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Bicycle Helmet Use Trends and Related Risk of Mortality and Traumatic Brain Injury among Pediatric Trauma

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Abstract

Introduction: An estimated 33 million children ride bicycles annually in the United States, resulting in ~450,000 emergency department visits and 384 deaths--most resulting from traumatic brain injury (TBI). Bicycle helmet use among children is low despite educational and injury prevention efforts. The study aims to evaluate helmet use trends and determine risk of in-hospital mortality and TBI among the national pediatric trauma population.

Materials and methods: We analyzed a nationally-representative sample of patients from the National Trauma Data Bank National Sample Program for 2003-2004 and 2007-2010. Patients ≤ 17 years of age admitted to a Level I or II trauma center with blunt injury due to pedal cycle and data for helmet use were included. Patients wearing a helmet at the time of injury were compared to those without a helmet. Adjusted logistic regression models determined the odds of helmet use, TBI, and in-hospital mortality.

Results: Overall, only 21% of children wore helmets at the time of injury. Helmet use decreased significantly from 28% in 2003-2004 to 19% in 2009-2010. Patients aged 10-17 years, females, Hispanics, African Americans, and those lacking private insurance had higher odds of not wearing a helmet. Helmet use and Hispanic and African American race/ethnicity were protective against TBI. Patients aged 13-17 years and African Americans were at greater risk of in-hospital mortality. Patients who wore a helmet, were male, or were Hispanic had lower odds of death.

Conclusions: Bicycle helmet use among the national pediatric trauma population is low and has not improved. While helmet use is protective against TBI and lowers risk of death following bicycle-related injury, certain age and racial/ethnic groups are at increased risk of mortality and have higher odds of suffering a TBI following bicycle-related injury. Knowledge dissemination of helmet use trends and related risks of injury and mortality from non-compliance could improve prevention efforts aimed at increasing helmet compliance among pediatric bicycle riders.

Keywords: Pediatric trauma; Bicycle helmet; Injury prevention; Protective device; Helmet use; Mortality

Abbreviations: US: United States; CDC: Centers for Disease Control; TBI: Traumatic Brain Injury; NTDB: National Trauma Data Bank; NSP: National Sample Program; ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification; MOI: Mechanism of Injury; OR: Odds Ratio; CI: Confidence Interval; NHW: Non-Hispanic White; AA: African American

Introduction

Trauma is the leading cause of death and disability among children (age < 1 to 19) and young adults (age 20-24) in the United States (U.S.) [1]. An estimated 33 million children ride bicycles each year [2]. The Centers for Disease Control (CDC) estimates approximately 824 bicycle-related fatalities and 600,000 bicycle-related emergency department visits occur annually [2]. Of those bicycle-related injuries, an average of 384 fatalities and approximately 450,000 emergency department visits were for children. More emergency department visits for children between the ages of 5 and 14 are related to bicycle injuries than any other sport [3-5]. Statistically, children are at increased risk for traumatic brain injuries (TBIs) due to falls and blunt head trauma, two common mechanisms of bicycle-related injuries [6]. Some suggest children are at increased risk of disrupted developmental and academic skills due to childhood brain injury [7,8]. The CDC reported roughly 8,566 patients 0 to 17 years of age were hospitalized for bicycle-related injuries, costing over $357 million in 2010 [9].

Bicycle helmets were introduced more than 30 years ago in the U.S. [10] Within the past 20 years, several epidemiologic studies have documented the efficacy of bicycle helmet use in decreasing risk for injury and death for cyclists [11,12]. However, despite evidence supporting the value of bicycle helmets in significantly reducing the severity of most cycling-related head and upper facial injuries [13,14], use among children is relatively low. Proper utilization of bicycle helmets has been found to reduce, not only the risk of head, brain, and facial injuries, but also death, with a protective effect in excess of 80% [10,13,15-20]. After years of demonstrated efficacy, several areas of the U.S. and other countries began to implement helmet laws [14,21,22]. Currently, only 21 U.S. states, the District of Columbia, the Northern Mariana Islands, and the Virgin Islands have helmet laws for bicyclists, typically for those under 16 years of age [23]. A national survey conducted from 2001-2003 found that less than 50% of children ages 5-14 wore bicycle helmets regularly when cycling, and observational studies report 50-75% of children continue to ride without helmet protection [3,24].

Although many studies describe trends in bicycle helmet use among children in specific populations and regions, currently there is a lack of information regarding national trends. Additionally, associated differences in helmet use on injury severity and outcomes have not been evaluated for pediatric trauma patients on a national scale, particularly by age group. The purpose of this study was to examine national trends in helmet use among the pediatric trauma population treated at Level I and II trauma centers for bicycle-related injuries and identify differences in outcomes by demographic characteristics using a large national database. We hypothesize helmet use among pediatric trauma patients has not changed over time and helmet use decreases as age increases [25-27].

Methods

We retrospectively analyzed the National Trauma Data Bank National Sample Program (NTDB NSP) for 2003-2004 and 2007-2010. The NTDB is the nation's most comprehensive trauma database with more than 1 million voluntarily provided records from 405 trauma centers. The NSP is an extension of the NTDB as it is a statistically representative sample of only 100 Level I and II trauma centers from the NTDB. The NSP may be used to develop national estimates [28,29].

All patients less than or equal to 17 years of age admitted to a Level I or II trauma center with blunt injury due to any pedal cycle and complete protective device data for helmet use were included. Pedal cycle injuries were identified using the International Classification of Diseases, Ninth Revision, Clinical Modification Ecodes (ICD-9-CM) (6.4, 800.3, 801.3, 802.3, 803.3, 804.3, 805.3, 806.3, 807.3, 810.6, 811.6, 812.6, 813.6, 814.6, 815.6, 816.6, 817.6, 818.6, 819.6, 820.6, 821.6, 822.6, 823.6, 824.6, 825.6, and 826 x). All patients greater than 17 years of age were excluded. Additionally, any patients meeting the age requirement but had a penetrating injury, blunt injury due to mechanisms of injury (MOI) other than pedal cycle, or missing protective device data for helmet use were excluded. We also excluded patients presenting between 2005 and 2006 due to an unexpectedly high volume of missing data. Prior to exclusion, all patients injured due to pedal cycle were analyzed for comparative purposes. The total injured pedal cycle population did not differ in demographic and injury characteristics from either helmeted or non-helmeted pediatric cyclists. Patients were divided into two groups: those reported wearing a helmet at the time of injury and those with no reported helmet use. The primary outcome of interest was helmet use. Secondary outcomes of interest included in-hospital mortality and TBI.

Weighted estimates were employed for all analyses. To compare representative samples of helmeted patients to non-helmeted patients, we used chi-square for categorical variables and Student's *t* Test for continuous variables. Results are presented as proportions, means, and standard deviations where appropriate. Three risk-adjusted models were created to analyze the odds of each of the following dependent variables: helmet use, TBI, and in-hospital mortality. To control for confounding, the following independent variables were included in each multivariate logistic regression model: helmet use; age group; sex; race/ethnicity; insurance status; and U.S. geographic region. However, helmet use was not included in the model that analyzed the odds of helmet use. Insurance status was grouped into three categories: public (e.g. Medicare, Medicaid, other government assistance programs), private (commercial insurance), and uninsured. The association of each independent predictor for helmet use, TBI, and in-hospital mortality are reported as adjusted odds ratios (OR) with a 95% confidence interval (CI). Any independent predictor with a p value greater than 0.05 is not reported. Statistical Package for the Social Sciences for Windows (SPSS Inc., version 20, Chicago, IL) was used for descriptive and statistical analysis, with p values less than 0.05 considered significant. This study was approved by the Institutional Review Board and adhered to established guidelines on the treatment of human subjects.

Results

A total of 16,681 patients met inclusion criteria: helmet use was reported for 3,537 (21%), and no helmet use was reported for 13,144 (79%) (Table 1). Helmeted patients were predominately non- Hispanic white (NHW; 76%), had private insurance (66%), and were more likely to be discharged home (82%). The average age of both helmeted and non-helmeted patients was 11 years. Based on age group, 6-9 year olds wore helmets more often than other age groups, while 13-17 year olds wore helmets least often. Helmet use was most common in the Northeast region of the U.S. and least so in the Midwest. Helmet use did not significantly differ between the Southern and Western regions. The proportion of patients with life threatening injuries (defined as Injury Severity Score ≥ 25 and Glasgow Coma Scale ≤ 8) were higher among non-helmeted patients. Helmeted patients suffered fewer TBIs, injuries to other regions of the head, face, and neck, and fewer contusion/superficial wounds. However, the proportion of injuries to extremities and the spine and back did not significantly differ compared to non-helmeted patients (Table 1).

Overall helmet use decreased significantly from 28% in 2003-2004 to 19% in 2009-2010. Reductions in helmet use were observed among males, NHWs and African Americans (AA), across all insurance groups, and among all age groups except 10-12 year olds. Helmet use decreased significantly in the Midwest, Northeast, and South. Despite overall decreases, helmet use significantly increased among Hispanics (Table 2).

After adjusting for independent predictors, only statistically significant results are reported in Table 3. The odds of wearing a helmet were significantly lower among patients aged 10-12 and 13-17, Hispanics and AAs, and in patients with public insurance or no insurance. The odds of suffering a TBI were greatest for uninsured patients and less likely for helmeted, Hispanic, and AA patients. The odds for in-hospital mortality were greater among patients aged 13-17, AAs, and patients in the Southern and Western regions of the U.S. ($p < 0.05$). The same model showed patients who wore a helmet, were male, or Hispanic had lower odds of death.

Discussion

We found helmet use among the pediatric population admitted for bicycle-related injuries is a nationwide problem and use did not improve over an eight-year period. Helmeted patients were less likely to suffer TBIs compared to their non-helmeted counterparts. Risk of in-hospital mortality was higher for AA patients compared to NHWs, as well as for children between 13 and 17 years of age, and patients living in the Southern and Western regions of the U.S. Lack of insurance is the most significant independent predictor of TBI compared to all other independent predictors of interest.

Helmet noncompliance is prevalent across U.S. regions, age groups, and races/ethnicities and is well documented in the trauma literature [24,25,30-33]. Our findings are consistent with previous studies suggesting helmet use among children is particularly low [34] and children between 5 to 14 years of age have the highest percentage of bicycle injuries of any age group [35]. However, our study indicates the proportion of helmet use among pediatric trauma patients admitted for bicycle-related injuries is lower than reported for observational studies, and our analysis of helmet use in pediatric patients expands upon previous research typically limited to state or institutional data [36]. Consistent with our findings, previous research has shown helmet use is lower among AA and Hispanic patients than NHW patients [37]. We found overall, males wore helmets more often than their female counterparts, but those differences were eliminated when evaluated between the two time points, as helmet use decreased significantly among males, but not females [38]. Additionally, our findings indicate helmet use reduced the likelihood of suffering a TBI [14,20,33,38].

	No Helmet n=13,144 (79%)	Helmet n=3,537 (21%)	p value
Age, y [mean ±standard deviation]:	11.4±3.9	11.0±3.8	<0.001
Age Groups (%)			<0.001
≤ 5	1173 (9)	298 (8)	NS
9-Jun	2,835 (22)	953 (27)	<0.001
12-Oct	3,183 (24)	880 (25)	NS
13-17	5,953 (45)	1,405 (40)	<0.001
Sex (%)			<0.01
Female	2,551 (19)	614 (17)	<0.01
Male	10,577 (81)	2,921 (83)	<0.01
Race/Ethnicity (%)			<0.001
non-Hispanic White	7,467 (57)	2,690 (76)	<0.001
Hispanic	2,079 (16)	158 (5)	<0.001
African American	1,783 (14)	276 (8)	<0.001
Injuries (%)			
Traumatic Brain Injury	5,735 (44)	866 (25)	<0.001
Other Head, Neck, Face	5,666 (43)	1,213 (34)	<0.001
Spine and Back	558 (4)	138 (4)	NS
Torso	3,087 (24)	1,007 (29)	<0.001
Extremity	4,506 (34)	1,247 (35)	NS
Contusion/Superficial	5,753 (44)	1,447 (41)	<0.001
Injury Severity Score ≥ 25	730 (6)	153 (5)	<0.05
Glasgow Coma Scale ≤ 8	779 (6)	82 (3)	<0.001
Systolic Blood Pressure ≤ 90 mmHg	273 (2)	59 (2)	NS
Length of Stay, days [mean ± standard deviation]	3.0±5.0	2.8±3.4	NS
Discharge Location (%)			<0.05
Home	10,546 (80)	2,913 (82)	<0.00
Another Facility	783 (6)	196 (6)	NS
Died	121 (1)	21 (1)	<0.05
Insurance Status (%)			<0.001
Private	5,515 (42)	2,323 (66)	<0.001
Public	3,285 (25)	268 (8)	<0.001
Uninsured	1,176 (9)	225 (6)	<0.001
Geographic Region (%)			<0.001
Midwest	2,428 (19)	422 (12)	<0.001
Northeast	2,294 (18)	859 (24)	<0.001
South	3,923 (30)	1,092 (31)	NS
West	4,498 (34)	1,164 (33)	NS

Table 1: Weighted Characteristic Differences for Pediatric Cyclists by Helmet Use
NS, not statistically significant
Note: Standardized residual for 6-9 year olds in the helmeted group was 2.1

Currently only 21 U.S. states, the District of Columbia, the Northern Mariana Islands and the Virgin Islands have helmet laws for bicyclist 16 years of age and under [23]. In the Northeast, eight out of nine states have pediatric helmet laws, 10 out of 17 states in the South, three out of 13 states in the West, and zero out of 12 states in the Midwest. Our findings show overall helmet use by U.S. region is highest in the Northeast and lowest in the Midwest, which supports an existing correlation between helmet use compliance and the presence of statewide bicycle helmet laws found in other studies [24]. Additionally, some studies have linked helmet noncompliance to lower socioeconomic status, [24] and our data indicate lack of private insurance is an independent predictor of helmet noncompliance. Helmet use by any person using a bicycle, including the pediatric population, should be encouraged and made universally acceptable, similar to the use of seat belts by those who ride in automobiles. Persistently low helmet use among young riders indicates a necessity for the development of successful outreach programs focused on the four E's

	2003-2004 n=4502	2009-2010 n=5836	p value	95% CI
Helmet Use (%)	1,245 (28)	11,13 (19)	<0.001	0.56-0.68
Age Range (%)				
≤ 5, n=924	8	9	NS	0.98-1.29
6-9, n=2,257	23	21	0.03	0.82-0.99
10-12, n=2,642	28	24	<0.001	0.75-0.90
13-17, n=4,515	41	46	<0.001	1.11-1.30
Sex (%)				
Female, n=2,004	18	21	0.00	1.08-1.32
Male, n=8,315	82	79	0.00	0.78-0.95
Race/Ethnicity (%)				
non-Hispanic White, n=6,042	58	59	NS	0.99-1.15
Hispanic, n=1,373	9	16	<0.001	1.69-2.16
African American, n=1,340	11	15	<0.001	1.21-1.54
Insurance Status (%)				
Private, n = 4,642	41	48	<0.001	1.25-1.46
Public, n = 2,345	16	28	<0.001	1.93-2.35
Uninsured, n =764	9	6	<0.001	0.62-0.83
Geographic Region (%)				
Midwest, n=1,779	17	18	NS	0.95-1.17
Northeast, n=1,828	16	19	0.00	1.09-1.33
South, n=3,213	29	33	<0.001	1.13-1.34
West, n=3,516	38	31	<0.001	0.65-0.77

Table 2: Weighted Helmet Use Trends by Demographic Characteristics, 2003-2004 vs. 2009-2010

Chi-square analysis used to compare helmet use between years 2003-2004 vs. 2009-2010;

p < 0.05 considered statistically significant; NS, not statistically significant

of injury control: education, enforcement, engineering, and evaluation [39]. Education about the protective efficacy of bicycle helmets is especially critical for young minority bicyclist populations, where helmet use was significantly lower. As previously reported, the average age for children riding bikes in our sample is 11 years of age. This finding illustrates the importance of targeting helmet education toward adults. Children of this age are usually supervised while participating in recreational sports like cycling; therefore, parents are also a prime target audience for preventive educational programs.

It is important to develop bicycle safety habits early, as children who wear helmets continue the habit into adulthood [35]. This need is most obvious among minority groups. We found helmet use rates among AAs and Hispanics increased with age (data not shown), therefore, we suspect it is possible that a large number of minority children initially learn about helmet use at school or from their peers. One study found 93% of riders less than 16 years of age who always or almost always wore a helmet cited family member insistence as one of the important reasons for wearing a helmet [40].

	p value	Odds Ratio	95% Confidence Interval
Odds of Helmet Use**			
Age Groups			
≤ 5	Reference		
10-12	<0.001	0.71	0.60-0.84
13-17	<0.001	0.56	0.47-0.65
Sex			
Female	Reference		
Male	<0.001	1.29	1.15-1.44
Race/Ethnicity			
non-Hispanic White	Reference		
Hispanic	<0.001	0.22	0.18-0.27
African American	<0.001	0.45	0.39-0.52
Geographic Region			
Midwest	Reference		
Northeast	<0.001	2.76	2.35-3.24
South	<0.001	2.13	1.83-2.49
West	<0.001	2.18	1.86-2.54
Insurance Status			
Private	Reference		
Public	<0.001	0.19	0.16-0.22
Uninsured	<0.001	0.51	0.43-0.60
Odds of TBI‡			
Helmet Use (Yes)	<0.001	0.44	0.40-0.48
Race/Ethnicity			
non-Hispanic White	Reference		
Hispanic	<0.001	0.84	0.76-0.94
African American	<0.001	0.71	0.64-0.79
Insurance Status			
Private	Reference		
Uninsured	<0.001	1.30	1.16-1.17
Odds of In-hospital Mortality#			
Helmet Use (Yes)	0.05	0.60	0.35-1.00
Age Groups			
≤ 5	Reference		
13-17	0.02	3.19	1.17-8.71
Sex			
Female	Reference		
Male	0.01	0.53	0.34-0.84
Race/Ethnicity			
non-Hispanic White	Reference		
Hispanic	0.02	0.18	0.04-0.74
African American	<0.001	2.43	1.51-3.91
Geographic Region			
Midwest	Reference		
South	<0.05	2.13	1.02-4.46
West	0.02	2.54	1.20-5.40
Insurance Status			
Private	Reference		
Public	<0.001	0.28	0.14-0.57

Table 3: Risk-adjusted Independent Predictors for Helmet Use, Traumatic Brain Injury, and in- hospital Mortality

Only statistically significant predictors are reported

** Independent predictors excluded by the model: age 6-93

‡ Independent predictors excluded by the model: ages ≤ 5, 6-9, 10-12, 13-17; male and female sex; public insurance; Midwest, Northeast, South, West U.S. geographic regions

Independent predictors excluded by the model: ages 6-9 and 10-12; Midwest, South, West U.S. geographic regions; uninsured status.

Although targeted prevention efforts may increase helmet use over a short period of time, most fail to deliver a measurable behavior outcome over a sustained period [41]. Legislative mandates are another option to encourage the use of bicycle helmets among the pediatric population, with one study finding a significant increase in helmet use (45-84%) after the introduction or enforcement of helmet legislation [42]. However, despite lawmaking efforts and enforcement of bicycle helmet use, injured pediatric cyclists, as our study shows, are not adhering to legislative mandates. Research has shown minimal increases in financial resources and time is required by police in helmet enforcement, and suggests the perception of enforcement may be more important than the actual enforcement itself [43]. Funds previously allocated to prevention programs not resulting in sustained helmet use could be reallocated to cover potential costs.

This study has several potential limitations. The retrospective study design cannot be used to demonstrate causality. We used data from the NTDB NSP, resulting in a representative sample containing voluntarily submitted data from participating institutions, with its inherent limitations that are well documented [2,3,41]. Data collection ends at discharge; subsequently, post-discharge outcomes cannot be tracked, which limits our primary outcome assessment to in-hospital mortality only. Additionally, many fields are loosely defined, increasing the potential for classification bias. We accounted for this limitation by using a conservative approach to clearly define our study population. Differentiation between MOI is difficult due to lack of sufficient specificity using ICD-9-CM Ecodes. For example, it is not possible to determine if pediatric bicycle riders were riding with another passenger or in a basket or attachment, specifically for patients less than 5 years of age. Regardless of whether or not pediatric patients had control of the bicycle, the potential for injury still exists, so we included all patients whose MOI was due to a pedal cycle.

The National Trauma Data Standard was adopted by the NTDB in 2007 and has significantly standardized and improved the quality of data [44]. Therefore, the quality of our data may not be consistent across the eight-year study period, and may account for large fluctuations among variables prior to 2007. Nevertheless, we felt it pertinent to use data prior to 2007 in order to assess trends over time, though we excluded data from 2005 and 2006 due to limited population size caused by missing data: another limitation of the NTDB. Approximately 41% of the pediatric population admitted for pedal cycle injuries were excluded from analysis because helmet data was not recorded. Efforts are needed to improve data collection on protective device use. Moreover, proportions and trends of helmet use may not reflect the national population, as those who did not sustain injuries or did not require admission following injury were not included in our sample.

Even still, the trauma community was one of the first to perform risk-adjusted analysis and has a long history of using such methods to improve trauma center performance and patient outcomes [45]. The NTDB and NSP are two prime examples of such methodological tools developed precisely for this purpose and utilized by trauma researchers across the nation. More specifically, the NSP is intended to 1) Create a traumatic injury database from a nationally representative sample of trauma hospitals; 2) collect a wide variety of diagnostic and clinical indicators complementary to the NTDB; 3) produce national baseline estimates of variables and indices associated with hospitalized traumatic injuries such as prehospital diagnosis and management, trauma outcomes, and other variables that characterize the dimensions of trauma treatment [29].

Although epidemiology is the study of disease incidence and distribution, its methodological processes are useful to study other factors related to health. It is for this reason we utilize epidemiological practices to highlight helmet use trends among the pediatric trauma population. Employing such techniques, our paper demonstrates that the incidence and distribution of pediatric helmet use is indeed a public health issue, therefore, warranting publication within an epidemiology and public health-focused journal.

Conclusions

We conclude that despite education, outreach, and legislative efforts aimed at improving bicycle helmet use, adherence among pediatric patients admitted for bicycle-related injuries is relatively low and has not improved over time. Of particular concern, AA males aged 13-17 living in the Southern and Western U.S. regions are at highest risk of in-hospital mortality due to bicycle-related injuries. Causes of helmet noncompliance may be due to several factors, and educational prevention efforts need to reach parents as well as children, particularly for parents of those at highest risk of mortality and TBI. Institution of federal laws regarding pediatric helmet use, including helmets in bicycle sales, community patrolling initiatives and pediatrician-driven inquiries during clinic visits may increase the prevalence of helmet use among this population. Further studies are needed to address the factors associated with helmet noncompliance as well as to examine which prevention efforts are best suited in reaching its target audience.

Author Contributions

Laureano Phillips and Overton contributed to the research hypothesis development, literature search, study design, data collection, data interpretation, statistical programming, writing, and critical revision of the manuscript. Campbell-Furtick contributed to the literature search, study design, data collection, writing, and critical revision and journal submission of the manuscript. Nolen contributed to the literature search, study design, data collection, and data interpretation of the manuscript. Gandhi, Duane, and Shafi contributed to the hypothesis development, study design, and critical revision of the manuscript.

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