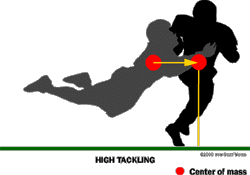
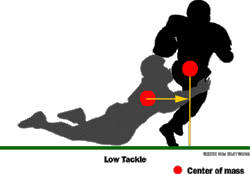
**Science and Football Crashes**

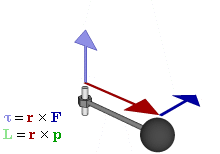
I enjoy watching American professional football. Aside from a minor interest in the competition, my fascination with this sport is with the athletes involved and the strategies deployed. The physicality of these athletes is uncommon. They are some of the fastest and strongest humans that you will encounter. What enhances the sport is the episodic spectacle of only sixteen games plus maybe four additional playoff games. Other professional sports in the U.S. have seasons ranging from 34 (soccer) to 82 (basketball) to 162 (baseball) games. Football is also a sport where virtually all 22 players on the field are only intensely active for less than 8 seconds for a typical play (Biderman, 2010). The short period of intensity allows for the players to give a maximum of physical effort for the length of the play. This effort is translated into running or blocking or tackling as hard and/or fast as possible. When I watch football – the clash and crash of bodies both intrigues me and makes me wince at the same time. The sport is fun to study and analyze from a scientific view, especially in examining the physics of tackling collisions.

**The Physics of the Tackle and Falling Down**

**Fig. 1**

Tackling can be deconstructed using the principle of physics. The center of mass for males is roughly at the navel or just above it. For females the center of mass is closer to the hips below the navel. When standing – your center of mass does not move and you are stable. When running in a straight line – your center of mass is moving but will remain stable. Newton’s first law of motion can summarize this basic principle – a body at rest stays at rest and a body in motion stays in motion unless an outside force acts upon that body. When the runner is moving in a straight line without impediment their center of mass is stable and relatively undisturbed, but as soon as the runner cuts or changes direction their center of mass is shifted and less stable, i.e. more prone to fall down. The addition of a tackler attached to the runner changes the center of mass for the runner. Although the runner is not thinking about Newton while running with the football, they instinctively know that it is better if, “my center of mass is not complicated by an additional force, so I better stiff arm that tackler away from me and remain a body in motion that stays in motion!” The tackler has become the outside force, albeit with violent intent, that acts upon the runner and is attempting to make the runner a body at rest.

One of the coaching axioms of football is the phrase, “Hit ‘em low.” In figure 1 (Freundenrich, 2001), the high tackler and the runner’s center of mass are on approximately the same level. The high tackle will tend to move the runner in a lateral plane, neither up nor down. The runner can continue in motion but with the added mass of the tackler. In contrast, the low tackle (fig. 1, Freundenrich, 2001) changes and shifts the center of mass of the runner diagonally downward towards the tackler. This shift makes it more likely that the runner will be headed for the ground.

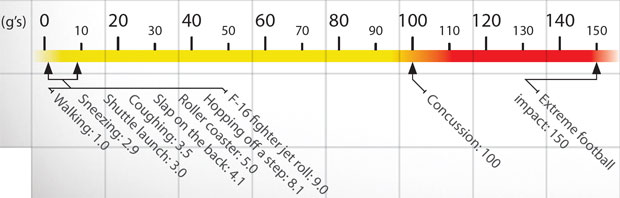
An additional force happening on the tackle is torque, which is a rotational force, and is the product of the amount of force applied and the distance from the center of mass.  The formula for torque is T=r x F, r is rotation and F is force. Rotation (r)

is a function of the linear momentum (L) divided by the angular momentum (p). Force (F) = mass of the body x the acceleration of the body or F=m x a. “All bodies will rotate easiest about their center of mass. So, if a force is applied on either side of the center of mass, the object will rotate (Freundenrich, 2001).” The low tackle causes the runner to radically twist; changing the runner’s mass downward toward the tackler. An added bonus for the tackler is that by going low it takes less force than tackling high.

**Tackles and the Force on the Body**

****

The force applied by the tackler on the body can be measured. A study by Usman, McIntosh, and Fréchèd (2010) looked at the force of a typical tackle. They found that the typical shoulder tackle applies a force of over 1600 Newtons. A Newton (N) is equal to 1 kilogram x the speed of gravity (meters/seconds2) . The force of 1600 Newtons can be imagined as a car crashing into a wall at 30 miles per hour. What saves the person being tackled from such a powerful force is the padding and safety equipment that they wear. The shields disperse and absorb the energy of direct impact of the tackle across a wider area and the padding absorbs more energy through special materials, e.g. neoprene, visco elastic foam, etc. Another way of visualizing tackle impact is in gravitational force (g’s) which can be seen in figure 2 (Higgins, 2009). Most people associate high g-forces with fighter pilots or astronauts. But common earthbound events can also boost g's. Few things can match the g-load of a wicked football hit.

Figure 2. 

**Summary**

American professional football is one of the most popular sports for kids and adults. My hope is that utilizing football’s popularity and connecting the science involved in analyzing the sport for students, I can create an active learning experience for the class. The physics involved in tackling is just one of many lessons that can be gleaned from football. Additionally, there are numerous extracurricular activities (e.g. skateboarding, hiking, etc.) and sports that students have an interest in, other than football, that one can apply active learning pedagogy.

Resources:

Biderman , David (2010, January 15). “11 Minutes of Action.” Retrieved July 16, 2014 from

<http://online.wsj.com/news/articles/SB10001424052748704281204575002852055561406>

Freudenrich, Ph.D., Craig. (2001, April 1). "How the Physics of Football Works."  Retrieved July 16, 2014. <http://entertainment.howstuffworks.com/physics-of-football5.htm>

Higgins, Matt (2009, December 18). “Football Physics: The Anatomy of a Hit.” Retrieved July 16, 2014 from <http://www.popularmechanics.com/outdoors/sports/physics/4212171>

Usman, J., McIntosh, A.J., Fréchèd, B. (2010). An Analysis Of Impact Forces In An Active Shoulder Tackle In Rugby.  *Br J Sports Med* . 45:310–384