HHS Public Access

Author manuscript

J Pediatr. Author manuscript; available in PMC 2018 July 03.

Published in final edited form as:

J Pediatr. 2018 June ; 197: 241–248.e1. doi:10.1016/j.jpeds.2018.01.075.

Variations in Mechanisms of Injury for Children with Concussion

Juliet Haarbauer-Krupa, PhD[1], **Kristy B. Arbogast, PhD**[2,3], **Kristina B. Metzger, PhD, MPH**[2], **Arlene I. Greenspan, DrPH, MPH, PT**[1], **Ronni Kessler, MEd**[2], **Allison E. Curry, PhD**[2,3], **Jeneita M. Bell, MD**[1], **Lara DePadilla, PhD, MPH**[1], **Melissa R. Pfeiffer, MPH**[2], **Mark R. Zonfrillo, MD, MSCE**[4], and **Christina L. Master, MD**[2,3,5]

[1]National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, Atlanta, GA

[2]Center for Injury Research and Prevention, The Children's Hospital of Philadelphia

[3]University of Pennsylvania Perelman School of Medicine, Philadelphia, PA

[4]Hasbro Children's Hospital and Alpert Medical School of Brown University, Providence, RI

[5]Sports Medicine and Performance Center, The Children's Hospital of Philadelphia, PA

Abstract

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.

Reprint requests: Juliet Haarbauer-Krupa, PhD, Division of Unintentional Injury Prevention, National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, 4770 Buford Highway, NE, MS-F62, Atlanta, GA 30341. JHaarbauerKrupa@cdc.gov.

Portions of this study were presented at the American Public Health Association Conference, November 2016, Denver, Colorado, and the International Brain Injury Association Annual Conference, March 2017, New Orleans, Louisiana.

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 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 socioeconomically 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 in-patient 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 concussion[23] (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, sub-dural, 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 initial concussion visit, and payor at the initial concussion visit. We calculated the frequency and proportion of concussions by specific SRR activities. All analyses were conducted in SAS, version 9.3 (SAS Institute Inc, Cary, NC, USA). This study was approved by the CHOP Institutional Review Board.

Results

Table I presents the characteristics at the time of initial concussion visit in the abstracted sample. Children were primarily white (68.8%), male (53.1%), and had private insurance (81.3%). Distribution of age was as follows: 4.5% were 0–4 years of age, 30.9% were 5–11 years of age, 34.5% were 12–14 years of age, and 30.1% were 15–17 years of age. In this sample, 53.4% had their initial clinical visit within primary care, 27.1% within specialty outpatient clinic, and 16.6% within ED or urgent care. Only 3.3% of this sample had other injuries at time of concussion. Approximately one-sixth of the children (15.2%) were seen on the same day of their injury; however, most children were seen 2 or more days after injury (58.3%). The injury to clinical visit is unknown for 9.8%.

Broad Mechanism of Injury

Concussions are described by broad mechanism of injury in Table I.The most common broad mechanisms were being struck by an object (31.1%), fall (29.9%), and being struck by a person (21.0%), with similar distributions among males and females. The proportion of concussions owing to falls decreased with age (71.2% of 0–4 year olds, 38.0% of 5–11 year olds, 26.9% of 12–14 year olds, and 18.8% of 15–17 year olds). These decreases were offset by increases in the proportion of concussions owing to being struck by a person or struck by

an object mechanisms as children age. Among non-Hispanic (NH) black children, the proportion presenting with assault (14.0%) or MVC (12.9%) is similar to the proportion of concussions sustained by being struck by an object (17.6%) or struck by a person (17.2%). The preponderance of injury mechanisms in NH white children and Hispanic children occurred primarily within the struck by an object, struck by a person, and fall categories as described.SRR concussions were primarily owing to being struck by an object (32.9%), falls (29.6%), and being struck by a person (29.3%). When concussions were sustained in non-SRR activities, primary mechanisms were falls (30.1%), being struck by an object (29.7%), MVC (20.0%), and assaults (15.5%). Additional injuries, such as fractured upper and lower extremities, were more likely to occur in non-SRR injury activities (58.8% of concussions with additional injuries) compared with those occurring in sports activities (41.2% of concussions with additional injuries; $P < .001$; Table I).

SRR and Non–SRR Injuries

Table II presents the demographic and characteristics of children with concussions from SRR and non-SRR activities. Although the majority of concussions were determined to be owing to an SRR (70.4%) activity, more than one-fourth (29.5%) were due to a non-SRR activity. Adjusting for payor, race/ethnicity, and sex, those 5–11 years, 12–14 years, and 15–17 years of age were more than 3 times more likely to sustain an SRR concussion versus a non-SRR concussion than 0–4 year olds. The Figure illustrates the percentage of SRR across the age span of 0–17 years. The proportion owing to SRR activities increase steadily up to age 10; from ages 10 to 16, the proportion is constant at approximately three-fourths; a small decrease occurs at age 17. Those with private insurance were 1.4 times more likely to sustain an SRR concussion versus a non-SRR concussion than those with Medicaid or who were self-pay (Table III). NH black children were less likely to have an SRR-related concussion (risk ratio of 0.8) versus a non-SRR concussion.

Classification of Sports and Recreation Activities

Table III presents SRR activities classified by contact level. The majority of SRR concussions occurred during activities involving contact or collision (57.1%), including football (15.9% of all concussions), soccer (14.7%), basketball (9.7%), ice hockey (5.4%), and lacrosse (4.2%). Several activities had undetermined contact such as playing, gym class, recess, and playground (12.8%). Cheerleading, a limited contact sport, led to 4.4% of SRR-related concussions. Playing and gym class were responsible for 3.9% and 3.6% of injuries, respectively.

Discussion

Our findings revealed that youth concussions occur from diverse mechanisms and activities that vary by age. Broadly, the most common mechanisms responsible for concussions were being struck by an object, falls, and being struck by a person. Younger children were most likely to have a concussion from a fall, whereas older children were more likely to have a concussion from being struck by an object or person. These findings align with previous estimates describing TBI-related ED visits.[17] Although sports-related injuries in children older than 5 years of age contributed to the majority of concussions in this cohort,

approximately 30% of concussions were from non–sports-related activities, with higher proportions for younger children. Specifically, for the age group of 0–4 years, fewer than 1 in 5 concussions were owing to SRR activities.

SRR activities become the primary source of concussions beginning at 6 years of age, a finding that aligns with previous reports of sports-related injuries across the lifespan.[27] The proportion of SRR concussions increased linearly to approximately three-quarters at 10 years of age, remaining constant through age 16 years. This increase corresponds with the ages when children are more likely to join organized sports, which have a higher risk compared with individual sports.[28,29] Further, this corresponds with a period in a child's life where sports exposure increases substantially owing to introduction of year-round play, or participation in multiple teams within a sport or multiple sports.[29,30] A national survey reports that 58.4% of 15- to 19-year-old high school students played on at least 1 sports team, with a higher prevalence among males (64.0%).[31] Among 17 year olds, there is slight decrease in SRR concussions that is potentially explained by an increased proportion owing to MVC. This age range aligns with independent driving initiation as well as attrition rates in adolescents withdrawing from sports.[32]

A greater proportion of males sustained SRR concussions compared with females, likely corresponding with higher rates of male participation in contact sports activities comprising the largest concussion findings. Females have a higher proportion of concussions from non-SRR mechanisms than males. Given the possible concern of sex-related factors predisposing females to non-SRR concussion, non-SRR injuries warrant further investigation.

Important differences existed across race/ethnicity and insurance payor (as a proxy for socioeconomic status). NH black children and Medicaid-insured or self-pay patients were less likely to have sustained their concussion from SRR activities. This finding warrants further study owing to epidemiologic evidence that overall sports participation are comparable among NH white, NH blacks, and Hispanic children.[33] This finding suggests that the differences in our cohort based on race and payor status may be due to other factors. It is important to note that the data analyzed do not represent incidence, but rather proportion of concussions sustained activities among those who presented for concussion care in a large health care network. The subject demographics in our analyzed cohort could be influenced by issues such as limited access to care, parents' inability to take time from work for doctor visits for what may be perceived as a "minor" injury, and varied presence of sideline health care providers in schools. Quantifying concussion incidence in demographic subgroups is an important area of future study that requires a broader sample beyond those presenting for care.

The data suggest that non-SRR concussions may be considered urgent; this condition was evident in the injury patterns and differences in time to seeking care. Approximately 60% of patients with a concussion sustaining clinically significant injuries to other body regions were injured in non-SRR activities. Further, more than one-fourth of those with non-SRR concussions sought care on the day of injury compared with just greater than 10% of those with SRR concussions. Two of the broad injury mechanisms—MVC and assault—have been previously reported as likely to cause more severe TBI.[18,19] These mechanisms typically

involve higher energy impacts that are more likely to affect multiple body regions. In addition, concussion symptoms often evolve over the subsequent hours and days after an injury, which may delay care seeking if there are no concomitant injuries.[34]

Children participate in diverse types of sports and recreational activities across the developmental age range. Although the highest number of concussions in this study occur in contact/collision sports, the results show a broad range of activities that children engage in on a daily basis, such as playing, recess, and gym class, which also can result in concussions. The combination of gym class, recess, and playground (all similar activities) would represent the fourth most common SRR activity, following football, soccer, and basketball, and ahead of ice hockey. A previous study examining all injuries in sports and recreational activities reported injuries in noncontact activities across the age span.[16] These findings highlight the importance of prevention efforts in children's activities at school and other locations outside of organized athletics to ensure that children receive quality care regardless of the injury mechanism.

Study participants were limited to those seeking care for concussion within a single healthcare network and did not include visits outside of this setting or those children who not seek care. Consequently, the findings cannot be extrapolated to represent all concussions among children in this age range. Those in the study cohort were primarily NH white children with private insurance. Although there are a limited number of papers examining race/ethnicity factors related to concussion, further examination of larger nationally representative samples would capture greater diversity. Some patients may have had more than 1 concussion during this period; however, the EHR medical record and data abstraction was not structured to identify multiple unique concussions.

In summary, the majority of concussions in this dataset were sustained by children 6 years of age and older primarily via SRR activities, as previously reported[35]; thus, concussion prevention in athletic settings is important to ensure safety for all children in sports and recreational activities. Importantly, these findings also show that approximately 30% of youth 0–17 years of age sustain concussions from activities other than sports. Having a similar index of suspicion for concussions from non-SRR falls and MVC is warranted,[36] as are efforts to promote safety in these activities. Currently, much of the work on protocols and guidelines for postconcussion care has been on return to play or organized sports. Expanding these approaches to include guidance for returning children to their previous activity level such as gym class and recess, addresses an important gap in educational efforts. Last, little is known about concussion in the very young (<5 years of age); these results suggest that they do sustain concussions, and generally from nonsports activities. Future research is needed to understand concussions in this age group, develop prevention strategies in other settings outside sports, addressing mechanisms such as falls, and to provide age-related guidance for return to activities of daily life for all children who sustain a concussion.

Acknowledgments

Supported by an intergovernmental personnel act agreement between the US Department of Health and Human Services (HHS) Centers for Disease Control and Prevention (CDC) and the Children's Hospital of Philadelphia.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the CDC. The authors declare no conflicts of interest.

Glossary

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

References

1. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Division of Unintentional. [Accessed September 3, 2015] http://www.cdc.gov/traumaticbraininjury/data/index.html
2. Institute of Medicine (IOM) and National Research Council (NRC). Sports-related concussions in youth: Improving the science, changing the culture. Washington, DC: The National Academies Press; 2013.
3. Metzl JD. Concussion in the young athlete. Pediatrics. 2006; 117:1813.doi: 10.1542/peds.2006-0480 [PubMed: 16651342]
4. Kirkwood MW, Yeates KO, Taylor HG, Randolph C, McCrea M, Anderson VA. Management of pediatric mild traumatic brain injury: a neuropsychological review from injury through recovery. Clin Neuropsychol. 2008; 22:769–800. DOI: 10.1080/13854040701543700 [PubMed: 17896204]
5. Faul, M., Xu, L., Wald, M., Coronado, V. [Accessed September 12, 2013] Traumatic brain injury in the United States: emergency department visits, hospitalizations and deaths 2002–2006. 2010. http://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf
6. Cassidy JD, Carroll LJ, Peloso PM, Borg J, von Holst H, Holm L, et al. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med. 2004; 43(Suppl):28–60.
7. Zonfrillo MR, Kim KH, Arbogast KB. Emergency department visits and head computed tomography utilization for concussion patients from 2006–2011. Acad Emerg Med. 2015; 22:872–7. [PubMed: 26111921]
8. Marin JR, Weaver MD, Yealy DM, Mannix RC. Trends in visits for traumatic brain injury to emergency departments in the United States. JAMA. 2014:311.
9. Emery CA, Meeuwisse WH. Injury rates, risk factors and mechanisms of injury in minor hockey. Am J Sports Med. 2006; 34:1960–9. [PubMed: 16861577]
10. Andersen TE, Arnason A, Engebretsen L, Bahr R. Mechanisms of head injuries in elite football. Br J Sports Med. 2004; 38:690–6. [PubMed: 15562161]
11. Guskiewicz KM, Mihalik JP, Shankar V, Marshall SW, Crowell DH, Oliaro SM, et al. Measurement of head impacts in collegiate football players: relationship between head impact biomechanics and acute clinical outcome after concussion. Neurosurgery. 2007; 61:1244–52. [PubMed: 18162904]

12. Viano DC, Casson IR, Pellman EJ. Concussion in professional football: biomechanics of the struck player, part 14. Neurosurgery. 2007; 61:313–27. [PubMed: 17762744]
13. Coronado VG, Haileyesus T, Cheng TA, Bell JM, Haarbauer-Krupa J, Lionbarger MR, et al. Trends in sports- and recreation-related traumatic brain injuries treated in US emergency departments: the National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) 2001–2012. J Head Trauma Rehabil. 2015; 30:185–97. DOI: 10.1097/htr.0000000000000156 [PubMed: 25955705]
14. Cheng TA, Bell JM, Haileyesus T, Gilchrist J, Sugerman DE, Coronado VG. Nonfatal playground-related traumatic brain injuries among children, 2001–2013. Pediatrics. 2016; 137:e20152721. [PubMed: 27244845]
15. Comstock, D. [Accessed March 31, 2016] High school RIO reporting information online. http://www.ucdenver.edu/academics/colleges/PublicHealth/research/ResearchProjects/piper/projects/RIO/Pages/default.aspx
16. Meehan WP, Hemecourt P, Comstock DR. High school concussions in the 2008–2009 academic year: mechanisms, symptoms and management. Am J Sports Med. 2010; 38:2405–9. [PubMed: 20716683]
17. Taylor CA, Bell JM, Breiding M, Xu L. Traumatic brain injury-related emergency department visits, hospitalizations, and deaths - United States, 2007 and 2013. MMWR Surveill Summ. 2017; 66:1–16.
18. Bechtel K, Stoessel K, Leventhal JM, Ogle E, Teague B, Lavietes S, et al. Characteristics that distinguish accidental from abusive injury in hospitalized young children with head trauma. Pediatrics. 2013; 114:165–8.
19. Seiger A, Goldwater E, Deibert E. Does mechanism of injury play a role in recovery from concussion? J Head Trauma Rehabil. 2015; 30:E52–6. [PubMed: 24901324]
20. Brown RL. Epidemiology of injury and the impact of health disparities. Curr Opin Pediatr. 2010; 22:321–5. DOI: 10.1097/MOP.0b013e3283395f13 [PubMed: 20375897]
21. Falcone RA, Martin C, Brown RL, Garcia VF. Despite overall low pediatric head injury mortality, disparities exist between races. J Pediatr Surg. 2008; 43:1858–64. DOI: 10.1016/j.jpedsurg.2008.01.058 [PubMed: 18926221]
22. Howard I, Joseph JG, Natale JE. Pediatric traumatic brain injury: do racial/ethnic disparities exist in brain injury severity, mortality, or medical disposition? Ethn Dis. 2005; 15(4 Suppl 5):S5-51-56.
23. Arbogast KB, Curry AE, Pfeiffer MR, Zonfrillo MR, Haarbauer-Krupa J, Breiding M, et al. Point of health care entry for youth with concussion within a large pediatric care network. JAMA Pediatr. 2016:e160294. [PubMed: 27244368]
24. Centers for Medicare and Medicaid Services & the National Center for Health Statistics (NCHS). [Accessed December 10, 2014] ICD-9-CM official guidelines for coding and reporting. 2011. https://www.cdc.gov/nchs/data/icd/icd9cm_guidelines_2011.pdf
25. American Academy of Pediatrics. Medical conditions affecting sports participation. Pediatrics. 2001; 107:1205–9. [PubMed: 11331710]
26. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1997; 33:159–74.
27. Schwebel DC, Brezausek CM. Child development and pediatric sport and recreational injuries by age. J Athl Train. 2014; 49:780–5. [PubMed: 25162780]
28. Theisen D, Frischa A, Malisouxa L, Urhausena A, Croisierc J, Seila R. Injury risk is different in team and individual youth sport. J Sci Med Sport. 2013; 16:200–4. [PubMed: 22902319]
29. Jayanthi N, Pinkham C, Dugas L, Patrick B, Labella C. Sports specialization in young athletes: evidence-based recommendations. Sports Health. 2013; 5:251–7. [PubMed: 24427397]
30. National Council of Youth Sports. [Accessed April 26, 2017] Report on trends and participation in organized youth sports. 2008. http://www.ncys.org/pdfs/2008/2008-ncysmarket-research-report.pdf
31. Centers for Disease Control and Prevention (CDC), National Center for Injury Prevention and Control. Youth risk behavioral surveillance-United States. Division of Adolescent and School Health, National Center for HIV/AIDS, Viral Hepatitis, STD & TB Prevention; 2011. http://www.cdc.gov/healthyyouth/yrbs/ [Accessed January 10, 2013]

32. DuRant RH, Pendergrast RA, Donner J, Seymore C, Gaillard G. Adolescents' attrition from school-sponsored sports. Am J Dis Child. 1991; 145:1119–23. DOI: 10.1001/archpedi.1991.02160100051022 [PubMed: 1928002]

33. Turner RW, Perrin EM, Coyne-Beasley T, Peterson CJ, Skinner AC. Reported sports participation, race, sex, ethnicity, and obesity in US adolescents from NHANES Physical Activity (PAQ_D). Glob Pediatr Health. 2015; 2:2333794. X15577944. doi: 10.1177/2333794X15577944

34. Giza CC, Hovda DA. The new neurometabolic cascade of concussion. Neurosurgery. 2014; 75:S24–33. DOI: 10.1227/NEU.0000000000000505 [PubMed: 25232881]

35. Zemek RL, Grool AM, Duque DR, DeMatteo C, Rothman L, Benchimol E, et al. Annual and seasonal trends in ambulatory visits for pediatric concussion in Ontario between 2003 and 2013. J Pediatr. 2017; 181:222–8. [PubMed: 27843008]

36. Zemekl R, Barrowman N, Freedman SB, Gravel J, Gagnon I, McGahern C, et al. Clinical risk score for persistent concussion symptoms among children with acute concussion in the ED. JAMA. 2016; 315:1014–25. [PubMed: 26954410]

Appendix. Concussion-related ICD9-CM codes

ICD-9-CM code	Description
800.02	Fracture of vault of skull w/brief (<1 h) LOC
800.09	Closed fracture of vault of skull without mention of intracranial injury, with concussion, unspecified
800.52	Open fracture of vault of skull without mention of intracranial injury, with brief (<1 h) LOC
800.59	Open fracture of vault of skull without mention of intracranial injury, with concussion, unspecified
801.02	Closed fracture of base of skull without mention of intracranial injury, with brief (<1 h) LOC
801.09	Closed fracture of base of skull without mention of intracranial injury, with concussion, unspecified
801.39	Closed fracture of base of skull with concussion, unspecified
801.52	Open fracture of base of skull without mention of intracranial injury with brief (<1 h) LOC
801.56	Open fracture of base of skull without mention of intracranial injury with LOC of unspecified duration
801.59	Open fracture of base of skull without mention of intracranial injury, with concussion, unspecified
803.02	Other and unqualified skull fractures with brief (<1 h) LOC
803.09	Other and unqualified skull fractures with concussion, unspecified
803.52	Other open skull fracture without mention of intracranial injury with brief (<1 h) LOC
803.59	Other open skull fracture without mention of intracranial injury, with concussion, unspecified
804.02	Closed fractures involving skull or face with other bones, without mention of intracranial injury, with brief (<1 h) LOC
804.09	Closed fractures involving skull of face with other bones, without mention of intracranial injury, with concussion, unspecified
804.52	Open fractures involving skull or face with other bones, without mention of intracranial injury, with brief (<1 h) LOC
850	Concussion
850.0	Concussion with no LOC
850.1	Concussion with brief LOC
850.10	Concussion with brief LOC
850.11	Concussion, with LOC of ≤30 minutes
850.5	Concussion with LOC of unspecified duration
850.9	Concussion, unspecified

LOC, loss of consciousness.

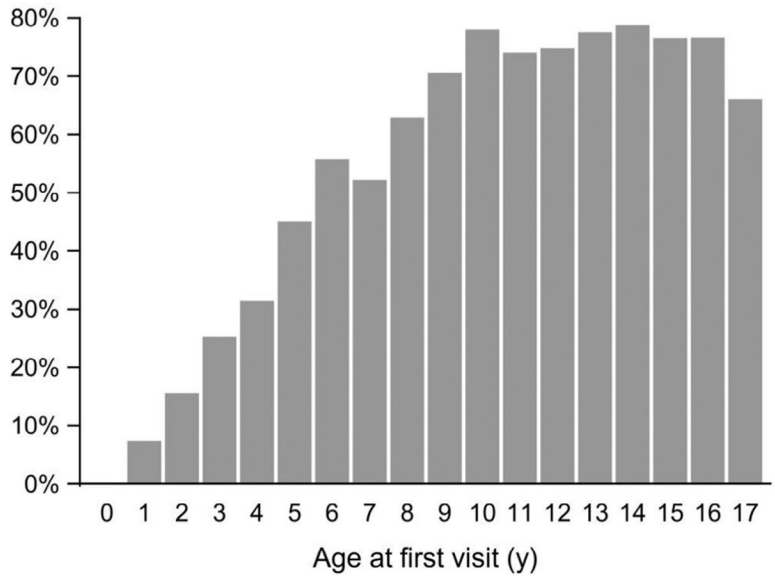

Figure.
Percentage of youth concussion with SRR activities by age in years (n = 1505).

J Pediatr. Author manuscript; available in PMC 2018 July 03.

Table I

Demographic and patient characteristics of youth concussions, overall and by broad mechanism of injury

	Broad mechanism of injury															
	All concussions		Struck by an object		Fall		Struck by a person		MVC		Assault		Bicycle related		Other	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Overall	1625	100	506	31.1	486	29.9	341	21.0	94	5.8	73	4.5	23	1.4	102	6.3
Age at first visit (y)																
0–4	73	4.5	9	12.3	52	71.2	2	2.7	5	6.8	2	2.7	1	1.4	2	2.7
5–11	502	30.9	151	30.1	191	38.0	75	14.9	32	6.4	19	3.8	10	2.0	24	4.8
12–14	561	34.5	192	34.2	151	26.9	137	24.4	21	3.7	23	4.1	8	1.4	29	5.2
15–17	489	30.1	154	31.5	92	18.8	127	26.0	36	7.4	29	5.9	4	0.8	47	9.6
Sex																
Female	762	46.9	299	39.2	217	28.5	124	16.3	54	7.1	22	2.9	4	0.5	42	5.5
Male	863	53.1	207	24.0	269	31.2	217	25.1	40	4.6	51	5.9	19	2.2	60	7.0
Race/ethnicity																
NH white	1118	68.8	373	33.4	330	29.5	242	21.6	55	4.9	29	2.6	10	0.9	79	7.1
NH black	279	17.2	49	17.6	90	32.3	48	17.2	36	12.9	39	14.0	7	2.5	10	3.6
Hispanic	58	3.6	26	44.8	13	22.4	11	19.0	1	1.7	1	1.7	2	3.4	4	6.9
NH																
Other/multiple race	43	2.6	15	34.9	13	30.2	9	20.9	1	2.3	2	4.7	1	2.3	2	4.7
Unknown	127	7.8	43	33.9	40	31.5	31	24.4	1	0.8	2	1.6	3	2.4	7	5.5
CHOP primary care patient																
Yes	1052	64.7	331	31.5	334	31.7	221	21.0	52	4.9	43	4.1	13	1.2	58	5.5
No	573	35.3	175	30.5	152	26.5	120	20.9	42	7.3	30	5.2	10	1.7	44	7.7
Insurance payor																
Private	1321	81.3	429	32.5	391	29.6	294	22.3	60	4.5	42	3.2	17	1.3	88	6.7
Medicaid	256	15.8	61	23.8	85	33.2	41	16.0	24	9.4	27	10.5	5	2.0	13	5.1
Self-pay	48	3.0	16	33.3	10	20.8	6	12.5	10	20.8	4	8.3	1	2.1	1	2.1
Other injury																
No	1572	96.7	496	31.6	469	29.8	339	21.6	83	5.3	67	4.3	19	1.2	99	6.3
Yes	53	3.3	10	18.9	17	32.1	2	3.8	11	20.8	6	11.3	4	7.5	3	5.7

	All concussions		Broad mechanism of injury													
			Struck by an object		Fall		Struck by a person		MVC		Assault		Bicycle related		Other	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
CHOP point of health care entry																
Primary care	868	53.4	291	33.5	261	30.1	203	23.4	32	3.7	25	2.9	9	1.0	47	5.4
Specialty outpatient	441	27.1	144	32.7	114	25.9	95	21.5	27	6.1	19	4.3	3	0.7	39	8.8
ED/urgent care	269	16.6	63	23.4	99	36.8	39	14.5	22	8.2	26	9.7	9	3.3	11	4.1
Hospital	47	2.9	8	17.0	12	25.5	4	8.5	13	27.7	3	6.4	2	4.3	5	10.6
Days from injury to first visit																
0	247	15.2	61	24.7	103	41.7	26	10.5	19	7.7	23	9.3	10	4.0	5	2.0
1	271	16.7	95	35.1	80	29.5	67	24.7	7	2.6	10	3.7	3	1.1	9	3.3
≥2	947	58.3	315	33.3	263	27.8	222	23.4	56	5.9	33	3.5	9	1.0	49	5.2
Unknown	160	9.8	35	21.9	40	25.0	26	16.3	12	7.5	7	4.4	1	0.6	39	24.4
Injury type																
SRR	1060	65.2	349	32.9	314	29.6	311	29.3	4	0.4	3	0.3	23	2.2	56	5.3
Non-SRR	445	27.4	132	29.7	134	30.1	17	3.8	89	20.0	69	15.5	0	0	4	0.9
Unknown	120	7.4	25	20.8	38	31.7	13	10.8	1	0.1	1	0.1	0	0	42	35.0

Table II

Distribution of demographic and patient characteristics of youth concussion

	Total		SRR injury		Non–SRR injury			
	N	%	n	%	n	%	aRR*	95% CI
Overall	1505		1060	70.4	445	29.6		
Age at first visit (y)								
0–4	68	4.5	12	17.6	56	82.4	Reference	
5–11	454	30.2	306	67.4	148	32.6	3.36	2.01–5.62
12–14	523	34.8	403	77.1	120	22.9	3.70	2.21–6.17
15–17	460	30.6	339	73.7	121	26.3	3.58	2.14–5.98
Sex								
Female	705	46.8	465	66.0	240	34.0	Reference	
Male	800	53.2	595	74.4	205	25.6	1.12	1.06–1.19
Race/ethnicity								
NH white	1029	68.4	780	75.8	249	24.2	Reference	
NH black	262	17.4	130	49.6	132	50.4	0.80	0.71–0.91
Hispanic	55	3.7	36	65.5	19	34.5	0.96	0.81–1.15
NH other/multiple race	42	2.8	26	61.9	16	38.1	0.91	0.72–1.15
Unknown	117	7.8	88	75.2	29	24.8	1.02	0.93–1.12
Insurance payor								
Medicaid/self-pay	288	19.1	132	45.8	156	54.2	Reference	
Private	1217	80.9	928	76.3	289	23.7	1.42	1.25–1.62

aRR, adjusted risk ratio.

*Multivariable log binomial regression models used to estimate the aRR and 95% CI included age at first visit, sex, race/ethnicity, and insurance payor at first visit.

Table III

Classification of SRR injuries by level of contact (N = 1060)

	n	% Group	% Sample		n	% Group	% Sample		n	% Group	% Sample		n	% Group	% Sample
Contacts or collisions*	**605**	**100**	**57.1**	**Limited contact***	**266**	**100**	**25.1**	**Noncontact***	**53**	**100**	**5.0**	**Undetermined***	**136**	**100**	**12.8**
Football	169	27.9	15.9	Cheerleading	47	17.7	4.4	Swimming	10	18.9	0.9	Playing	41	30.1	3.9
Soccer	156	25.8	14.7	Baseball	30	11.3	2.8	Dancing	8	15.1	0.8	Gym class	38	27.9	3.6
Basketball	103	17.0	9.7	Volleyball	23	8.6	2.2	Swinging	7	13.2	0.7	Playground	22	16.2	2.1
Ice hockey/hockey	57	9.4	5.4	Bike riding	23	8.6	2.2	Monkey bars	5	9.4	0.5	Recess	19	14.0	1.8
Lacrosse	45	7.4	4.2	Softball	21	7.9	2.0	Track	4	7.5	0.4	Nonspecified	6	4.4	0.6
Wrestling	26	4.3	2.5	Gymnastics	14	5.3	1.3	Tennis	3	5.7	0.3	Playing outside	4	2.9	0.4
Field hockey	22	3.6	2.1	Snowboarding	14	5.3	1.3	Running	3	5.7	0.3	Rip stick	2	1.5	0.3
Rugby	11	1.8	1.0	Ice skating	10	3.8	0.9	Hunting	2	3.8	0.2	Other¶	3	2.2	0.3
Water polo	3	0.5	0.3	Sledding	10	3.8	0.9	Roller coaster	2	3.8	0.2				
Martial arts	3	0.5	0.3	Skiing	9	3.4	0.8	Zipline	2	3.8	0.2				
Diving	2	0.3	0.2	Equestrian	7	2.6	0.7	Other§	7	13.2	0.7				
Floor hockey	2	0.3	0.2	Skateboarding	6	2.3	0.6								
Street hockey	2	0.3	0.2	Dodgeball	5	1.9	0.5								
Other†	4	0.1	0.4	Kickball	5	1.9	0.5								
				Trampoline	5	1.9	0.5								
				Squash	4	1.5	0.4								
				Go carts	4	1.5	0.4								
				Flag football	3	1.1	0.3								
				Bouncy house	3	1.1	0.3								
				Rollerskating	3	1.1	0.3								
				Playing tag	2	0.1	0.2								
				Wallball	2	0.1	0.2								
				Other‡	16	6.0	1.5								

*Definition: Contact or collision sports: Athletes purposely hit or collide with each other or with the ground, includes consistent, frequent or inadvertent contact; limited contact: contact with other athletes or inanimate objects is infrequent and/or inadvertent; noncontact: does not involve contact or inadvertent contact; undetermined: unclear about the level of contact.

†Other in contact or collision include bumper cars, floor hockey in gym class, paintball, and wrestling (playing).

‡Other in limited contact group include fencing, back flips, dirt bike riding, flipping, frisbee, kickball in gym class, laser tag, pogo stick, riding quad, scooter, surfing, tether ball, touch football, tubing, and whiffle ball.

§Other in noncontact group include crew, colorguard, kayaking, pull ups, running around, sailing, and tubing.

¶Other in undetermined group include exercising, sliding board, and physical activity at school.