Hit Parade: The Future of the Sports Concussion Crisis

By Chris Nowinski

Editor's Note: While concussions have long been linked to brain and central nervous system issues, a new study suggests that repeated hits to the head—mild or otherwise—can lead to memory loss, depression, and dementia. This postmortem brain study, conducted at the Boston University Center for the Study of Traumatic Encephalopathy, provides new and troubling evidence about chronic traumatic encephalopathy (CTE), a long-term degenerative and incurable brain disease. Although military personnel and others are vulnerable to the disease, the highest risk is among athletes involved in contact sports in which hits to the head are considered "part of the game."

Ten years ago, few would have predicted that brain injuries would one day dominate the sports headlines. When former NFL star Junior Seau committed suicide this past August, the media focused almost entirely on whether the thousands of head blows he endured during his 19-year career as a middle linebacker were a contributing factor. More than 3,000 former NFL players are suing the league for allegedly misleading them about the risks of brain injury, and new policies and studies aimed at protecting the brains of athletes seem to be announced every week. But it's not just professional athletes who are the focus of attention. No fewer than 40 states have passed laws requiring athletes in schools and recreational programs to schedule a doctor's appointment when a concussion is suspected.

I might be a different person today if I had been more aware of the risk I was facing as a football player at Harvard University and, later, as a professional wrestler. In 2003, I suffered a concussion during an in-ring wrestling accident. Despite suffering temporary amnesia, I finished the match. Over the next few days, I developed a throbbing headache every time my heart rate became elevated. Yet I continued to wrestle or exercise nearly every day for five weeks until developing rapid-eye movement (REM) behavior disorder, a condition which triggers abnormal physical movements during sleep.

During my five year recovery from the concussion, I delved into brain trauma literature and decided that it wasn't worth risking what might develop if I took more blows to the head. The literature, which included article after article pointing to the serious consequences of even seemingly mild brain injury, moved me to dedicate my life to making others aware of the dangers and to work toward developing a treatment for chronic traumatic encephalopathy (CTE). A progressive, degenerative brain disease, CTE can manifest in athletes and others with a history of repetitive brain trauma months, years, or even decades after injury. Memory loss, confusion, depression, aggression, impaired judgment or impulse control, and, eventually, progressive dementia may result. With all the head hits I took, I know I am at risk for the disease. But even if I never suffer from CTE, I suspect that many of my friends and former teammates will.

With this newfound awareness about the dangers of concussion, parents face tough choices about which sports their children should be allowed to play. Some of the more dangerous sports for the brain, such as football, soccer, ice hockey, and lacrosse, are also the most popular. Although everyone agrees that brain trauma may have lasting and debilitating effects, and science continues to make slow progress toward understanding the disease, we cannot yet entirely quantify those effects. As a result, parents and even medical professionals are left to search their hearts and scour Web sites for answers. But a decade's worth of research has made one thing clear: We need to find better ways to protect the brains of athletes.

Old and New Science

Multiple brain banks throughout North America have recently reported that CTE is commonly diagnosed postmortem in athletes with a history of repetitive brain trauma. And while regular media reports on CTE are a new phenomenon, the problem itself is an old one. It was first described in 1928 as "punch drunk" by a New Jersey medical examiner writing in the *Journal of the American Medical Association*[1] and pathological case reports, mostly in boxers, have been published for decades. By 1954, the condition was so well established in the public consciousness that Marlon Brando, in the classic film *On the Waterfront*, would win a best actor Oscar for portraying Terry Malloy, a punch-drunk ex-boxer with slurred speech, a poor memory, and a hot temper.

Because the risk factors for CTE have yet to be formally investigated, there is limited understanding of the behaviors that cause or contribute to the disease. We are hyperfocused on concussions—brain injuries that cause clinical symptoms—but there is a poor correlation between number of concussions and the risk and severity of CTE. Most experts once believed subconcussive impacts, in which there are no clinical symptoms, were harmless. Yet new research has found that many athletes who suffer hundreds of impacts during a season, even without a concussion, show the same brain abnormalities that concussed athletes exhibit on imaging tests and multiple measures of brain activity.[2] [3] [4]

These findings have led experts such as Dr. Robert Cantu, medical director of the Sports Legacy Institute in Boston, to suggest that CTE appears most correlated with total lifetime brain trauma, which could be defined as a combination of subconcussive brain trauma and concussions. Many postmortem diagnoses of CTE, in fact, are made in athletes who never had a diagnosed concussion. Nearly all, however, had long careers involving thousands of blows to the head.

Whatever the causal relationship between concussion and CTE, there is no question that CTE has been the driving force behind the new national awareness of concussion. We've known concussions are bad for the brain even longer than we've known about CTE, but what we *did* know about concussion was never enough, on its own, to inspire us to make sports safe for the brain. It is imperative, now, that we do.

Difficult to Measure

Concussions suffer from a perception problem. On the surface, they might not seem to have a lasting, serious impact. They are an invisible injury: there is no blood, there are no displaced bones, and the patient rarely complains. Even when an athlete is knocked unconscious and observers react with panic, the concern quickly fades. Ninety-nine percent of concussed athletes wake up in seconds or minutes, and then seem fine. When symptoms persist beyond the day of injury, in the vast majority of cases, they dissipate within a month. The injury seems as if it is gone forever, leaving no scars or overt indication that it ever happened.

Even acute negative outcomes are easily missed. Persistent postconcussion syndrome, for example, is rarely witnessed because sufferers are often so impaired that they stop going to school and work or no longer socialize. The worst acute outcome, a condition called second-impact syndrome (SIS), is so rare that only a few cases worldwide are identified each year, meaning few neurologists have ever seen it. The likely cause of SIS is a blow to the head before a prior concussion has resolved. The patient is unconscious within a minute due to rapid brain swelling linked to a loss of autoregulation of the brain, making SIS especially serious. Despite having 50 percent mortality and 50 percent morbidity rates, SIS occurs so rarely that few medical professionals appreciate the risk and, until recently, did not caution against returning concussed athletes into the same game.

In contrast, CTE is not an invisible injury. Postmortem histological staining creates dramatic pictures of diseased and damaged brain cells. Using advanced techniques, Dr. Ann McKee's lab at the Boston University School of Medicine has produced unique images of coronal slices of the two hemispheres of postmortem brains, allowing researchers to observe the diffusion of hyperphosphorylated tau protein. Stained dark brown, these aggregates of tau protein are biomarkers of damaged brain cells. CTE, therefore, can be called a tauopathy. Recent breakthroughs in tau imaging should allow CTE to soon be diagnosed in living people, but for now diagnosis requires post-mortem analysis of the brain.

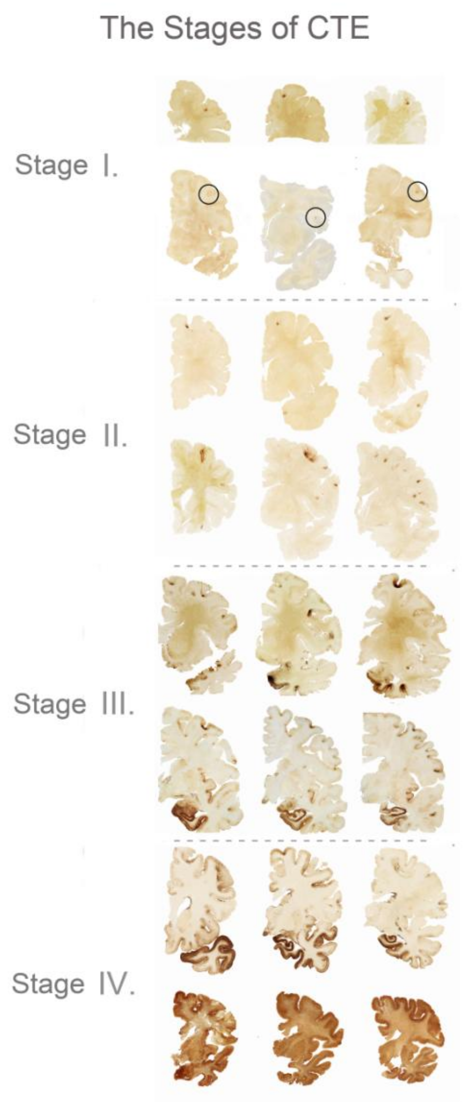

Figure 1. The four stages of chronic traumatic encephalopathy .In stage I CTE, p-tau pathology is found in isolated foci in the cortex. In stage II CTE, there are multiple focal areas of p-tau pathology and involvement of nearby brain. In stage III, p-tau pathology is spread throughout the brain including the medial temporal lobes. In stage IV CTE, most regions of the brain show severe p-tau pathology. Photo by Ann C McKee, MD, VA Boston/Boston University School of Medicine.

While imaging tau remains in the future, symptoms of advanced CTE have been visible for a long time as they have reduced athletes—including the famous and powerful—into unrecognizable versions of their former selves. Helping our team at Boston University's Center for the Study of Traumatic Encephalopathy better understand CTE was the late Dave Duerson, one of the great NFL strong safeties, a two-time Super Bowl champion, and the 1987 NFL Man of the Year. An honors graduate of the University of Notre Dame, he went on to serve on its board of trustees. He was both a dedicated family man and a successful businessman. By the age of 45, however, he began to suffer headaches, developed cognitive problems, and ended up making poor business decisions that put his firm into receivership and himself into millions of dollars in debt. He developed impulse control problems that led to violent outbursts toward his family, leading to divorce. When he took his life in 2011, he left a note requesting that his brain be donated for study by our team.

Our studies revealed that Duerson had sustained damage to his frontal lobes and hippocampus. This damage may have contributed to the cognitive impairment that led to his trouble with such executive functions as planning and organizing. He also had damage to his amygdala, which may have contributed to his emotional outbursts. We still haven't found a way to diagnose CTE in living individuals, nor have we found a treatment. What we know is that CTE tauopathy is associated with memory, cognition, mood, and behavior disorders. Although a direct causative relationship between brain trauma and CTE has yet to be established, everyone in the published literature -diagnosed postmortem with CTE had received significant brain trauma, and there currently are no other identified common variables.

Our team recently published findings from a study of the first 85 brains donated to our brain bank by the families of diseased athletes and military veterans.[5] Sixty-eight were found positive for CTE, which lead author McKee broke down into a new four-stage classification system that elucidates the progressive nature of the disease. Of major concern is that in our sample, 34 of the 35 professional football players were positive for CTE, nine of nine college football players, and four of four professional hockey players. Admittedly, a brain bank case series gives no indication of disease prevalence; the population is biased, especially because families are most likely to donate if the donor was exhibiting abnormal symptoms. Nonetheless, the results are disconcerting, and should inspire us to not allow the next generation of athletes to suffer the same fate.

Children at Risk

Until I became involved in CTE research, I never considered that most brain trauma in the industrialized world occurs in children playing sports. Since participation is voluntary, and the rules of recreational sports are malleable, it seems reasonable to make every effort to reform each individual sport, with the goal of reducing risk of concussions and CTE. As logical as that sounds, adoption of brain trauma limits and other protections for athletes has been remarkably slow. Based on what we know today, there are a number of steps we can take to lower the risk of concussion and CTE.

The rules of sports are not static. Committees meet each year to rewrite rules based on new information. Most of these changes have to do with keeping the game fun and entertaining; for example, adding the three-point line in basketball or tweaking the offside rule in soccer. Occasionally, the rules are changed for safety, and no issue has come along that is more crucial than protecting a young athlete's brain function.

Historically, athletes have participated in sports with rules that ignored the risks. Until recently, ice hockey players were allowed to intentionally use their skating momentum to slam into any part of their opponent, including the head, with little concern for penalties, fines, or suspensions. When I played football, which wasn't that long ago, coaches taught us to lead with our heads as the point of initiating contact for blocking or tackling. Athletes were encouraged to play through concussions if they were able.

New rules in both these sports have since been designed to lessen brain trauma, but with every new horror story that emerges on the sports pages, parents worry even more. What sports should I allow my child to play? What power do I have to protect my child on the field? To evaluate the risk, simply compare how that sport is played at the youth versus adult level, and consider the safeguards professionals are provided. Football is a prime example since, amazingly, 6-year-olds play by essentially the same rules as professionals. Right now we have a healthy national discussion about whether the NFL is too dangerous for adults, yet we pay lesser attention to the risks of youth leagues, despite the fact that football is far more dangerous for kids.

We need to consider the way the human brain develops and recognize that children are at an anatomical disadvantage compared with NFL players. A child's axons, which connect brain cells to one another, are not fully myelinated (in other words, insulated), and his or her brain cells are more sensitive to the neuron-damaging shock of concussions, making each impact and concussion potentially more damaging to the brain.[6]

Children are also at a biomechanical disadvantage. A child's head grows much faster than his or her body, so the head is nearly fully grown by the age of 4, a time when body mass is about 20 percent of full size. Even by age 12, when a child's head is 95 percent of its eventual full size, his or her body is only half its eventual full mass.[7] Combine the child's mature head with a weak neck and torso, and a comparison might be made to a bobble-head doll. It doesn't take much force to accelerate the head to dangerous levels, such that the brain pitches back and forth and twists within the skull, producing chemical, metabolic, and even structural injury to the brain. In fact, studies with sensors in helmets have revealed children take blows to the head of almost equal force as college players.[8]

When it comes to diagnosing concussions, children also face inadequate safeguards. There is no biomechanical or neuroanatomical reason to believe that children aren't suffering as many concussions as adults, and yet they are rarely diagnosed with the injury. A few years ago sports leaders believed that children didn't actually suffer concussions—they were somehow resilient. Now we know there are two major reasons children aren't frequently diagnosed with concussions.

First, rarely is anyone on hand to diagnose the injury and, second, young players seldom report symptoms. Your average NFL team has multiple medical professionals at every game and practice. Your average youth football game or practice has no medical personnel on hand. A recent study found that high schools with athletic trainers diagnosed eight times as many concussions as high schools without medical staff.[9] Another study found that medical doctors who aggressively evaluated hockey players displaying concussion symptoms diagnosed seven times as many concussions as teams that only had athletic trainers on the bench.[10] Do the math: if we provided children with athletic trainers and doctors on the sideline, we'd diagnose about 56 times more concussions. By not providing these resources, a solid case can be made that we will continue to miss 55 of every 56 concussions.

If this statistic seems hard to believe, consider that most concussions are not diagnosed unless the player self-reports symptoms. Educational programs from the Centers for Disease Control and Prevention advise players, "It's better to miss a game than the season," an effective message for prompting high school and college athletes to consider their long-term futures and self-report their symptoms. Young athletes, however, are not likely to have the cognitive capacity to recognize their symptoms as being connected to trauma, nor to realize they should inform an adult. Moreover, such messaging is rarely provided to children. Because there is no validated educational program for child athletes, parents, coaches, and other adults must actively teach youngsters about concussions and also encourage them to report their own symptoms or those of a teammate.

Recommended Reforms

When reviewing the evidence, as well as the empirical data, it is hard to argue that football isn't dramatically more dangerous for children than it is for adults. Even simple protective measures, such as reducing full contact in practices, are more common in professional than youth leagues. NFL players average full-contact practices less than one day per week during the season, while the vast majority of youth programs set no limits. Youth football needs to follow the lead of other sports, which have recognized the difference between children and adults and have instituted aggressive rule changes that reduce the risk of concussion and repetitive brain trauma. USA Hockey has increased the age at which checking—a source of many concussions—is allowed, from 11 to 13. Some soccer organizations recommend not introducing heading, a basic fundamental of the sport, until at least age 10.

To further reduce exposure to brain trauma, the Sports Legacy Institute has launched the Hit Count Initiative, which is modeled on youth baseball's Pitch Count System. This system was developed after data revealed that the more times a pitcher threw the ball in a day, week, or year, the greater the risk of wear and tear to the ulnar collateral ligament. Although elbow injuries are rare in youth baseball, every player is now limited in the number of times he or she can throw in a day and is required to take multiple days of rest after pitching exposure. Dr. Cantu and I believe that such exposure limits make even more sense for the brain. In high school football, for example, a player takes nearly 700 blows to the head each season that have forces of 10 g or greater, and some players have recorded almost 2,500 hits.[11] More than half of these hits are sustained in practice, meaning they can be eliminated without dramatic change to the game.

Sensors in helmets, headbands, skullcaps, mouthpieces, and chinstraps will soon become widely available and inexpensive. The Sports Legacy Institute is working with several manufacturers of these products to define the threshold for a hit and to develop recommendations for exposure limits. College football programs at Virginia Tech, Dartmouth, Brown, North Carolina, and

Oklahoma have started using the Head Impact Telemetry System, which costs around $50,000 to $60,000. For high school and college programs, this system can make a real difference, especially if the school's authorities choose to tackle the tricky question of how many severe hits are too many for a player. I envision a day when the price tag comes down for measuring hits to the head, allowing a real-time count to be accessible to all parents and coaches. Armed with that knowledge, coaches can adjust practice habits to limit exposure, and coaches can identify players who are utilizing techniques that may be putting their brain at greater risk. I also hope that parents will be able to use this information to inspire coaches to effect change quickly.

Technology can make us safer, but it's only one piece of the puzzle. There is no simple answer. Every sport involves risk, just as crossing the street does. While we can quantify the risk of driving in a car or jumping from a plane, without a way to diagnose CTE in living individuals, we can't quantify the relative risk of each sport. We are left with case studies, media stories, hypotheses, and confusion.

If we were starting from scratch, armed with our current knowledge about sports-related brain injury, I am confident we would limit children's participation to those sports in which head trauma is both *rare* and *always accidental*. Perhaps that's a guideline for parents to consider. We must remember that many of the world's most popular—and entertaining—sports were designed for fully mature adults who are competing with informed consent. Professional sports are designed to sell tickets and increase television ratings. Children's sports should focus less on viewership and more on improving health, teaching lessons, and building character. More troubling is the future of high school and college football, where aspects of both worlds collide. The issue has reached a fever pitch with more and more professional football players expressing a fear for their future health and the future of their sport every day. Even President Barack Obama recently entered the conversation, expressing concern about college football players and the NCAA's role in addressing "problems with concussions and so forth." The "so forth" he alludes to clearly is CTE.

There is little doubt that athletic activity is great for children, but now there is also little doubt that science is revealing the grave consequences of repetitive brain trauma. In the future, our children should play sports with rules that are designed around the limits of their brains, rather than the limits of their will.

Chris Nowinski*, a co-author of the new study, is the founding executive director of the Sports Legacy Institute, a nonprofit organization dedicated to concussion awareness, advocacy, and prevention. A former Ivy League football player and professional wrestler, Nowinski chronicled his own struggle with postconcussion syndrome in the book* Head Games. *He is now a PhD candidate in behavioral neuroscience at Boston University School of Medicine and a co-director of the Boston University Center for the Study of Traumatic Encephalopathy.*

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