EMERGENCY DEPARTMENT VISITS IN A PEDIATRIC POPULATION: AN EXAMINATION OF SPORTS AND RECREATION-RELATED INJURIES AND TRAUMATIC BRAIN INJURIES AMONG SCHOOL-AGE CHILDREN IN NORTH CAROLINA

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A dissertation submitted to the faculty at the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Epidemiology in the Gillings School of Global Public Health.

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ABSTRACT

Katherine Jean Harmon: Emergency Department Visits in a Pediatric Population: An Examination of Sports and Recreation-Related Injuries and Traumatic Brain Injuries among School-Age Children in North Carolina
(Under the direction of Stephen Marshall)

Sports and recreational activities provide numerous physical and mental health benefits. However, these activities also involve an inherent risk of injury, including traumatic brain injury (TBI). Although the relationship between sports and recreational activities and injury is well documented, there is still much to be described about the characteristics of these injuries, particularly in children. This dissertation included two studies using emergency department (ED) data to describe the burden of sports and recreation-related (SR) injuries among youth. The first study used 2010-2014 North Carolina ED visit data to describe the incidence of SR injuries among school-age youth, 5-18 years of age. The second study utilized data collected as part of a prospective study of youth, 5-17 years of age, with suspected TBIs presenting to a large, metropolitan hospital system during 2013-2014.

In our first study, we identified 767,075 unintentional injury-related ED visits among school-age youth from 2010-2014, of which 213,518 (28%) were SR-related. The incidence rate of SR ED visits among school-age youth was 23.7 ED visits per 100,000 person-years (95% confidence interval, 23.6-23.8). In comparison to other injuries among school-age youth, SR ED visits were more likely to have a diagnosis of an injury to the upper extremity, the lower extremity, and a TBI or other head, neck, or facial injury. The leading category of SR-related injury was sports/athletics played as a group or team (e.g. American tackle football).

In our second study, we identified 1,526 ED visits among school-age children with suspected TBIs enrolled in the parent study, of which 352 visits were due to SR activities. Children with suspected TBIs due to SR activities were more likely to have a history of TBI, report signs and symptoms of TBI, and require imaging services, as compared to children with injuries related to other causes.

Sports and recreation-related injury places a heavy burden on the youth population. While programs and policies exist to minimize the risk of injury due to sports and recreational activities, our finding emphasize that such prevention activities need to consider sex, age, and type of sport/recreational activity, among other factors, when assessing injury risk.

I dedicate this dissertation to my parents, Steve and Betty Harmon, who have provided me with never-ending support; to my sister Rebecca Harmon and niece Stevie Rice, who have provided me with endless joy; to my partner Sam Haney for his enduring patience; and for Evie and all the other good dogs in this world. I love you guys.

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LIST OF ABBREVIATIONS

AED	Automated External Defibrillator
ATV	All-Terrain Vehicle
BMI	Body Mass Index
CCHI	Carolina Center for Health Informatics
CDC	Centers for Disease Control and Prevention
CHIRI	Child Head Injury Research Initiative
CI	Confidence Interval
CPR	Cardiopulmonary Resuscitation
CT	Computed Tomography
E-code	External Cause of Injury Code
ED	Emergency Department
EMR	Electronic Medical Record
EMS	Emergency Medical Services
ESI	Emergency Severity Index
GCS	Glasgow Coma Scale
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification

ICD-10-CM	International Classification of Diseases, Tenth Revision, Clinical Modification
ImPACT	Immediate Post-Concussion Assessment and Cognitive Testing
IPR	Injury Proportion Ratio
IQR	Interquartile Range
IR	Incidence Rate
MRI	Magnetic Resonance Imaging
mTBI	Mild Traumatic Brain Injury
MVC	Motor Vehicle Crash
NC	North Carolina
NC DETECT	North Carolina Disease Event Tracking and Epidemiologic Collection Tool
NC DPH	North Carolina Division of Public Health
NCHS	National Center for Health Statistics
NCIPC	National Center for Injury Prevention and Control
NEC	Not Elsewhere Classifiable
NEDS	Nationwide Emergency Department Sample
NEISS	National Electronic Injury Surveillance System
NEISS-AIP	National Electronic Injury Surveillance System – All Injury Program

NES	National Health Examination Survey
NFHS	National Federation of State High School Associations
NHAMCS	National Hospital Ambulatory Medical Care Survey
NHANES	National Health and Nutrition Examination Survey
NHIS	National Health Interview Survey
NHTSA	National Highway Traffic Safety Administration
NINDS	National Institute of Neurological Disorders and Stroke
PECARN	Pediatric Emergency Care Applied Research Network
PreMIS	Prehospital Medical Information System
SR	Sports and Recreation-Related
TBI	Traumatic Brain Injury
UNC-CH	University of North Carolina at Chapel Hill
US	United States
WHO	World Health Organization
YRBS	Youth Risk Behavior Survey

CHAPTER 1: INTRODUCTION

Sports and recreation-related injuries among children and adolescents is a growing public health concern. At the national level, participation in sports and recreational activities, along with other forms of physical activity, has been promoted as a solution to the childhood overweight and obesity epidemic.[1,2] While physical activity has many benefits to childhood health and well-being, physical activity has an often neglected, and consequential health risk, injury.[3–5]

Sports and recreation-related injury (SR) is a common class of injury among United States (US) children with an annual estimate of 3.2 million medically attended SR injury episodes per year among children, 5-14 years of age.[6] While most SR injuries are relatively minor and treated in a medical clinic or outpatient setting, SR injuries may result in severe trauma or death.[6,7] Traumatic brain injuries (TBIs) are the leading cause of severe SR injury and the second leading cause of SR death, after drowning.[7,8] Even SR injuries that are not life-threatening may be profoundly disabling to the young athlete and may result in lengthy recovery periods, medical disqualification from sports participation, and surgical intervention.[9] As participation in youth sports increases, the frequency of SR injury will likely increase as well, particularly in the absence of comprehensive injury prevention programs.[10] Therefore, it is important to describe the burden of SR injury on the youth population. This dissertation approaches the problem of youth SR injury through two studies of SR injury and TBI.

The first study identified and described SR injury and TBI at the population level, while the second study characterized SR TBI presentation and treatment in one large, metropolitan hospital system. Both studies compared characteristics of SR injury to other common causes of unintentional injury among youth.

CHAPTER 2: REVIEW OF THE LITERATURE

2.1 Physical Activity and Youth Sports and Recreation

The impact of sports and recreation-related (SR) injuries among youth is of concern to clinicians, public health practitioners, policy-makers, and the public. This topic is significant because of recent efforts to encourage children to participate in physical activity and organized sports as a means of reducing rising rates of childhood obesity. While physical activity has numerous benefits in terms of physical and mental health, it is important to address the risks inherent in participation in sports and recreational activities, particularly injuries (such as traumatic brain injuries), that may lead to long-term disability or death.

2.1.1 The Emergence of Childhood Obesity as a Public Health Problem

Over the last few decades, the public health community has raised concern about a precipitous rise in the prevalence of obesity among the US population. The National Center for Health Statistics (NCHS) identified an increase in the percent of adults who had a body mass index (BMI) classified as overweight or obese (a BMI of $\geq$27.8 for men and $\geq$27.3 for women) using data collected from the National Health Examination (NHES) and National Health and Nutrition Examination Surveys (NHANES) over the years 1960-1991. During the period 1960-1980, the percent of the adult population characterized as overweight or obese increased slightly from 24.3% to 25.4%. During the following study period, 1988-1991, the percent of the US adult population characterized as overweight or obese increased to an estimated 33.3%.[11]

NCHS followed their adult study with an examination of children, in their follow-up study, NCHS classified 10.9% of children overweight or obese during the period 1988-1991.[12] The proportion of youth characterized as overweight or obese has continued to increase since the early 1990s. In 2000, 15.3% of 6-11 year-olds and 15.5% of 12-17 year-olds were characterized as overweight or obese. The prevalence of overweight among black (non-Hispanic) and Hispanic children was considerably higher than white (non-Hispanic) children.[13] Recent studies have suggested that the percentage of US children that are overweight or obese may have plateaued. During the period 2015-2016, the prevalence of obesity (18.5%) among youth had not changed significantly since 2013-2014 (17.2%).[14,15]

Although the prevalence of overweight and obesity has plateaued over the last few years, it remains an important public health problem. For one, overweight and obese children are more likely to be overweight and obese as adults than their normal weight peers.[16] Other long-term health risks associated with elevated BMI in childhood and adolescence include cardiovascular disease, diabetes, cancer, and premature mortality, although much of the excess risk of these latter conditions may be at least partially explained by the persistence of obesity into adulthood.[17–22]

Notwithstanding the long-terms risks associated with obesity, childhood overweight and obesity carries considerable short-term health risks as well.[23,24] Childhood overweight and obesity carries a considerable burden in terms of social consequences and mental well-being. For example, evidence suggests that obese children are more likely to be the subject of bullying and to suffer low self-esteem than their non-obese peers.[25] In addition, childhood obesity is associated with cardiovascular and metabolic comorbidities similar to those observed among adults, such as elevated blood pressure, dyslipidemia, and insulin resistance.[26] Although rates of

Type I diabetes are still higher than Type II diabetes among US youth 0-19 years of age (except among American Indians), the prevalence of Type II diabetes among US children has increased by 30.5% during the period 2001-2009.[27]

Researchers have suggested a number of public health interventions to combat childhood obesity. In general, these interventions have centered on two major lifestyle components: eating less and exercising more. In practice, most of these interventions have focused on the family and the school.[2,28] In 1996, the Surgeon General issued a report outlining the benefits of physical activity on human health and in 2001, the Surgeon General followed up this report by issuing a Call to Action for the American public to engage in routine physical activity as a means of maintaining a healthy weight and preventing overweight and obesity.[29,30] The Surgeon General's 2001 Call to Action recommended that youth participate in a minimum of 60 minutes of physical activity per day.[30] However, few children meet recommended daily levels of physical activity.[31]

2.1.2 Physical Activity

Physical activity is a generic term that refers to any bodily movement that raises energy expenditure over a basal level. In addition to organized sports activities, examples of physical activities include aerobics, weightlifting, yoga, gymnastics, running, swimming, and unstructured active play. As children enter adolescence, patterns of physical activity often change from less structured (e.g. running, jumping, playing, etc.) to more structured activities (soccer, tennis, golf, etc.).[32] Since physical activity encompasses a large range of activities, many of which are unstructured and unsupervised, it is difficult to measure and, consequently, estimates vary. In general, younger children are more likely to engage in vigorous physical activity than older children and teenagers and boy are more likely to engage in physical activity than girls. There is general consensus that less than half of all youth meet the recommended daily physical activity level of 60 minutes per day, most days per week.[31–33]

2.1.3 Youth Sports Participation

Estimates of youth participation in sports and other forms of physical activity vary according to the specific study definition used to constitute "physical activity". The National Federation of State High School Associations (NFHS) estimated a total of 7.8 million US high school students participated in at least one organized sport based on survey results of 51 NFHS member state high school associations. The total number of high school sports participants nearly doubled between 1971-1972 and 2013-2014. Among boys, the sport with the highest number of participants was American tackle football (Table 2.1) and for the girls it was outdoor track and field (Table 2.2). In terms of participation in organized school sports, the NFHS ranked NC as the 13th highest in participation with a total of 194,352 high school participants.[10]

The Youth Risk Behavior Survey (YRBS), a cross-sectional survey of high school youth behaviors, reported that over one-half of all high school students (57.6%) participated in at least one school or community sports/athletics team during the past year. This percentage was higher among boys (62.2%) than girls (53.0%).[31] Less information is available in regards to organized sports participation among elementary and middle school athletes and participation in non-scholastic sports (e.g. youth leagues such as Little League Baseball).

TABLE 2.1 Ten most popular athletic programs in terms of US high school participation among boys– National Federation of State High School Associations, 2014-2015[10]

Rank	Sport/athletics	No. of participants
1	Football	1,083,617
2	Track and field (outdoor)	578,632
3	Basketball	541,479
4	Baseball	486,567
5	Soccer	432,569
6	Wrestling	258,208
7	Cross country	250,981
8	Tennis	157,240
9	Golf	148,823
10	Swimming and diving	137,087
	Other sport/athletics	444,109
TOTAL		**4,519,312**

Abbreviations: No., number

TABLE 2.2 Ten most popular athletic programs in terms of US high school participation among girls– National Federation of State High School Associations, 2014-2015[10]

Rank	Sport/athletics	No. of participants
1	Track and field (outdoor)	478,726
2	Volleyball	432,176
3	Basketball	429,504
4	Soccer	375,681
5	Softball	364,103
6	Cross country	221,616
7	Tennis	182,876
8	Swimming and diving	166,838
9	Cheerleading	125,763
10	Lacrosse	84,785
	Other sport/athletics	425,667
TOTAL		**3,287,735**

Abbreviations: No., number

As mentioned previously, routine physical activity, along with a healthy diet, is one of the most commonly suggested solutions to the childhood overweight and obesity epidemic.[2,34] In addition to maintaining a healthy weight, youth participation in physical activities, such as sports/athletics, is associated with lowered blood pressure, improved cognitive functioning, and improved overall well-being.[3,35,36] Despite these many health benefits, participation in physical activity can have some negative health consequences, primarily injury.

2.1.4 Epidemiology of Injuries Related to Sports and Recreational Activities

The association between volume of physical activity and overall risk of acute traumatic sports and recreation-related (SR) injury is well-documented. An estimated 38% of high school children and 34% of middle school children will have a SR injury requiring medical attention.[37] Although fatalities are rare, serious injuries related to SR injury do occur and may result in costly medical treatment, lengthy hospitalizations, and long-term disability. Medical record reviews have indicated that the sports and recreational activities associated with high lethality include bicycling, football, off-road motor sports (e.g. all-terrain vehicles), swimming, mountaineering, and equestrian activities.[7,8,38]

It is far more common for SR injuries to require acute medical care in a primary and/or emergency department (ED) setting than hospitalization or death. Results from the 1997-1999 National Health Interview Survey (NHIS), a nationally representative sample of 30,000-40,000 US households in which respondents were queried about their and their children's health, indicated that a total of seven million Americans required medical treatment for a SR injury per year.[39,40] Nearly two-thirds of Americans (4.5 million individuals) treated for sports and recreation-related injuries were 5-24 years of age. The annual rate of medically attended sports and recreation-related injuries were 59.3 injury episodes and 56.4 injury episodes per 1,000 person-years for 5-14 and 15-24 year-olds, respectively. Although this study did not differentiate between the types of medical treatment that the patient received (e.g. treatment at an outpatient facility versus treatment at an ED), the authors estimated that 58% of individuals 5-24 years of age visited an ED for medical treatment by comparing their results to a separate study examining National Hospital Ambulatory Medical Care Survey (NHAMCS) ED visit data (described in the following paragraph).[40,41] According to the NHIS, the most common activity associated with injury among children 5-14 years of age was pedal cycling; among persons 15-24 years of age, basketball was the most common cause of injuries. The most common types of injuries observed in this study were strains and sprains of the upper and lower extremities.[40]

A contemporary study used NHAMCS ED visit data (a probability sample of 486 US EDs in which sports injuries were identified from the narrative text of the ED encounter record) to estimate nationwide incidence of ED visits related to sports injuries. This study estimated that there were 2.6 million ED visits (out of a total of 3.7 million ED visits by persons of all ages) related to sports injuries among 5-24 year-olds per year (33.9 ED visits per 1,000 person-years; 95% CI: 30.3-37.5). Similar to the NHIS study, both pedal cycling (5.5 visits per 1,000 person-years; 95% CI: 4.5-6.5) and basketball (5.8 visits per 1,000 person-years; 95% CI: 4.7-6.8) were the two most common sports mechanisms associated with injury. In addition, patients with sports-related injuries were more likely to have a fracture or sprain/strain than patients with other types of injuries.[41]

A third study using 2008 data from the Nationwide Emergency Department Sample (NEDS) database, a nationally representative sample of all-payer ED visit discharge data, estimated that there were over 400,000 sports-related ED visits among 13-19 year-olds.[42,43] Although this study did not calculate incidence rates, one can estimate an unadjusted incidence rate of 14 ED visits per 1,000-person-years using Centers for Disease Control and Prevention (CDC) Bridged-Race Population Estimates for 2008.[44] This rate seems somewhat low in comparison to the other two morbidity studies. Unlike the previously mentioned studies, this study used a case definition based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) External Cause of Injury Codes (E-codes). While the public health community makes frequent use of ICD-9-CM-based case definitions, this particular definition seemed somewhat restrictive and included only three sports-related E-codes (E886.0: fall on same level from collision, pushing, or shoving, by or with other person in sports; E917.0: striking against or struck accidentally by objects or persons in sports; E917.5: striking against or struck accidentally by object in sports with subsequent fall). The NEDS study determined that the mean cost for a sports-related ED visit among youth 13-19 years of age was $1,205 (assumed to be 2008 dollars). For the 1.6% of youth who were hospitalized for their injuries, the mean length-of-stay was 2.4 days and the mean hospital charge for ED and inpatient care was $22,703.[43]

The studies referenced above all utilize data that are over five years old, rely on probability samples, and are national (rather than state-specific). Aim 1 of this study describes SR injuries among youth in NC using a census of all 24/7 civilian acute-care hospital-affiliated EDs in NC. Part of Aim 1 was the development of a SR case definition based on assigned E-codes used with hospital administrative data sets. This SR injury case definition is more inclusive than previous ICD-9-CM-based case definitions and does not require the lengthy and resource-intensive process of abstracting data from the narrative text. Through the development and application of this novel case definition, we have a better understanding of the burden that SR injuries place on the state of North Carolina.

Although sprains, strains, and fractures of the extremities are the most common injuries associated with sports and recreational activities, traumatic brain injuries (TBIs) are one of the most common causes of *severe* injury.[7] TBIs are the most common sports and recreation-related injury to lead to hospitalization and death.[32] The focus of Aim 2 of this dissertation is the epidemiology of youth SR TBIs treated in a large, metropolitan hospital system.

2.2 Traumatic Brain Injury

Traumatic brain injury (TBI) is a serious public health problem. This section will provide a brief overview of the epidemiology of TBI and the epidemiology of TBIs among youth sports participants.

2.2.1 Definition of a Traumatic Brain Injury

According to the National Institute of Neurological Disorders and Stroke (NINDS), a TBI is a type of injury that occurs when "sudden trauma causes damage to the brain."[45] Injuries may result when the skull comes into contact with an external force or object or when a foreign body penetrates the skull and damages the neural tissue. TBIs are often classified according to their external mechanism of injury. Examples of common TBI mechanisms include contact with other persons (such as contact with a fist during a fight or brawl), objects (such as contact with a soccer ball), forces generated from blasts or explosions, a sudden acceleration or deceleration of the brain without direct trauma to the head, or foreign bodies penetrating the brain.[46]

There is a variety of clinical guidelines available for the diagnosis of TBI. Clinicians classify TBIs using methods that take into account factors such as presentation (closed versus penetrating), clinical severity (e.g. Glasgow coma scale), and neuroimaging results.[47,48] TBIs are often categorized by their perceived clinical severity. Typical designations for TBI are mild, moderate, and severe. However, TBIs may be difficult to diagnose, even in a healthcare setting.

The criteria for assigning TBI severity are not standard across all medical organizations.[46] To further complicate matters, the term "mild TBI (mTBI)" is often used interchangeably with the term "concussion."[49] In discussion of the literature, this dissertation will use the term TBI to refer to concussions and more severe TBIs, noting that such terminology is not used consistently across all studies.

In the 1990s, the Centers for Disease Control and Prevention (CDC) developed a surveillance definition for identifying TBIs using hospital administrative data routinely collected by state public health systems based on a definition described in its 1995 publication "Guidelines of Central Nervous System Injury".[50] The original project encompassed four states (later expanded to 14 states) and used the ICD-9-CM codes: 800.0-801.9 (fractures of the vault or base of the skull), 803.0-804.9 (other and unspecified multiple fractures of the skull), 850.0-854.1 (intracranial injury), and 959.01 (head injury, unspecified [beginning October 1, 1997]) to identify TBI cases in population-based data.[51,52] Although the CDC found greater than expected differences in rates across the states, reflecting both individual state differences as well as differences in case ascertainment methodology, this project marked the first time that the CDC had used population-level data for surveillance of nonfatal TBIs.[52] A few years later, the CDC would add the following ICD-9-CM codes to the surveillance definition: 950.1-950.3 (injury to the optic nerves and visual cortex) and 995.55 (shaken infant syndrome).[53]

The CDC has incorporated its TBI case definition into its routine national TBI surveillance and regularly reports results in publications such as special emphasis reports, other governmental reports, fact sheets, and *Morbidity and Mortality Weekly Report* articles.[51,52,54–58]

Researchers affiliated with academic institutions have also used the CDC TBI case definition for public health research. Some of these studies attempted to quantify the ability to which the CDC TBI case definition (based largely on ICD-9-CM codes) captured “true” TBI cases in hospital discharge and/or ED data. When ICD codes were introduced in 1900, their primary function was to classify morbidity and mortality information for various statistical purposes. Today, ICD-9-CM codes captured in hospital administrative databases serve as the basis for hospital reimbursement for the treatment of disease and injuries. However, these codes also play an important role in epidemiology and health services research. The accuracy of ICD-9-CM diagnosis codes depends on a variety of factors, including communication between patient and clinician, clinician training and experience, communication between clinician and medical coder through the medical record documentation, medical coder training and experience, nuances of hospital-level informatics and data systems, and administrative quality-control initiatives.[59] One study found that 19% of injury-related hospital discharges had an error in the principle diagnosis code when compared to the medical record. However, most of these errors were minor and involved the last two digits of the diagnosis code. The researchers identified the following factors as being associated with a greater likelihood of error: length of stay > one day, type of injury (e.g. fractures), and death as the outcome.[60]

Among those studies that have examined the CDC TBI case definition directly, sensitivity is generally high for identifying the presence of any TBI when compared to the medical record (89%); however, the definition is not as successful in identifying the specific type of TBI (e.g. closed skull fracture).[61] Two studies that examined patients with “mild” TBIs found that the CDC case definition did not accurately capture the incidence of patients with mTBIs.[62,63] In one of these studies, the authors found that the CDC case definition had a low sensitivity (45.9%) and high specificity (97.8%). Patients who were false-positive for a mTBI were more likely to have an ICD-9-CM code for an unspecified head injury and were more likely to be intoxicated at the time of arrival at the ED.[62] A third study examining the CDC TBI surveillance case definition found reasonable agreement between hospital discharge data and medical record data in regards to skull fractures and intra-cranial lesions, with a PPV of 72.1% (κ = 0.73) and 89.5% (κ = 0.83), respectively. Since the study authors sampled only positive cases of TBI, they were unable to calculate sensitivity or specificity.[64]

Few studies have examined the CDC TBI case definition in a pediatric population. One study compared the CDC case definition with the National Electronic Injury Surveillance System (NEISS) case definition for capturing TBI among children < 18 years of age. In this particular study, the CDC TBI case definition was considered the "gold standard". The two definitions had a percent agreement of 71.1%. For cases that did not agree, the most common reason was that the cases were coded as having lacerations and contusion to the head rather than a TBI according to one or the other definitions.[65]

This dissertation used two different methods to identify TBI. In Aim 1, SR TBIs were identified using the CDC TBI case definition. In Aim 2, cases of suspected TBI were directly identified in the ED by the attending clinicians.

2.2.2 Epidemiology of Traumatic Brain Injury

TBI is a common, and potentially life-threatening, injury. In 2009, there were an estimated 2.4 million combined ED visits, hospitalizations, and deaths due to TBIs. In addition, there were another 1.2 million visits to outpatient centers and office-based practices for incident or follow-up care. The US incidence of TBI morbidity as seen in EDs has increased in recent years with age-adjusted rates of TBI-related ED visits increasing from 434.1 visits per 100,000 person-years in 1995 to 686.0 visits per 100,000 person-years in 2009 (Figure 2.1). On the other hand, mortality rates decreased over this same period, from 19.9 deaths per 100,000 person-years in 1995 to 16.6 deaths per 100,000 person-years in 2009.[66] This increase in the rate of TBI-related ED visits may be related to increased awareness of the dangers posed by TBIs through such media campaigns as the CDC's *Heads Up* program and through the passage of state legislation aimed at preventing disability and death due TBIs sustained during school activities.[67,68] The decrease in mortality rates may be at least partly explained by a dramatic decrease in motor vehicle fatalities over this same period, improvement in trauma management, and increased adoption of preventative measures such as seatbelts and helmets.[69,70]

TBIs impose a considerable burden on the population of NC. In 2010, TBIs accounted for nearly a third of all injury fatalities in the state.[71] In 2009, the NC mortality rate was 19.4 deaths per 100,000 person-years, considerably higher than the national rate (16.6 deaths per 100,000 person-years).[66,71] In terms of ED visits, a recent descriptive epidemiologic study documented a rate of 7.6 NC ED visits per 1,000 person-years in 2011; this represented an 8.6% increase over the 2010 rate (7.0 ED visits per 1,000 person-years).[72]

Nationally, the leading mechanisms of TBI-related ED visits, hospitalizations, and deaths are: falls (28%), motor vehicle traffic-related collisions (20%), struck by an object or person (19%), assaults (11%), pedal cycle collisions (3%), other transportation-related collisions (2%), self-inflicted injuries (1%), other specified injury mechanisms (7%), and unknown injury mechanisms (9%).[73] North Carolina ED visit data displayed a similar pattern of injury, with unintentional injury mechanisms, such as falls, accounting for the majority of visits (Table 2.3).[72] This may be related to the choice of study population (ED visits, hospitalizations, and deaths versus just ED visits). Many common unintentional injury mechanisms (e.g. falls) have a lower mortality rate than common intentional injury mechanisms (e.g. assault by firearms).

FIGURE 2.1 Age-adjusted rates per 100,000 person-years for traumatic brain injury-related emergency department visits, hospitalization, and deaths, by year – United States, 1995-2009[66]

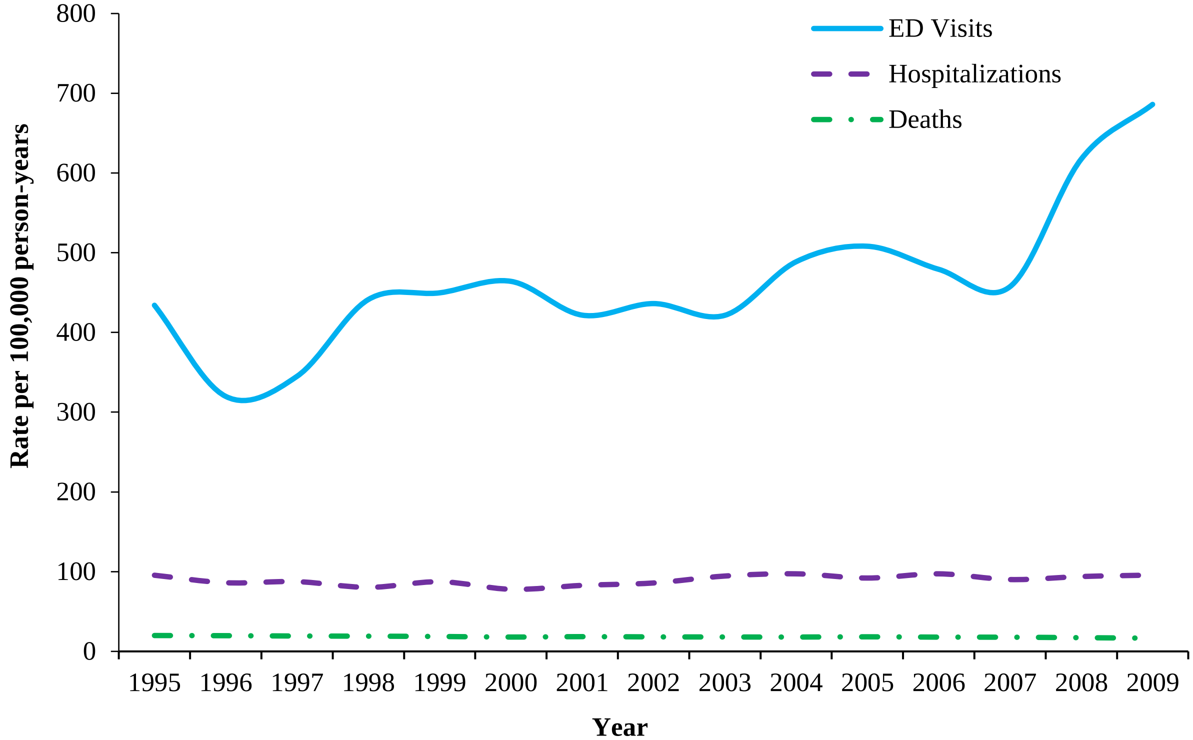


TABLE 2.3 Intent and mechanism of injury among traumatic brain injury-related emergency department visits – North Carolina, 2010-2011[72]

Intent	Mechanism	Percent of ED visits
Unintentional		72.3%
	Falls	39.0%
	MVTC	14.1%
	Struck by/against	12.7%
	Other/Unspecified	6.5%
Assault		8.6%
Self-harm		0.1%
Undetermined intent		0.1%
Adverse effects of medical care		0.2%
Not classifiable[a]		18.6%

Abbreviations: ED, emergency department; MVTC, motor vehicle traffic-related crash
[a]Includes ED visits in which the External Cause of Injury Code (E-code) was missing or did not code for an injury mechanism (e.g. Place of Occurrence E-code).

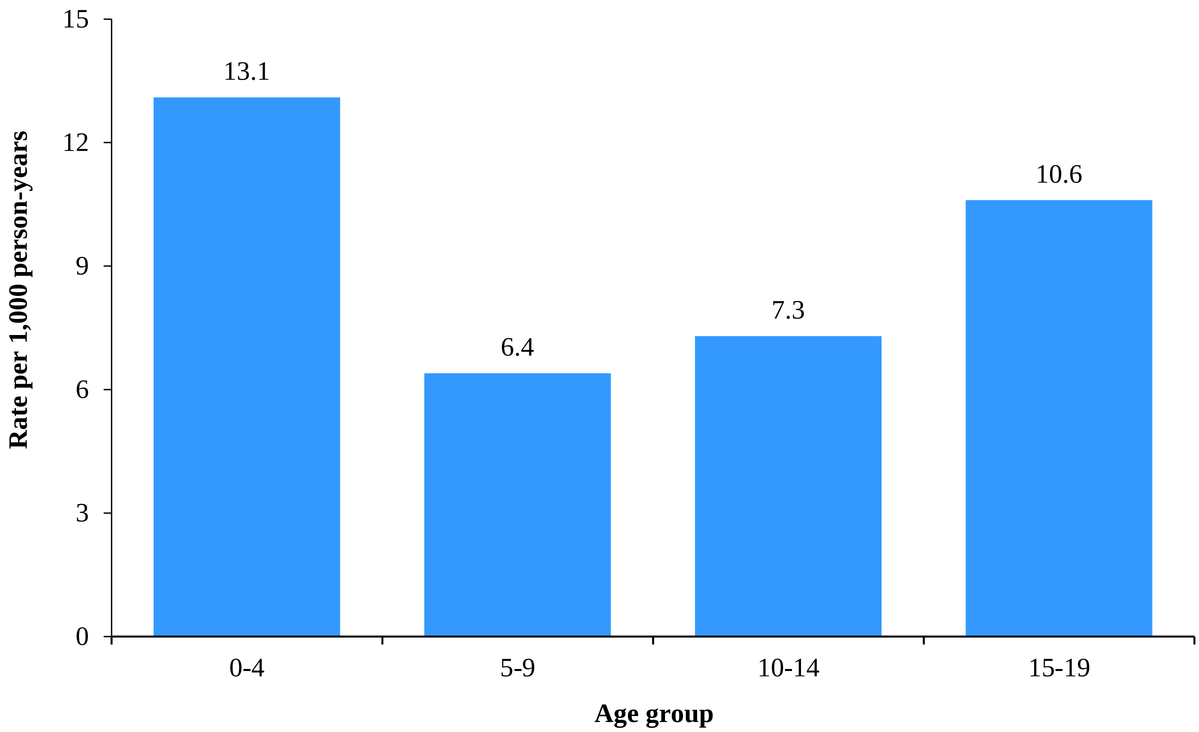
2.2.3 Epidemiology of Traumatic Brain Injury among Youth

A 2005 study pooled data from three sources: National Vital Statistics System, National Hospital Discharge Survey (NHDS), and NHAMCS for estimating the total combined number of TBI-related deaths, hospitalizations, and emergency department visits for the period 1995-2001. This study estimated that an average of 475,000 TBIs resulted in emergency medical treatment or death among US children 0-14 years of age. Among these 475,000 cases, 91.6% resulted in an emergency department visit (treated and released, only), 7.8% resulted in a hospitalization, and 0.6% resulted in a death. The annual rate of TBI-related deaths among US children 0-14 years of age was 4.5 deaths per 100,000 person-years. Children 0-4 years of age had the highest mortality rate, compared to children 5-9 years and 10-14 years of age (5.7, 3.1, and 4.8 deaths per 100,000 person-years, respectively). Children 0-4 years of age also had a higher rate of TBI-related ED visits than children 5-9 and 10-14 years of age (1,035.0, 603.3, and 567.0 visits per 100,000 person-years, respectively). US mortality rates were higher for black children (6.0 deaths per 100,000 person-years) than white children (4.3 deaths per 100,000 person-years), but overall rates of hospitalizations and ED visits did not differ by race.[74]

A second study used data from the Kids' Inpatient Database (KID), a stratified random sample of over 2,000 nonfederal hospitals from 27 states, to examine healthcare utilization patterns by pediatric TBI patients. This study estimated that there were more than 50,000 TBI-related hospitalizations among US children ≤17 years of age in the year 2000. This study also found that the median LOS in the KIDs database was two days with a median hospital charge of $8,056 (assumed 2000 dollars). In general, older age was associated with a longer length of stay and a higher total hospital charge.[75]

Among NC youth, rates of TBI related ED visits peak among at 0-4 years of age and 15-19 years of age (Figure 1.2). Among children 0-14 years of age, the most common injury mechanism is falls; however, the most common injury mechanism among teenagers 15-19 years of age is motor vehicle collisions.[72]

FIGURE 2.2 Youth rates of traumatic brain injury-related emergency department visits stratified by age group – North Carolina, 2010-2011[72]



2.2.4 Epidemiology of Traumatic Brain Injury among Youth Engaged in Sports and Recreational Activities

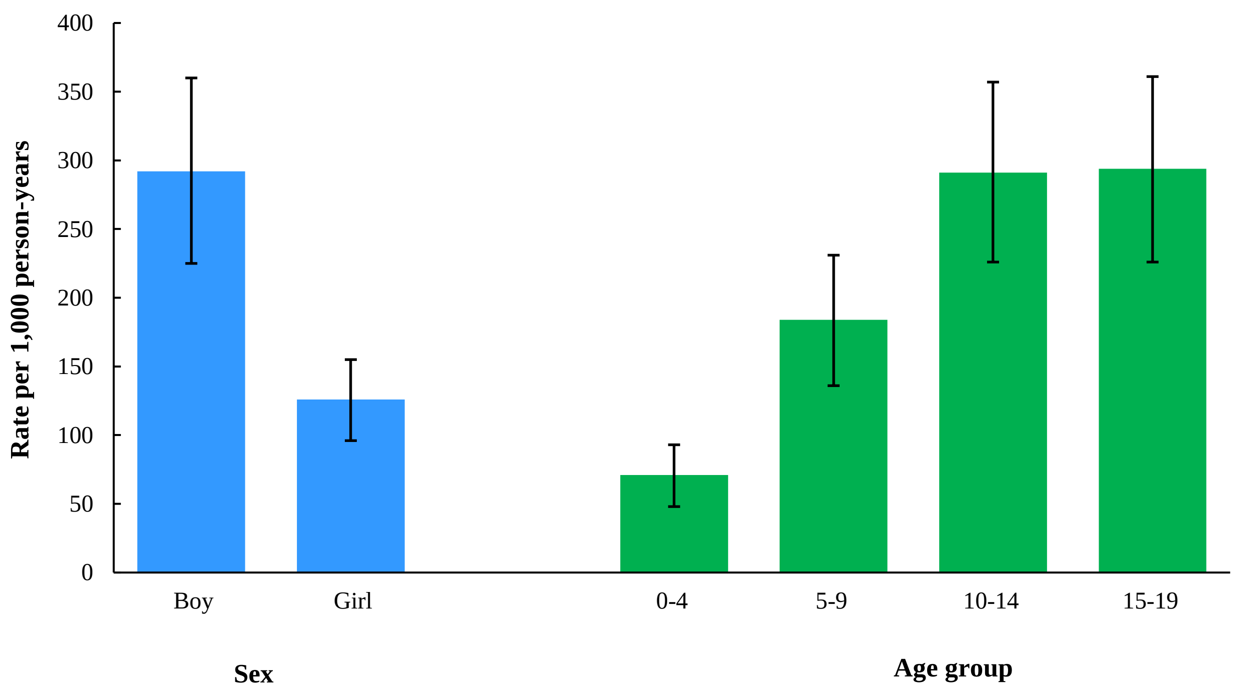
Although TBIs are not the most common type of injury associated with sports and recreational activities, they are the most likely type of injury to lead to hospitalization, disability, and death.[7] A 2007 study using a national probability sample of EDs estimated that there were 4.0 million US ED visits due to sports and recreational activities per year, of which 5.1% of visits were due to TBIs. TBI incidence was higher among children than the incidence among adults. In particular, boys, 10-14 years of age, had the highest incidence of sports and recreation related TBIs across the age spectrum.[76]

A 2011 update to this study estimated the number of ED visits related to sports and recreational activities among youth ≤ 19 years of age to be 2.7 million ED visits per year, of which 6.5% were due to TBIs. The proportion of SR ED visits due to TBI varied by age group with children ≤ 4 years of age having the highest proportion of TBI (9.1%) related to sports and recreational activities. For the remaining age groups, 5-9, 10-14, and 15-19, the proportion of SR ED visits due to TBIs was 6.9%, 5.6%, and 7.0%, respectively. Over the study period, the annual rate increased from 190 visits per 100,000 person-years in 2001 to 211 ED visits per 100,000 person-years in 2009 (Figure 2.3).[57]

Among youth ≤ 19 years of age, the activities with the highest proportion of TBIs were equestrian activities, ice-skating, volleyball, all-terrain vehicle (ATV) riding, and sledding. Among boys, the activities with the highest population-based rates of TBI were football, bicycling, playground activities, basketball, and baseball. Among girls, the activities with the highest TBI incidence were playground activities, bicycling, soccer, basketball, and equestrian activities.[57]

The two studies described in the preceding paragraphs utilized National Electronic Injury Surveillance System--All Injury Program (NEISS-AIP) data in their analyses. These data are collected from a "nationally representative" sample of 66 NEISS hospitals with a minimum of six beds and a 24/7 acute-care ED. This sample was drawn over 4 decades ago, and has never been updated or regenerated.[57,76] Although NEISS-AIP data are important for the calculation of national incidence rates, NEISS-AIP data cannot be used for estimates at the state or county level. The AIM 1 study described in this dissertation used a population-based ED visit data source that facilitated the direct calculation of incidence rates at both the state and county level. It is one of the first studies to estimate incidence at the state level using population-based ED visit data.

FIGURE 2.3 Estimated annual rate (per 100,000 person-years) of emergency department visits for all nonfatal traumatic brain injuries related to sports and recreational activities among youth aged ≤19 Years, by selected characteristics and 95% confidence intervals — NEISS-AIP, United States, 2001–2009[57]



2.3 Importance of Injury Surveillance

The discipline of epidemiology provides a variety of research design strategies that are appropriate for the study of youth sports and recreation-related injuries. Therefore, why use public health surveillance methods for the investigation of these types of injuries? Despite some weaknesses, public health surveillance using secondary data sources has considerable strengths in terms of cost, timeliness, and representativeness. In addition, these methods may be deployed in a variety of settings and when resources are scarce. It is these benefits, to be discussed in more detail in the following paragraphs, which make public health surveillance a useful tool for identifying and describing youth sports and recreation-related injuries.

2.3.1 Overview of Public Health Surveillance

The definition of public health surveillance is "the ongoing, systematic collection, analysis, interpretation, and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and mortality and to improve health."[77] Public health surveillance provides many important functions, such as describing the size and distribution of an emerging public health problem, monitoring trends related to an existing problem, evaluating the impact of an intervention or other prevention or control measure, aiding community planning and prevention efforts, and generating research hypotheses.[78] Historically, public health surveillance has focused on infectious disease events such as outbreaks of foodborne illness and sexually transmitted infections. However, as the public health community has become more aware of the preventability of injuries, in much the same way as other health conditions, efforts have been made to design and implement injury surveillance programs.[79] Since their widespread implementation, injury surveillance programs have become central to the development, execution, and evaluation of injury prevention initiatives at the local, state, and national level.[80]

Surveillance systems may take many different forms. The design of the surveillance program depends on the scientific focus, the needs of the community, and the resources available.[81] Surveillance programs are often designated as active or passive. A *passiv*e surveillance system is one in which cases are identified from a system in which data are collected primarily for some other purpose, such as the collection of routine health information from hospital records for which the primary purpose is of patient care, hospital administration, and billing. On the other hand, an *active* surveillance system is one in which investigators directly seek out and identify cases from the community or healthcare setting. Although active surveillance systems often perform better than passive surveillance systems for identifying cases of disease or injury, they tend to require more resources to implement and maintain.[82]

Aim 1 utilized NC ED visit data collected by a passive surveillance system, the NC Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT), for identifying SR ED visits among school-age youth. NC DETECT collects ED data, along with Carolinas Poison Center and Prehospital Medical Information System (PreMIS) data, in near real-time. The NC DETECT ED data are collected from all 24/7 acute-care civilian hospital affiliated NC emergency departments as part of a statewide mandate.[83]

There are considerable benefits (and limitations) of using secondary data sources, such as NC DETECT ED data, for research purposes. One benefit of using a population-based secondary data source is representativeness.[84] NC DETECT ED data are collected from all 24/7 acute care civilian hospital affiliated NC EDs and, therefore, findings based on NC DETECT ED data should be generalizable to the entire population of NC. Theoretically, NC DETECT captures all visits from qualifying EDs in the state, thus permitting the direct calculation of population-based incidence rates. In reality, NC DETECT misses some ED visits due to unforeseen circumstances (e.g. hospital data outages); however, the complete loss of NC DETECT ED data are believed to minimal (<1% of total NC ED visits).[85]

In addition to representativeness, secondary data sources tend to be more cost-efficient than other types of data sources. The collection of raw data can be expensive, time-consuming, labor-intensive, and at times poses a serious ethical consideration (depending on the nature of the data). On the other hand, secondary data sources are not designed with the specific purpose of public health surveillance, and so they may be somewhat limited in terms of the data collected. For example, administrative data may only contain information required to process payment for services and may exclude pertinent clinical information that is helpful for research but of less value for billing. Fields that are not required for payment, such as those designating injury mechanism, may not be as complete as those fields that are directly required for payment. Although the usefulness of secondary data sources depends on both the study question and the nature of the specific data set, multiple studies have demonstrated reasonable agreement between the diagnoses and procedures documented in the administrative database and those documented in the corresponding medical records.[84,86]

CHAPTER 3: STATEMENT OF SPECIFIC AIMS

The purpose of this dissertation is to describe youth injuries due to sports and recreational activities in North Carolina. As youth are encouraged to participate in sports and other forms of physical activity as a means of combating escalating obesity rates, it is plausible that the incidence of sports and recreation-related (SR) injuries may increase. The current literature indicates that SR injuries are relatively commonplace, costly, and, at times, disabling and even life-threatening. Because of their inherent severity, traumatic brain injuries (TBIs) due to sports and recreation-related injuries are a focal point of this research. In order to describe the burden of injuries due to sports and recreational activities, this dissertation contains two separate, but related, studies.

3.1 Aim 1: Incidence of Sports and Recreation-Related Injuries in North Carolina among School-Age Youth

The first study used population-based NC emergency department (ED) visit data for determining the incidence of youth SR injuries in NC. Although several studies have provided estimates of the incidence of SR injuries at the state or national level, this study has characteristics that make it unique. These characteristics include the use of a statewide ED data source and the development of a new ICD-9-CM-based case definition for surveillance purposes. Each of these features are discussed in the next two paragraphs.

One strength of this dissertation is the use of statewide ED data rather than mortality, trauma registry, or hospital discharge data for estimating incidence. Most of the current literature on the incidence of SR injuries relies on the use of mortality (e.g. vital statistics), trauma registry, and/or hospital discharge data. Although SR injuries are often serious and require medical treatment, they rarely result in death and a low proportion are catastrophic.[87] Among patients who require treatment in the ED, few are admitted to the hospital and even fewer patients die from these injuries. Therefore, the selection of ED visit data serves as a more suitable data source for describing the incidence of SR injuries.

Another strength is the development of a case definition for identifying SR injuries using ED data collected for billing purposes. The secondary use of administrative data has many benefits. As noted above, these benefits may include timeliness, low cost, ease with which statistics can be prepared and disseminated, and, in situations in which data collection covers an entire geographic region, representativeness. Therefore, it is no surprise that many public and private organizations are utilizing secondary data sources, such as hospital administrative data, for research purposes. In hospital administrative data, much of the clinical information is captured using ICD-9-CM billing codes. Organizations such as the CDC have classified many types of health conditions, including injuries, using these billing codes. Although there are a number of published case definitions for SR injuries, there is little consensus on how best to identify these injuries using ICD-9-CM codes. For example, some studies incorporate only the ICD-9-CM E-codes that are specifically sports related (i.e. E8860: fall on same level from collision, pushing, or shoving, by or with other person in sports; E917.0: striking against or struck accidentally by objects or persons in sports without a subsequent fall; and E917.5: striking against or struck accidentally by objects or persons in sports with a subsequent fall). Although these specifically sports-related E-codes should be included in any ICD-9-CM-based sports injury case definition, relying solely on these E-codes may lead to an underrepresentation of the true number of sports and recreation-related injuries. This dissertation contains a more comprehensive sports and recreation-related injury case definition that makes use of a much wider variety of E-codes, including activity and place of occurrence E-codes.

Finally, the Aim 1 study is the first study to use statewide ED visit data to estimate the incidence of SR ED visits in the state of NC, and to estimate the incidence of ED visits due to SR traumatic brain injuries (TBIs) in NC.

This study addresses the following Specific Aim:

Aim 1. Describe the Incidence of Sports and Recreation-Related Injuries among School-Age Youth in North Carolina.

Aim 1A: Develop a sports and recreation-related case definition to use with emergency department visit data based on a review of the published literature.

Aim 1B: Estimate the incidence of emergency department visits related to sports and recreational activities among school-age youth in North Carolina.

Aim 1C: Estimate the incidence of emergency department visits related to sports and recreational activities among school-age youth in North Carolina with a diagnosis of traumatic brain injury.

3.2 Aim 2: Epidemiology of Emergency Department Visits Due to Suspected Traumatic Brain Injuries among School-Age Youth

The second study used clinical data collected from a large NC hospital system to describe TBI-related ED visits among youth, with an emphasis on SR TBIs. Rather than focusing on population incidence, this study takes a more in-depth examination of youth presenting to the ED with a suspected TBI.

The Aim 2 study used data collected as part of a research initiative at a NC metropolitan hospital system to provide a comprehensive picture of the patient demographics and the nature, the circumstances, and the treatment of TBI among pediatric patients presenting to the ED. We examined the demographics, circumstances, and the treatment of patients presenting to the ED with a TBI due to unintentional injury mechanisms. The characteristics of SR ED visits were compared to non-SR ED visits.

This study addresses the following Specific Aim:

Aim 2: Describe the Epidemiology of Emergency Department Visits Due to Suspected Traumatic Brain Injuries among School-Age Youth.

Aim 2A: Describe the demographics, clinical signs and symptoms, circumstances, and healthcare resource utilization patterns of school-age youth presenting with suspected traumatic brain injuries at a large, metropolitan hospital system.

Aim 2B: Compare demographics, clinical signs and symptoms, circumstances, and healthcare resource utilization patterns between school-age youth presenting with suspected traumatic brain injuries related to sports and recreational activities and school-age youth presenting with suspected brain injuries unrelated to sports and recreational activities at a large, metropolitan hospital system.

CHAPTER 4: METHODS

Institutional Review Board approval for this study was obtained from the University of North Carolina at Chapel Hill (IRB # 16-1789) and WakeMed Health and Hospitals (IRB # 970094-1).

4.1 Methods for Aim 1: Incidence of Sports and Recreation-Related Injuries in North Carolina among School-Age Youth

4.1.1 Study Design

The Aim 1 study used a descriptive epidemiologic study design to describe SR injuries treated in North Carolina EDs among school-age children 5-18 years of age. These data are accessible through NC's statewide electronic syndromic surveillance system, the NC Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT).

4.1.2 Overview of the NC DETECT System

NC DETECT collects ED data from all acute-care 24/7 civilian EDs in NC as well emergency medical services (EMS) data from the Prehospital Medical Information System (PreMIS), data from the Carolinas Poison Center, and pilot data from select urgent care centers. For the Aim 1 study, only NC ED visit data were used in descriptive analyses. NC DETECT is the product of a collaboration between the Carolina Center for Health Informatics (CCHI), based at the University of North Carolina at Chapel Hill (UNC-CH), and the NC Division of Public Health (NC DPH) and addresses the need for early event detection and timely public health surveillance.

In 2004, NC passed a statewide legislative mandate requiring the collection of select data elements from all 24/7 civilian acute-care EDs. Although the focus of NC DETECT has been the use of syndromic surveillance data to monitor acute public health emergencies (e.g. disease outbreaks, natural disasters, etc.), the legislation provides for the use of data for more routine public health surveillance, including injury surveillance.[83,85,88] Authorized users, such as public health personnel and clinicians, are able to access near real time data through the NC DETECT web interface. NC DPH/CCHI release annual data sets six months after the close of the calendar year that are available to researchers through a Data Use Agreement (DUA). A DUA agreement (DUA # 20160530161732910) was obtained from the Communicable Disease Branch of NC DPH.

4.1.3 Study Population

The study population consisted of NC residents during 2010-2014. The denominator estimates for this population were obtained from the Bridged-Race Intercensal Population Estimates released by the US Census Bureau and NCHS for the years 2010-2014.[44] The numerator consisted of all NC DETECT ED visits made by patients 5-18 years of age with an injury diagnosis from January 1, 2010 through December 31, 2014. The numerator included visits from non-NC residents as well as NC residents. The reasoning for the inclusion of out-of-state residents is that out-of-state ED visits for NC residents are not readily available and, therefore, excluding visits from out-of-state residents to NC EDs would introduce a downwards bias in the incidence rates.

4.1.4 Case Definition of an Injury

It is important to establish the baseline incidence rate of injury among youth 5-18 years of age before identifying which of these injuries were sports and recreation-related. This study defined an injury as an ED visit with an ICD-9-CM diagnostic code in the range of 800-999 in any one of the eleven possible diagnosis fields and/or an E-code in any one of five E-code fields captured by NC DETECT. Emergency department visits containing the code of 995.9 (without an E-code or other diagnosis code in the range of 800-999) were excluded, because 995.9 is the code for systemic inflammatory response syndrome, a health condition that is not unique to injuries.

Some researchers adopt the convention of limiting their analysis to ED visits in which the injury diagnosis code is listed in the first position. Although many surveillance studies assume that the first-listed diagnosis code is the "primary" diagnosis code, i.e., the primary reason for the ED visit, prior studies using NC DETECT ED data have demonstrated this is not necessarily true in NC hospitals.[89] This methodology is consistent with other injury reports and publications released by the NC DPH and CCHI.[85]

4.1.5 Definition of a Traumatic Brain Injury

Aim 1 uses the CDC case definition for a traumatic brain injury (TBI). A positive identification of a TBI was made if the ED visit included one of the ICD-9-CM codes 800-801 (.00-.99): fracture of the vault or base of the skull; 803-804 (.00-.99): other and unqualified or multiple fractures of the skull; 850 (.0-.9): concussion; 851-854 (.00-.19): intracranial injury, including contusion, laceration, and hemorrhage; 950 (.1-.3): injury to the optic chiasm, optic pathways, or visual cortex; 959.01: head injury, unspecified.[53] This TBI definition excluded code 995.55: shaken infant syndrome, because it is unlikely that an ED visit with a diagnosis code of 995.55 would be directly related to a sports and recreational activity.

4.1.6 Definition of Sports and Recreation-Related Injuries Using Emergency Department Visit Data

4.1.6.1 Conceptual Definition of Sports and Recreation-Related Injuries

Broadly defined, physical activity is any bodily movement generated by skeletal muscles that produces an expenditure of energy and can be illustrated by the following formula:

Physical Activity $(PA)_{\text{total daily activity}} = PA_{\text{sleep/sedentary activity}} + PA_{\text{occupation}} + PA_{\text{leisure}} + PA_{\text{other activity.}}$[90]

In the context of this dissertation, sports and recreational activities are a subset of leisure-time physical activity. In addition to the focus of this dissertation (sports/athletics participation, exercise, and outdoor recreational activities) leisure-time physical activity also includes household tasks and other related activities (not performed for pay) such as preparing food, cleaning, gardening, playing computer games, home maintenance, etc.[90] While the terms "sport" and "recreational activity" have no precise meaning and their differentiation from other forms of leisure-time physical activity is somewhat vague, these terms connote a sense of personal enjoyment, physical ability, and means to improve one's fitness and health. In general, the physical activities classified as sports and recreational activities in this dissertation adhere to the definitions developed by the Australian Bureau of Statistics:

> Sport: "An activity involving physical exertion, skill and/or hand-eye coordination as the primary focus of the activity, with elements of competition where rules and patterns of behavior governing the activity exist formally through organizations."
>
> Recreation: "An activity or experience that involves varying levels of physical exertion, prowess and/or skill, which may not be the main focus of the activity and is voluntarily

engaged in by an individual in leisure time for the purpose of mental and/or physical satisfaction."

Organized sport or recreation: "Sport or recreational activities may be organized by a club or association or other organization, such as a sporting club, social club, church group, workplace, or gymnasium." [91]

4.1.6.2 Applied Definition of Sports and Recreation-Related Injuries

Figure 4.1 (adapted from a figure developed by the Australian Bureau of Statistics) displays the relationship between the conceptual definition of sports and recreational activity and the ICD-9-CM code-based definition of sports and recreational activity created for use with this dissertation.[91]

Eight studies have utilized ICD-9-CM based case definitions to identify SR ED visits and/or hospitalizations using administrative data sets. These case definitions are provided in Appendix A. There is a large degree of heterogeneity in the codes selected to identify sports and recreation-related injuries in these studies. This table of prior studies excludes research in which the case definitions used a coding structure other than ICD-9-CM or relied on SR injuries identified through medical record abstraction or survey. Appendix B displays the number and incidence rate of SR NC ED visits among school-age youth stratified by applied SR case definition.

Based on the review of the methods used in these prior studies, and on a high degree of familiarity with ICD-9-CM and administrative data sets such as NC DETECT ED data, we developed a new definition for identifying SR injuries (Table 4.1). To provide a comprehensive characterization of SR injuries, the case definition encompasses personal recreational activities as well as organized sports activities. This contrasts with the sports injury case definition employed by Taylor and Attia, Yang et al, and Nalliah et al which consists only of those E-codes that specifically refer to sports injuries (E886.0, E917.0, and E917.5). Our case definition includes, but is not limited to, these three sports injury E-codes.[43,92,93]

Transportation-related injuries

The SR injury case definition includes all ED visits with an E-code for transportation incidents involving a pedal cycle, motorized off road or snow vehicle, or animal transport. We included these E-codes because these visits are more likely be recreation-related than related to commuting to work or school. A study published by McDonald et al. in 2011 estimated that only 0.8% of children in grades K-12 traveled to and from school by bicycle.[94] The National Highway Traffic Safety Administration's (NHTSA's) National Survey of Bicyclist and Pedestrian Attitudes and Behavior (these data refer only to individuals $\geq$ 16 years of age) found that the most common reasons cited for bicycle trips were recreation (33%) or exercise (28%).[95] Dempsey et al., Bijur et al, and Socie, Falb, and Beeghly included at least some of these transportation related E-codes in their respective definitions for sports and recreation-related injuries; however, only Dempsey et al. included the entirety of E-codes related to pedal cycle, motorized off road and snow vehicles, and animal transport injuries.[38,96,97]

Recreational water-related injuries

The SR injury case definition also includes all E-codes describing injuries in or near bodies of water. This is a diverse category that includes incidents involving watercraft, water-skiing, swimming, diving or jumping into a water source, and scuba diving. E-codes that are likely to be occupational in nature, were excluded. The only case definition that includes all of the E-codes for injuries in or near bodies of water is Dempsey et al. (Bijur et al. includes some, but not all of these water -related E-codes).[38,96] It is possible that some of the water transport E-codes (E830-E838) may capture ED visits that are not related to sports or recreation; however, an assumption will be made that this number is minimal in comparison to the number of ED visits related to recreation. A prior study of fatal sports and recreation-related incidents, estimated that 100% of incidents involving watercraft causing submersion, drowning, or fall were recreation-related (excluding incidents in which the person involved was a member of a crew or a related position).[40]

Falls-related injuries

The SR injury case definition also includes E-codes for falls related to recreational activities. This definition includes falls due to snow skiing, snowboarding, roller-skating, skate-boarding, and falls from a non-motorized scooter and playground equipment. At least some of these sports and recreation-related falls E-codes are included in the case definitions developed by Dempsey et al.; Bijur et al.; Socie, Falb, and Beeghly; and Howard et al.[38,96–98] Unlike Dempsey et al., our case definition does not include E-codes for general falls-related ED visits (e.g. fall from curb; fall from one level or another; and fall on same level from slipping, tripping, and stumbling). Dempsey et al. somewhat qualifies the inclusion of these E-codes in their case definition, by assuming that only 1%-10% of hospitalizations that received these E-codes were sports and recreation-related. Our SR injury case definition only includes these E-codes if there is *supplementary information,* such as an activity code or place of occurrence code, which indicates a SR activity.[38]

E-codes that indicate the activity of the patient seeking healthcare for an injury

The Centers for Medicare and Medicaid Services introduced activity E-codes on October 1, 2009. These E-codes (E001-E030) provide information describing the activity that most likely resulted in the injury or other health condition requiring medical care. These E-codes are to be used in conjunction with E-codes describing the injury mechanism (e.g. fall) and place of occurrence (e.g. home). The E-codes E001-E010 describe SR activities; E-codes E011-E030 describe mainly household activities such as cleaning, cooking, home repair, and gardening.[99] These E-codes are important to include as part of a sports and recreation case definition, because these E-codes will capture ED visits in which the E-code for injury mechanism cannot be labeled with certainty as a sports and recreation-related ED visit. For example, an ED visit with an E-code of E888.8, "Other specified fall" may or may not be due to a sports and recreational activity; however, if this ED visit also included an E-code of E009.3, "Activity involving circuit training", then this ED visit would be positively identified as being recreation-related. Only Howard et al. included activity E-codes as part of their case definition.[98]

E-codes that indicate the place of occurrence of an injury

The SR injury case definition also includes any ED visit with a supplementary E-code of E849.4, "Place of recreation or sport." Bijur et al.; Socie, Falb, and Beeghly; and Howard et al. also included this E-code as part of their case definitions.[96–98]

FIGURE 4.1. Conceptual model: Recreational activities, exercise, and sports/athletics performed during leisure time in a nonprofessional capacity and not for pay[91]

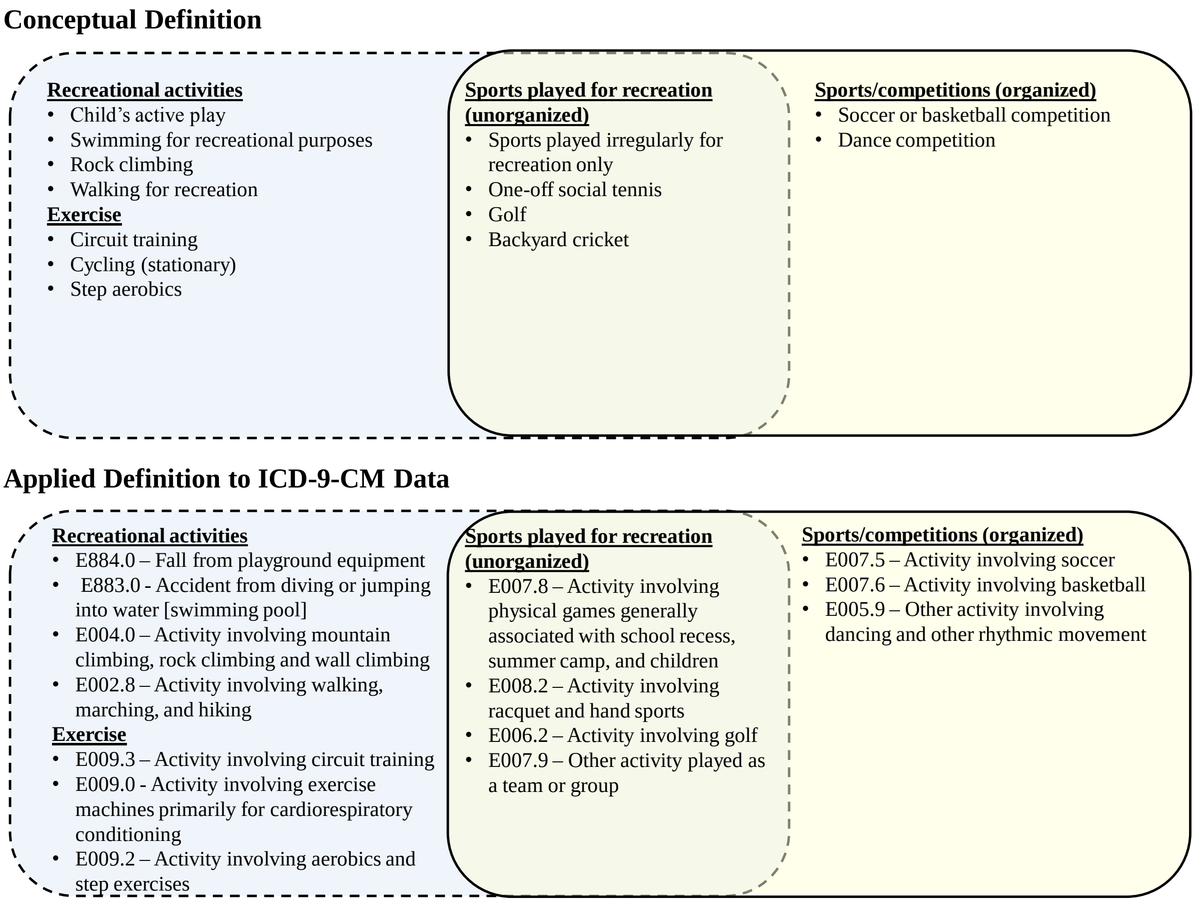


TABLE 4.1 Sports and recreation-related case definition to be used with NC DETECT emergency department visit data

Include any ED visit with one or more of the E-codes listed below:

E-code Range	Description of E-code(s)	
E001-E010 (.0-.9)	**Activity E-codes for sports and recreational activities**	
	E001	Activity involving running and walking
	E002	" "Water and watercraft
	E003	" "Ice and snow
	E004	" " Climbing, rappelling, and jumping off
	E005	" " Dancing and other rhythmic movement
	E006	" " Other sports and athletics played individually
	E007	" " Other sports and athletics played as a group or a team
	E008	" " Other sports and athletics
	E009	" "Other cardiorespiratory activity
	E010	" " Other muscle strengthening exercises
E800-E807 (.3), E820-E825 (.6), E826-E829 (.1), E826.9	**Non-traffic related crash involving a pedal cyclist**	
E810-E819 (.6)	**Traffic-related crash involving a pedal cyclist**	
E820 (.0, .1, .8, .9)	**Nontraffic-related crash of a motorized snow vehicle**	
E821 (.0, .1, .8, .9)	**Nontraffic-related crash of other off-road vehicle**	
E820-E825 (.5), E826-E829 (.2)	**Nontraffic-related crash of person riding animal**	
E810-E819 (.5)	**Traffic-related crash of person riding animal**	
E830-E838 (.0, .1, .3, .4, .5, .8, .9), E883.0, E902.2, E910 (.0, .1, .2, .8, .9)	**Recreational activities involving bodies of water**	
	E830-E838 (.0, .1, .3, .4, .5, .8, .9)	Watercraft
	E883.0	Injury from diving or jumping into water
	E902.2	Injury due to changes in air pressure from diving
	E910 (.0, .1, .2, .8, .9)	Drowning/submersion
E885.0-E885.2	**Recreational activity involving wheels (non-motorized)**	
	E885.0	Fall from non-motorized scooter
	E885.1	Fall from roller skates
	E885.2	Fall from skateboard
E884.0, E885.3, E885.4	**Other recreation activity (without mention of wheels)**	
	E884.0	Fall from playground equipment
	E885.3	Fall from snow skis
	E885.4	Fall from snowboard
E886.0, E917.0, E917.5	**Sports activity**	

E-code Range	Description of E-code(s)	
	E886.0	Fall on same level from collision, pushing, or shoving, by or with other person in sports
	E917.0	Striking against by person or object in sports without subsequent fall
	E917.5	Striking against by person or object in sports with subsequent fall
E922 (.4-.5)	**Air gun missile**	
	E922.4	Injury caused by air gun (e.g. BB gun)
	E922.5	Injury caused by paintball gun
E849.4	**Event occurred at a place for recreation or sport**	

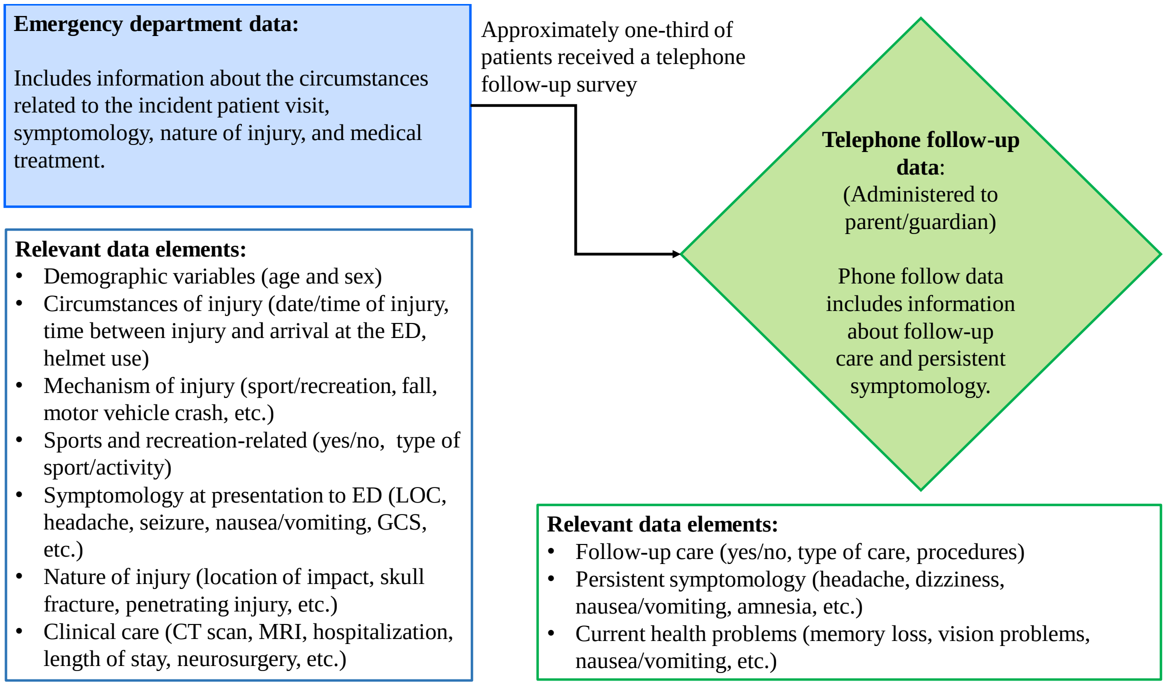
4.2 Methods for Aim 2: Epidemiology of Emergency Department Visits Due to Suspected Traumatic Brain Injuries among School-Age Youth

4.2.1 Study Design

Aim 2 used a clinical epidemiologic study design to characterize ED visits and follow-up care among school-age youth 5-17 years of age presenting with a suspected TBI at a large, metropolitan hospital system. This study described characteristics of the initial ED visit related to the head injury. In addition, for about one-third of patients, follow-up information was available describing delayed/persistent symptomology and additional medical treatment (Aim 2A). Furthermore, characteristics of SR TBIs were compared to visits due to other causes (i.e. unrelated to sports and recreational activities) to characterize differences in demographics, signs and symptoms, and healthcare utilization between these two groups (Aim 2B).

This study utilized data from two sources: ED and hospitalization data and telephone follow-up data. These data provided information on the patient's demographics, clinical signs and symptoms at presentation to the ED, the circumstances and nature of the injury (or injuries), clinical care provided in the ED, clinical care provided in the hospital for admitted patients, imaging results for patients who underwent a computed tomography (CT) scan or magnetic resonance imaging (MRI), clinician assigned diagnosis codes, and discharge disposition. The data sources available contribute complementary information about the incident TBI, including the circumstances leading up to the injury, the nature of the injury, acute clinical care, and short-term follow-up medical care. Figure 4.2 provides a brief description of these data sources. The combination of these data sources provides a multi-faceted portrayal of youth TBI presenting at the ED.

FIGURE 4.2 Relationship between Aim 2 data sources: Emergency department and hospitalization and telephone follow-up data: Child Head Injury Research Initiative, March 2013-February 2014



Abbreviations: ED, emergency department; LOC, loss of consciousness; GCS, Glasgow Coma Scale; CT, computed tomography; MRI, magnetic resonance imaging

4.2.2 Overview of the CHIRI Data

The WakeMed Raleigh Emergency Services Institute's Clinical Research Unit created the Child Head Injury Research Initiative (CHIRI) with the aim of collecting comprehensive patient data for suspected TBIs among youth. WakeMed Raleigh has a long history of excellence in clinical research and has a Level I Trauma center and Teaching Hospital with emergency medicine and pediatrics residency programs (among others) through a collaboration with the University of North Carolina at Chapel Hill.

4.2.3 Study Population

The CHIRI data set captured all ED visits to a WakeMed Health and Hospitals affiliated ED made by pediatric patients with a suspected head injury (including TBIs) from March 1, 2013 to February 28, 2014. The inclusion criteria for the CHIRI data set was as follows: 1) the patient presented for care at a participating WakeMed Health and Hospitals affiliated ED during the period March 1, 2013 and February 28, 2014 with a suspected TBI and 2) the patient was in the range of 0-17 years of age.

For the purpose of this study (and to be consistent with Aim 1), we incorporated the following inclusion criteria to the CHIRI patient population: 1) incident ED visit (exclude repeat/follow-up visits), 2) duration between TBI and ED visit $\leq$3 days (exclude visits >3 days post-TBI or missing), 3) ED visit due to an unintentional injury mechanism (exclude visits due to assault, self-harm, suspected child abuse, or missing), and 4) patient age $\geq$5 years of age (exclude children <5 years of age). In addition, we excluded one child from the study with a diagnosis of brain tumor.

4.2.4 Definition of Sport and Recreation-Related Traumatic Brain Injury

One of the objectives of Aim 1 was the development of a new case definition for SR injury based on ICD-9-CM E-codes. Aim 2 takes a different approach and utilized the sport and recreational indicator collected by the CHIRI project staff. Mechanism of injury was one of the many items collected by the clinicians specifically for this project. The clinicians recorded the mechanism of injury (assault; pedestrian struck by moving vehicle; motor vehicle accident; head struck by object/body part; fall from standing, walking or running; bicycle fall; sport/wheeled transport crash; fall from height other than stairs; fall down stairs; walk/run into stationary object; bicycle struck; sports related; other; unknown). Additionally, the data collection form had a specific question on whether the injury was sports-related. For ED visits for which this specific sports-related indictor was selected, the visits were further categorized by type of sport (baseball/softball, ice-hockey, track and field, basketball, lacrosse, volleyball, cheerleading, martial arts/wrestling, skating, football, soccer, and other). For all sports-related injures marked as “other”, the clinicians were further prompted to specify the type of sport in a text field.

To maintain consistency with Aim 1 and the overall theme of the dissertation, injuries likely due to recreational activities will also be included as a SR injury. The CHIRI questionnaire identified ED visits as being due to a “sport/wheeled” transport crash (e.g. ATVs and jet-skis), bicycle crashes, falls from bicycles, and water-related injuries (e.g. swimming, diving, tubing, etc.). These ED visits were included in the definition of a suspected TBI due to a sport or recreational activity.

4.2.5 Telephone Follow-Up

For a subset of the CHIRI population, a telephone survey was administered (in English or Spanish) approximately 10-14 days after the initial ED visit. The legal guardian of the patient provided follow-up data on TBI symptomology and follow-up medical care post initial ED visit. TBIs are complex injuries in that symptomology may be delayed for some time after the initial injury or may not resolve in an acute manner, even for those TBIs deemed to be “minor” or “not serious.” The telephone survey collected information on whether the patient was currently experiencing headaches, and if so, how severe (mild, moderate, or severe). In addition to headache, the survey collected information on vision problems, episodes of vomiting since leaving the ED, seizures since leaving the ED, difficulty concentrating, memory loss, difficulty maintaining balance, and limb weakness. Interviewers also queried parents/guardians on whether their child was unable to return to normal activities and, if so, to list these activities. The parent/guardian was also asked if the child required follow-up medical care related to his/her head injury and, if so, to describe the type of medical care received (outpatient clinic, specialty clinic, urgent care, ED, hospitalization, etc.).

CHAPTER 5: CHARACTERISTICS OF SPORTS AND RECREATION-RELATED EMERGENCY DEPARTMENT VISITS AMONG SCHOOL-AGE CHILDREN AND YOUTH IN NORTH CAROLINA, 2010-2014 (MANUSCRIPT 1)

5.1 Introduction

Physical activity, along with a healthy diet, is one of the most commonly suggested solutions to the childhood overweight and obesity epidemic. [2,34] Despite the benefits of physical activity and organized sports participation, there are inherent risks to engaging in physical activity, in particular, risk of injury. [4] Children and youth bear a disproportionate burden of sports and recreation-related (SR) injuries, with an estimated two-thirds of all medically attended SR injuries occurring among 5-24 year-olds. [40,100] As compared to other types of injury, youth are more likely to have a diagnosis of a strain/sprain, fracture, superficial wound/contusion, and traumatic brain injury (TBI), including concussion. [41] TBIs are of particular concern because of the potential for possible long-term adverse health outcomes. [101–104]

Most prior studies of SR injuries have used survey or sampling methods to estimate incidence. In addition, many of these publications are greater than 10 years old and have focused on high school and college athletes. This is one of the first studies to use a broad definition to describe the characteristics and incidence of sports and recreation-related injury and TBI among school-age youth in a well-defined population, only.

5.2 Methods

This population-based descriptive epidemiologic study examined the incidence, circumstances, and characteristics of SR injuries in children and youth. All NC ED visits for SR injury made by children 5-18 years of age during the period January 1, 2010 – December 31, 2014 were included. A broad and inclusive definition of SR injury was utilized, based on a public health model that underscores the importance of children developing lifetime patterns of healthy public activity within an environment of effective public health interventions designed to minimize injury risk. [4]

5.2.1 Injury Ascertainment

The ED visit data were obtained from the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT) for the period January 1, 2010 – December 31, 2014. The Department of Emergency Medicine at the University of North Carolina at Chapel Hill and the NC Division of Public Health operate NC DETECT for the purpose of timely syndromic public health surveillance as mandated under state law since 2005. [83,88] As of December 31, 2014, NC DETECT collected ED visit data from 123 acute-care, hospital-affiliated, civilian EDs in the state, representing an estimated 99% of total NC ED visits. [83,85] During the five-year period of study, NC DETECT collected over 23 million ED visits, with an average of 4.7 million ED visits per year. [83]

An ED visits was defined as injury-related if it received an ICD-9-CM External Cause of Injury Code (E-code) indicating a valid mechanism of injury, and unintentional-injury-related if it contained an E-code indicating an injury of an unintentional intent (i.e. an injury not inflicted on purpose; “accidental”) in the range of E800-E869 or E880-E929. [105,106] The NC Division of Public Health and the University of North Carolina at Chapel Hill approved this study.

5.2.2 Case Definition of a Sports and Recreation-Related Injury

The E-code-based case definition of SR injury was designed specifically for this study. Table 5.2 contains a list and brief description of the E-codes included in the definition of SR injury. For certain categories of sports and recreational activities, E-codes were grouped together due to the relatedness of the E-codes and/or due to small numbers of ED visit totals.

NC DETECT captures up to five E-codes for each patient visit. When multiple E-codes met the case definition (Table 5.2), the ED visit was classified according to the most specific E-code. For example, if an individual patient visit contained the following two E-codes: E849.4 (place for recreation and sport) and E007.0 (American tackle football), then ED visit was classified as being due to American tackle football. If the patient visit contained two E-codes of similar specificity, the visit was classified according to the first listed E-code. For example, if an ED visit contained the following two E-codes: E001.0 (walking, marching and hiking) and E001.1 (running), the ED visit would be classified as being due to walking, marching, and hiking. Table 5.2 contains the order in which E-codes were assigned, with "1" (e.g. E006.2 "Activities involving golf") referring to the highest level of specificity and "7" referring to the lowest level of specificity (e.g. E849.4 "Accidents occurring in place for recreation and sport"). Over two-thirds of ED visits contained only one E-code for a SR (68.0%), with 26.0% and 6.0% of ED visits contained two and three E-codes for a SR injury, respectively.

5.2.3 Case Definition of a Traumatic Brain Injury

This study used the Centers for Disease Control and Prevention (CDC) TBI case definition to identify ED visits due to TBIs. The CDC TBI definition comprises ICD-9-CM codes 800.00-801.99 (fracture of the vault or base of the skull); 803.00-804.99 (other or multiple fractures of the skull); 850.0-850.9 (concussion); 851.00-854.99 (intracranial injury); 950.0-

950.9 (optic chiasm, optic pathways, or visual cortex); and 959.01 (head injury, unspecified). The following code was excluded from the definition: 995.55 “shaken infant syndrome”.[53] As NC DETECT collects up to eleven ICD-9-CM diagnosis codes per patient visit, the ED visit was classified as being due to a TBI if the visit contained a TBI diagnosis code in any position. The majority of ED visits contained one diagnosis code for TBI (90.8%) while the maximum number of diagnosis codes for TBI was five (0.01%).

5.2.4 Covariates

Sociodemographic covariates included patient sex, patient age (categorized as 5-9, 10-14, and 15-18 years), and urban-rural classification based on NC county of residence. Patient county of residence was classified according to US Census urban-rural designations (urban, mostly rural, completely rural, and out-of-state).[107]

This study also examined discharge disposition (admitted, died, discharged from the ED, and other disposition), mode of transport (walk-in, ambulance, and other specified mode of transport), expected source of medical payment (Medicaid, insurance company, self-pay, and other specified source of payment), seasonality of visit (December-February, March-May, June-August, and September-November), and time of visit (12:00-5:59 AM, 6:00-11:59 AM, 12:00-5:59 PM, and 6:00-11:59 PM).

Injury diagnoses were categorized using the Barell Injury Diagnosis Matrix according to the nature of injury (e.g. fracture) and location (e.g. upper extremity) using the first listed ICD-9-CM injury diagnosis code.[108]

5.2.5 Statistical Analysis

This study used descriptive epidemiologic methods such as the Pearson’s chi-square test and Fisher’s exact test (for expected cell counts <5) to characterize SR ED visits. In addition, injury proportion ratios (IPRs) and 95% confidence intervals (CIs) were calculated to compare differences among Barell Injury Diagnosis Matrix classifications between SR injuries and other unintentional injuries. All 95% CIs not containing 1.00 for IPRs were considered statistically significant with an IPR >1.00 suggesting a risk association.[109] As an example, the following calculation compares the proportion of SR upper extremity fractures to the proportion of fractures due to other types of unintentional injury:

$$IPR = \frac{\left(\frac{Number\ of SR\ ED\ visits\ with\ an\ upper\ extremity\ fracture}{Total\ number\ of\ SR\ ED\ visits}\right)}{\left(\frac{Number\ of\ other\ unintentional\ injury - related\ ED\ visits\ with\ an\ upper\ extremity\ fracture}{Total\ number\ of\ other\ unintentional\ injury - related\ ED\ visits}\right)}$$

There is no comprehensive and systematic data collection method that enumerates exposure to sports and recreational activity in the US. Therefore, the denominator for all rate calculations consisted of the NC resident population of 5-18 year-olds. All rates are presented per 100,000 person-years to ensure comparability across the thousand-fold range of incidence. Age group and sex specific incidence rates were calculated using the National Center for Health Statistics bridged-race mid-year population estimates for NC as the denominator. [110]. The numerator included visits from non-NC residents as well as NC residents. Out-of-state residents were included in the numerator (injury cases) because comprehensive data for out-of-state ED visits by NC residents were not readily available and excluding NC ED visits by out-of-state residents would introduce a downwards bias in the rates. Incidence rate estimates and 95% confidence intervals (CIs) were generated using a Poisson model. All analyses were performed using SAS software, version 9.4 (SAS Institute, Inc.; Cary, NC).

5.3 Results

5.3.1 Injury Incidence

During the period 2010-2014, 767,075 (27.6%) ED visits were identified as being due to unintentional injury mechanisms, out of a total 2.8 million ED visits among children 5-18 years of age. Of these 767,075 unintentional-injury related ED visits, 213,518 visits (27.8%) were related to SR activities. From 2010 through 2014, there was an annual average number of 42,704 SR NC ED visits or 2,374.5 (95% CI, 2,364.4 -2,384.6) ED visits per 100,000 person-years among school-age youth, 5-18 years of age.

5.3.2 Selected Characteristics of Emergency Department Visits

Table 5.1 displays the characteristics of ED visits due to total unintentional injury-related ED visits in comparison to SR ED visits among youth, 5-18 years of age. About two-thirds of all SR ED visits involved boys, a higher proportion than total unintentional injury-related ED visits. In the majority of SR and unintentional injury-related ED visits, the patient was discharged from the ED without admission to the hospital. The most common mode of transport to the ED for both SR and total unintentional injury-related ED visits was “walk-in” to the ED via private or public transportation; however, the proportion was slightly higher for SR ED visits (88.2%) versus total unintentional injury-related ED visits (85.2%). Among SR ED visits, the most commonly cited expected source of payment was Medicaid (42.7%) followed by insurance company (38.5%). The fall and spring seasons contained the highest proportion of ED visits for both SR and total unintentional injury-related ED visits, but SR ED visits exhibited greater seasonal trends, with more pronounced differences between fall/spring and winter/summer seasons. For both SR and unintentional injury-related ED visits, the time of day with the highest proportion of visits was during evening hours of 6:00-11:59 PM.

Table 5.2 displays the case definition for SR injuries organized by E-code category. The three most common E-code categories observed among school-age children and youth 5-18 years of age was “Sports/athletics played as a group or team” (e.g. American tackle football, basketball, and soccer), “other outdoor recreational activities” (e.g. outdoor activities such as roller-skating/skateboarding and snow/off-road vehicles), and “falls/struck by/against in sports”.

TABLE 5.1 Selected characteristics of unintentional injury-related emergency department visits among school-age youth: North Carolina, 2010-2014

Characteristics	ED visits due to sports and recreation-related injuries	Total number of unintentional injuries
Age, No. (%)		
5-9 years	49,491 (23.2)	232,316 (30.3)
10-14 years	94,875 (44.4)	275,738 (35.9)
15-18 years	69,142 (32.4)	259,021 (33.8)
Sex, No. (%)		
Male	145,005 (67.9)	443,797 (57.9)
Female	68,500 (32.1)	323,228 (42.1)
Missing	13	50
Disposition, No. (%)		
Discharged	202,313 (96.8)	722,624 (96.7)
Admitted[a]	5,234 (2.5)	16,871 (2.3)
Died	33 (0.0)	183 (0.0)
Other[b]	1,419 (0.7)	7,916 (1.1)
Missing	4,519	19,481
County urban/rural designations, No. (%)		
Urban	136,871 (64.2)	487,227 (63.6)
Mostly rural	62,117 (29.1)	232,223 (30.3)
Completely rural	4191 (2.0)	14,929 (1.9)
Out-of-state	10,094 (4.7)	31,782 (4.1)
Missing	245	914
Mode of transport, No. (%)		
Walk-in	166,709 (88.2)	681,567 (85.2)
Ambulance[c]	12,784 (6.8)	80,712 (10.1)
Other[d]	9,517 (5.0)	37,935 (4.7)
Missing	24,508	118,448
Expected source of payment, No. (%)		
Medicaid	89,376 (42.7)	354,035 (47.2)
Insurance company	80,573 (38.5)	240,262 (32.1)
Self-pay	17,212 (8.2)	73,835 (9.9)
Other[e]	21,913 (10.5)	81,461 (10.9)
Missing	4,444	31,348
Month, No. (%)		
Dec. - Feb.	37,622 (17.6)	148,609 (19.4)
March - May	61,015 (28.6)	212,405 (27.7)
June - Aug.	48,733 (22.8)	197,943 (25.8)
Sept. - Nov.	66,148 (31.0)	208,118 (27.1)
Hour of day, No. (%)		
12:00 - 5:59 AM	8,480 (4.0)	42,083 (5.5)

Characteristics	ED visits due to sports and recreation-related injuries	Total number of unintentional injuries
6:00 - 11:59 AM	28,400 (13.3)	115,875 (15.1)
12:00 - 5:59 PM	73,124 (34.2)	266,935 (34.8)
6:00 - 11:59 PM	103,514 (48.5)	342,182 (44.6)
TOTAL	**213,518 (100.0)**	**767,075 (100.0)**

Abbreviations: ED, emergency department; no., number; Dec., December; Feb., February; Aug., August; Sept., September; Nov., November

[a]The category of admitted includes transfers.

[b]The category other disposition contains left against medical advice, left without being seen, observation unit, and other disposition.

[c]The category ambulance contains ground, helicopter, fixed wing, other type of ambulance, and unspecified type of ambulance.

[d]The category other mode of transport contains other mode of transport.

[e]The category other expected source of payment contains Medicare, no charge, other form of government payment, workers' compensation, and other expected source of payment.

TABLE 5.2 Sports/Recreation-related emergency department visits among school-age youth: North Carolina, 2010-2014

E-code[a]	Description	Specificity[b,c]	N (%)
E007 (.0-.7, .9)	**Sports/athletics played as a group or team**	**1**	**72,821 (34.1)**
E007.0	American tackle football	1	24,420 (11.4)
E007.6	Basketball	1	23,342 (10.9)
E007.5	Soccer	1	10,108 (4.7)
E007.3	Baseball and softball	1	8,840 (4.1)
E007.7	Volleyball	1	1,708 (0.8)
E007.4	Lacrosse and field hockey	1	883 (0.4)
E007.1	American touch/flag football	1	636 (0.3)
E007.2	Rugby	1	285 (0.1)
E007.9	Other activities played as a group or team	5	2,599 (1.2)
E006(.2, .3, .6, .9), E008 (.0-.2, .4)	**Sports/athletics played individually**	**1**	**6,162 (2.9)**
E008.1	Wrestling	1	3,572 (1.7)
E008.4	Martial arts	1	525 (0.2)
E008.2	Racquet and hand sports	1	186 (0.1)
E006.2	Golf	1	159 (0.1)
E008.0	Boxing	1	156 (0.1)
E006.3	Bowling	1	106 (0.0)
E006.6	Track and field events (excludes running)	1	100 (0.0)
E006.9	Other activities played individually	5	1,358 (0.6)
E886.0, E917 (.0, .5)	**Fall, or struck by/striking against, in sports**	**6**	**23,934 (11.2)**
E917.0	Struck by/against in sports, no subsequent fall	6	19,060 (8.9)
E917.5	Struck by/against in sports with subsequent fall	6	2,627 (1.2)
E886.0	Fall on same level from collision, pushing, or shoving, by or with other person in sports	6	2,247 (1.1)
E008.9	**Other specified sports/athletic activity (NEC)**	**5**	**779 (0.4)**
E005 (.0, .2, .4, .9)	**Dancing and other rhythmic movement**	**1**	**5,517 (2.6)**
E005.4	Cheerleading	1	2,080 (1.0)

E-code[a]	Description	Specificity[b,c]	N (%)
E005.2	Gymnastics	1	1,796 (0.8)
E005.0, E005.9	Dancing and other activity involving rhythmic movement	1	1,641 (0.8)
E005.1, E001 (.0-.1), E009 (.0-.9), E010 (.0-.9)	**Cardiorespiratory and muscle strengthening activities, not elsewhere specified**	**5**	**15,413 (7.2)**
E001.1	Running	5	9,130 (4.3)
E001.0	Walking, hiking, and marching	5	4,311 (2.0)
E009 (.0-.9)	Other cardiorespiratory exercise	2	321 (0.2)
E010 (.0-.9)	Other muscle strengthening exercises	2	1,641 (0.8)
E005.1	Yoga	1	10 (0.0)
E005.3, E006.5, E007.8, E008.3, E884.0	**Activities involving play and other activities usually unstructured**	**5**	**18,209 (8.5)**
E884.0	Fall from playground equipment	5	11,811 (5.5)
E005.3	Trampoline	1	4,623 (2.2)
E008.3	Frisbee	1	152 (0.1)
E006.5	Jumping rope	1	147 (0.1)
E007.8	Physical games generally associated with school recess, summer camp and children	5	1,476 (0.7)
E006.4, E800-E807 (.3), E810-E819 (.6), E820-E825 (.6), E826 (.1,.9), E827-E829 (.1)	**Pedal cycle**	**3**	**20,984 (9.8)**
E800-E807 (.3), E820-E825 (.6), E826 (.1,.9), E827-E829 (.1)	Nontraffic-related (i.e. off-road)	3	18,591 (8.7)
E810-E819 (.6)	Traffic-related (i.e. on-road)	3	1,006 (0.5)
E006.4	Bike riding, unspecified	5	1,387 (0.6)
E002 (.0-.9), E830-E838 (.0, .1, .3, .4, .5, .8, .9), E883.0, E902.2, E910 (.0, .1, .2, .8, .9)	**Recreational activities involving bodies of water**	**4**	**3,889 (1.8)**
E002.6, E910.0, E830-E838 (.4)	Waterskiing	2	212 (0.1)
E002 (.0-.5, .7-.9), E830-E838 (.0, .1, .3, .5, .8, .9), E883.0, E902.2, E910 (.1, .2, .8, .9)	Other activities involving water and watercraft	4	3,677 (1.7)
E003 (.0-.9), E004 (.0-.9), E006 (.0, .1), E820-E821 (.0, .1, .5, .8, .9), E822-E825 (.5), E826-E829 (.2), E885 (.0-.2), E922 (.4, .5)	**Other outdoor recreational activities**	**4**	**30,774 (14.4)**

E-code[a]	Description	Specificity[b,c]	N (%)
E006.0, E885 (.1,.2)	Roller skating and skateboarding	4	12,376 (5.8)
E820-E821 (.0, .1, .8, .9)	Snow and other off-road vehicles	3	6,477 (3.0)
E003 (.0-.9), E885 (.3, .4)	Snow skiing, snowboarding, and other activities involving snow and ice	3	3774 (1.8)
E006.1, E820-E825 (.5), E826-E829 (.2)	Animal being ridden	3	2,515 (1.2)
E885.0	Fall from non-motorized scooter	3	2,485 (1.2)
E922 (.4, .5)	Air gun	2	1,593 (0.7)
E004 (.0-.9)	Climbing, rappelling and jumping off	3	1,554 (0.7)
E849.4	**Injury occurred at a place of recreation or sport, no further detail**	**7**	**15,036 (7.0)**
TOTAL			**213,518 (100.0)**

Abbreviations: ED, emergency department; NEC, not elsewhere classified.
[a]Activity E-codes (E-codes E001-E030) describing activities resulting in injury were added to ICD-9-CM starting October 1, 2009. (Bronnert 2009).
[b]During the period 2010-2014, NC DETECT collected up to five E-codes describing the type of injury. For emergency department visits with more than one E-code, preference was given to ED visits with more specific E-codes (“1”) over visits with less specific E-codes (“7”). For ED visits with more than one E-code of the same specificity level, assignment was based on the first-listed E-code.
[c]For each category header, the level of specificity is the mode for that category.

5.3.3 Location and Nature of Injury

Table 5.3 compares SR ED visits and ED visits due to other unintentional injury mechanisms, as classified by the Barell Injury Diagnosis Matrix. Among SR ED visits, the most common location of injury was upper extremities, lower extremities, and head/face/neck. Fractures of the upper extremity were particularly common in comparison to the proportion of injuries that were due to upper extremity fractures among ED visits due to other mechanisms of unintentional injury (6.1%; IPR: 2.44 [95% CI, 2.40 – 2.48). In addition, both lower extremity, lower extremity strains/sprains, and upper extremity sprains/strains were nearly twice as common among SR ED visits relative to other unintentional injury mechanisms.

NC DETECT contains data fields for up to eleven diagnoses. Among SR ED visits, 5.0% of visits had a diagnosis of TBI in the first data field and 12.0% of SR ED visits had a diagnosis of TBI in any one of the eleven available data fields. The proportion of SR ED visits with a diagnosis of TBI was higher than that for other unintentional injury mechanisms (1.8%; IPR = 2.74 [95% CI, 2.66-2.82]). Although not as common, fractures to the head/face/neck were also higher among SR ED visits (0.9%; IPR=2.90 [95% CI, 2.71-3.11]).

TABLE 5.3 Unintentional injury-related emergency department visits among school-age children, by Barell injury diagnosis category: North Carolina, 2010-2014

Barell injury diagnosis category[a]	ED visits due to sports and recreation-related injuries	Other unintentional injury-related ED visits	Total unintentional injury-related ED visits	IPR (95% CI)[e]
Upper extremity, No. (%)	**69,581 (36.7)**	**135,251 (28.7)**	**204,832 (31.0)**	**1.28 (1.27-1.29)**
Fracture	28,024 (14.8)	28,542 (6.1)	56,566 (8.6)	2.44 (2.40-2.48)
Open wound	2,142 (1.1)	29,464 (6.3)	31,606 (4.8)	0.18 (0.17-0.19)
Sprain/strain	14,367 (7.6)	20,715 (4.4)	35,082 (5.3)	1.72 (1.69-1.76)
Superficial wounds and contusions	12,050 (6.4)	33,487 (7.1)	45,537 (6.9)	0.89 (0.88-0.91)
Other and unspecified injuries[b]	12,998 (6.9)	23,043 (4.9)	36,041 (5.5)	1.40 (1.37-1.43)
Lower extremity, No. (%)	**53,450 (28.2)**	**116,833 (24.8)**	**170,283 (25.8)**	**1.14 (1.13-1.15)**
Fracture	7,188 (3.8)	10,032 (2.1)	17,220 (2.6)	1.78 (1.73-1.83)
Open wound	3,958 (2.1)	23,450 (5.0)	27,408 (4.2)	0.42 (0.41-0.43)
Sprain/strain	23,868 (12.6)	37,266 (7.9)	61,134 (9.3)	1.59 (1.57-1.61)
Superficial wounds and contusions	9,268 (4.9)	29,120 (6.2)	38,388 (5.8)	0.79 (0.77-0.81)
Other and unspecified injuries[b]	9,168 (4.8)	16,965 (3.6)	26,133 (4.0)	1.34 (1.31-1.37)
TBIs and other head/face/neck, No. (%)	**46,858 (24.7)**	**103,632 (22.0)**	**150,490 (22.8)**	**1.12 (1.11-1.13)**
TBI	9,424 (5.0)	8,543 (1.8)	17,967 (2.7)	2.74 (2.66-2.82)
Fracture	1,778 (0.9)	1,519 (0.3)	3,297 (0.5)	2.90 (2.71-3.11)
Open wound	12,732 (6.7)	38,912 (8.3)	51,644 (7.8)	0.81 (0.80-0.83)
Sprain/strain	37 (0.0)	78 (0.0)	115 (0.0)	1.18 (0.80-1.74)
Superficial wounds and contusions	9,472 (5.0)	29,119 (6.2)	38,591 (5.8)	0.81 (0.79-0.83)
Other and unspecified injuries[b]	13,415 (7.1)	25461 (5.4)	38,876 (5.9)	1.31 (1.28-1.33)
Torso, No. (%)	**9,431 (5.0)**	**27,366 (5.8)**	**36,797 (5.6)**	**0.86 (0.84-0.88)**
Fracture	367 (0.2)	552 (0.1)	919 (0.1)	1.65 (1.45-1.88)
Open wound	488 (0.3)	2,200 (0.5)	2,688 (0.4)	0.55 (0.50-0.61)
Sprain/strain	842 (0.4)	5,209 (1.1)	6,051 (0.9)	0.40 (0.37-0.43)
Superficial wounds and contusions	5,735 (3.0)	14,461 (3.1)	20,196 (3.1)	0.98 (0.96-1.01)
Other and unspecified injuries[b]	1,999 (1.1)	4,944 (1.1)	6,943 (1.1)	1.00 (0.95-1.06)
Vertebral column, No. (%)	**4,609 (2.4)**	**26,302 (5.6)**	**30,911 (4.7)**	**0.43 (0.42-0.45)**
Fracture	269 (0.1)	669 (0.1)	938 (0.1)	1.00 (0.87-1.15)
Open wound	0 (0.0)	0 (0.0)	0 (0.0)	--
Sprain/strain	4,331 (2.3)	25,615 (5.4)	29,946 (4.5)	0.42 (0.41-0.43)
Superficial wounds and contusions	0 (0.0)	0 (0.0)	0 (0.0)	--

Barell injury diagnosis category[a]	ED visits due to sports and recreation-related injuries	Other unintentional injury-related ED visits	Total unintentional injury-related ED visits	IPR (95% CI)[e]
Other and unspecified injuries[b,c]	<10	18 (0.0)	27 (0.0)	--
System-wide and late effects of injury, No. (%)	**1,324 (0.7)**	**38,897 (8.3)**	**40,221 (6.1)**	**0.08 (0.08-0.09)**
Other and unspecified location of injury[d], No. (%)	**4,426 (2.3)**	**22,470 (4.8)**	**26,896 (4.1)**	**0.49 (0.47-0.50)**
TOTAL	**189,679**	**470,751**	**660,430**	

Abbreviations: ED, emergency department; no., number; IPR, injury proportion ratio; CI, confidence interval; TBI, traumatic brain injury.

Missing: 23839 visits due to sports and recreation-related injuries and 106645 ED visits due to other unintentional injury mechanisms were missing a valid injury diagnosis code.

[a]Categorization based on first-listed injury diagnosis code.

[b]Other and unspecified injuries include injuries to the internal organs, nerves, and blood vessels, as well as burns, amputations, dislocations, crushing injuries, and unspecified injuries.

[c]In order to protect patient anonymity, cells with counts of 1-9 ED visits are suppressed.

[d]Other and unspecified location consists of spinal cord injuries, system wide injuries, late effects of injuries, and other and unspecified injuries.

[e]Injury Proportion Ratio and 95% CI compares percent in sports/recreational to percent in non-sport /rec recreational.[109]

5.3.4 Activity at Time of Injury

Tables 5.4 and 5.5 display the absolute numbers and incidence rates of injury-related ED visits as well as the proportion of these visits with a diagnosis of TBI, stratified by the type of sport or recreational activity for age group and sex. Among 5-9 year-olds, the most common category of sport and recreational injury was activities involving “play and other activities, usually unstructured” such as “falls from playground equipment”. On the other-hand, “sports/athletics played as a group or team” were by far the most common activity for 10-14 and 15-18 year-olds. Among 10-14-year-olds, American tackle football was the most common cause of injury related to team sports; however, among 15-18 year-olds, basketball was the most common cause of injury related to team sports. For recreational activities, the most common cause of injury was pedal cycling for both 5-9 and 10-14-year-olds. Among 15-18-year-olds, the most common cause of injury was “falls and other injuries resulting from roller skating and skateboarding”. Regarding sports/athletic categories with a diagnosis of TBI, the category of sport with the highest proportion of TBI was American touch/flag football among 5-9-year-olds and rugby among 10-14 and 15-18 year-olds (33.3% and 29.1% respectively). Among recreational activities, the activity with the highest proportion of TBI across all age groups was water-skiing (Table 5.4).

There was also a difference in injury patterns by sex. Except for volleyball, rates of “sports/athletics played as a group or team” were higher among boys for all listed sports categories. Among boys, rates of ED visits due to American tackle football were highest, while for girls, rates of basketball-related ED visits were highest for team sports/athletics. Not all categories of sports/recreational activities were higher for boys, however. Girls were nearly nine times more likely to visit an ED due to “activities involving dancing and rhythmic movement” than boys (Table 5.5). In terms of TBI diagnosis, the three sports/athletics activities with the greatest proportion of TBI-related ED visits among boys were rugby (29.3%), lacrosse/field hockey (22.6%), and American touch/flag football (17.0%). Among girls, the three sports/athletics activities with the greatest proportion of TBI-related ED visits were rugby (32.1%), lacrosse/field hockey (26.6%), and soccer (16.1%) (Table 5.5).

TABLE 5.4 Age-group specific rates of sports/recreation-related injuries and proportions of traumatic brain injury among school-age children: North Carolina, 2010-2014

Sport/recreational activity[a,b]	Age group											
	5-9 years of age				10-14 years of age				15-18 years of age			
	No.	**Rate[c]**	**% with TBI**	**P-value[d]**	**No.**	**Rate[c]**	**% with TBI**	**P-value[d]**	**No.**	**Rate[c]**	**% with TBI**	**P-value[d]**
Team sports	**6,551**	**204.6**	**13.2**	**<.001**	**35,750**	**1,108.3**	**11.5**	**0.002**	**30,520**	**1,190.2**	**13.7**	**.87**
American tackle football	2,274	71	12.8	.05	12,953	401.6	13.4	<.001	9,193	358.5	16.9	<.001
Basketball	1,427	44.6	12.5	.21	10,204	316.3	8.6	<.001	11,711	456.7	8.5	<.001
Soccer	1,196	37.3	9.8	.06	4,897	151.8	12.2	.01	4,015	156.6	19.0	<.001
Baseball/softball	1,266	39.5	17.9	<.001	4,821	149.5	11.8	.14	2,753	107.4	14.1	.44
Volleyball	36	1.1	11.1	>.99	879	27.3	7.5	<.001	793	30.9	10.8	.02
Lacrosse/field hockey	28	0.9	10.7	>.99	302	9.4	21.5	<.001	553	21.6	25.1	<.001
Touch/flag football	85	2.7	21.2	.005	309	9.6	14.2	.08	242	9.4	17.4	.090
Rugby	0	0.0	0.0	--	48	1.5	33.3	<.001	237	9.2	29.1	<.001
Other team sports	239	7.5	12.6	.61	1,337	41.4	10.8	.76	1023	39.9	13.3	.75
Individual sports	**755**	**23.6**	**8.7**	**.02**	**2,542**	**78.8**	**10.2**	**.15**	**2,865**	**111.7**	**13.0**	**.32**
Wrestling	277	8.7	9.4	.27	1,419	44	11.5	.64	1,876	73.2	13.7	.94
Martial arts	106	3.3	8.5	.33	259	8.0	10.0	.58	160	6.2	13.1	.85
Racquet	16	0.5	6.3	>.99	79	2.4	8.9	.53	91	3.5	7.7	.10
Golf	58	1.8	17.2	.17	58	1.8	15.5	.28	43	1.7	16.3	.61
Boxing[e]	<10				40	1.2	2.5	.12	115	4.5	7.8	.07
Bowling	44	1.4	2.3	.06	34	1.1	0.0	.03	28	1.1	0.0	.03
Track and field[e]	<10				39	1.2	5.1	.31	58	2.3	10.3	.46
Other individual sports	250	7.8	7.6	.05	614	19.0	8.5	.04	494	19.3	13.4	.86
Fall/struck by/against in sports	**2,724**	**85.1**	**15.2**	**<.001**	**11,714**	**363.2**	**15.8**	**<.001**	**9,496**	**370.3**	**19.7**	**<.001**
Other team/individual sports, NEC	**128**	**4**	**9.4**	**045**	**375**	**11.6**	**10.1**	**.55**	**276**	**10.8**	**12**	**.41**
Dancing and rhythmic movement	**1,009**	**31.5**	**5.9**	**<.001**	**2,604**	**80.7**	**10.1**	**.09**	**1,904**	**74.2**	**14.5**	**.24**

Sport/recreational activity[a,b]	Age group											
	5-9 years of age				10-14 years of age				15-18 years of age			
	No.	Rate[c]	% with TBI	P-value[d]	No.	Rate[c]	% with TBI	P-value[d]	No.	Rate[c]	% with TBI	P-value[d]
Cheerleading	103	3.2	10.7	.80	1,006	31.2	16.6	<.001	971	37.9	20.2	<.001
Gymnastics	563	17.6	5.0	<.001	938	29.1	7.0	<.001	295	11.5	10.2	.08
Other dancing/rhythmic movement	343	10.7	6.1	.002	660	20.5	4.4	<.001	638	24.9	8	<.001
Cardio and strength training	**4,453**	**139.1**	**13**	**.001**	**6,084**	**188.6**	**6.3**	**<.001**	**4,872**	**190.1**	**4.8**	**<.001**
Running	3,253	101.6	14.5	<.001	3,948	122.4	6.7	<.001	1,929	75.2	5.4	<.001
Walking	1,071	33.4	8.9	.007	1,631	50.6	6.4	<.001	1,609	62.7	5.3	<.001
Other cardio	64	2.0	9.4	.6	134	4.2	2.2	.001	123	4.8	4.1	.002
Strength training	63	2.0	12.7	.76	367	11.4	4.1	<.001	1,211	47.2	3.3	<.001
Yoga[e]	<10				<10				<10			
Play/Unstructured activities	**12,188**	**380.6**	**8.1**	**<.001**	**5,039**	**156.2**	**7.5**	**<.001**	**982**	**38.3**	**9**	**<.001**
Fall from playground equipment	9,290	290.1	8.9	<.001	2,246	69.6	9.7	.03	275	10.7	13.8	.93
Trampoline	2,396	74.8	4.6	<.001	1,816	56.3	3.6	<.001	411	16.0	4.1	<.001
Frisbee	12	0.4	8.3	>.99	61	1.9	11.5	.93	79	3.1	12.7	.80
Jumping rope	58	1.8	8.6	.49	74	2.3	4.1	.05	15	0.6	6.7	.71
Activities involving physical games	432	13.5	9.5	.19	842	26.1	10.0	.30	202	7.9	10.9	.25
Pedal cycle	**9,145**	**285.6**	**12.8**	**<.001**	**8,713**	**270.1**	**10.6**	**.14**	**3,126**	**121.9**	**14.3**	**.25**
Nontraffic	8,297	259.1	12.7	<.001	7,775	241	10.4	.045	2,519	98.2	14.1	.46
Traffic	210	6.6	25.7	<.001	382	11.8	24.1	<.001	414	16.1	17.6	.020
Unspecified	638	19.9	8.9	.04	556	17.2	4.3	<.001	193	7.5	9.8	.12
Activities involving water	**1,001**	**31.3**	**13.1**	**.11**	**1,528**	**47.4**	**14.8**	**<.001**	**1,360**	**53.0**	**15.0**	**.14**
Waterskiing	17	0.5	47.1	<.001	77	2.4	27.3	<.001	118	4.6	23.7	.001
Other activities involving water	984	30.7	12.5	.32	1,451	45.0	14.1	<.001	1,242	48.4	14.2	.58
Other recreational activities	**7,244**	**226.2**	**11.7**	**.56**	**14,149**	**438.6**	**10.5**	**.02**	**9,381**	**365.8**	**13.9**	**.45**
Roller skating/ skateboarding	2,428	75.8	7.5	<.001	6,514	201.9	8.0	<.001	3,434	133.9	11.5	<.001

Sport/recreational activity[a,b]	Age group											
	5-9 years of age				10-14 years of age				15-18 years of age			
	No.	**Rate[c]**	**% with TBI**	**P-value[d]**	**No.**	**Rate[c]**	**% with TBI**	**P-value[d]**	**No.**	**Rate[c]**	**% with TBI**	**P-value[d]**
Snow/off-road vehicles	1,257	39.3	16.8	<.001	2,791	86.5	14.5	<.001	2,429	94.7	15.9	.001
Snow skiing, snowboarding, etc.	541	16.9	22.4	<.001	1,706	52.9	14.0	<.001	1,527	59.5	17.3	<.001
Animal being ridden	414	12.9	21.5	<.001	978	30.4	20.9	<.001	1,123	43.8	20.7	<.001
Scooter	1,433	45.1	11.4	.96	929	28.8	9.3	.07	123	4.8	2.4	<.001
Air gun	377	11.8	2.7	<.001	768	23.8	2.3	<.001	448	17.5	1.1	<.001
Climbing/ rappelling	794	24.8	8.7	.01	463	14.4	4.8	<.001	297	11.6	5.7	<.001
Place of recreation/sport	**4,293**	**134.1**	**13.0**	**.001**	**6,387**	**198.0**	**9.4**	**<.001**	**4,356**	**169.9**	**9.9**	**<.001**
TOTAL	**49,491**	**1,545.5**	**11.5**	**--**	**94,885**	**2,941.6**	**11.1**	**--**	**69,142**	**2,696.3**	**13.6**	**--**

Abbreviations: No., number; TBI, traumatic brain injury; NEC, not elsewhere classifiable

[a]Among ED visits with more than one sports and recreation-related E-code, categorization was based on the most specific E-code. In instances when two or more E-codes were the same level of specificity, categorization was based on the first-listed E-code.

[b]Sport/recreational activity designations have been abbreviated for display; for complete descriptions, please see Table 5.2.

[c]Population-based incidence rates are per 100,000 person-years.

[d]Pearson chi-square tests (expected cell counts >5) and Fisher's Exact tests used (expected cell counts <5) were used for calculation of p-values.

[e]In order to protect patient anonymity, cells with counts of 1-9 ED visits are suppressed.

TABLE 5.5 Sex-specific rates of sports/recreation-related injuries and proportions of traumatic brain injury among school-age children: North Carolina, 2010-2014

Injury sport/recreational activity[a,b]	Sex							
	Boys				Girls			
	No.	Rate (95% CI)[c]	% with TBI	P-value[d]	No.	Rate (95% CI)[c]	% with TBI	P-value[d]
Team sports	**56,562**	**1,231.9 (1,221.8-1,242.1)**	**12.5**	**0.32**	**16,256**	**369.4 (363.8-375.1)**	**12.9**	**<.001**
American tackle football	23,603	514.1 (507.5-520.7)	14.9	<.001	817	18.6 (17.3-19.9)	6.9	<.001
Basketball	18,204	396.5 (390.8-402.3)	7.7	<.001	5,137	116.7 (113.6-120.0)	12.7	<.001
Soccer	5,930	129.2 (125.9-132.5)	13.6	.02	4,177	94.9 (92.1-97.8)	16.1	<.001
Baseball/softball	5,315	115.8 (112.7-118.9)	14.9	<.001	3,524	80.1 (77.5-82.8)	11.1	.52
Volleyball	288	6.3 (5.6-7.0)	6.9	.004	1,420	32.3 (30.6-34.0)	9.6	.14
Lacrosse/field hockey	695	15.1 (14.1-16.3)	22.6	<.001	188	4.3 (3.7-4.9)	26.6	<.001
Touch/flag football	519	11.3 (10.4-12.3)	17.0	.003	117	2.7 (2.2-3.2)	13.7	.31
Rugby	232	5.1 (4.4-5.7)	29.3	<.001	53	1.2 (0.9-1.6)	32.1	<.001
Other team sports	1,776	38.7 (36.9-40.5)	11.9	.36	823	18.7 (17.5-20.0)	12.2	.21
Individual sports	**5,023**	**109.4 (106.4-112.5)**	**12.0**	**.17**	**1,139**	**25.9 (24.4-27.4)**	**8.6**	**.02**
Wrestling	3,256	70.9 (68.5-73.4)	12.9	.55	316	7.2 (6.4-8.0)	7.9	.10
Martial arts	361	7.9 (7.1-8.7)	12.5	.94	164	3.7 (3.2-4.3)	6.7	.09
Racquet	90	2.0 (1.6-2.4)	10.0	.46	96	2.2 (1.8-2.7)	6.3	.15
Golf	111	2.4 (2.0-2.9)	15.3	.39	48	1.1 (0.8-1.4)	18.8	.08
Boxing	144	3.1 (2.7-3.7)	6.3	.02	12	0.3 (0.2-0.5)	8.3	>.99
Bowling	52	1.1 (0.9-1.5)	1.9	.02	54	1.2 (0.9-1.6)	0.0	.004
Track and field	59	1.3 (1.0-1.7)	6.8	.24	41	0.9 (0.7-1.3)	9.8	>.99
Other individual sports	950	20.7 (19.4-22.0)	10.0	.02	408	9.3 (8.4-10.2)	10.3	.74
Fall/struck by/against in sports	**18,414**	**401.0 (395.3-406.9)**	**17.2**	**<.001**	**5,518**	**125.4 (122.1-128.7)**	**17.7**	**<.001**
Other team/individual sports, NEC	**496**	**10.8 (9.9-11.8)**	**10.7**	**.20**	**283**	**6.4 (5.7-7.2)**	**10.6**	**.92**
Dancing and rhythmic movement	**587**	**12.8 (11.8-13.9)**	**8.9**	**.006**	**4,930**	**112.0 (108.9-115.2)**	**11.1**	**.48**

Injury sport/recreational activity[a,b]	Sex							
	Boys				Girls			
	No.	Rate (95% CI)[c]	% with TBI	P-value[d]	No.	Rate (95% CI)[c]	% with TBI	P-value[d]
Cheerleading	38	0.8 (0.6-1.1)	10.5	>.99	2,042	46.4 (44.4-48.5)	18.1	<.001
Gymnastics	250	5.4 (4.8-6.2)	10.4	.30	1,546	35.1 (33.4-36.9)	6.3	<.001
Other dancing/rhythmic movement	299	6.5 (5.8-7.3)	7.4	.006	1,342	30.5 (28.9-32.2)	5.9	<.001
Cardio and strength training	**8,601**	**187.3 (183.4-191.3)**	**9.5**	**<.001**	**6,810**	**154.7 (151.1-158.5)**	**5.7**	**<.001**
Running	5,257	114.5 (111.4-117.6)	11.4	.009	3,872	88.0 (85.3-90.8)	6.2	<.001
Walking	1,930	42.0 (40.2-44.0)	8.4	<.001	2,381	54.1 (52.0-56.3)	5.2	<.001
Other cardio	152	3.3 (2.8-3.9)	6.6	.03	168	3.8 (3.3-4.4)	2.4	<.001
Strength training	1,258	27.4 (25.9-29.0)	3.4	<.001	383	8.7 (7.9-9.6)	5.2	<.001
Yoga[e]	<10				<10			
Play/unstructured activities	**9,633**	**209.8 (205.7-214.0)**	**8.8**	**<.001**	**8,575**	**194.9 (190.8-199.0)**	**7.0**	**<.001**
Fall from playground equipment	6,150	133.9 (130.6-137.3)	9.9	<.001	5,660	128.6 (125.3-132.0)	8.4	<.001
Trampoline	2,420	52.7 (50.6-54.8)	5.4	<.001	2,203	50.1 (48.0-52.2)	2.9	<.001
Frisbee	119	2.6 (2.2-3.1)	10.1	.41	33	0.7 (0.5-1.1)	18.2	.16
Jumping rope	43	0.9 (0.7-1.3)	11.6	.85	104	2.4 (2.0-2.9)	3.8	.02
Activities involving physical games	901	19.6 (18.4-20.9)	10.3	.04	575	13.1 (12.0-14.2)	9.4	.28
Pedal cycle	**14,561**	**317.1 (312.0-322.3)**	**13.4**	**.004**	**6,420**	**145.9 (142.4-149.5)**	**9.3**	**<.001**
Nontraffic	12,757	277.8 (273.1-282.7)	13.3	.02	5,832	132.5 (129.2-136.0)	9.1	<.001
Traffic	845	18.4 (17.2-19.7)	21.1	<.001	160	3.6 (3.1-4.2)	25.6	<.001
Unspecified	959	20.9 (19.6-22.3)	7.8	<.001	428	9.7 (8.8-10.7)	5.8	<.001
Activities involving water	**2,397**	**52.2 (50.2-54.3)**	**14.4**	**.006**	**1,492**	**33.9 (32.2-35.7)**	**14.4**	**<.001**
Waterskiing	133	2.9 (2.4-3.4)	26.3	<.001	79	1.8 (1.4-2.2)	27.8	<.001
Other activities involving water	2264	49.3 (47.3-51.4)	13.7	.10	1,413	32.1 (30.5-33.8)	13.7	<.001
Other recreational activities	**1,9297**	**420.3 (414.4-426.3)**	**12.3**	**.15**	**11,475**	**260.8 (256.0-265.6)**	**11.1**	**.27**
Roller skating/ skateboarding	8,012	174.5 (170.7-178.4)	11.0	<.001	4,364	99.2 (96.3-102.2)	4.9	<.001
Snow/off-road vehicles	4,541	98.9 (96.1-101.8)	15.1	<.001	1,935	44.0 (42.1-46.0)	16.4	<.001

Injury sport/recreational activity[a,b]	Sex							
	Boys				Girls			
	No.	Rate (95% CI)[c]	% with TBI	P-value[d]	No.	Rate (95% CI)[c]	% with TBI	P-value[d]
Snow skiing, snowboarding, etc.	2,470	53.8 (51.7-56.0)	17.7	<.001	1,304	29.6 (28.1-31.3)	14.4	<.001
Animal being ridden	627	13.7 (12.6-14.8)	16.9	.001	1,887	42.9 (41.0-44.9)	22.2	<.001
Scooter	1,321	28.8 (27.3-30.4)	12.5	.91	1,164	26.5 (25.0-28.0)	7.6	<.001
Air gun	1,380	30.1 (28.5-31.7)	2.2	<.001	213	4.8 (4.2-5.5)	1.4	<.001
Climbing/ rappelling	946	20.6 (19.3-22.0)	7.0	<.001	608	13.8 (12.8-15.0)	6.9	.002
Place of recreation/sport	**9,434**	**205.5 (201.4-209.7)**	**10.7**	**<.001**	**5,602**	**127.3 (124.0-130.7)**	**10.3**	**.23**
TOTAL	**145,005**	**3,158.2 (3,141.9-3,174.5)**	**12.6**	--	**68,500**	**1,556.6 (1,545.0-1,568.3)**	**10.8**	--

Abbreviations: No., number; CI, confidence interval; TBI, traumatic brain injury; NEC, not elsewhere classifiable.
Missing: 13 missing sex.
[a]Among ED visits with more than one sports and recreation-related E-code, categorization was based on the most specific E-code. In instances when two or more E-codes were the same level of specificity, categorization was based on the first-listed E-code.
[b]Sport/recreational activity designations have been abbreviated for display; for complete descriptions, please see Table 5.2.
[c]Population-based incidence rates are per 100,000 person-years.
[d]Pearson chi-square tests (expected cell counts >5) and Fisher's Exact tests used (expected cell counts <5) were used for calculation of p-values.
[e]In order to protect patient anonymity, cells with counts of 1-9 ED visits are suppressed.

5.4 Discussion

This study used a broad case definition to identify SR ED visits among school age children and youth in a large, well-defined US population. Results indicate that injuries due to sport and recreational activities have substantial high incidence and represent a potentially serious public health problem in the population. There are approximately 43,000 ED visits per year in NC for youth sports injury, 12% of which received a diagnosis of TBI. In addition, much of the literature has focused on more severe SR injuries resulting in hospitalization and death. These injuries represent the "tip of the iceberg" of the total number of SR injuries. [111] ED visit data provide a more comprehensive picture of the total number, type, and severity of injuries associated with SR activities. [7,38,93,112,113]

Consistent with previous population-based studies of SR injuries, fractures and strains/sprains of the upper and lower extremities were the most common types of injuries identified in this study. [40,41,96] There were also more diagnoses of TBI among SR ED visits than other mechanisms of unintentional injury. NC DETECT ED visit data do not capture information on medical cost or length of hospital stay. However, due to the higher proportion of TBI diagnosis reported among SR ED visits, it is possible that these visits may have greater long-term cost than other types of unintentional injuries among children. Previous studies have found that diagnoses of even mild to moderate TBI are associated with high medical costs and may result in sequelae requiring long-term medical care. [75,101,114]

Consistent with the literature, population-based rates of SR injuries were higher among boys in comparison to girls. [40,41,98] This likely reflects different patterns of participation; that is, the elevated incidence rate among boys is likely a reflection of their greater participation in organized sports activities. These findings may also reflect differences in the perception of risk, variation in the likelihood of injury, and gender differentials in care-seeking by parents. [10,115]

Incidence rates of SR injury peaked among children 10-14 years of age. The rate of SR injury declined by 26% among 10-14 and 15-18 year-old girls. Meanwhile, the corresponding decrease among boys was less than one percent. While physical activity levels tend to decrease in adolescence for both sexes, the baseline level of physical activity and the age at which activity levels start to decline is lower for girls than boys. [116,117]

The team sports with the greatest proportion of ED visits with a diagnosis of TBI were rugby and lacrosse/field hockey. The sport with the highest population-based incidence of TBI was American tackle football. Overall, boys had higher incidence rates of SR TBIs. However, for select sports such as basketball, baseball/softball, rugby, and soccer, the proportion of ED visits with a diagnosis of TBI was higher for girls than boys. This finding is consistent with prior literature indicating that girls may be at a greater risk for several types of sports injuries, including knee injuries and TBIs, than boys. [9,118–120] In particular, soccer has a relatively high risk of acute injury, especially among girls. [121] Soccer-related TBIs are most commonly caused by collision with other players, contact with the ground, inadvertent contact with the ball, and intentional contact with the ball (i.e. “heading”). [120] While prevention efforts have often focused on instructing children in proper heading technique, or banning heading altogether, it is unclear whether these efforts have made much of an impact on preventing TBIs among children. [122,123]

Similar to other states, NC has developed legislation and prevention programs for preventing and managing sports injuries, particularly TBIs.[124,125] In general, these programs have increased the availability of certified athletics trainers at schools; have improved education of coaching staff, student-athletes, and parents; and have led to the development of return-to-play guidelines after TBI. In addition to school-based programs, the medical community has an important role in tackling SR injuries. For example, NC student-athletes with a diagnosis of TBI must be cleared by a physician before returning to play. Therefore, EDs have developed programs linking patients with community services, such as designated concussion clinics, designed to promote TBI recovery and prevent future injuries. [126] While these school- and healthcare-based programs are commendable, they often fail to address injury among younger student-athletes and do little to prevent injury due to unorganized sports and recreational activities.

This study has several limitations. NC DETECT ED visit data are collected by hospitals for clinical, billing, and other administrative purposes. The use of these data for public health surveillance is a secondary function. However, data missingness was low (<15%) for individual data elements used in analyses. Another limitation of this study is related to the use of statewide NC ED visit data. While population-based studies have many strengths, results may not be generalizable to other jurisdictions. Although NC is a large state, (ranked 9th in the US in terms of population) the distribution of physical activity, as well as injury and healthcare usage, may differ from other regions of the US. Ice hockey and lacrosse, for example, have strong regional bases in the mid-east, mid-west, and north-east regions, but currently are less popular in the south, whereas there is less regional variation in participation in sports such as baseball, softball, soccer, football, and basketball.

Finally, the broad definition of sports and recreational activities used in this study included organized school sports, organized community sports, unorganized sports, and recreational outdoor activities. While this comprehensive definition is a strength, it precluded the use of specific activity-time denominators for the calculation of exposure-based rates due to the lack of exposure data sources at the population level in NC (or any other US jurisdiction). While this study identified American tackle football, basketball, and soccer as the three organized sports activities with the highest population-based rates of injury, it is possible that the use of an exposure-based denominator would produce different results.

5.5 Conclusion

Sports and recreational activities are an important source of morbidity among school-aged children and youth in NC. This is one of the first descriptive epidemiologic studies to use a comprehensive definition to characterize sports and recreation-related injury in a well-defined US population. In addition, this study indicates that physical activity promotion programs should consider differences in risk of sports and recreation-related injury by sex and age group.

5.6 Data Attribution and Disclaimer

NC DETECT is a statewide public health syndromic surveillance system, funded by the NC Division of Public Health (NC DPH) Federal Public Health Emergency Preparedness Grant and managed through collaboration between NC DPH and UNC-CH Department of Emergency Medicine’s Carolina Center for Health Informatics. The NC DETECT Data Oversight Committee does not take responsibility for the scientific validity or accuracy of methodology, results, statistical analyses, or conclusions presented.

CHAPTER 6: CHARACTERISTICS OF EMERGENCY DEPARTMENT VISITS FOR SUSPECTED TRAUMATIC BRAIN INJURY FROM SPORTS AND RECREATIONAL ACTIVITIES IN SCHOOL-AGE YOUTH (MANUSCRIPT 2)

6.1 Introduction

Traumatic brain injury (TBI), including concussion, is a common injury among youth with an annual average number of 1.1 million United States (US) emergency department (ED) visits. Sports and recreational activities are leading causes of youth TBI.[57,127,128] There is increasing concern about sports and recreation-related (SR) TBIs, as the number of reported US cases continues to increase and the short and long-term impacts of TBI are better understood.[129,130] Over the course of 2001-2012, the rate of SR TBI-related ED increased by 108%.[130] Factors that may be driving this upturn include an increased awareness of the signs and symptoms of TBI, and an increased awareness of the potential health impacts of TBI.[129,130,75,131,10]

While the full impact of TBI on the developing brain is not fully understood, evidence suggests that even relatively minor TBI, may lead to adverse neurologic outcomes in children, particularly if the head trauma is repetitive.[129,132] The purpose of this manuscript is to characterize the presentation of pediatric TBI and to identify and describe differences in TBIs related to sports and recreational activities to TBIs related to other causes of injuries.

This study accomplished this objective through an in-depth examination of the patient demographics, circumstances, symptomology, and treatment of school-age youth with suspected TBIs presenting at a large, metropolitan hospital system.

6.2 Methods

This descriptive epidemiologic study examined data from the Child Head Injury Research Initiative (CHIRI).

6.2.1 CHIRI Study Design (Parent Study)

CHIRI's primary objective was the collection of comprehensive data on all pediatric patients with a suspected TBI across the continuum of care from presentation at the ED through discharge from the ED or hospital. In addition, for about one-third of all patients, a telephone survey was administered to the patient's parent or guardian for the collection of follow-up medical information.

CHIRI enrolled all patients, 0-17 years of age with a suspected TBI, entering a single, large hospital system, based in Wake County, North Carolina (NC), during the period March 1, 2013 through February 28, 2014. At the time of study, the hospital system represented six of the eight EDs in the county and had a total combined annual census of greater than 200,000 ED visits. The flagship hospital contained a Level I Trauma Center, children's hospital, children's ED, and pediatric and neonatal intensive care unit. In 2010, Wake County was the second most populous county in NC with a population consisting of 69% white, 21% black, and 10% some other race. Wake County is classified as a metropolitan statistical area and has a higher than average per capita income (and a lower percent of its population below the poverty threshold) than the state average.[133] Due to the extensive healthcare resources available at the flagship ED, the hospital system also provided care to residents from less populous neighboring counties.

A patient entered the CHIRI database through one of two ways: 1) a medical provider at an affiliated ED proactively accessed the CHIRI data entry form through the electronic medical record (EMR) for a pediatric patient with a suspected TBI or 2) the medical provider accessed the CHIRI data entry form after the patient's EMR was flagged as a suspected TBI, based on information captured in the chief complaint (e.g. loss of consciousness, altered mental status, motor vehicle crash, etc.). The medical provider recorded patient characteristics, injury characteristics, clinical diagnoses, medical procedures, and inpatient information, including neurosurgical results. For a subset of the patients, a trained CHIRI staff member administered a telephone follow-up survey to the parent/guardian of the patient, in English or Spanish, approximately two weeks after the initial ED visit.

The Institutional Review Boards at the University of North Carolina at Chapel Hill and WakeMed Health and Hospitals approved this study and the original CHIRI study.

6.2.2 Study Sample

This study focused on incident ED visits made by patients, 5-17 years of age, with suspected head injury related to unintentional causes. We therefore utilized a subset of the CHIRI database. Specifically, we excluded CHIRI records who met any of the following criteria 1) age less than 5 years; 2) patient was making a repeat ED visit; 3) duration between injury and initial ED visit greater than three days or unknown; 4) a patient history of a brain tumor; and 5) injury was suspected of being related to abuse, assault, self-harm, or unknown. Of the original

CHIRI study population of 3,271 ED visits, slightly more than half were excluded by these criteria, leaving a total sample of 1,526 patient visits in this study (Figure 6.1).

6.2.3 Measures

6.2.3.1 Injury Type

We classified injuries according to the text descriptions provided by clinicians. We defined an injury as SR if it was described as “sports-related”, “bicycle-fall”, “bicycle-struck”, “sport/wheeled transport crash” (e.g. all-terrain vehicle), “water-related” (e.g. swimming, diving), or involving a “non-motorized scooter”. We selected these categories based on prior studies that have examined the relationship between injuries and sports/recreational activities.[38,41,134]

For SR ED visits, we further classified the ED visit according to the type of sport (e.g. football, basketball, soccer, etc.). For the remaining unintentional injury-related ED visits, we classified the ED visit as related to a fall if it was described as a “fall down stairs”, “fall from height (not stairs)”, or “fall from standing, walking, or running”; a motor vehicle crash if it was described as related to a “motor vehicle accident” or “pedestrian-struck”; and other injury if it was related to a “head struck by object/body part (accidental)”, “walk/run into stationary object”, “hanging”, “animal bite”, or “other mechanism”.

6.2.3.2 Traumatic Brain Injury

CHIRI collected information on all pediatric patients with a *suspected* TBI and as such not all patients received a final diagnosis of TBI upon discharge. A positive diagnosis of TBI was assigned if the patient had at least one clinician assigned International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code meeting the Centers for Disease Control and Prevention (CDC) definition of TBI (excluding diagnosis code 995.55 for "shaken infant syndrome").[53] Since CHIRI collected physician assigned diagnosis codes rather than diagnosis codes assigned at billing, a lack of a qualifying TBI diagnosis code should not be considered a definitive non-diagnosis of TBI. For suspected TBIs that did not contain a diagnosis code for TBI, the injury was classified according to the Barell Injury Diagnosis Matrix.[108]

6.2.3.3 Patient and Clinical Characteristics

Medical providers recorded information describing the patient's medical history, circumstances preceding injury, location of injury, nature of injury, symptoms, clinical exam results, medical procedures, and patient disposition among other characteristics. In addition, CHIRI collected all medical imaging results (X-ray, computed tomography, magnetic resonance imaging, etc.) performed on the patient in the emergency department or after admission to the hospital. In addition to information provided directly by the medical provider, additional elements, such as hospital stay and neurosurgical information, were pulled directly from the EMR.

6.2.3.4 Telephone Follow-Up

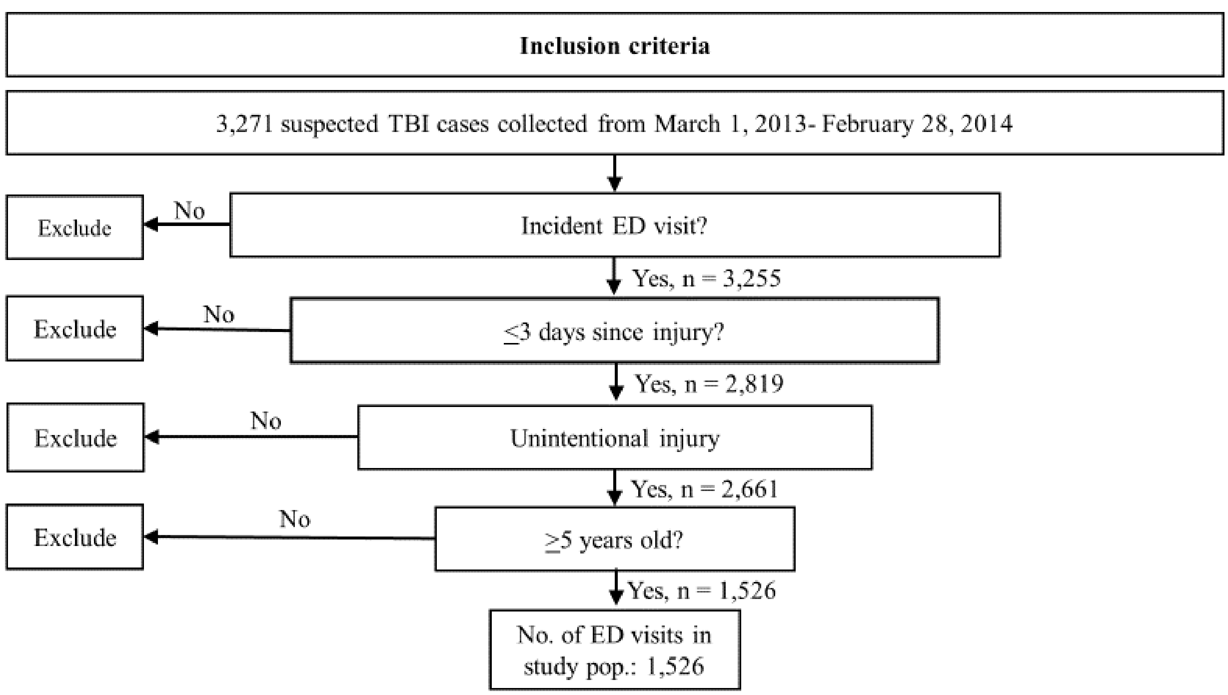
A trained member of the CHIRI research staff contacted the parent or guardian for follow-up information regarding additional medical treatment and imaging and continued or delayed symptomology (i.e. symptoms not apparent at time of initial visit) approximately one to two weeks after the initial ED visits. Approximately one-third of the patient population had telephone follow-up information collected.

6.2.4 Statistical Analyses

Categorical variables were summarized using frequencies and percentages. Continuous variables were summarized with medians and interquartile ranges (IQRs). Pearson's chi-square test, Fisher Exact test, and Wilcoxon Signed-Rank test were used to make comparisons between youth with suspected TBIs related to sports and recreational activities and youth with suspected TBIs unrelated to sports and recreational activities.

In addition, for selected characteristics, injury proportion ratios (IPRs) and 95% confidence intervals (CIs) were calculated to compare differences among children presenting with suspected TBIs related to sports and recreational activities to children with suspected TBIs related to other causes.[109]

FIGURE 6.1 Flowchart of inclusion and exclusion criteria for study population: CHIRI, March 2013-February 2014



Abbreviations: TBI, traumatic brain injury; ED, emergency department; pop, population

6.3 Results

There were 1,526 ED visits that met the inclusion criteria of a suspected TBI among children 5-17 years of age with an unintentional injury. Of these 1,526 visits, 352 (23.1%) were related to sports/recreational activities and 1,174 were related to some other type of unintentional injury (76.9%).

6.3.1 Initial Presentation

Over one-half of all SR ED visits due to suspected TBI were related to three activities (Table 6.1): bicycling, playing football, and riding off-road vehicles (e.g. all-terrain vehicles). There was variation in the type of activity by age group. Bicycling was the most common cause of SR TBI among youth 5-9 and 10-14 years of age, whereas football was the most common cause among youth 15-17 years of age. Among suspected TBIs related to non-sports and recreation-related activities, the most common causes of injuries were unintentional falls among 5-14 year-olds and motor vehicle crashes among 15-17 year-olds.

Patient and ED visit characteristics differed between sports and recreational activities and non-sports and recreational activities (Table 6.2). Children with suspected TBIs related to sports and recreational activities were more likely to be male and older (median age: 13.3 years, IQR: 10.8-15.5) than children with injuries related to non-sports and recreational activities (median age: 10.2 years, IQR: 7.0-14.5). In addition, a greater proportion of SR ED visits occurred during the months of September through November; a span of time that roughly corresponds with football season, along with other school-organized team sports (IPR: 1.32, 95% CI: 1.13-1.55). However, the proportion of ED visits related to suspected SR TBIs was not elevated during the months of March – May, a period corresponding with spring school-organized sports season (IPR: 0.97, 95% CI: 0.78-1.20). Although counts were low and not statistically significant, children with SR TBIs were 1.57 times more likely to have a history of prior head injury than children with non-SR TBIs (95% CI: 0.96-2.57).

TABLE 6.1 Frequency of unintentional injury mechanism type among school-age children with a suspected traumatic brain injury, stratified by age group: CHIRI, March 2013-February 2014

	Age Group[a]			**TOTAL**
	5-9 n (%)	**10-14 n (%)**	**15-17 n (%)**	
TOTAL	**644 (100.0)**	**519 (100.0)**	**363 (100.0)**	**1,526 (100.0)**
Type of unintentional injury				
Falls	297 (46.1)	143 (27.6)	72 (19.8)	512 (33.6)
MVC	53 (8.2)	47(9.1)	88 (24.2)	188 (12.3)
Other	218 (33.9)	162 (31.2)	94 (25.9)	474 (31.1)
Sports/Recreation	76 (11.8)	167 (32.2)	109 (30.0)	352 (23.1)
Total Sports/Recreation (n=352)				
Bicycle crash	39 (51.3)	39 (23.4)	10 (9.2)	88 (25.0)
Football	3 (3.9)	37 (22.2)	21 (19.3)	61 (17.3)
Off-road vehicle (e.g. ATV)	6 (7.9)	17 (10.2)	14 (12.8)	37 (10.5)
Soccer	4 (5.3)	14 (8.4)	11 (10.1)	29 (8.2)
Baseball/Softball	4 (5.3)	13 (7.8)	9 (8.3)	26 (7.4)
Basketball	3 (3.9)	9 (5.4)	12 (11.0)	24 (6.8)
Roller & ice skating/skateboarding	4 (5.3)	12 (7.2)	7 (6.4)	23 (6.5)
Water-related activities (e.g. swimming/diving)	1 (1.3)	8 (4.8)	3 (2.8)	12 (3.4)
Ice Hockey	1 (1.3)	4 (2.4)	5 (4.6)	10 (2.8)
Volleyball	0 (0.0)	3 (1.8)	5 (4.6)	8 (2.3)
Lacrosse/Field hockey	0 (0.0)	2 (1.2)	5 (4.6)	7 (2.0)
Martial arts/Wrestling	0 (0.0)	0 (0.0)	5 (4.6)	5 (1.4)
Cheerleading	0 (0.0)	2 (1.2)	0 (0.0)	2 (0.6)
Winter sports (e.g. sledding)	1 (1.3)	0 (0.0)	1 (0.9)	2 (0.6)
Other/Unknown	10 (13.2)	7 (4.2)	1 (0.9)	18 (5.1)

Abbreviations: MVC, motor vehicle crash; ATV, all-terrain vehicle
[a]Column totals sum to 100%.

TABLE 6.2 Selected characteristics of school-age children with a suspected traumatic brain injury: CHIRI, March 2013-February 2014

	Injury Type[a]				
	Sport/ Recreation[b] n (%)	Other Unintentional[c] n (%)	TOTAL n (%)	Not Recorded/ Evaluated (n)	P-value[d]
TOTAL	**352 (100.0)**	**1,174 (100.0)**	**1,526 (100.0)**		
Age (categorical)[e]				0	<.001
5-9	76 (21.6)	568 (48.4)	644 (42.2)		
10-14	167 (47.4)	352 (30.0)	519 (34.0)		
15-17	109 (31.0)	254 (21.6)	363 (23.8)		
Sex, n (%)				0	<.001
Male	260 (73.9)	719 (61.2)	979 (64.2)		
Female	92 (26.1)	455 (38.8)	547 (35.8)		
Arrived via ambulance	60 (17.0)	188 (16.0)	248 (16.3)	2	.65
Time since injury (hours				0	.90
<24 hours	298 (84.7)	997 (84.9)	1,295 (84.9)		
≥24 hours	54 (15.3)	177 (15.1)	231 (15.1)		
Season[e]				0	.001
Dec. - Feb.	52 (14.8)	270 (23.0)	322 (21.1)		
Mar. - May	82 (23.3)	283 (24.1)	365 (23.9)		
June - Aug.	83 (23.6)	280 (23.9)	363 (23.8)		
Sept. - Nov.	135 (38.4)	341 (29.0)	476 (31.2)		
History of head injury	22 (6.4)	47 (4.1)	69 (4.6)	27	.07

Abbreviations: IQR, interquartile range; Dec., December; Feb., February; Mar., March; Aug., August; Sept., September; Nov., November
[a]Column totals sum to 100%.
[b]Defined as an injury related to organized/unorganized sports/athletics, bicycle crashes, sport/wheeled transport crashes, non-motorized scooter crashes, and recreational water-related activities.
[c]Defined as all other types of unintentional injuries (e.g. motor vehicle crashes, falls from stairs/steps, etc.); excludes assaults and injuries related to self-harm.
[d]Pearson chi-square tests (categorical variables) and Wilcoxon Signed-Rank Test (continuous variables) were used for calculation of p-values.
[e]Due to rounding, percentages may not add to 100 percent.

6.3.2 Symptomology and Diagnosis

Youth presenting with suspected TBIs related to sports and recreational activities were more likely to have a higher acuity (ESI-1 or ESI-2) at triage than children with suspected TBIs related to non-sports and recreational activities (IPR: 1.68, 95% CI:1.24-2.29; Table 6.3).

Overall, children with injuries related to sports and recreational activities were more likely to report symptoms consistent with TBI than children with non-sports injuries, with nearly one-half reporting ≥ 2 symptoms when assessed at the ED (IPR: 1.48, 95% CI: 1.30-1.70; Table 6.3). In contrast, only about one-third of patients with suspected TBIs related to non-sports and recreational activities reported ≥2 symptoms. For the entire study population, headache was the most common reported symptom at presentation. Moreover, children with suspected TBIs related to sports and recreational activities were 1.38 times more likely to report headache than children with injuries related to non-sports and recreational activities (95% CI: 1.21-1.57). When assessed at the ED, children with SR TBIs were also more likely to report nausea (IPR: 1.40, 95% CI: 1.12-1.75), loss of consciousness (IPR: 1.41, 95% CI: 1.10-1.82), dizziness (IPR: 1.52, 95% CI: 1.14-2.02), amnesia (IPR: 2.43, 95% CI: 1.78-3.30), and confusion (IPR: 2.56, 95% CI: 1.61-4.05) than children with non-SR TBIs. Children with suspected TBIs related to sports and recreational activities were also twice as likely to have an abnormal neurologic exam as compared to children with TBIs related to non-sports and recreational activities (IPR: 2.05, 95% CI: 1.50-2.80).

Over one-half of the study population had a clinician-assigned diagnosis code indicating a TBI (Table 6.3). Children with injuries related to sports and recreational activities were 1.3 times more likely to receive a diagnosis indicating a TBI than children with suspected TBIs related to other types of injuries (95% CI: 1.19-1.45). In contrast, a larger proportion of children with injuries related to non-sports and recreational activities had a clinician-assigned diagnosis code indicating an injury to the face, head, or neck. Less than five percent of the entire study population was admitted to the hospital. Likelihood of admission to the hospital was similar across the two groups (IPR: 1.13, 95% CI: 0.86-1.49).

TABLE 6.3 Selected clinical characteristics of school-age children with a suspected traumatic brain injury: CHIRI, March 2013-February 2014

	Injury Type[a]				
	Sport/ Recreation[b] n (%)	**Other Unintentional[c] n (%)**	**TOTAL n (%)**	**Not Recorded/ Evaluated (n)**	**P-value[d]**
TOTAL	**352 (100.0)**	**1,174 (100.0)**	**1,526 (100.0)**		
Acuity					
ESI				0	.001
ESI-1 (resuscitation) or ESI-2 (emergent)	53 (15.1)	105 (8.9)	158 (10.4)		
ESI-3 (urgent)	109 (31.0)	305 (26.0)	414 (27.1)		
ESI-4 (less urgent) or ESI-5 (non-urgent)	190 (54.0)	764 (65.1)	954 (62.5)		
Hospital admission					
Admitted	13 (3.7)	39 (3.3)	52 (3.4)	7	.74
Clinical signs and symptoms[e]					
Headache	174 (50.6)	412 (36.7)	586 (39.9)	58	<.001
Nausea	87 (24.9)	206 (17.7)	293 (19.4)	14	.003
Abnormal behavior[e]	63 (18.2)	194 (16.9)	257 (17.2)	32	.59
LOC	70 (20.2)	165 (14.3)	235 (15.6)	22	.008
Dizziness	59 (17.5)	127 (11.5)	186 (12.9)	84	.004
Vomiting	36 (10.3)	128 (11.0)	164 (10.8)	14	.73
Amnesia	61 (18.0)	82 (7.4)	143 (9.9)	81	<.001
Visual disturbance	29 (8.5)	58 (5.3)	87 (6.0)	81	.03
Photophobia	26 (7.8)	49 (4.4)	75 (5.2)	76	.01
Confusion	30 (8.9)	39 (3.5)	69 (4.7)	73	<.001
Balance problem	18 (5.3)	32 (2.8)	50 (3.4)	58	.03
Seizure	1 (0.3)	9 (0.8)	10 (0.7)	30	.47
Total signs/symptoms count[f]				7	<.001
0 symptoms	103 (29.4)	515 (44.1)	618 (40.7)		
1 symptom	75 (21.4)	267 (22.8)	342 (22.5)		
2 symptoms	62 (17.7)	162 (13.9)	224 (14.7)		
≥3 symptoms	110 (31.4)	225 (19.2)	335 (22.1)		
Clinical examination[g]					
Delayed response to verbal communication	30 (8.7)	40 (3.5)	70 (4.7)	25	<.001
Altered mental status	17 (4.9)	30 (2.6)	47 (3.1)	21	.03
GCS < 15[g]	6 (1.7)	30 (2.6)	36 (2.4)	3	.36
Lethargy	13 (3.8)	23 (2.0)	36 (2.4)	48	.07
Irritability	5 (1.4)	21 (1.8)	26 (1.7)	18	.63
Perseveration	6 (1.7)	15 (1.3)	21 (1.4)	34	.55

	Injury Type[a]				
	Sport/ Recreation[b] n (%)	**Other Unintentional[c] n (%)**	**TOTAL n (%)**	**Not Recorded/ Evaluated (n)**	**P-value[d]**
TOTAL	**352 (100.0)**	**1,174 (100.0)**	**1,526 (100.0)**		
Deterioration	7 (2.2)	13 (1.3)	20 (1.5)	186	.23
Neurologic deficits	6 (1.7)	11 (1.0)	17 (1.1)	43	.23
Skull fracture	0 (0.0)	6 (0.5)	6 (0.4)	22	.21
Total exam count[f]				13	<.001
0 + exam results	293 (84.0)	1,073 (92.2)	1,366 (90.3)		
1 + exam result	33 (9.5)	48 (4.1)	81 (5.4)		
≥2 + exam results	23 (6.6)	43 (3.7)	66 (4.4)		
Clinician assigned diagnosis[i] (n=1,243)				283	
TBI[j,k]	202 (68.9)	499 (52.5)	701 (56.4)		<.001
Other face/head/neck injury[l]	44 (15.0)	206 (21.7)	250 (20.1)		.01
Upper/Lower extremity injury[l]	6 (2.0)	21 (2.2)	27 (2.2)		.87
Torso injury[l]	7 (2.4)	8 (0.8)	15 (1.2)		.06
Other/Unspecified injury[l]	21 (7.2)	87 (9.2)	108 (8.7)		.29
Non-injury diagnosis	13 (4.4)	129 (13.6)	142 (11.4)		<.001

Abbreviations: ESI, Emergency Severity Index; LOC, loss of consciousness; sec, seconds; min, minutes; GCS, Glasgow Coma Scale; TBI, traumatic brain injury

[a]Column totals sum to 100%.

[b]Defined as an injury related to organized/unorganized sports/athletics, bicycle crashes, sport/wheeled transport crashes, non-motorized scooter crashes, and recreational water-related activities.

[c]Defined as all other types of unintentional injuries (e.g. motor vehicle crashes, falls from stairs/steps, etc.); excludes assaults and injuries related to self-harm.

[d]Pearson chi-square tests (expected cell counts ≥5) and Fisher's Exact tests used (expected cell counts <5) were used for calculation of p-values.

[e]Refers to symptoms reported by patient or parent/guardian at time of visit; categories are not mutually exclusive.

[f]Due to rounding, percentages may not add to 100 percent.

[g]Refers to clinical exam results; categories are not mutually exclusive.

[h]Combined nonverbal and verbal total GCS score.

[i]Diagnosis based on clinician assigned ICD-9-CM codes.

[j]Definition of TBI based on CDC ICD-9-CM definition of a TBI; ICD-9-CM code of 995.55, "Shaken infant syndrome" excluded from definition.

[k]Up to three ICD-9-CM physician assigned diagnosis codes were recorded for each ED visit; a visit was considered to have a diagnosis of TBI if it contained an ICD-9-CM code in any one of the three available positions.

[l]ICD-9-CM definition based on Barell Injury Diagnosis Matrix.[108]

6.3.3 Healthcare Utilization and Follow-up Care

In the ED, children with suspected TBIs related to sports and recreational activities were 1.37 times more likely to receive computed tomography (CT) scans than children with TBIs related to non-sports and recreational activities (95% CI: 1.17-1.59; Table 6.4). For both groups, the overwhelming majority of CT scan results were normal. Less than five children had brain magnetic resonance imaging (MRI) or head X-rays.

Approximately one-third of the study population responded to a telephone survey requesting information about follow-up medical treatment and on-going or delayed TBI symptomology (Table 6.4). Out of the 536 respondents, one-third obtained additional medical treatment. Out of the children who obtained additional treatment, most sought care at primary care facilities. Although non-significant, children with injuries related to sports and recreational activities were slightly more likely to seek follow-up medical care after discharge from the ED than children with injuries related to other causes (IPR: 1.27, 95% CI: 0.97-1.65). In addition, children with SR TBIs were more likely to visit a concussion clinic (IPR: 2.61, 95% CI: 1.07-6.35). During the CHIRI study, the flagship hospital offered a concussion clinic for treating children with TBI.

At the time of telephone follow-up, one-fifth of respondents reported that their child still had symptoms consistent with a TBI, with headache being the most common symptom reported. The proportion of children reporting symptoms at the time of follow-up did not vary between the two groups (Table 6.4).

As compared to the children whose parents/guardians were not surveyed, the children of the telephone respondents were less likely to have reported $\geq$2 symptoms (IPR: 0.49, 95% CI: 0.41-0.59) or to have had an abnormal neurologic exam (IPR: 0.13, 95% CI: 0.07-0.24).

TABLE 6.4 Imaging and follow-up medical treatment among children with a suspected traumatic brain injury: CHIRI, March 2013-February 2014

	Injury Type[a]				
	Sport/ Recreation[a] n (%)	Other Unintentional[b] n (%)	TOTAL n (%)	Not Recorded/ Evaluated (n)	P-value[c]
TOTAL	**352 (100.0)**	**1,174 (100.0)**	**1,526 (100.0)**		
Imaging (ED)					
Head CT	144 (40.9)	351 (29.9)	495 (32.4)	0	<.001
Outcome (n=495)					.22
Abnormal	6 (4.2)	25 (7.1)	31 (6.3)		
Normal	138 (95.8)	326 (92.1)	464 (93.7)		
Brain MRI	1 (0.3)	1 (0.1)	2 (0.1)	0	.41
Head X-ray	0 (0.0)	1 (0.1)	1 (0.1)	0	>.99
Phone follow-up survey					
Parent/Guardian responded to survey				0	.18
Yes	113 (32.1)	423 (36.0)	536 (35.1)		
No	239 (67.9)	751 (64.0)	990 (64.9)		
Patient received follow-up care (n=536)				0	.09
Yes	45 (39.8)	133 (31.4)	178 (33.2)		
No	68 (60.2)	290 (68.6)	358 (66.8)		
If yes, type of care received[d,e] (n=177):				1	
Primary care	27 (60.0)	94 (71.2)	121 (68.4)		.06
Concussion clinic	8 (17.8)	9 (6.8)	17 (9.6)		.03
Other type of care[f]	10 (22.2)	29 (22.0)	39 (22.0)		.97
Symptomology at time of follow-up (n=536)					
Headache	12 (10.6)	42 (10.0)	54 (10.1)	2	.84
Difficulty concentrating	11 (9.8)	36 (8.6)	47 (8.9)	5	.68
Unable to return to normal activities	6 (5.3)	19 (4.5)	25 (4.7)	0	.71
Difficulty memorizing/memory loss	4 (3.5)	15 (3.6)	19 (3.6)	5	.98
Vomiting	2 (1.8)	15 (3.5)	17 (3.2)	0	.34
Limb weakness	1 (0.9)	9 (2.1)	10 (1.9)	0	.70
Balance problem	3 (2.7)	5 (1.2)	8 (1.5)	0	.37
Seizure	0 (0.0)	1 (0.2)	1 (0.2)	0	>.99
Total symptom count				0	.91
0 symptoms	91 (80.5)	333 (78.7)	424 (79.1)		
1 symptom	14 (12.4)	58 (13.7)	72 (13.4)		
$\geq$2 symptoms	8 (7.1)	32 (7.6)	40 (7.5)		

[a]Column totals sum to 100%.
[a]Defined as an injury related to organized/unorganized sports/athletics, bicycling crashes, sport/wheeled transport crashes, non-motorized scooter crashes, and recreational water-related activities.
[b]Defined as all other types of unintentional injuries (e.g. motor vehicle crashes, falls from stairs/steps, etc.); excludes assaults and injuries related to self-harm.
[c]Pearson chi-square tests (expected cell counts $\geq$5) and Fisher's Exact tests used (expected cell counts <5) were used for calculation of p-values.
[d]Patients may have had more than one type of follow-up care; categorization was based on the initial date of follow-up care.
[e]Due to rounding, percentages may not add to 100 percent.
[f]Includes emergency department care, orthopedic care, urgent care, neurology, otorhinolaryngology, sports and exercise medicine, chiropracty, physical therapy, and rehabilitation.

6.4 Discussion

This study describes the comprehensive characterization of circumstances, symptoms, treatment, and demographics of school-age youth with TBI presenting at a large, metropolitan healthcare system. School-age youth with suspected TBI related to sports and recreational activities were more likely to have a history of head injury, had a higher acuity at triage, displayed more clinical signs and symptoms consistent with TBI, had increased use of imaging, and were more likely to seek follow-up care than youth with suspected TBIs related to non-sports and recreational activities. In addition to characterizing the initial presentation at the ED, this study described on-going or delayed symptomology and follow-up medical care for one-third of the patient population. This is also one of the first studies to compare characteristics of children with suspected TBIs related to sports and recreational activities to those of children with suspected TBIs related to non-sports and recreational activities.

Sports and recreation-related TBIs may result in serious long-term consequences such as cognitive impairment, mental health issues, and death.[135] While death and long-term disability are rare outcomes, more common consequences of TBI include adverse behavioral and psychological outcomes, particularly in the period immediately following injury, with worse prognoses being associated with more severe TBIs, repeat TBIs, and a prior diagnosis of a mental illness.[132,136] In this study, the proportion of children with a history of TBI was less than ten percent for both sports and recreation-related and non-sports and recreation-related injury. However, among children with suspected TBIs related to sports and recreational activities, history of prior TBI was higher than among children with TBIs related to other types of injuries. This is of particular concern, as children with a history of prior TBI have up to twice as long a recovery period as children with no prior history of TBI.[137] In addition, history of TBI appears to place an athlete at risk of a *future* TBI.[138]

In this study, children with SR TBIs, as compared to children with non-SR TBIs, were more likely to have a higher acuity at triage, $\geq$2 clinical signs and symptoms of TBI, and $\geq$2 abnormal results upon neurologic examination. This suggests that, on average, TBIs presenting in the ED due to SR activities may be more severe or more symptomatic than TBIs due to other common causes of brain injury among children (such as falls). Furthermore, children with SR TBIs were more likely to report loss of consciousness and amnesia, two symptoms associated with worse outcomes and prolonged recovery.[129,139,140] These findings may be related to the specific types of sports and recreational activities most commonly observed in the CHIRI population. Over one-half of all suspected TBIs related to sports and recreational activities were related to three specific activities: bicycling, football, and off-road motor vehicles. All of these activities have been associated with severe injury resulting in hospitalization, death, or prolonged recovery.[7,9,38] Another explanation for the increased symptomology may be related to patient, parental, and provider knowledge and perception of TBI related to sports versus non-sports activities. At the time of study, patient and parental concern about TBI may have been elevated due to pervasive media attention of the health risks associated with TBI. Surveys of high school athletes and parents have indicated that both student-athletes and parents of student-athletes recognize some, but not all, of the common symptoms and potential outcomes of TBI.[141–144]. While there are serious gaps in TBI education and awareness among student-athletes and parents of student-athletes, knowledge of non-sports TBI is likely less extensive. One study that examined the ability of parents to correctly identify TBI in their children found that parents were half as likely to suspect TBI when the injury was caused by non-sports as compared to sports activities.[145] This highlights the need for comprehensive TBI education of both children and parents, regardless of involvement with school and other organized sports activities.

In this study, children with TBIs related to sports and recreational activities were 1.4 times more likely to receive a head CT than children with TBIs related to non-sports and recreational activities. These results are consistent with a prior study that found children with SR TBI were more likely to have head CT scans than children with TBI related to other causes.[146] The proportion of children receiving a CT scan in the CHIRI study (32%) was consistent with other studies of pediatric CT, although CT scan use is highly variable by facility.[147–149] However, the proportion of children receiving a CT scan was higher than that observed among comparable pediatric and teaching hospitals, despite having Pediatric Emergency Care Applied Research Network (PECARN) guidelines in place at the time of the CHIRI study.[150,151] PECARN guidelines are designed specifically to reduce the use of unnecessary head CT in pediatric patients.[152] Having guidelines in place does not necessarily mean that all medical providers will follow the guidelines under all circumstances. Common reasons cited for performing CTs when contraindicated by institutional guidelines include: a lack of knowledge and training in use of the guidelines, preference for making clinical decisions based on personal experience, and patient/parental insistence on CT.[153,154] Despite these barriers, large hospital systems have decreased unnecessary CT use and have successfully balanced the health and monetary costs of CT with the risk of missing a TBI requiring life-saving intervention.[155]

The overwhelming majority of the CHIRI patients had brain injuries categorized as "mild" with a Glasgow Coma Scale Score (GCS) of 15. Nevertheless, one-third of parents/guardians surveyed at two weeks post discharge reported that their children required follow-up medical treatment for their injuries. Over 20% of children were reported as having had delayed or on-going symptomology at the time of the telephone follow-up survey, 10-14 days post initial ED visit, with headache and difficulty concentrating being the most commonly reported symptoms. This result is consistent with the literature, with most studies indicating that symptoms of mild TBI resolve one to two weeks after injury, with longer recovery times observed for more severe injuries and repeat head injuries, among other factors.[137,151,156–158] The children with telephone follow-up information had fewer symptoms and adverse exam results at the time of the initial ED visit than children for whom information was not collected through the follow-up survey. This suggests that the proportion of children with symptoms at the time of follow-up may be an underrepresentation of the total proportion of children with ongoing or delayed symptomology, as number and severity of symptoms is one of the strongest predictors of delayed recovery from TBI.[159]

6.4.1 Limitations

This study had several limitations. As the CHIRI study was performed at a single, large metropolitan hospital system in the southern United States, results may not be generalizable to other geographic regions. While the CHIRI population contained a mix of patients from both community EDs and a pediatric ED, for most patients, the point-of-entry was the pediatric ED. While our study consisted of an ED patient population, in actuality, most children with medically attended TBIs seek initial treatment in a primary care setting.[127,160] Children treated in the ED tend to be younger and have a lower socioeconomic status than children treated in an outpatient setting.[160] In addition, this study does not include data on the estimated 23%-53% of children who do not seek treatment for TBI at a healthcare provider.[127]

Another limitation of this study was that the patient population consisted of clinician suspected TBIs, of which one-half received a diagnosis of TBI. Results were differential across injury type, with suspected TBIs related to sports and recreational activities having a higher proportion of clinician assigned TBI diagnosis codes. However, TBI ascertainment was limited by a few factors. Clinicians were only able to provide up to three total diagnosis codes. As patients may have multiple traumatic injuries, it is possible that clinicians may not have had enough fields provided to capture the TBI diagnosis. A solution to the problem would have been to augment the CHIRI data with ICD-9-CM codes assigned at billing; however, we were unable to obtain these data. Therefore, some suspected TBIs may have been misclassified as "not TBIs" when, in actuality, they were TBIs.

For patient and ED visit descriptors, data missingness was low (<15%) for most variables. However, for variables describing patient symptomology and exam results, data missingness was higher. It is unknown whether these missing values represent an absence of a specific symptom or negative exam result or if the medical provider failed to report these values. Examination of missing values indicated that missingness was not random and was influenced by provider type (e.g. attending physician, resident, fellow, etc.) and hospital shift.

6.5 Conclusion

Among youth who visited the ED with suspected TBIs related to sports and recreational activities, a higher proportion had a documented history of head injury, worse symptomology, adverse exam results, and greater utilization of healthcare resources as compared to youth with suspected head injuries related to non-sports and recreational activities. These results were limited to patients whose point of entry was the ED and so these results may not reflect the characteristics of patients who initially sought care at urgent care and primary care practices. However, these results suggest that suspected youth head injuries arising from sports and recreational activities may have higher severity than those related to non-sport and recreational activities.

CHAPTER 7: DISCUSSION

7.1 Summary of Findings

This dissertation had two primary aims: 1) describe the incidence of sports and recreation-related (SR) injuries among school-age youth in North Carolina (see Chapter 5) and 2) describe the epidemiology of emergency department (ED) visits due to suspected traumatic brain injuries (TBIs) among school-age youth (see Chapter 6). Both Aims sought to address SR injuries with an emphasis on SR TBIs among school-age youth. Aim 1 used a population-based approach by describing the incidence of SR injuries in NC using statewide ED visit data collected by hospitals primarily for administrative purposes. Aim 2 focused on SR TBIs treated within a single hospital system using clinical data abstracted from the electronic medical record. Despite the differences in study population, setting, and data collection methods, the combined results of these two studies highlight the burden of SR injuries on the NC youth population.

7.1.1 Summary of Findings: Aim 1

Aim 1 sought to describe the population-based incidence of injuries due to sports and recreational activities among school-age youth, 5-18 years of age. To accomplish this Aim, we developed a case definition using ICD-9-CM billing codes (Aim 1A). Ultimately, we included over 200 codes in our SR injury case definition. While a number of ICD-9-CM-based SR injury case definitions have been published previously, few of these definitions included codes for specific recreational activities (i.e. “Activity Codes”, E001-E030).[43,92,93,96–98,113]

As part of Aim 1B, we used our SR injury case definition to identify the incidence of SR injuries among school-age youth. We identified 767,075 NC ED visits due to unintentional injuries among school-age youth during 2010-2014. Over one quarter of these ED visits were related to sports and recreational activities. During this five-year period, there was an annual average count of 42,704 SR ED visits per year, or 117 visits per day. The average annual population-based incidence rate (IR) was 23.7 visits per 1,000 person-years. The IR per 1,000 person-years was higher among boys (31.6) than girls (15.6) and highest among 10-14 year-olds (29.4) as compared to 5-9 year-olds (15.5) and 15-18 year-olds (27.0).

As part of Aim 1A, we examined differences by sex and age group. For both sexes, rates of unintentional injuries increased with age. Among boys, the rate of SR injuries increased from ages 5-9 to 10-14 and then remained steady from ages 10-14 to 15-18. Among girls, the IR increased from ages 5-9 to 10-14; however, the IR dropped 26% from ages 10-14 to 15-18 years of age (Figure 7.1). This decrease likely reflects declining levels of physical activity and sports participation observed among adolescent girls.[161]

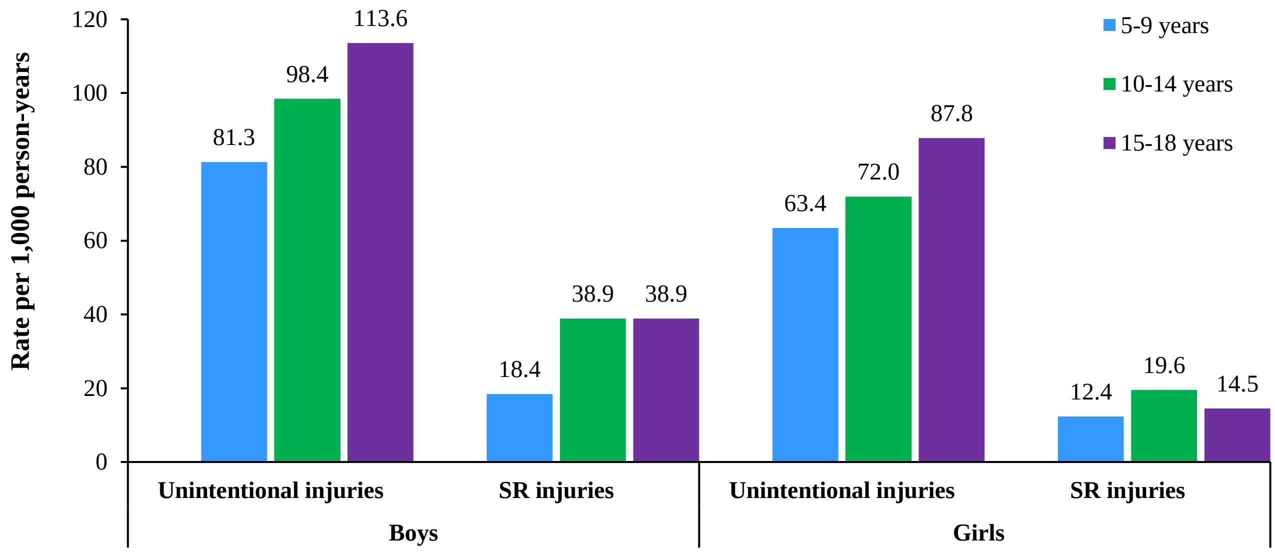
We identified American tackle football (N=24,420 visits), basketball (N=23,342 visits), and soccer (N=10,108 visits) as the three most common sports/athletics activities resulting in ED visits among NC school-age youth. By a large margin, the most common recreational activity identified in our study was pedal cycling (N=20,984 visits). The distribution of sports and recreational activities varied by sex and age group. Recreational activities and activities involving play were more common causes of injury among younger children, while team sports/athletics were more common causes of injury among older children.

We also compared injury diagnoses between ED visits due to sports and recreational activities and ED visits related to other unintentional injury mechanisms using the Barell Injury

Diagnosis Matrix.[108] Overall, children with SR injuries were more likely to be diagnosed with a fracture to the upper (injury proportion ratio [IPR]:2.44 [95% CI: 2.40-2.48]) and lower extremities (IPR: 1.78 [95% CI: 1.73-1.83]). Of concern (due to their potential for long-term effects) were the higher proportions of TBIs and other head/face/neck fractures among SR ED visits with IPRs of 2.74 (95% CI: 2.66-2.82) and 2.90 (95% CI: 2.71-3.11), respectively.

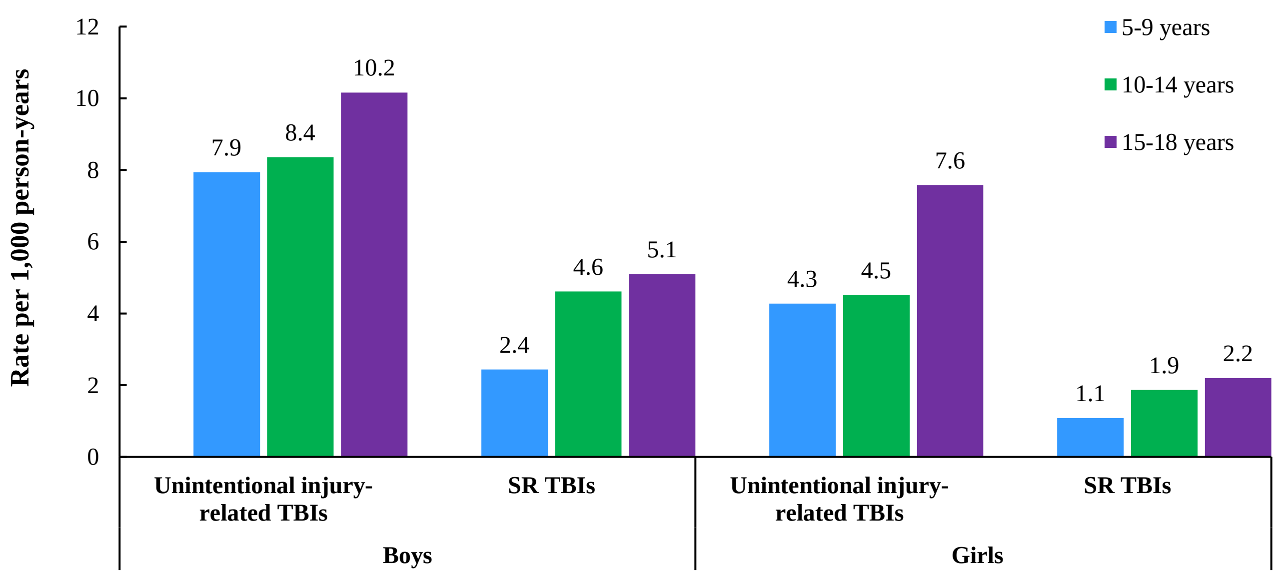
TBIs may result in negative short and long-term outcomes among children. Therefore, we determined the statewide population-based incidence of SR TBIs among school-age youth in NC (Aim 1C). During 2010-2014, the average annual count of SR ED visits with a TBI diagnosis was 5,131 visits per year with an IR of 2.9 visits per 1,000 person-years. Figure 7.2 displays ED visit rates with TBI diagnoses stratified by sex and age group. For boys and girls, IRs increased with age. Overall, a higher proportion of boys were diagnosed with a SR TBI than girls. However, among team sports/athletics in which both sexes commonly participate, girls tended to have higher proportions of TBI diagnoses. For example, girls had higher proportions of TBI diagnoses for ED visits related to playing basketball (13%), soccer (16%), and rugby (32%) as compared to boys (8%, 14%, and 29%, respectively).

FIGURE 7.1 Incidence rates (per 1,000 person-years) of emergency department visits due to unintentional injuries[1] and sports and recreation-related injuries among school-age youth, stratified by sex and age group: North Carolina, 2010-2014



Abbreviations: SR, sports and recreational-related
[1]Total unintentional injuries; includes SR injuries.

FIGURE 7.2 Incidence rates (per 1,000 person-years) of emergency department visits with TBI diagnoses due to unintentional injuries[1] and sports and recreation-related injuries among school-age youth, stratified by sex and age group: North Carolina, 2010-2014



Abbreviations: SR, sports and recreational-related; TBI, traumatic brain injury
[1]Total unintentional injuries; includes SR injuries.

7.1.2 Summary of Findings: Aim 2

In Aim 2, we described the clinical characteristics of school-age youth, 5-17 years of age, presenting at a large, metropolitan hospital system with a suspected TBI. While Aim 1 identified the population-based incidence of TBI treated in NC EDs among school-age youth, that study provided little clinical information about the presentation or treatment of TBI at the healthcare provider level. Therefore, we analyzed a rich, detailed data set containing clinical information captured from all pediatric patients presenting to the WakeMed Health and Hospitals system with a suspected TBI. These data were collected by ED personnel during the period March 1, 2013-February 28, 2014 as part of the Child Head Injury Research Initiative (CHIRI) managed by the WakeMed Raleigh Emergency Services Institute's Clinical Research Unit.

In Aim 2A we described the clinical and demographic characteristics of youth who sought treatment for a suspected TBI at WakeMed Health and Hospitals, a system consisting of six EDs, including a pediatric ED and intensive care unit. Over the course of the one-year study, 1,526 youth visited a WakeMed Health and Hospitals ED for treatment of a suspected TBI due to unintentional causes. The most common causes of injuries were falls (34%), other types of injuries (e.g. struck by/against stationary object; 31%), sports/recreational activities (23%), and motor vehicle crashes (12%). The median age of the patient population was 11.2 years of age (Interquartile Range [IQR]: 7.4-14.8), with boys making up nearly two-thirds of the patient population (64%). Most of the patient population arrived via walk-in, e.g. private or public transportation, (84%), within 24 hours of the initial injury (85%) and were discharged home after being treated in the ED (97%).

According to the Emergency Severity Index (ESI), a five-level algorithm used to categorize patient acuity at triage, most patient visits were categorized as low acuity, with an ESI of 4 (less urgent) or 5 (non-urgent). The majority of patients reported at least one symptom consistent with TBI (59%), with headache being the most common symptom reported (40%), followed by nausea (19%) and abnormal behavior (17%). Upon clinical examination, less than 10 percent of children had an abnormal neurologic exam result. About one-third of patients had a head computed tomography (CT) scan, of which six percent had an abnormal scan.

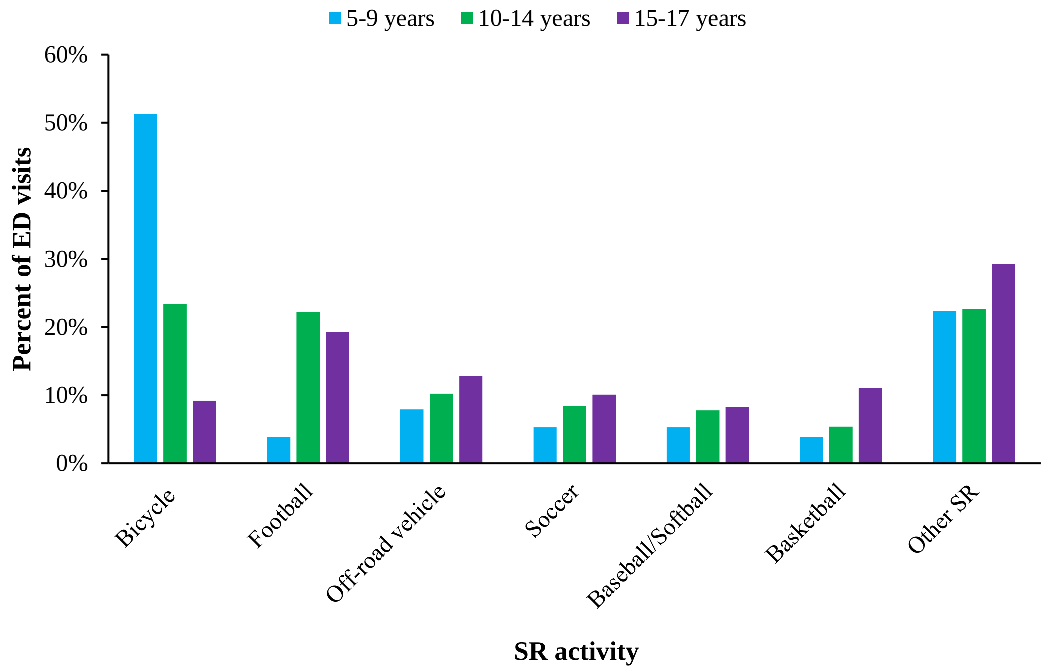
A subset (35%) of the patients' parents/legal guardians responded to a follow-up telephone survey administered 10-14 days after the initial ED visit. Among this subset, 33 percent of patients were reported to have obtained follow-up medical care post-ED visit. For 20 percent of the patient population with follow-up information, the parent/guardian reported that their child was experiencing continued or delayed symptomology, or some other adverse outcome related to their injury. The most common signs/symptoms/sequela reported were headache (10%), difficulty concentrating (9%), and failure to return to normal daily activities (5%).

In Aim 2B, we compared the demographics, signs and symptoms, healthcare resource utilizations patterns, and other clinical characteristics of SR and non-SR TBIs among school-age youth. Among school-age youth with suspected TBIs related to sports and recreational activities, the most common sports/recreational activities reported were bicycling (25%), American tackle football (17%), and riding off-road motor vehicles (11%). The distribution of sports/recreational activities varied by age group (Figure 7.3). As compared to patients with non-SR TBIs, children with SR TBIs were older (median age 13.3 [IQR: 10.8-15.5] versus median age 10.2 [IQR: 7.0-14.5]), more likely to be male (74% versus 61%), and more likely to have a history of head injury (6% versus 4%). School-age youth with SR TBIs were also 1.3 times (95% CI: 1.1-1.5) more likely to visit the ED during the months of September-November than youth with suspected TBIs unrelated to sports and recreational activities.

School-age youth with suspected TBIs due to sports and recreational activities had a higher acuity (ESI-1 or ESI-2; IPR: 1.7 [95% CI: 1.2-2.3]), were more likely to report $\geq$1 symptom (IPR: 1.3 [95% CI: 1.2-1.4]), and more likely to have an abnormal neurologic examination (IPR: 2.1 [1.5-2.8]) than youth presenting with non-SR TBIs. There was no difference in the likelihood of hospital admission between the two groups, however (IPR: 1.1 [95% CI: 0.9-1.5]).

In the ED, youth with suspected TBIs due to sports and recreational activities were 1.4 times more likely to receive a head CT scan (95% CI: 1.2-1.6), although there was no difference in the proportion of children with abnormal scan results (IPR: 0.6 [95% CI: 0.2-1.4]). For the subset of patients with follow-up survey results, we found few differences between the two groups.

FIGURE 7.3 Type of sport/recreational activity among school-age children with suspected traumatic brain injuries, stratified by age group: CHIRI, March 2013-February 2014



Abbreviations: CHIRI, Child Health Injury Research Initiative; SR, sports and recreational-related

7.2 Limitations

The specific limitations of each study conducted as part of this dissertation are summarized in the "Discussion" subsections of Chapters 5 and 6. Here, we expand in more detail on key limitations and summarize some of research limitations common to both studies.

First, both the Aim 1 and Aim 2 studies relied upon existing data sources collected for purposes other than the objectives outlined in this dissertation. While the use of existing data sources reduces the amount of time and resources required for data collection, cleaning, and analysis, it can lead to problems in data quality. Many of our limitations were based on underlying data quality issues.

Aim 1 analyzed NC DETECT ED visit data. These data are used primarily by state public health for syndromic surveillance. The Aim 1 study used data elements collected by hospitals chiefly for patient care, administration, and billing, such as the ICD-9-CM codes. While ICD-9-CM diagnosis codes are required for financial reimbursement, injury mechanism codes (i.e. E-codes) are not. In our study, if a large proportion of ED visits were missing E-codes, we would have underestimated the "true" incidence of SR injury among school-age youth in NC. Fortunately, among NC DETECT ED visits with injury diagnoses, 89% of visits contained a corresponding E-code in 2010.[85] A related issue to E-code missingness is E-code accuracy. We assumed that misclassification of non-SR ED visits as SR ED visits would be minimal, and that it would be more likely that SR ED visits would be misclassified as non-SR ED visits, due to the relatively frequent use of vague and nonspecific E-codes such as "E888.9 – Fall, unspecified" in hospital billing data.[162] Such misclassification would result in an underestimate of the total number of SR ED visits. However, we did not perform a sensitivity analysis to evaluate this assumption.

A limitation for both the Aim 1 and Aim 2 studies was data missingness. In both data sets, some variables were almost always complete or near complete, such as sex (0.01% and 0% missing in the NC DETECT and CHIRI data sets, respectively). Other variables were more problematic, such as "transportation mode" in the NC DETECT data set (15% missing) and clinician assigned diagnosis codes in the CHIRI data set (19% missing). While most of the variables used in analyses had data missingness levels of less than 10%, we determined that when data missingness was present, it was correlated with facility (Aim 1) or provider level/time of shift (Aim 2). Therefore, data missingness was unlikely to be Missing Completely at Random and may have introduced bias into our results. Methodologic techniques, such as multiple imputation and inverse probability weighting, would produce less biased results, but were not used in our analyses.[163] In future research using these data sources, it may be worthwhile to incorporate more robust missing data methodologies.

For Aim 1, another limitation was our decision to use the NC youth population as the denominator for the calculation of IRs. Population-based denominators do not take into account the number of individuals who participate in sports and recreational activities and time at risk (i.e. exposure).[164] While the use of exposure-based denominators is generally considered superior, this information is not widely available for non-school sports, recreational activities, and for younger children.

Another limitation of the Aim 1 and Aim 2 studies is generalizability. In Aim 1, we calculated the population-based incidence rates of ED visits related to sports and recreational activities for the state of NC. Many sports and recreational activities have strong regional bases due to cultural, socioeconomic, and climate/geographic factors.[10,165] While NC is a large, populous state with a mixture of urban, suburban, and rural geographies, the results from this study may not be generalizable to other populations.

While the NC DETECT ED visit data used in Aim 1 may not be generalizable to other states, the CHIRI data used in Aim 2 may not be generalizable to other populations within NC. The primary catchment area for the CHIRI patients was Wake County. Wake County is the second most populous county in NC. It is also one of the wealthier counties in the state.[166] As WakeMed Health and Hospitals contains a Level I Trauma center and a pediatric ED, it also serves patients from more rural neighboring counties. However, it is unlikely that the CHIRI case mix is identical to hospitals serving low-income rural populations.

Finally, we only examined SR injuries treated in emergency departments. Most youth SR injuries, including TBIs, are treated in outpatient clinics or treated outside of the formal health care setting.[127,167] In addition to treating patients with relatively severe injuries, patients treated in EDs are more likely to be younger, poorer, and ethnic/racial minorities. Therefore, it is unlikely that the results of this dissertation are generalizable to all SR injuries.[168] However, it is extremely difficult to obtain information on injuries treated in outpatient and non-medical settings. Therefore, we feel that that the ED is one of the best sources of existing data for studying SR injuries among school-age children. Still, this is an opportunity for future research (see section 7.5 "Directions for Future Research").

7.3 Strengths

This dissertation provides a detailed description of the epidemiology of SR injuries among school-age youth in NC. We examined SR injuries using two separate, but related, studies. Through these two studies, we were able to characterize SR injuries at the population and healthcare provider level.

This is the first study to use population-based ED visit data to describe the incidence of SR injuries in NC. While many studies have examined SR injuries at the high school or collegiate level, we focused on school-age children, 5-18 years of age. Including younger age groups yielded valuable insights. For instance, we found that children 10-14 years of age (a period that roughly corresponds to middle school) had the highest rate of SR injury. This has important public health and policy implications, as children in this age group are less likely to be the focus of school-based injury prevention programs than their high school counterparts. In addition, while many studies have focused on team sports/athletics such as American tackle football and soccer, fewer studies have examined recreational injuries. We found that recreational activities are common causes of injuries, especially among younger children. This highlights the need for a more holistic approach to injury prevention among children, especially for children participating in activities outside the structured parameters of supervised practices and competitions.

Another strength of this dissertation is the comparison of SR injuries to non-SR injuries. By comparing these two groups, we were able to identify key differences between SR TBIs and non-SR TBIs. For example, we determined that TBIs make up a larger proportion of injury diagnoses among SR ED visits than for visits related to other causes. In addition, we found that children presenting with SR TBIs were both more symptomatic and more likely to have abnormal neurological exam results and imaging than children presenting with non-SR TBIs.

7.4 Public Health Implications

The public health community should continue to encourage children to engage in a physically active lifestyle and participate in sports/athletics for the numerous benefits these activities provide. These benefits include, but are not limited to, maintaining a healthy weight, improving cardiometabolic health (e.g. blood pressure, cholesterol, blood lipoproteins, and insulin resistance), improving bone health, improving immune system response, and improving mental health and well-being.[3,36,169–172] While public health experts extoll the health benefits of physical activity, youth are more likely to cite enjoyment, experimentation, formation and reinforcement of social networks, mastery of skills, and peer/parental acknowledgement and support as motivating factors for participating in sports and recreational activities.[173]

Irrespective of which set of benefits are the most important, there is widespread agreement that injury remains the primary negative outcome from a physically active lifestyle. Thus, it is important that we develop and implement injury prevention strategies in tandem with promoting an active lifestyle. We will discuss some possible injury prevention strategies through the framework of the Haddon Matrix.[174,175]

The Haddon Matrix consists of three rows and four columns. The three rows are labeled pre-event, event, and post-event. These three rows correspond to the concepts of primary, secondary, and tertiary prevention. The four columns refer to host (person at risk of injury); agent (mechanical, thermal, chemical, and electrical energy); vehicle (inanimate object that transmits energy), or vector (animate object that transmits energy); physical environment (physical location of the injury event); and social environment (social, cultural, and legal context of injury).[176]

In Table 7.1, we present a Haddon Matrix for sports and recreational activities based on the published literature.[175,177–180] While we will not go through each cell in its entirety, we will discuss how this framework can inform injury prevention. Rather than addressing all sports and recreational activities, we will discuss this framework through its application to American tackle football and bicycling. We selected these two activities because a) football and bicycling were responsible for high population-based incidence rates of NC ED visits (Aim 1) and b) football and bicycling were the two most common sports/recreational activities identified among youth presenting to the ED for a suspected TBI (Aim 2). Many of the strategies discussed will be applicable to other youth sports and recreational activities.

7.4.1 Pre-Event (Primary Prevention)

The pre-event phase contains strategies that eliminate the transfer of energy from the vehicle or vector to the host. This period is analogous to primary prevention and seeks to prevent the injury event from occurring in the first place.[176]

Pre-Event: Host

There are numerous opportunities for preventing SR injuries at the host level. We will discuss a few of these approaches using our American tackle football and bicycling example. One common host intervention is education. Parents, coaches, pediatricians, etc. can educate young football players and bicyclists on how to safely participate in these activities. As part of their education, children can be taught how to prevent, recognize, and respond to injuries, including TBIs.

General good health and physical fitness are protective factors against injury. Participating in strength, balance, and endurance training programs may reduce the risk of injury among athletes.[181–183] In addition, recovery and rehabilitation from previous injuries, is important for the prevention of future injuries, including TBIs.[138,184,185] Among youth initiating new sports programs, medical examinations can identify potential injury risk factors as well as other relevant health conditions.[186] In addition to modifiable risk factors, non-modifiable risk factors, such as sex and age, should be taken into account when assessing injury risk.[184,187]

For bicyclists, wearing proper fitting attire made of colorful, reflective materials may increase visibility to motorists and reduce the risk of an injury event, such as a crash.[188] In addition, addressing gender differences in risk perception and attitudes towards safe behavior, such as helmet use, may prevent injuries.[189,190]

Pre-Event: Agent/Vehicle/Equipment

As compared to the host, there are fewer targets for intervention regarding the pre-event phase of the agent/vehicle sector of the Haddon Matrix for the prevention of SR injuries. Athlete mass and velocity is one risk factor. Among sports teams with considerable variation in player height and weight, lighter players are at a greater risk of injury than heavier players.[191] Another option is to delay tackling until a certain age, or to prohibit tackling altogether for young athletes, as well as other changes to game rules.[192,193] Proper maintenance of safety equipment and bicycles may also reduce the risk of injury.[194]

Pre-Event: Physical and Social Environment

The physical and social environment plays an important role in injury prevention. In terms of the physical environment, the type of surface (artificial versus natural) and condition of the playing surface may impact risk of injury among American tackle football players. Although the evidence is inconclusive, some studies suggest that injury rates are higher on artificial playing surfaces as compared to natural surfaces.[195] Weather conditions influence risk of injury among football players. Most youth football players practice and compete on fields exposed to the natural elements. Hot/cold and wet/dry conditions alter the playing surface and impact injury risk. The influence of weather conditions differs across artificial and natural playing surfaces.[196] In addition to the playing surface, elevated ambient temperatures and humidity can result in heat-related illness and injury. Avoiding peak temperatures and limiting the duration of play can reduce the risk of heat-related illness and injury.[197]

The social environment has emerged as a powerful venue for the prevention of American tackle football injuries. For many Americans, attitudes toward American tackle football have changed. This is clearly expressed in former President Barack Obama's statement that he "would not let my [his] son play pro [American tackle] football."[198] Despite the widespread public perception that American tackle football is associated with a high risk of injury, including TBI, many children still participate in the sport. Many states have passed legislation aimed at preventing youth TBI. For example, NC has mandated that all middle/high school athletes, coaches, parents, and school nurses receive education in identifying the symptoms, treatment, and risks of concussions.[199] While evidence suggests that current legislation is effective in preventing youth football-related TBIs, it seems to be less effectual for other sports activities.[200] This is concerning, as our research indicates that sports such as lacrosse/field hockey, rugby, and cheerleading all have high relative proportions of TBI. In addition, most legislation does not address elementary school sports and sports that take place outside of the formal school setting.

The physical and social environments also play a large role in bicycling safety. In general, when communities take an integrated approach to bicycling infrastructure, policy, and programs, the rate of bicycling injuries decreases. In terms of the physical environment, separating cars from bicycles through the construction of bicycle lanes, bicycle boulevards, bicycle paths, etc. all reduce the risk of injury. Increasing signage and demarcating bicycle lanes also reduces the risk of injury.[201]

Similar to American tackle football, changing societal norms may have an impact on bicycling safety. In general, bicycling safety and positive attitudes towards bicycling are higher in communities that already have high levels of bicycling.[201] For example, Berlin, a city with a long history of bicycling culture, doubled its share of bicycling trips over a twenty-year period, while it simultaneously decreased its rate of bicycling injuries by a third.[202] Law enforcement of existing motor vehicle traffic regulations (speeding, driving under the influence, etc.) may also reduce the risk of bicycling injuries, although the evidence is inconclusive.[203]

7.4.2 Event (Secondary Prevention)

The event phase contains strategies that minimize the transfer of energy from the vehicle or vector to the host. Continuing with our focus on American tackle football and bicycling, examples of “events” would be player-to-player contact and bicyclist collisions with mailboxes and other objects. This phase is the target of secondary prevention efforts.[176]

Event: Host and Agent/Vehicle/Equipment

As there is some overlap between host and agent/vehicle/equipment during the event phase, we will discuss these factors in combination.

In terms of the host, athletes can be taught to reduce the likelihood of serious injury. For example, young athletes can be taught falling, landing, and recovery skills to minimize the extent of injury.[204] Equipment is also important for preventing and mitigating injury during the event phase. Helmets, mouthguards, padding, and other safety equipment are designed to minimize the transfer on energy upon impact. Helmets prevent TBIs among American tackle football players and bicyclists.[205,206] Mouthguards and external joint supports have also been shown to prevent orofacial and extremity injuries, respectively.[207,208] Among bicyclists, wearing long sleeves, pants, gloves, and closed-toed shoes has been shown to be protective against superficial injuries.[209]

Event: Physical and Social Environment

In the previous section, we discussed playing surfaces under the pre-event phase. In the event phase, playing surfaces can also act as protective/risk factors for American tackle football injuries. For example, a well-maintained natural playing surface can provide some cushioning for falls.

In terms of the social environment, helmets have been required for decades among primary/secondary school, collegiate, and professional American tackle football players. However, helmet use is not as widespread among bicyclists. According to the CDC, as of 2011, 21 states and 201 county and local jurisdictions had helmet laws, nearly all aimed at children under the age of 16.[210] States with mandatory helmet laws have lower incidence of fatal bicycle-motor vehicle collisions than states without legislation.[211] Statewide legislation is only effective if there is public awareness and buy-in. North Carolina has a statewide helmet law for children < 16 years of age. However, in a survey of NC residents, less than 20% respondents reported that their children wore helmets "all" or "most of the time".[212]

7.4.3 Post-Event (Tertiary Prevention)

The post-event phase is akin to tertiary prevention and seeks to mitigate the acute and long-term impacts of injuries.

During the post-event phase, interventions should focus on successfully treating the patient and returning the child to good health. After stabilizing the acute injury, a return to a pre-event state is accomplished through physical therapy, strength training, balance training, and other forms of rehabilitation. The extent and duration of rehabilitation depends on the severity of injury and the physiology of the host. Some children will need extensive rehabilitation, while others will not require any rehabilitation.[9,213] In regard to agent/vector/equipment, bandages, braces, and splints can be provided to the injured athlete to stabilize the injury until additional medical services are obtained.

The physical and social environments are also targets for intervention in the post-event phase. For example, first aid kits and automated external defibrillators (AEDs) can be kept at or near the football field for the administration of first aid following an injury event. In addition, sports complexes (American tackle football) and roadways (bicycling) can be designed to facilitate access to EMS vehicles, so that injured players/bicyclists can be transported to medical facilities safely and quickly. Regarding the social environment, coaches and support staff can be instructed in sideline concussion evaluation and management. In addition, jurisdictions can implement strict guidelines for return to play after serious injuries, including TBIs.[213]

The emergency department, the study setting of this dissertation, is one example of tertiary prevention. The purpose of the ED is to stabilize the patient and refer the patient to hospital or specialty care, if necessary. While the ED may not be the ideal location for public health interventions, it is one of the most common settings for the treatment of injuries related to sports and recreational activities, as highlighted in this dissertation. Therefore, the ED should have a role in primary injury prevention in addition to tertiary prevention. Examples of primary prevention interventions appropriate to the ED include the distribution of free bicycle helmets to low-income families or the provision of educational information about the risks of SR TBI.

TABLE 7.1 The Haddon matrix applied to the prevention of sports and recreation-related injury among children[175,177–180]

<table>
<tr><th></th><th colspan="4"><u>Influencing factors</u></th></tr>
<tr><th>Phase</th><th>Host (child)</th><th>Agent/ Vehicle/ Equipment</th><th>Physical environment</th><th>Social environment</th></tr>
<tr><td>Pre-event (primary)</td><td>• <u>Training</u>
- Strength training
- Swimming/ skiing/horseback riding/etc. lessons
- Improve overall physical fitness
• <u>Education</u>
- Rules of the road and helmet laws
- Educate and enforce rules of play
- Raise awareness of TBI and other injuries
- Raise awareness of injury prevention techniques
• Wear reflective materials to enhance visibility
• Routine sports physical exams
• Adequate recovery from previous injuries
• Ensure that all clothing is appropriate for play and fits properly</td><td>• Fence pool to reduce access
• Ensure that all sports equipment and exercise machines are well-maintained and meet consumer product standards
• <u>Construct playground equipment to minimize falls and fall-related injuries</u>
- Safety grips
- Safety rails
- Safe surfaces</td><td>• Traffic calming measures to reduce risk of bicycling injuries
• Separate bicyclists and runners/joggers from motor vehicles
• Ensure that playing surfaces are safe
•Post visual cues for safe behavior
• <u>Ensure that weather conditions are safe for play</u>
- Heat/Humidity
- Thunderstorms</td><td>• <u>Education</u>
- Coaches
- Referees
- Parents
- Youth/Athletes
• <u>Rules and regulations for preventing injury</u>
- Traffic safety laws
- Mandate pool fencing
- Delay or prohibit tacking/scrumming/ heading/other risky sport maneuvers
• Change safety culture</td></tr>
<tr><td>Event (secondary)</td><td>• <u>Training</u>
- Teach falling, landing, and recovery
- Teach proper use of safety equipment</td><td>• Breakaway goal posts and baseball bases
• <u>Mandate use of safety equipment</u>
- Helmets
- Life jackets
- Mouth guards
- Safety padding
- Footwear/orthotics
- Knee/ankle braces</td><td>• Safe/Soft surfaces</td><td>• <u>Rules and regulations for mitigating injury</u>
- Helmet laws
- On-site athletic trainers and medical personnel
- On-site lifeguards</td></tr>
<tr><td>Post-event (tertiary)</td><td>• <u>Rehabilitation</u>
- Balance training
- Strength training</td><td>• <u>Provide first aid materials</u>
- AED
- Braces
- Tape
- Bandages</td><td>• Design schools, recreational centers, parks, etc. to allow easy access for EMS vehicles</td><td>• Provide support for treatment and rehabilitation programs
• <u>Rules and regulations for injury recovery</u>
- Guidelines for return to play</td></tr>
</table>

Abbreviations: TBI, traumatic brain injury; AED, automated external defibrillator; EMS, emergency medical services; CPR, cardiopulmonary resuscitation

7.5 Directions for Future Research

Results from this dissertation highlight several areas for future research. We have described five of these potential research areas in the ensuing paragraphs.

First, the case definition described in Aim 1 could be updated to include ICD-10-CM injury mechanism codes. Our current SR case definition is based on ICD-9-CM injury mechanism codes (E-codes). On October 1, 2015, ICD-9-CM was discontinued, and ICD-10-CM was adopted in its place. The new ICD-10-CM coding structure is more complex and contains more than five times the number of codes as ICD-9-CM. Fortunately, ICD-10-CM still contains injury mechanism codes, although the organization of the codes is different.[214]

Second, the research described in Aim 1 can be expanded upon using the updated case definition. This can include a more in-depth evaluation of our case definition, such as a formal sensitivity analysis. Another area for potential research is examining trends in SR injuries over time. For example, although the Gfeller-Waller Concussion Awareness Act was signed in 2011, it was not fully implemented until 2014.[199] Therefore, it is unknown what influence, if any, the implementation of this legislation is having on the incidence of SR ED visits in NC.

Third, our case definition can be applied to other populations and the results compared to those reported for North Carolina (Aim 1). This can include other state populations and/or special populations. Since we performed our study, NC DETECT has added race and ethnicity to its ED visit data, providing the opportunity to examine SR injury in minority populations.

Fourth, while Aim 2 provides invaluable information about youth TBI, there is utility in examining pediatric patient data from sources other than a large, metropolitan hospital system with a pediatric emergency department and a Level I trauma center. Other study populations of interest include patients from rural and suburban community hospitals, as well as patients from urgent care centers and primary healthcare providers. The latter two provider settings are especially important, as these sites treat a substantial proportion of medically-attended SR TBIs.[127]

Fifth, while the Aim 2 study provided some insight into the delayed/prolonged symptomology of youth with TBIs, we did not have the sample size or number of data collection points to characterize TBI sequela in children in detail. As much still needs to be learned about the intermediate and long-term effects of TBI on the developing brain, a robust prospective study design with an expanded sample size is needed to provide valuable insights for this area of research.

7.6 Conclusion

In conclusion, the incidence and associated costs of SR injuries pose a considerable burden on the youth population. It is likely that the incidence of SR injuries will increase in response to public health measures aimed at encouraging youth to participate in physical activity as a response to the childhood obesity crisis. Although the relationship between physical activity and injury is well understood, there is limited research describing the characteristics and incidence of SR injuries at the state or regional level.

In Aim 1 we used a novel case definition to describe the population-based incidence of SR ED visits in NC. In this study, we described the incidence of SR injuries and SR TBIs by sex, age group, and specific sports and recreational activity. This research will inform timely, ongoing sports injury surveillance in NC and other jurisdictions. In Aim 2, we examined the clinical characteristics of SR TBIs. Although descriptive in nature, this study suggested SR TBIs may be more symptomatic, require more resources, and possibly be more severe than non-sports TBIs. This exploratory study has strong potential to catalyze future research in this area.

APPENDIX A: SPORTS AND RECREATION-RELATED INJURY CASE DEFINITIONS

Case Definition[a,b]	
Taylor BL, Attia MW[92]	Included: E886.0, E917.0
Yang J, et al.[93]; Gao Y, Johnston RC, Karam M[113]; Nalliah RP, et al.[43]	Included: E886.0, E917 (.0, .5)
Dempsey RL, et al.[38]	Included: E810-E819 (.5, .6), E820 (.0, .1, .8, .9), E821 (.0, .1, .2, .3, .5, .6, .7, .8, .9), E822-E825 (.5, .6) E826-E829 (.1, .2), E830-E838 (.0, .1, .3, .4, .5, .9), E883.0, E884.0, E885.0, E886.0, E910 (.0, .1, .2, .8), E917.0, E922 (.4, .5) Not included: E821 (.2, .3, .7), E840 -E844 (.6, .7), E847, E848, E884 (.1, .9), E888 (.0-.9), E907, E914, E922 (.0, .1, .2, .8, .9), E927
Socie E, Falb M, Beeghly C[97]	Included**:** E801-E807 (.3), E810-E819 (.6), E820-E825 (.6), E826-E829 (.1), E849.4, E883.0, E884.0, E885 (.0-.4), E886.0, E902.2, E910 (.0-.2), E917 (.0-.5), E922 (.4, .5) Not included: E922.2, E987.2
Bijur PE, et al.[96]	Included: E813.6, E821.9, E826 (.1, .9), E828 (.2), E832.9, E838.4, E883.0, E884.0, E886.0, E917.0 Not included: E826.0, E825.9, E828.9, E848, E886.9, E927 (.0-.9),
Howard AF, et al.[98]	Included: E001-E010 (.0-.9), E849.4, E885 (.0-.4), E886.0, E910 (.0-.2), E917 (.0, .5)
Harmon KJ, et al.[134]	Included: E001-E010 (.0-.9), E800-E807 (.3), E810-E819 (.5, .6), E820 (.0, .1, .8, .9), E821 (.0, .1, .8, .9), E820-E825 (.5, .6), E826-E829 (.1, .2), E826.9, E830-E838 (.0, .1, .3, .4, .5, .8, .9), E849.4, E883.0, E884.0, E885 (.0-.4), E886.0, E902.2, E910 (.0, .1, .2, .8, .9), E917 (.0, .5), E922 (.4, .5)

[a]"Included" refers to E-codes included in the KJ Harmon, et al. case definition.
[b]"Not included" refers to E-codes not included in the KJ Harmon et al. case definition.

APPENDIX B: NUMBER AND INCIDENCE RATE (PER 100,000 PERSON-YEARS) OF SPORTS AND RECREATION-RELATED ED VISITS STRATIFIED BY CASE DEFINITION AMONG SCHOOL-AGE YOUTH: NORTH CAROLINA, 2010-2014

Case Definition	**No.**	**Rate**	**95% CI**	
			Lower	**Upper**
Taylor BL, Attia MW[92]	52,216	580.7	575.7	585.7
Yang J, et al.; Gao Y, Johnston RC, Karam M; Nalliah RP, et al.[43,93,113]	60,213	669.6	664.3	675.0
Dempsey RL, et al.[a138]	100,711	1,120.0	1,113.1	1,126.9
Socie E, Falb M, Beeghly C[97]	108,754	1,209.4	1,202.3	1,216.6
Bijur PE, et al.[96]	156,596	1,741.5	1,732.9	1,750.1
Howard AF, et al.[98]	177,995	1,979.4	1,970.3	1,988.7
Harmon KJ, et al.[134]	**213,518**	**2,374.5**	**2,364.4**	**2,384.6**

Abbreviations: No., number; CI, confidence interval
[a]Based on medium estimate (estimated range of 87,726 - 115,111)

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