Editorial

Special Issue on Concussion Biomechanics in Football

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This special issue is focused on the biomechanics of concussion in football. These papers are timely given increased public awareness concerning concussions in recent years, which has led to a push for more research in the area. Repetitive head impact exposure leading to long-term neurocognitive deficits is particularly concerning, with evidence for poorer outcomes associated with longer exposure.¹⁰ The study of concussion in football has broad applications both within the sport as well as more general areas of impact protection. Player safety can be improved through rule and practice structure changes informed by analysis of athlete head impact exposure. Improvements in helmets and other safety equipment can be guided by laboratory and on-field evaluations. Fundamental injury mechanisms and brain injury tolerance can be translated to enhanced safety for other sports and recreational activities, automotive environments, and military personnel. This special issue will highlight the most recent advances in football concussion biomechanics research including analysis of real-world impacts, new head impact sensor technologies, and laboratory evaluation of helmets.

The biomechanics of on-field head impacts have been analyzed through reconstructions of video-recorded impacts and wearable head impact sensors. Video recordings of National Football League (NFL) games were used to reconstruct concussive or severe impacts at the professional level.¹¹ The videos were analyzed for pre-impact velocity and location, and impacts were recreated in the lab with anthropomorphic test devices (ATDs). The results of the reconstructions provided average linear and rotational head accelerations for concussed players as well as risk functions based on head kinematics and head injury metrics. More recently, the NFL reconstructions were reanalyzed due to inconsistencies in the original instrumentation, resulting in error in the head kinematics of concussed players.¹⁶

Wearable head impact sensors have been used to measure head impact kinematics in football since the early 1960s.¹² Helmet-mounted sensors have been used to collect a large dataset of head impacts to determine head impact exposure and concussion biomechanics in

collegiate and high school football players.^{3,4,18} Analysis of head impact exposure during different drills and event types can inform rule and practice structure changes to improve player safety.^{1,17} These data have also been used to evaluate concussion tolerance and risk in football players, with recent work showing that tolerance varies on an individual basis and may have a number of underlying factors.¹⁴

There are limitations and advantages to both laboratory reconstructions and wearable sensors for studying real-world head impact biomechanics. Laboratory grade instrumentation for reconstructions is highly accurate, but the impact conditions are not identical to what occurs on the field. Videos used for reconstructions are adequate for determining pre-impact velocity and in some cases helmet kinematics, but head kinematics are substantially less than what the helmet experiences during impact.^{2,8} Wearable sensors such as the helmet-mounted ones previously mentioned are able to capture head kinematics under real-world conditions, but the sensors vary in accuracy largely due to difficulty tightly coupling sensors to the skull.²⁰ Relative motion between the sensor and skull often results in overprediction of head kinematics and injury risk. One solution for improved coupling and more accurate measurement of athlete head kinematics is sensors embedded in mouthguards or retainers.¹³

Head impact data collected on the field have been used to develop helmet evaluation methods to inform consumers about the relative performance of different models and drive improvements in helmet design.^{5,15,19} These evaluations use laboratory impacts representative of on-field head impacts along with injury metrics to rank relative performance of football helmets. The injury criteria are based on head kinematics, however some more recent work has developed metrics that predict brain strain based on input head kinematics.^{6,7} The strain-based metrics consider the injury mechanism for concussion rather than just a kinematic variable that correlates with injury.

A comprehensive understanding of concussion biomechanics requires reliable and objective concussion diagnostic tools to differentiate injurious and non-injurious impacts. Blood biomarkers have shown

promise for concussion diagnosis, and can be paired with biomechanical data from players for a more complete understanding of injury mechanisms.⁹ We hope that the papers in this special issue serve as a reference and foundation for future advancements in football concussion biomechanics research.

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