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Youth Motorcycle-Related Brain Injury by State Helmet Law Type: United States, 2005–2007

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KEY WORDS

hospitalizations, hospital discharges, motorcycle, motorcycle helmets, helmet laws, scooters, traffic accidents, non-traffic accidents, adolescents, injury, traumatic brain injury, injury severity

ABBREVIATIONS

TBI—traumatic brain injury
AHRQ—Agency for Healthcare Research and Quality
HCUP—Healthcare Cost and Utilization Project
SID—State Inpatient Database
ICD-9-CM—*International Classification of Diseases, Ninth Revision, Clinical Modification*
RR—relative risk
CI—confidence interval

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WHAT'S KNOWN ON THIS SUBJECT: Youth fatality rates from motorcycle crashes are higher in states with partial-age helmet laws, but whether this difference is traumatic brain injury–related has not been determined. This study focused on TBI by using hospital morbidity data from states with different helmet laws.



WHAT THIS STUDY ADDS: Study results highlight and quantify the head-injury risks of different partial-age helmet laws for young riders and offers caution for the many states that have or are considering replacement of universal all-age laws with age-specific laws.

abstract

BACKGROUND AND OBJECTIVES: Twenty-seven states have youth-specific helmet laws even though such laws have been shown to decrease helmet use and increase youth mortality compared with all-age (universal) laws. Our goal was to quantify the impact of age-specific helmet laws on youth under age 20 hospitalized with traumatic brain injury (TBI).

METHODS: Our cross-sectional ecological group analysis compared TBI proportions among US states with different helmet laws. We examined the following null hypothesis: If age-specific helmet laws are as effective as universal laws, there will be no difference in the proportion of hospitalized young motorcycle riders with TBI in the respective states. The data are derived from the 2005 to 2007 State Inpatient Databases of the Healthcare Cost and Utilization Project. We examined data for 17 states with universal laws, 6 states with laws for ages <21, and 12 states with laws for children younger than 18 (9287 motorcycle injury discharges).

RESULTS: In states with a <21 law, serious TBI among youth was 38% higher than in universal-law states. Motorcycle riders aged 12 to 17 in 18 helmet-law states had a higher proportion of serious/severe TBI and higher average Abbreviated Injury Scores for head-region injuries than riders from universal-law states.

CONCLUSIONS: States with youth-specific laws had an increased risk of TBI that required hospitalization, serious and severe TBI, TBI-related disability, and in-hospital death among the youth they are supposed to protect. The only method known to keep motorcycle-helmet use high among youth is to adopt or maintain universal helmet laws. *Pediatrics* 2010;126:e1589–e1595

TABLE 1 Helmet-Law Types and Percentage of Population in the AHRQ HCUP SIDs: United States, 2007

Helmet-Law Type in 2007 ^a	No. of States (Including Washington, DC) 2007	Percentage of 2007 US Population	Percentage of 2007 Youth Population (Ages 12–20 y)	HCUP SIDs 2005, No. of States	HCUP SIDs 2006, No. of States ^b	HCUP SIDs 2007, No. of States
Universal law (all ages) (CA, DC, GA, LA, MD, MA, MI, MS, MO, NE, NV, NJ, NY, NC, OR, TN, VT, VA, WA, WV)	21	51.2	50.5	16	17	15
<21 law (AR, FL, PA, RI, SC, TX, KY)	7	22.3	21.6	5	6	4
<19 law (DE)	1	0.3	0.3	0	0	0
<18 law (CO, CT, HI, ID, IN, KS, MN, MT, NM, ND, OH, OK, SD, UT, WI, WY, AK, AZ)	18	20.1	20.1	11	11	12
<15 law (ME)	1	0.4	0.4	0	1	1
No law (CO, IA, IL, NH)	3	5.7	7.1	4	4	3
Total	51	100.0	—	36	39	35

Helmet-law source: Insurance Institute for Highway Safety (www.iihs.org/laws/HelmetUseCurrent.aspx).

^a In 2007, Colorado changed from a no-helmet-law state to a <18-law state. It was the only state whose helmet-law status changed during the study period. Maine changed to a <18-law from a <15-law state in mid-2009. The Missouri governor vetoed a bill in July 2009 that would have changed it to a <21-law state.

^b States included in the SIDs are Arizona, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Vermont, Washington, West Virginia, Wisconsin, and Wyoming.

Motorcycling is risky. Motorcyclists are 35 times more likely than passenger-car occupants to die in a motor vehicle traffic crash and 8 times more likely to be injured per vehicle-mile.¹ They are 58 times more likely to be killed than passenger-vehicle occupants on a per-trip basis.²

The numbers of motorcycle deaths and injuries are rising because of increased use of motorcycles for recreation, more powerful motorcycles, more older riders, and the desire for fuel-efficient travel. An additional factor is the repeal of universal (all-age) helmet laws.³

The contemporary increase in motorcycle injuries is also observed among young riders aged 12 to 20 years. Their motorcyclist death rate was 0.52 per 100 000 population in 1999 and increased to 0.98 in 2006 (88% increase).⁴ Their nonfatal emergency department visit motorcycle traffic-related injury rate (per 100 000 persons) also increased from 63.9 in 2001 to 78.1 in 2007 (22% increase).⁴ In a recent review of trends in traumatic brain injury (TBI) that require hospitalization, a significant increase in teen-aged male TBI hospitalization rates from 1998 to 2005 was reported for

motorcycle crashes, one of but a few TBI causes that showed increases.⁵ Youth are especially at risk for injury from motorcycles because of increased risk-taking behavior and a lack of experience.^{6,7}

Fundamental to reducing motorcycle head injury among motorcycle riders is the use of a proper safety helmet. In a recent Cochrane meta-analysis of 61 different observational studies, Liu et al⁸ concluded that motorcycle helmets reduce death from head injury by 42% and head injury by 69%. Despite demonstrated efficacy, 30 states abandoned universal helmet laws after withdrawal of federal sanctions. In 1975, after 8 years of sanctions, all but 3 states had universal helmet laws.⁹ However, in 1976, congressional action eliminated the withholding of highway-safety appropriations from states that did not require helmets among motorcyclists over the age of 17. Federal helmet-law incentives were reintroduced in the early 1990s, only to be reversed again in 1995. Currently, 20 states and the District of Columbia (51% of the US population) have universal helmet laws.⁹ Three states (6% of the population) have no helmet

laws*; 27 remaining states (43% of the population) have retained age-specific laws (Table 1).

There is evidence that partial age-specific youth helmet laws do not work well. In North Dakota (1977–1980), a “substantial decline” in helmet use by children younger than 18 years was noted after passage of a partial-age law.¹⁰ In Texas (1991), only 29% of injured riders younger than 18 were found to be helmeted under their partial-age helmet law.¹¹ In Florida (2000), downgrading to an age-specific law was associated with a 26% decline in helmet usage among young riders killed and a twofold increase in young-rider fatalities.¹²

In a 2006 study, the Insurance Institute for Highway Safety reported that in states with weak laws, helmets were worn by fewer than 40% of fatally injured minors.⁹ In a national study from 1975 to 2004, Houston¹³ reported that universal helmet laws were correlated with a substantial reduction in motorcyclist fatalities and that partial-coverage laws did not result in a reduction of youth fatality rates

*Colorado introduced a helmet law on July 1, 2007, to cover riders under the age of 18, which resulted in 3 states having no helmet laws.

compared with universal-law states. Another multistate study that addressed this issue was conducted by Coben et al³ with 2001 Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP) hospital discharge data from 33 states. It was the first study to cover hospital discharges from multiple states, and the authors reported that “partial requirement laws may not be protective of young riders.” However, this study had the broader aim of addressing all-age morbidity effects of helmet requirements and did not focus on youth.

The goals of our study were to fill these gaps by using additional states, covering a larger population, and more recent (2005–2007) AHRQ HCUP data. We examined the null hypothesis that if age-specific helmet laws are as effective as universal laws, there should be no difference in the proportion of motorcycle-related TBI versus other motorcycle injury in states with age-specific laws versus those with universal helmet laws.

METHODS

Retrospective data were obtained from the 2005–2007 State Inpatient Databases (SIDs),¹⁴ which were developed as part of the HCUP. There were 36, 39, and 35 states available through the SIDs in 2005–2007, respectively, which include data on almost 90% of all US community hospital discharges.† The SIDs contain both patient (demographic and clinical data) and hospital-level data. Details on how SID data are collected can be found elsewhere.¹⁴ The University of Pittsburgh institutional review board categorized this study as exempt. Analyses were performed by using Stata 10.0 (Stata

Corp, College Station, TX) and SAS 9.1 (SAS Institute Inc, Cary, NC).

Cases were selected from 99.3 million discharges across the 3 years. In contrast to customary 5-year age groups, we used a 9-year range, because many state motorcycle-helmet laws require youth aged 20 years or younger to wear a helmet even when persons aged 21 years and older are exempt. The lower age bound was chosen because of the sharp decrease in exposure and incidence among children younger than 12. Three equal age groups were used (12–14, 15–17, and 18–20 years). Injuries caused by motorcycles were selected on the basis of *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) external cause-of-injury codes (E-codes) (E810–E819, traffic) with a fourth digit of .2 (motorcyclist) or .3 (passenger) in any of the 4 E-code fields. Analyses were conducted on the combined group of riders and passengers (passengers made up ~7%).

Although predominantly made up of street-registered motorcycles, selected E-codes may include motorized bicycles (mopeds), scooters, and minibikes. “Traffic” crashes are those that occurred on a public highway. Non-traffic cases, which make up approximately one-third of the hospital discharges related to injury caused by motorcycles, were excluded because helmet laws often differ according to whether vehicles are used on- or off-road.¹⁵ Thirteen cases with ambiguous traffic status codes were set to “missing traffic status.”

TBI was defined on the basis of a TBI-related diagnoses in any of the first 10 diagnosis fields in accordance with ICD codes specified by the Centers for Disease Control and Prevention (CDC) TBI surveillance case definition.¹⁶ This definition includes ICD-9-CM diagnosis codes 800.0–801.9, 803.0–804.9, and

850.0–854.1. The code 959.01 (head injury unspecified) was also included. TBI codes that included late effects and complications (905.0 and 907.0) were excluded. TBI cases that met the CDC case definition were grouped into 3 different types according to the Barell body-region by nature-of-injury diagnosis matrix and injury severity.¹⁷ Intracranial injury was defined by using the AHRQ Clinical Classification Software.¹⁸ To avoid duplicate counts because of hospital transfers, 265 patients who were discharged to another short-term care facility were excluded, consistent with the approach of other population-based hospitalization studies.⁵

Estimates for TBI-related long-term disability were computed from regression coefficients provided by Selassie et al.¹⁹ Injury severity was calculated by using the algorithms of the ICD Programs for Injury Categorization (ICDPIC), which translates ICD diagnosis codes into Abbreviated Injury Scores and Injury Severity Scores.²⁰

Under the assumption that the proportion of motorcycle-related head injuries is inversely related to helmet use by motorcyclists, we compared the proportion of young motorcyclists with head injuries in states with different helmet laws. This assumption is reasonable, because helmet use has been shown to reduce head injuries.⁸ Non-head injury serves as a proxy measure of exposure to head-injury risk. When focused on severe injury (which requires hospitalization), this proxy has been shown to be a reasonable alternative measure of exposure; other exposure indices, such as hours of riding or miles traveled, were not available.²¹ This approach has been used in evaluating the effectiveness of similar bicycle- and motorcycle-helmet laws.^{21–25}

Most comparisons were limited to the 3 major helmet-law types: (1) for all

†This percentage dropped in 2007 because data from Connecticut, Texas, Massachusetts, and New Hampshire were not available at the time of the study.

ages (universal); (2) for youth younger than 21 years (<21); and (3) for children younger than 18 years (<18). Only 1 small state used the <15 partial helmet law, which made it unsuitable for separate analysis, so it was excluded from our analyses. Another state with a <19 partial helmet law was not part of the HCUP data set. Relative risks (RRs) and 95% confidence intervals (CIs) for proportional differences were calculated.

RESULTS

There were 9287 motorcycle traffic-related hospital discharges among 12- to 20-year-olds (representing 2.8% of all injuries in this age group) over the 3-year period. The age distribution was 1134 12- to 14-year-olds (12%), 2400 15- to 17-year-olds (26%), and 5753 18- to 20-year-olds (62%). The number of discharges observed within each of the law types was 4602 (50%) universal, 1916 (21%) <21 years, and 2313 (25%) <18 years. Analyses excluded the cases from <15 helmet-law states ($n = 32$ [0.3%]) and no-helmet-law states ($n = 424$ [4.6%]). Mean ages and the percentage of boys were similar across all 3 major law types (Table 2). Mean length of stay was greater for discharges in the <21 group but no different in the <18 group compared with those in the universal-law states.

Significant increases in the proportion of discharges in which the patient was transferred to another facility and in-hospital deaths for all youth aged 12 to 20 were found between each of the 2 major partial-law states compared with universal-law states (Table 2). The proportion of cases with the first listed diagnosis (principal diagnosis) of intracranial injury also varied significantly according to partial-law type. In states with universal helmet laws, 16.2% of discharges had a principal diagnosis of intracranial injury compared with 18.0% and 20.0% for <21

TABLE 2 Characteristics of Youth Hospital Discharges Resulting From Motorcycle Injury According to State Law Type: USAHRQ, HCUP, SIDs, 2005–2007

	Universal Helmet-Law States ($n = 16$) (Ages 12–20 y)	<18 Helmet-Law States ($n = 16$) (Ages 12–20 y)	<21 Helmet-Law States ($n = 4$) (Ages 12–20 y)
No. of cases in group	4602	2313	1916
TBI, %	30.9	37.8	32.1
Principal diagnosis of intracranial injury, % ^a	16.2	20.2	18.0
Age, mean, y	17.6	17.6	17.7
Age, %			
12 y	2.3	3.0	3.1
13 y	4.2	4.5	3.6
14 y	5.3	5.7	6.0
15 y	7.5	7.3	6.4
16 y	9.0	8.4	7.6
17 y	11.6	9.3	8.6
18 y	15.0	17.6	15.9
19 y	20.4	21.7	23.0
20 y	24.7	22.7	25.9
Males, % ^a	89.5	87.3	88.2
Length of stay, d			
Mean	5.1	5.1	6.3
Median	3.0	3.0	3.0
Disposition, % ^b			
Routine	83.9	82.4	80.1
Transfer to other facility	6.4	8.2 ^a	8.6
Home health care	7.3	6.5	8.2
Left against advice	0.7	<0.5	0.8
Died	1.6	2.6	2.4
Payer, % ^b			
Medicaid	20.4	16.5	16.7
Private	61.2	63.0	55.8
Self-pay	11.6	12.9	17.2
No charge	0.3	0.5	4.0
Other	6.5	7.0	6.2

^a χ^2 , $p < .05$.

^b χ^2 , $p < .0001$.

TABLE 3 RRs of Youth TBI Injury, Using Barell Matrix, Comparing Partial-Law and Universal-Law States: USAHRQ, HCUP, SIDs, 2005–2007

Law Type	Type 1 (Serious/Severe)	Types 2 and 3 (Moderate/Mild)
Universal law (referent), n (%)	476 (10.3)	326 (7.1)
All partial law for ages 12–20, n (%)	600 (14.2)	281 (6.6)
RR (95% CI)	1.37 (1.23–1.54) ^a	0.94 (0.80–1.10)
<18 law for ages 12–20, n (%)	382 (13.7)	176 (6.3)
RR (95% CI)	1.32 (1.16–1.50) ^a	1.08 (0.91–1.30)
<21 law for ages 12–20, n (%)	273 (14.3)	103 (5.4)
RR (95% CI)	1.38 (1.20–1.58) ^a	0.76 (0.61–0.94)
<18 law for only ages 12–17, n (%)	109 (12.4)	73 (8.3)
RR (95% CI)	1.20 (0.98–1.45) ^b	1.17 (0.92–1.49)

^a $P < .001$.

^b $P = .072$.

and <18 partial-law states, respectively (χ^2 , $P < .05$ for both categories compared with universal-law states). Table 3 lists the RR of TBI severity (categorized according to the Barell ma-

trix) comparing partial-law states to universal-law states. Significant increased risks were demonstrated for serious/severe TBI in both types of partial-law-helmet states compared

with universal-law states. The RR was smaller and of borderline statistical significance for <18-law states when restricted to ages 12 to 17 ($P = .072$). The probability of long-term disability among cases with TBI was 25% (95% CI: 23–26) in universal-law states, 30% (95% CI: 27–33) in <21-law states and 27% (95% CI: 25–30) in <18-law states (data not shown). There were no significant differences observed for cervical or thoracic spinal cord injury between the states with 1 of the 2 major partial-law types and universal-law states.

The age-group-specific pattern for 3 measures of TBI are compared for states with universal helmet laws to all states with partial helmet laws in Figs 1 and 2. Although each of the partial-law states demonstrated higher risks of TBI across the combined age groups (Table 3), when the age groups were analyzed separately, significant differences were observed in the (larger) 18- to 20-year age group alone. As shown in Fig 2, a significantly higher percentage of severe TBIs occurred in partial-law states compared with universal-law states in the 18- to 20-year age group. This increase was not observed in the 12- to 17-year age group. Similarly, mean Abbreviated Injury Scores for the head region were significantly higher in the states with partial helmet laws in the 18- to 20-year age group. Finally, the percentage of severe/serious TBIs were significantly higher in the partial-law states compared with universal-law states in the 18- to 20-year age group. There is less difference between the discharges in states with universal helmet laws compared with states with partial helmet laws in the <18 population.

DISCUSSION

Our results revealed a 37% increased risk of serious/severe TBI that required hospitalization for youth motorcycle riders in states with limited-age

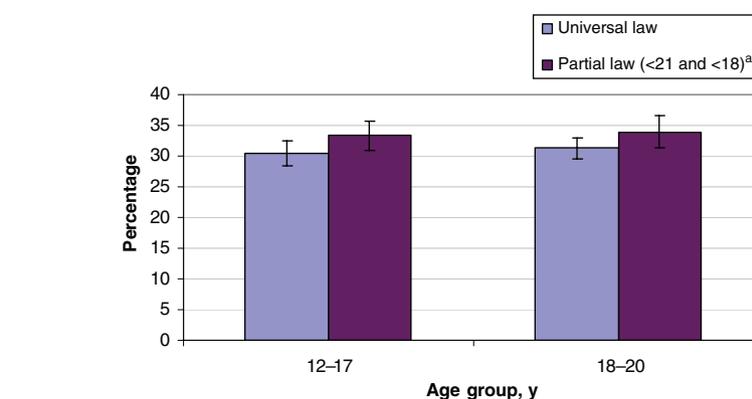


FIGURE 1

Percentage of TBIs according to age group and helmet-law type for motorcycle-related hospital discharges: HCUP SID, 2005–2007. ^a Cases of youth aged 18 to 20 were excluded from <18 helmet-law states.

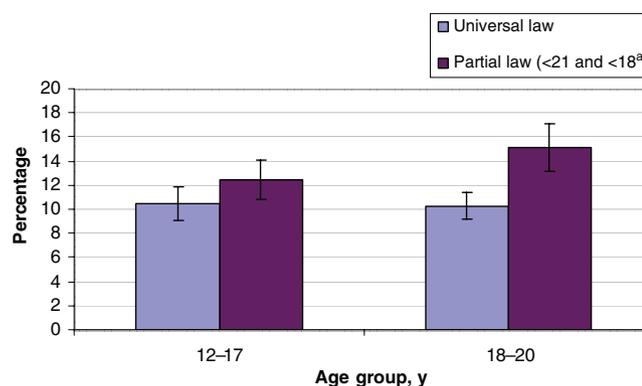


FIGURE 2

Percentage of serious/severe TBIs according to age and helmet-law type for motorcycle-related hospital discharges: HCUP SID, 2005–2007. ^a Cases of youth aged 18 to 20 were excluded from <18 helmet-law states.

helmet laws compared with youth in states with universal helmet laws. The largest effects were observed for the most severe type of head injury in the largest group of injured young motorcycle riders: ages 18 to 20. There was also a significantly increased probability of long-term TBI-related disability and in-hospital death after a motorcycle crash for youth in states with limited-age helmet laws. Helmet-usage rates for youth decrease substantially when universal helmet laws are repealed, even in states in which youth riders are theoretically covered by partial age-specific laws.^{3,13,26} This decrease has been shown to affect youth motorcycle fatality rates and overall morbidity. Our results extend estab-

lished findings to hospitalized patients specifically with TBI, precisely where effects would be expected to be seen.

The lower helmet use in states with limited-age laws is likely related to the difficulty law enforcement officers experience in gauging the rider's age during a potential traffic stop and enforcing a helmet law on a relatively small segment of the motorcycle-riding population. Less rigorous enforcement may also result from perceived lack of priority once older age groups have been exempted from helmet-use compliance. From a behavioral perspective, these findings are consistent with “deterrent” theory, which assumes that in states with the

narrowest coverage of motorcycle helmet law, enforcement is the weakest. Youth are less likely to use a helmet if they perceive a low likelihood of enforcement in a state with limited-age laws than in states in which enforcement is high and punishment is likely.²⁷ This was an ecological study. No data on patient helmet use were available from hospital discharge data, nor were age-specific observational data available. Exposure-based risk comparisons (eg, ownership levels, registration rates, licensing, number of trips, or miles traveled) were not considered. This study was also limited because it did not include data from children who died before their hospitalization or were not admitted to the hospitals and thus, may have underestimated the impact of helmet use if out-of-hospital deaths were higher in partial-helmet-law states.

As in all observational studies, there was a risk for confounding that could have influenced the frequency of observed TBIs beyond helmet-law differences.²⁸ Confounding was minimized, though, in several ways. First, by studying a population-based intervention (helmet laws) and by selecting many large groups (states) for analysis and using all the states available for study, confounding was reduced. Second, because the selection of cases is a census from states that includes most of the population (90%) of the United States, the results are nationally representative. Third, the nature of the diagnosis and treatment of severe head injury indicate that almost all children in these cases would have been hospitalized in the states under study; thus, their data were captured with little state-by-state bias. Although different states may have different out-of-hospital TBI survival rates because of variation in emergency medical services and trauma system development, bias could have been introduced as to

who survived to be admitted and captured by the database; however, fatal cases were a small part of our analyses and such variation should have had little to do with the status of the state law and, thus, should have been fairly randomly distributed across the states and groups under study. Fourth, we avoided differences in temporal confounding by using the same period of analysis for all groups. Fifth, all states but 1 had instituted their helmet-law type under study several years before data were collected, which ensured proper classification of both the social and legal climates. Sixth, different age-related demographic characteristics were minimized by selecting a narrow age range for study. Finally, although demographic variables such as income, gender, and ethnicity and environmental variables such as speed, weather, and daylight hours may have been factors in riding frequency and crash risk, they are not known to affect the distribution of serious injury types after a crash. In other words, the biomechanical forces that influence the likelihood of a TBI, relative to other injuries, are not likely to be affected by such differences among serious (requiring hospitalization) injuries. Nevertheless, the proportional morbidity approach underlying our study, although appropriate for examining state-level policy interventions, has its limitations. A regression model with a variety of state-specific panel data that takes into account individual state differences (ie, registration and crash rates, drinking age, speed limits, climate, alcohol consumption, quality of medical care, and income, among others) would complement this study.

CONCLUSIONS AND RECOMMENDATIONS

This study quantifies for serious/severe TBI what the National Transportation Safety Board has declared from

fatality data, namely, that “the most vulnerable and least risk-averse segments of the motorcyclist population are more likely to be unprotected in the absence of universal laws.”²⁹ In states with a <21 law, serious TBI among youth was 38% higher than in universal-law states. Motorcycle riders aged 12 to 17 years in <18-law states had a higher proportion of serious/severe TBI and higher average Abbreviated Injury Scores for head-region injuries than riders from universal-law states.

Effective prevention efforts to reduce the risk of both crashes and injury among youth, as in adult riders, are needed. TBIs are of particular concern because of their long-term effects and high mortality risk. Although the youth helmet mandates were purportedly passed to maintain head protection for young riders (and also for political expediency to facilitate passage of this always controversial legislation), age-specific helmet laws increase the risk of death and serious head injury compared with universal laws. The only method shown to keep helmet use high among youth is to adopt or maintain universal laws.

Unfortunately, it seems that the number of states with partial age-based laws may continue to rise. State legislative tracking in 2008 showed that bills were introduced in 10 state legislatures to repeal universal coverage, and most of them were aimed at mandating helmet use for those younger than 21.³⁰ Advocates for repealing universal helmet laws often assert that this retains their desire for choice while protecting young adults. This assertion is dubious; with consistent evidence of increased death and serious injury to young adults and minors who are supposed to be protected.

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pare TBI and non-TBI diagnoses according to the type and coverage of motorcycle-helmet legislation. We also acknowledge the key role of the state data organizations, the HCUP participation of which made this study possible. These state data organizations are listed in a companion article in this issue of *Pediatrics*.³¹

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Youth Motorcycle-Related Brain Injury by State Helmet Law Type: United States, 2005 2007

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