

Variations in Mechanisms of Injury for Children with Concussion

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Objectives To assess the distribution of injury mechanisms and activities among children with concussions in a large pediatric healthcare system.

Study design All patients, age 0-17 years, who had at least 1 clinical encounter with an *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis of concussion in the Children's Hospital of Philadelphia's electronic health record system from July 1, 2012 to June 30, 2014, were selected (N = 8233) and their initial concussion-related visit identified. Approximately, 20% of the patients (n = 1625) were randomly selected for manual record review to examine injury mechanisms and activities.

Results Overall, 70% of concussions were sports related; however, this proportion varied by age. Only 18% of concussions sustained by children aged 0-4 were sports related, compared with greater proportions for older children (67% for age 5-11, 77% for age 12-14, and 73% for age 15-17). When the concussion was not sports related, the primary mechanisms of injury were struck by an object (30%) and falls (30%).

Conclusions Sports-related injuries in children older than 6 years of age contributed to the majority of concussions in this cohort; however, it is important to note that approximately one-third of concussions were from non-sports-related activities. Although there is increased participation in community and organized sports activities among children, a focus on prevention efforts in other activities where concussions occur is needed. (*J Pediatr* 2018;■■:■■-■■).

Youth concussion has received heightened attention in recent years owing to evidence suggesting that concussions may lead to long-term physical, behavioral, and neurocognitive effects that affect learning and school performance.¹⁻⁴ Recent estimates report an increase in the number of youth with medically attended concussion, possibly owing to increased involvement in youth sports, introduction of return-to-play legislation, and increased concussion awareness among healthcare providers, parents, and youth.^{2,5-8}

Understanding the circumstances where concussions occur can provide insights for targeting intervention efforts. Most studies of youth concussion focus on injuries sustained from participation in specific sports teams or leagues,⁹⁻¹² injuries treated in emergency departments (EDs),^{13,14} or injuries reported through systems such as High School Reporting Information online,¹⁵ a surveillance system of interscholastic sports injuries.^{15,16} As a result, most prevention efforts, including return-to-play policies, state laws, and education, are focused on athletic environments. However, like more serious brain injuries, concussions can occur via diverse mechanisms and activities beyond sports, which likely vary by age and patient demographics. Recent estimates of ED visits for all severities of traumatic brain injury (TBI) point to the importance of falls in young children up to 4 years of age.¹⁷ As children age, injuries caused by being struck by or against an object, assaults, and motor vehicle crashes (MVCs) make up greater proportions.¹⁷ Limited pediatric studies on causes of TBI in children indicate that TBI severity may be related to injury mechanism, with abusive head trauma and MVC resulting in more severe TBI.^{18,19} In addition to age, pediatric TBI mechanisms vary by sociodemographic characteristics, such as race and insurance status.²⁰⁻²²

To inform prevention efforts and promote increased care consistency, delineating the proportion of youth concussions occurring from specific mechanisms

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CHOP	Children's Hospital of Philadelphia
ED	Emergency department
EHR	Electronic health record
ICD-9-CM	<i>International Classification of Diseases, Ninth Revision, Clinical Modification</i>
MVC	Motor vehicle crash
NH	Non-Hispanic
SRR	Sports- and recreation-related (injury)
TBI	Traumatic brain injury

or activities, and describing the demographics across circumstances, is critical. Using a linked electronic health record (EHR) system in large pediatric healthcare network, we aimed in this study to (1) categorize the broad mechanisms of injury for concussions sustained by youth aged 0-17 years, (2) quantify the proportion of concussions owing to sports-related and non-sports-related activities, and (3) describe the distribution of sports-related concussions by activity level of contact.

Methods

The Children's Hospital of Philadelphia (CHOP) network encompasses more than 50 locations throughout southeastern Pennsylvania and southern New Jersey, including 31 primary care centers, 14 specialty care centers, a 535-bed inpatient hospital, 2 EDs, and 2 urgent care centers supporting more than 1 million visits annually. The CHOP network serves a socio-economically and racially diverse patient population, and accepts most insurance plans, including Medicaid. In addition to primary care clinicians, sports medicine, neurology, and trauma care providers evaluate and manage concussions using a linked EHR system (EpicCare, Epic Systems, Inc, Madison, Wisconsin). The EHR is used for managing all aspects of inpatient and outpatient clinical care, including initial office visits and all follow-up care.

Study Sample

Using the CHOP EHR database, we identified a total of 9704 patients, age 0-17 years, who visited for concussion within the CHOP network from July 1, 2012, through June 30, 2014. Visits were defined as when the healthcare provider selected an *International Classification of Diseases, Ninth Revision Clinical Modification* (ICD-9-CM) diagnosis code indicative of a concussion²³ ([Appendix](#); available at www.jpeds.com). Each patient was counted only once, using their initial visit, defined as the first clinical encounter for a concussion within the study period. Patients receiving ongoing concussion treatment during the study period but whose initial concussion visit occurred before July 1, 2012, were excluded (n = 1436). Patients also were excluded from the study if they had a moderate or severe TBI diagnosis (eg, cerebral contusion, laceration, subarachnoid, subdural, epidural, intracranial hemorrhage, and moderate [1-24 hours] or prolonged [>24 hours] loss of consciousness) within 2 weeks of the initial concussion visit (n = 35). From the remaining 8233 subjects, we selected a simple random sample of 20% (n = 1647) using the SAS surveyselect procedure (SAS Institute, Cary, North Carolina) for manual EHR abstraction to code the injury mechanism. No differences were observed in patient demographic characteristics between the underlying population and the randomly selected sample (data not shown). From the random sample, patients who met the inclusion/exclusion criteria as described (n = 1625) were manually abstracted and included in the analysis.

Injury Mechanism Coding

Injury mechanism was defined as circumstances leading up to the injury. Two trained data abstractors, blinded to study aims,

reviewed each patient's EHR narrative describing the injury and the child's activity at injury. We developed and used a structured coding system based on external causes of injury codes to categorize broad mechanism of injury: falls, MVC (occupant or pedestrian), being struck by a person (unintentional), being struck by an object, bicycle related, assault, not documented, unknown, or other. Data were coded in a hierarchical sequence based on guidelines for injury mechanism coding assignment.²⁴ If multiple mechanisms were described, the first description in the series of events was selected, except in the case of a documented head impact occurring after a non-head impact event. After broad injury mechanism was assigned, coders then categorized each concussion as either a sports- and recreation-related (SRR) injury or a non-SRR injury using a list of abstracted SRR activities agreed upon by the authors. Cases in which the SRR activity could not be identified definitively by the coders were not included in the analysis comparing SRR and non-SRR activities (n = 120). Because riding a bicycle is considered an injury mechanism and a category within recreational activities for children,^{13,14} all concussions assigned bicycle riding as the broad mechanism of were categorized as an SRR injury. SRR injuries were coded subsequently by the contact level associated with that activity using a classification system developed by the American Academy of Pediatrics' Committee on Sports Medicine and Fitness.²⁵ Categories included contact sports, sports with limited or no contact, and undetermined. Activities not included in the American Academy of Pediatrics' system were assigned categories based on the likelihood of contact or collision by consensus of the coauthors.

The abstractors received coding system training from 1 study author and achieved 100% agreement on 10 test cases before coding data. Upon coding completion, 20% of the cases were randomly assigned for agreement assessment by the lead author. Interrater reliability was excellent (Cohen kappa = .804; $P = .000$) with the observed percentage of agreement of 91%.²⁶ All disagreements were reviewed and resolved by the authors.

Other Variables

Sex, race/ethnicity, age, and insurance payor at the initial visit were abstracted from the EHR. The presence of clinically important injuries to body regions other than the brain was identified using ICD-9-CM codes 800-957, excluding minor injuries such as sprains/strains, superficial injuries, and contusions. When noted in the EHR narrative, we calculated the number of days between concussion injury and date of first visit to CHOP. Last, we classified a healthcare system point of entry for concussion care for each CHOP network patient.²³

Statistical Analyses

We determined the distribution of relevant characteristics among patients across broad mechanism of injury and SRR and non-SRR activities. To identify demographic factors that were independently associated with likelihood that a concussion was SRR vs non-SRR, we used log-binomial regression models to estimate directly risk ratios and corresponding 95% CIs. Multivariable models included sex, race/ethnicity, age at

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