Biomechanical analysis of head injury in pediatric patients

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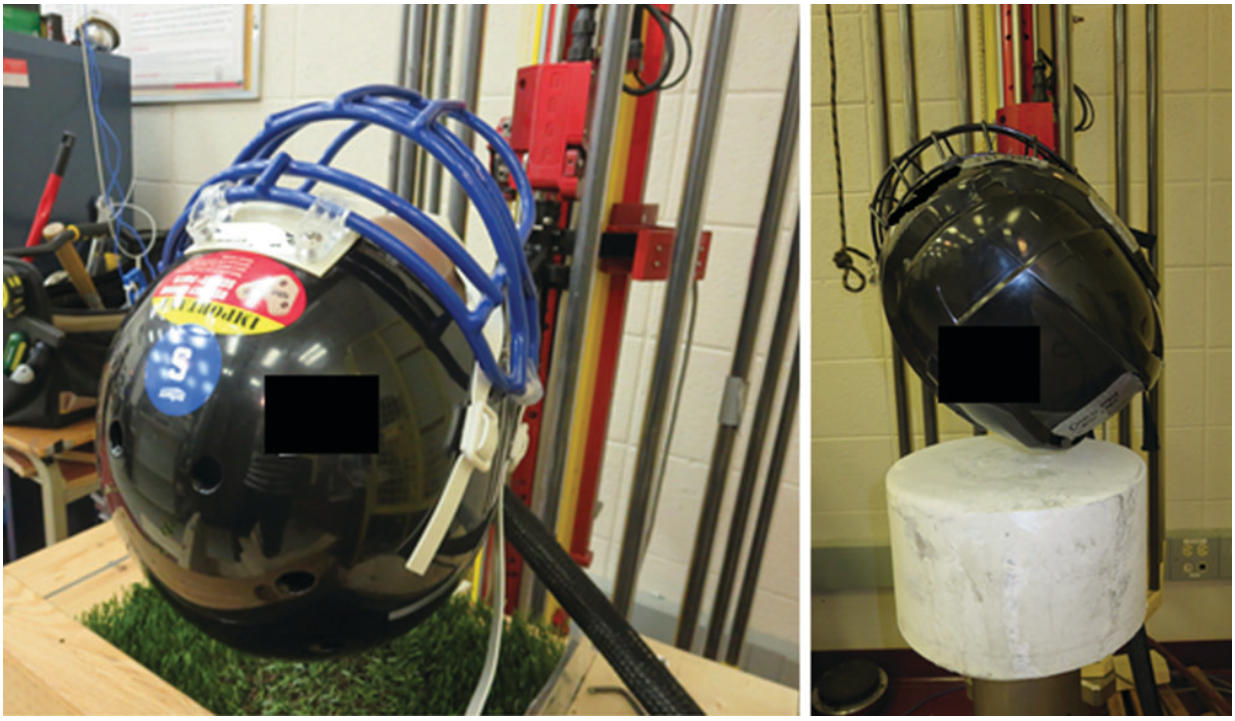

Reconstruction impacts on a monorail for Canadian football (left) and hockey (right) are shown. Credit: AANS.

The biomechanics of head injury in youths (5 to 18 years of age) have been poorly understood. A new study reported in the *Journal of Neurosurgery: Pediatrics* set out to determine what biomechanical characteristics predispose youths with concussions to experience

transient or persistent postconcussion symptoms.

Background. A form of traumatic brain injury, concussion is usually caused by a blow to the head or some other event that causes the brain to suddenly shift position within the skull. Various symptoms are associated with concussion: headache, dizziness, confusion, visual problems, concentration difficulties, irritability, depression, and more. Some young patients experience concussion-related symptoms for only a short time, but for others, symptoms linger. When symptoms resolve within a few weeks after the incident, they are known as transient post-concussion symptoms (TPCSs); when three or more concussion-related symptoms last more than four weeks after the incident, they are called persistent post-concussion symptoms (PPCSs).

The Study. To determine the biomechanics of head impacts leading to transient or persistent post-concussion symptoms in youths, a Canadian group of concussion researchers recruited patients 5 to 18 years of age, who had been treated for concussion at any of nine emergency departments within the Pediatric Emergency Research Canada (PERC) network. A questionnaire about the incident was completed by patients or their parents/guardians; the questions elicited information about the type of head impact, what surface impacted the head, and what area of the head was impacted, as well as a detailed description of the event. Based on the information provided by the questionnaires, the researchers were able to reconstruct individual head-impact events in their laboratory. Completed questionnaires from 233 pediatric patients (182 with TPCSs and 51 with PPCSs) had sufficient information to recreate the head-impact event.

The reconstructions of concussion scenarios were restricted to head impacts resulting from a vertical, gravity-related fall—onto the floor, grass, or ice, for example. Falls may have occurred in the home or during a sports event, from a height or standing position. Youths may

have worn helmets or been bareheaded at the time of impact. All of this information was taken into account in the reconstruction.

To simulate head impacts in youths with transient or persistent symptoms, the researchers used a headform, approximately the size of the patient's head, and a monorail drop rig that dropped the headform onto an anvil at an impact velocity estimated for each head-impact incident. The surface of the anvil impacted by the headform was covered by material corresponding to the surface struck by the patient's head: concrete, hardwood, grass, ice, etc. The angle of the headform when dropped was adjusted so that the area of impact on the headform corresponded to the site of impact on the patient's head. If the patient had been wearing a helmet and/or mask at the time of injury, a similar helmet or mask was used in the simulation.

In addition to physical models of head impact, the researchers used computational and finite element models to determine force, energy, peak linear and rotational acceleration, and maximal principal strain in brain tissue, and to measure cumulative strain damage associated with falls in the young patients. The researchers then compared values for these variables between patients with TPCSs and those with PPCSs. They found no statistically significant differences between the two patient groups for any of these variables.

The researchers also examined whether one or more of the biomechanical variables could predict the occurrence of persistent symptoms (PPCSs). Again they found no statistically significant evidence that any of the biomechanical variables examined led to PPCSs, although "a trend shown for some variables indicated larger magnitudes of response were associated with PPCSs."

An important finding in these pediatric patients was "higher brain tissue strain responses for lower energy and impact velocities than those

measured in adults, suggesting that youths are at higher risk of concussive injury at lower event severities."

Using the same techniques in head-injured adults, the researchers previously were able to identify statistically significant differences between patient groups. They offer several suggestions as to why this was not the case with youths and suggest other means by which one may be able to differentiate TPCSs from PPCSs, such as structural magnetic resonance imaging, diffusion tensor imaging, and arterial spin labeling. They also pose the possibility that PPCSs may be related more to the amount of brain tissue altered by the injury than to symptomology. Future biomechanical studies of pediatric brain injury, the investigators suggest, should include quantitative measures of the injury linked to clinical outcomes, patient predisposition, and history of concussion.

Although this study was unable to definitively identify biomechanical variables that differentiate between TPCSs and PPCSs in youths, the researchers believe it is the first biomechanical analysis of a large number of pediatric concussion cases. Thus the data collected can be used in later investigations of youth concussions, both as a reference for future studies and as validation of the physical and computation models that were used.

Details of the study are reported in the article, "Pediatric concussion: biomechanical differences between outcomes of transient and persistent (> 4 weeks) postconcussion symptoms," by Andrew Post, Ph.D., and colleagues (published online today in the *Journal of Neurosurgery: Pediatrics*).

When asked about the importance of this paper, Dr. Post stated, "This work is the first to examine the biomechanics of brain injury for youth using these types of methods. It has provided the first look into the mechanics of injury and provides a detailed dataset from which to

improve our understanding of brain trauma in pediatric populations."

More information: Post A, Hoshizaki TB, Zemek R, Gilchrist MD, Koncan D, Dawson L, Chen W, Ledoux A-A, and the Pediatric Emergency Research Canada (PERC) 5P Concussion Team: Pediatric concussion: biomechanical differences between outcomes of transient and persistent (> 4 weeks) postconcussion symptoms. *Journal of Neurosurgery: Pediatrics*, published online, ahead of print, March 28, 2017; DOI: 10.3171/2016.11.PEDS16383