American Football
Problems and Solutions

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Fueled by well-publicized lawsuits and sensational stories in the press about former football players suffering from a variety of neurological disorders, there is increasing concern among many that American football is a dangerous sport. (I use the adjective "American," because, in our increasingly diverse society, "football" is often taken to mean "soccer.") Many important public figures have weighed in on this topic:

> "You see how hard the 'reforming the game' argument is going to be? Every time someone comes up with one thing that might reduce brain impacts, it seems to raise another problem. My guess? Football slowly dies out....look at the collateral damage this game has left in its wake. You have to ask the question, is it time to say enough?"
> - *Malcolm Gladwell (one of* Time *Magazine's 100 Most Influential People – 2005)*

> "That's because college football has no academic purpose, which is why it needs to be banned. A radical solution, yes – but necessary in today's times."
> - *Buzzy Bissinger (Pulitzer Prize Winner and author of* Friday Night Lights*)*

> "I have to tell you -- if I had a son, I'd have to think long and hard before I let him play football."
> - *President Barack Obama*

Actually, these concerns are not new. Early in the 20th century, in the days of the flying wedge when the game had no penalties whatsoever, football was considered by some to be the moral

equivalent of lynching. In 1908, before the days of professional football teams such as the Decatur Staleys and the Massillon Tigers, 19 college players died as a result of their exploits on the field. This prompted the *New York Times* to opine:

> "A young gentleman engaged in getting an education ought not to exhibit himself for money, and he and his fellows ought not to raise a mere sport to the dignity of an occupation. The tremendous loss of time which overattention to football occasions is its worst feature, though the brutality and maiming are serious evils too. Both will be cured by cutting off the money supply, which the Faculties can do with a two-line resolution. Make lynching expensive and public football unprofitable."
>
> -Two Curable Evils, New York Times *1908*

President Eliot of Harvard had similar views:

> [The rules of football] "are justifiable in that consummate savagery called war, but they should have no place in sport. No sport is wholesome in which ungenerous or mean acts which easily escape detection contribute to victory."
>
> *-- Harvard President Charles Eliot, 1903*

As a result of these concerns, President Theodore Roosevelt convened, in that year, an august group at the White House comprising, among others, the Secretary of State and the Athletic Directors from Harvard, Yale, and Princeton. This meeting resulted in the birth of the National Association of Collegiate Athletics (NCAA) and the institution of the forward pass, the line of scrimmage, and the required use of helmets and pads. The NCAA, as well as the National Football League (NFL), are now embroiled in efforts to solve the football problem - to make our American game of football safe.

What exactly is the problem and what are its causes? Before I go into specifics, and in the interests of full disclosure, I would like to make it clear that I am an advocate, in large part, of the status quo, and that my hope for the future of the game of football is that it will remain largely unchanged by the current controversy. I also wish to disclose that I am currently a consultant for Pro Sports Technologies, a football helmet development company in which I hold equity, and that I have worked in the past for Schutt Sports, a manufacturer of, among other sports-related equipment, football helmets. The opinions I present here, however, are mine alone, and do not necessarily represent the positions of the companies I mentioned or my employer, the University of Nebraska - Lincoln.

I come at this from a physicist's perspective. Let's begin with the basic problem. Football is a violent game; that's one of the things we love about it. When one watches a game of football, the action on the field – the blocking, tackling, and passing - are all governed by the laws of classical physics discovered by Isaac Newton in the 17th century. To review, Newton's First Law says that a mass will continue forever in its state of motion, changing neither its speed nor direction, unless it is acted upon by an external force. His Second Law quantifies this idea by relating that external force mathematically to the mass' rate of change of its velocity - it's acceleration. Finally, Newton's Third Law says that when two bodies interact, for example, when two football players collide with each other, the force exerted by player A on player B is equal in magnitude, but opposite in direction to the force exerted by player B on player A.

These laws may seem obvious at first, and in some applications they are, but they have counterintuitive aspects as well. Consider, for example, a hypothetical hit involving Doug

Flutie, whose playing weight was 180 pounds dripping wet, and Warren Sapp, the 330-pound Hall-of-Fame defensive end who was extraordinarily quick and a vicious tackler. Flutie has set up in the pocket to pass, and Sapp is bearing down on him at top speed like a ton of bricks (I use this analogy advisedly, as we will soon see). As Sapp sacks Flutie, which player exerts a bigger force on the other? Newton's Third Law tells us that they exert the *same* force on each other, albeit in opposite directions. So why is Flutie the one that goes flying after the hit? Newton's Second Law reveals the answer. Having less mass, Flutie is more easily accelerated, and the force that Sapp applies to him launches Flutie in a high speed trajectory off his feet. The equal force Flutie applies to Sapp acts only to slow him down as he and Flutie collide.

The forces encountered in football, especially at the professional and college levels, can be huge. Consider a big hit between a running back and a charging linebacker. They collide at full speed, and both fall to the ground. We can show, by the application of Newton's Second Law, that the force one player exerts on the other exceeds three-quarters of a ton (more than 1500 pounds!). This is why they call football a "contact" sport. Two players who collide at full speed helmet to helmet are essentially experiencing the same forces to their heads that one of them would feel had he had a 16-pound bowling ball dropped on his head from a height of eight feet. When you are a running back, making a guy miss is good – unless he grabs your facemask on the way by. Then, your neck experiences a torque about like the one it would had you jammed your head into an industrial washing machine full of wet towels at full rotation.

Forces to the head and neck can cause concussions, and we have just heard how big they can be. Another problem is that the forces involved in American football are getting bigger. Since 1920,

the average weight of professional football lineman has increased by almost 60% from 190 pounds to over 300 pounds. Using basic kinesiological models of sprinting, I have determined that their top-end speeds have increased over the same time period by almost 10%. Combining the factors of speed and mass to calculate kinetic energy – the energy available to cause injury – we can show that the amount of energy dumped into the pit at the line of scrimmage on any given play has almost doubled in the years since the NFL began. This is shown in Figure 1.

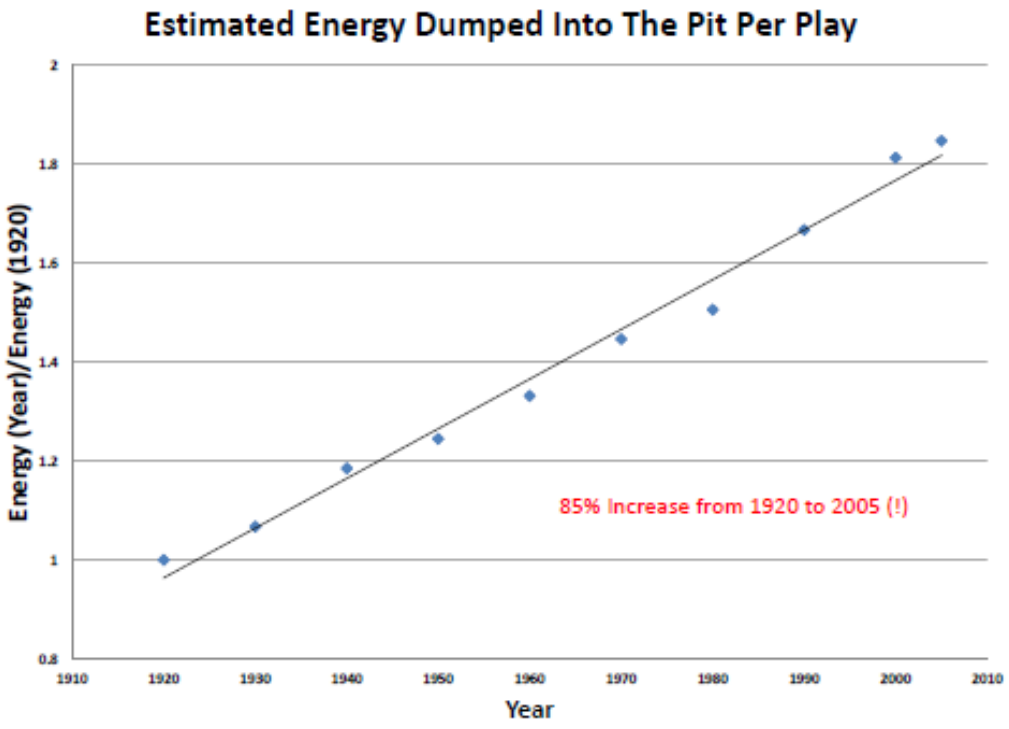

Figure 1. *Kinetic energy (energy that can produce an injury) in a typical play from scrimmage .*

Given the size of the forces about which we have been talking, and the fact that they are getting bigger every year, we might ask, "Why aren't players get injured with increasing frequency?" There are two major factors to consider here. The first involves football equipment. Equipment technology has improved dramatically in the last century. In the beginning, there *were* no

shoulder pads. By the 1920s, shoulder pads had evolved to strips of cotton batting over which one pulled his jersey. Now we have teams of mechanical engineers producing light, sophisticated shoulder pads. The earliest football helmets, introduced at about the time of the Taft administration, were essentially leather skull caps. Today, football helmets have very sophisticated designs with multiple foam layers, quick-release chinstraps, protective visors, and conformal polycarbonate shells. Barring a major technological breakthrough, it is accurate to say that football equipment is about as good as skill, craftsmanship, and science can make it.

The countertrend to the impressive technological prowess that has been brought to bear on this problem is that players, in the desire to be faster and more agile, are shedding equipment. Decisions about which helmet to wear, usually up to the player at the elite levels of the game, are based more often on how cool the helmet looks, not on its collision-cushioning ability. The venerable horse collar, an almost sure bet to eliminate concussions due to severe neck rotation, and a standard equipment item for players of my generation, has essentially been eliminated from the game. The reason? Linemen and other players do not like the limitations it poses to their ability to quickly swivel their heads to keep an eye on opposing players. Knee and thigh pads, that used to be substantially thicker than a centimeter, now often bear a remarkable resemblance to a teacup saucer pads.

A second, crucially important factor, is the poor state of our medical knowledge about what concussions actually are and what causes them. This is a very complicated problem, and the answers are affected by a player's physical and genetic disposition for suffering a concussion. The answers require an understanding of the physics and physiology of mechanical stresses on

the brain and spine, as well as their consequences at the cellular level. The state of this understanding is in its infancy. Right now, it is impossible to predict the concussive effect of a blow to a given part of the head or neck with a given force and torque. Much is made of the relative importance of direct blows to the head that cause linear acceleration versus glancing blows that result in rotational acceleration of the brain about the axis of the spine. But there exist to my knowledge no conclusive epidemiological studies that tell us which is worse. As our understanding of these physiological issues improves, we may in fact find that injury rates due to the increasing energy of the game and the shedding of equipment have increased faster than we thought. It is crucial that extensive, carefully done medical research be done to get at the heart of these questions.

So, succinctly, what are problems and challenges that American football faces?

1) The forces on the players are big and getting bigger.

2) Players are shedding their gear.

3) Increasing understanding of the physics and physiology of concussions is raising awareness of potential long-term medical problems resulting from violent sports. Of course, medical knowledge is also the solution to these problems.

4) Football is big business, especially at the college and professional levels. When monetary forces become manifest in how the game is played, as they do in, for example, bounty programs and illegal doping to improve performance, the game become more dangerous.

What are the solutions? In my opinion, the following measures will help maintain the integrity of the game of football, and minimize, to the extent possible, the physical danger of this inherently violent sport.

1) We need better equipment, but there are constraints here. Marginal improvements are to be gained in the area of better body, arm, and leg padding. More important is protection for the head and neck. But improving helmet performance is a tricky business. It is apparent that adding more energy-absorbing foam to a helmet will lower the maximum forces delivered to a player's skull, and thus reduce the risk of a concussion. This has been tried in the past. The Pro Cap was perhaps the most visible example of the "added foam" idea to ward off concussive blows. You may remember NFL players in the late 80s and early 90s roaming the field with helmets sporting large foam rubber tops – making them look a bit like visitors from another planet. The problem is that whenever padding is retrofitted to the outside of a helmet, its diameter increases, and the torque that can be applied by a glancing blow is subsequently increased. This dramatically increases the risk of neck injuries. Nonetheless, several manufacturers today are proposing the same basic idea for youth football, where the risk of collision to the head is almost certainly riskier. There is a good reason, other than the cosmetic one, why equipment room managers shine up the exterior of helmets to make them really slick.

The use of the Star system, developed at Virginia Tech, that gives a simple numerical rating for a helmet's impact performance, is a good first step in helmet assessment. There is, in my opinion, significant room for the improvement of this system, but it is undergoing ongoing

development and is the currently the best tool we have for analyzing the merits of various helmet systems.

Helmet telemetry systems (e.g., the Head Impact Telemetry, or HITS System), in which *in situ* helmet accelerometers are used to determine the orientation and severity of blows to the head in real time, should be used more widely. If nothing else, these systems would give us a wealth of data about the consequences of blows to the head in game and practice situations. Attempts to implement such systems in the NFL have been stalled because of the concern by players that data indicating a severe blow might be used to limit playing time or adversely affect salary negotiations. Expense and concern about lawsuits may be limiting the use of such systems at the college level.

2) Our understanding of the medical issues related to concussion must be dramatically improved. The NFL is now providing significant funding for research of this type. The Department of Defense, understanding the importance of traumatic brain injury (TBI) suffered by warfighters in combat, has been funding work in this area as well. Better coordination of these efforts is crucial. My academic home, the University of Nebraska-Lincoln, has launched a pioneering collaboration between athletics and academic research to understand at a fundamental level the nature of concussions and how they are linked to variables in athletic performance. The combination of research in brain biology, neurological links to behavioral issues and athletic performance, and the development of better, more rapid concussion diagnostic tools, carried out collaboratively by the Center for Brain, Biology, and Behavior (CB^3)

and the Nebraska Athletic Performance Lab (NAPL) and all housed in Memorial Stadium on our campus, is unique in academics and should serve a guide for academic research in this area.

3) Some incremental rule changes, and more stringent enforcement of existing rules, are needed. In my opinion, some of the new rules regarding targeting, peel back blocking, and defenseless players are making players more hesitant on the field, and thus actually increase the risk of injury in a game. These should be modified or eliminated. One hall of fame running back perhaps put it best:

> "If I'm a running back, and I'm running into a linebacker, you're telling me I have to keep my head up so he can take my chin off?"
>
> *- Emmitt Smith (NFL all-time leading rusher)*

It is my belief that a return to the level of padding worn in the1970s would make the game significantly safer. Until a better understanding of the effect on the brain of smaller but repetitive blows is attained, horse collars should be required, at least for linemen. More thorough doping rules should be developed and more aggressively enforced. The NFL season should be reduced to 14 games, and the college season returned to 11. Finally, more stringent requirements regarding when a player who has suffered a concussion can return to the game need to be implemented.