# Solving the Concussion Crisis

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## The Problem

Brain injury has been a rising fear associated with many sports in our society, including football, soccer, hockey, lacrosse, baseball, and softball. While these health concerns are on the rise, participation numbers are declining as parents take their children out of these sports in order to keep them safe – opting for non-contact sports like cross country, track and field, or tennis. Like soccer in many other nations, football is at the heart and center of American culture, but safety concerns are dramatically altering the way the game is played. While proper technique and sound coaching are crucial pieces to the overall safety of these athletes, outright changes in rules diminish the integrity or nature of the game. In response, it is foreseeable that the popularity of the sport may diminish to levels heretofore unheard of in the modern era. Through science and research, this future can be avoided, but only if proactive steps are taken now to improve the safety performance of protective gear, ensuring that the core fabric of football remains unchanged.

Clinicians treating athletes have identified devastating long-term consequences of repeated concussions and in some cases, repeated sub-concussive impacts including debilitating diseases such as Chronic Traumatic Encephalopathy (CTE) and dementia. These consequences must be eliminated if contact sports are to be saved. Unfortunately, the nation's accumulated knowledge about the cause of concussion is very limited. The development of any impact attenuation system for preventing human injury must begin with a detailed analysis of the mechanisms that produce the injury. For example, development of the SAFER Barrier for NASCAR and Indy Car race tracks began with a detailed reconstruction of all crashes involving impacts with concrete barriers that resulted in serious injury or death. This study revealed that all of the fatal crashes involved basal skull fracture. Prior research into basal skull fracture had identified the primary cause of this injury to be a tensile force of 4,000 N (900 lb) or greater applied to the skull. Designers of the SAFER Barrier were able to develop a system that controls the tensile load on a driver's neck soon after this injury causation was identified and threshold values were established. The SAFER Barrier has eliminated basal skull fracture on all racetracks where NASCAR and Indy Car race. A similar approach can be applied to the concussion crisis in order to develop impact attenuation systems that effectively address the source of the problem.

## Research Approach

The proposed study incorporates three goals, each working independently and synergistically toward understanding and eliminating concussions in contact sports.

<u>Goal 1: Measure Impact Conditions</u>: High-speed, high-resolution video and body mounted accelerometers will be used to reconstruct high-energy impacts from both practice and games, aiding in identifying concussive impact conditions and supporting the advanced finite element analysis (FEA) of neural tissue distortion.

<u>Goal 2: Identify DT-MRI Changes:</u> Prior to the start of fall camp, football players will be subjected to MRI scanning at the UAB Highlands Hospital using a whole-body 3T scanner. Any player subjected to evaluation for concussion will then undergo the same scanning conducted prior to the season. Differences between pre- and post-impact scans will be evaluated to determine the areas

where the structural or functional changes can be isolated. The precise locations and nature of the detected changes will then be documented for comparison with FEA. In addition, Diffusion Weighted Imaging (DWI), Susceptibility Weighted Imaging (SWI), and Resting State Imaging (RSI) will take place at the University of Minnesota Center for Magnetic Resonance Research (CMRR). Fractional Anisotropy (FA) and Mean Diffusivity (MD) will be analyzed with a focus on specific regions of interest defined by areas of maximal strain based on finite element modeling, as identified in Goal 3. High-order tractography will also be used in the analysis to track fibers in the brain.

Goal 3: Reconstruct Impacts using Finite Element Analyses: The exact structure of the players' heads will be established from the pre-season MRI scans and will be used to develop advanced finite element models. Using multi-scale modeling techniques, each impact included in the study will be simulated and regions of high neural tissue distortion will be mapped. Maps of the neural distortion parameters will be compared with the changes in the functional or structural characteristics of the players' brains. The tissue distortion parameters that provide the best correlation to structural or functional neural tissue injury will be identified leading to improved understanding of the mechanisms of concussion and predictive models that can be used in the development of impact mitigating devices.

## EXPECTED OUTCOMES

This research will identify which material distortion parameters are most closely correlated to the risk of brain injury. Further, the study will identify threshold values that indicate the magnitudes at which the risk of brain injury becomes significant. These findings will allow helmet manufacturers and regulating bodies to create new and effective helmet performance standards that actually measure the effectiveness of helmets for preventing concussions, leading to rapid improvements in helmet performance. These findings can also be applied to other contact sports as well as occupations where head injury mitigation devices are necessary, including fire fighters, military personnel, and industrial workers.

## FINAL THOUGHTS

While there are some details of the research plan described above that need further refinement, most of the key elements of this approach have been successfully demonstrated in ongoing pilot studies. This research approach provides the only viable path to defining the neural tissue distortion parameter(s) that govern the development of concussive injuries. Unfortunately, the wide variety of impact conditions that have produced concussions indicates that there are likely to be multiple causes of concussion that produce multiple measures of risk. Further, the wide variations in player sizes, speeds, musculature, and skill levels ranging from youth to professional magnify the scope of the problem. The urgent need for meaningful progress in reducing concussions mandates that multiple research teams undertake the study described above at every level of play.

By developing a deeper understanding of the mechanisms of concussion it is possible to create effective tools for keeping athletes safe and mitigating the long-term consequences of mTBI. Addressing this Grand Challenge will maintain the integrity of a game that is a vital part of the fabric of American culture and keep people safer over a wide range of sports and professions where the risk of head injury looms large.

## RESEARCH TEAM

The following faculty and entities will collaborate on this study:

- Kenneth Walls (UAB Mechanical Engineering)
- Dean Sicking (UAB Mechanical Engineering)
- Kevin Schrum (UAB Mechanical Engineering)
- Blake Feltman (UAB Mechanical Engineering)
- Jerzy Szaflarski (UAB Neurology Department)
- Heath Hale (UAB Team Doctor)
- Defend Your Head (Sports Safety Equipment Manufacturer)
- Michael Goodlett (Auburn Team Doctor)
- UAB & Auburn Football Team and Athletic Training Staff