give a diagnosis for a concussion . Nor is it possible at this time to use fMRI scans to diagnose CTE, however, it can show patterns in different patients but not a concrete diagnosis (Narayanna et al.). If brain imaging technology can advance enough to diagnose concussions, athletes would be at less risk of SIS or further injury as there would be visual evidence if the athlete was attempting to hide symptoms. Since this concept is just an idea of the future, further change to the culture surrounding concussions must be done.

A competitive environment breeds success and if an athlete can't be on the field, they can't compete. Concussions in the past have been seen as an injury to push past or shake off. So what if the star player got their "bell rung", they'll go back in. This mentaily is incredibly dangerous for a young athlete's brain. However, it can happen often, as athletes are pressured on all sides by their teammates, coaches, and parents to perform. The injury is invisible, making it easier to ignore. However, ignoring this particular injury has drastic long term effects. Using prevention methods is the first step to ensure athletes are protected from concussions, but it means nothing if the culture does not allow an athlete to properly heal.

The next Brett Farve, Lionel Messi, Mike Webster, or Saquon Barkley is out there. They

might be the star high school quarterback, the college forward who can't be defended, the high school goalkeeper who blocks every shot, the fortress college center, or an unstoppable pro running back. Despite the greatness that these players will eventually achieve, if nothing is done to protect their brains now, they will go down the same path as the greats before them, the next brain to be studied for Chronic Traumatic Encephalopathy.

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