D15 A Computational Analysis of Traumatic Head Injuries Resulting From Falls and Impacts in Sports

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Learning Overview: The goal of this presentation is to explain the development and use of 3D computational simulation tools, specifically multibody dynamics and finite element analysis, with reference to equestrian fall accidents that resulted in head injury. These tools can equally be used to reconstruct other sport impact events, collisions, falls, and both workplace and road traffic accidents.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by showing simulation tools that are powerful, allowing forensic engineers to quantify the forces, stresses, and strains sustained by a person or safety equipment during an impact, and to compare the relative severity of alternative accident scenarios without the need for extensive experimental laboratory facilities.

This presentation demonstrates and explains the use of advanced 3D computational simulation tools, specifically rigid multibody dynamics and finite element analysis, in reconstructing various sporting accidents that led to head injuries. While the analysis of concussive head injuries sustained during equestrian racing are a particular focus of this presentation, these same techniques can be used to investigate different injuries from other sports and general falls, as well as workplace and road traffic accidents.

Equestrian sports are popular worldwide, although racing jockeys have higher incidence rates of concussion than people competing in football, soccer, cycling, skiing, or boxing. The objective of this research is to improve the design, quality, and safety of helmets that are currently being worn to protect against head injury. Equestrian helmets are currently designed to pass certification standards that involve a linear drop test against a rigid steel surface. Concussions in equestrian sports, however, typically occur after being thrown from a horse and impacting relatively compliant surfaces, such as turf or sand, at an oblique angle. The mechanics of oblique impacts against compliant surfaces are more complex and require the use of advanced engineering simulation techniques. Understanding the event characteristics and mechanics that lead to concussion in equestrian sports has positive implications for tomorrow's equestrian helmets and associated certification standards.

In-depth reconstructions have been conducted on concussive and non-concussive cases for which high-quality video data was available. Cases in which multiple impacts occurred to a jockey's head (e.g., both a fall and a kick) were excluded from this research. Approximately 500 videos of accidents in which jockeys fell from their horses have been examined using the Kinovea video player. This, together with accident report forms, determined impact location, surface type, and initial velocity. Multibody dynamics simulations (Mathematical Dynamic Models (MADYMO)) were conducted based on body position, impact location, and velocity determined from video analysis. Impact velocity and trajectory angle of jockeys at the point of contact were obtained from these simulations. Corresponding accelerations can either be obtained by analyzing a succession of high-quality video frames or by using an instrumented head form under laboratory-controlled conditions. Linear and rotational acceleration time histories were subsequently used as input into a University College Dublin Brain Trauma Model to determine levels of maximum principal strain within the brain tissue.

The impacts were of long duration (>22ms) with low peak rotational acceleration, similar to collisions in ice hockey, but relatively high peak linear accelerations with magnitudes more comparable to American football and Australian rules football. The low rotational accelerations and long impact durations are due to the compliant turf surface. The relatively high linear accelerations were a consequence of the large amount of energy transferred to the jockeys' heads during impact. These results confirm that oblique impacts to a compliant surface can lead to concussion and that this head injury occurs at acceleration levels that are significantly lower and of longer duration than current safety thresholds set in equestrian standards. It is apparent that the current equestrian helmet standards and design do not necessarily account for the loading conditions associated with concussion.

Equestrian Accidents, Head Injury, Concussion