

**TITLE:**

Autopsy Study of Motorcyclist Fatalities: The Effect of the 1992 Maryland  
Helmet Use Law

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**ABSTRACT:**

**Objectives:** The purpose of this study was to determine the impact of Maryland's all-rider motorcycle helmet law (enacted on October 1, 1992), on preventing deaths among motorcyclists and to examine the association between traumatic brain injury (TBI) and helmet use.

**Methods:** Autopsy data on statewide motorcyclist fatalities occurring between 1/90 and 12/96 were abstracted at the Office of the Chief Medical Examiner. The analysis period includes the 33 months preceding and 33 months immediately following enactment of the law.

**Results:** A total of 130 pre-law deaths and 83 post-law deaths were identified, representing a 36% reduction in the number of post-law fatalities. Following enactment of the law, there was a significant increase in helmet use (>78% post-law vs. <25% pre-law). Findings revealed that motorcycle helmets protected against TBI, odds ratio (OR)=0.26 (95% CI: 0.12, 0.57). The pre-law motorcyclist fatality rate dropped from 10.3 to 4.5 per 10,000 registered motorcycles post-law despite almost identical numbers of registered motorcycles.

**Conclusions:** Results presented provide further evidence that controversial helmet laws are an effective public health policy that succeeds in saving lives.

The debate about the need for motorcycle helmets has been ongoing. Since the enactment of the Highway Safety and National Traffic and Motor Vehicle Safety Act of 1966, more than 100,000 motorcyclists have died in traffic crashes<sup>1</sup>. Nationally in 1998, 2,284 motorcyclists were killed and an additional 49,000 were injured in traffic crashes<sup>2</sup>. In multi-vehicle crashes, while 5% of incidents involving motorists result in injury, 80-85% of motorcyclists are injured<sup>3</sup>. Per vehicle mile, motorcyclists are about 14 times as likely as passenger car occupants to die in a traffic crash, yet in 1997 motorcycles made up less than 2% of all registered vehicles in the United States and accounted for only 0.4% of all vehicle miles traveled<sup>2</sup>.

Head injury is common among motorcyclists<sup>4-6</sup>; the use of motorcycle helmets has been the primary countermeasure for decreasing these injuries. Although it is well known that motorcycle helmets are effective in preventing or reducing the severity of motorcycle-related head injuries<sup>5, 7-20</sup>, between 1975 and 1983, 28 states either weakened or repealed their motorcycle helmet use laws.

Opponents of mandatory helmet laws have argued against them, claiming that they would restrict personal freedom<sup>21</sup>, cause head and neck injuries<sup>22</sup>, restrict hearing and peripheral vision, decrease the number of organ donors<sup>23</sup>, and cause fatigue resulting in more crashes.

Motorcycle-related injuries generate enormous financial costs for acute medical care, rehabilitation, disability, and lost productivity. It has been estimated that, on the average, motorcycle crash patients incur direct hospital charges ranging from \$15-28,000<sup>6, 12, 19, 20, 24-27</sup>. These direct costs are often not paid for by the injured, as over 50% of motorcyclists' medical bills are paid for by public funds such as Medicaid<sup>12, 24</sup>. While the National Highway Traffic Safety Administration (NHTSA) has estimated that \$12.1 billion was saved from 1984 through 1998 because of the use of motorcycle helmets, an additional \$10.4 billion in medical costs would have been saved if all motorcyclists had worn helmets<sup>2</sup>.

In response to the National Traffic and Motor Vehicle Safety Act of 1966, the state of Maryland mandated in 1967 that all motorcycle operators or passengers wear Department of Motor Vehicle approved helmets. In 1979, this law was weakened to require only minors to wear approved helmets, but on October 1, 1992, a new law reestablishing a helmet requirement for all motorcycle operators and passengers was enacted.

The purpose of this study was to determine the impact of the enactment of the most recent helmet law on preventing deaths among motorcyclists in Maryland and to examine the association, if any, between traumatic brain injury (TBI) and helmet use.

## **Methods**

### *Study period*

All Maryland motorcyclist fatalities were identified from January 1990 through December 1996 using computerized autopsy records. Initial comparisons were made between the 33 months immediately preceding and the 33 months immediately following the enactment of the law. This was done for two reasons. First, computerized records

were available from the Office of the Chief Medical Examiner (OCME) of the state of Maryland beginning January 1990, allowing for 33 months (01/90-09/92) of pre-law data for evaluation. Second, in order to have equal time frames available for comparison, we elected to use data for the 33 months (10/92-06/95) immediately following implementation of the law.

#### *Data abstraction and linkage*

Each motorcyclist/motorbicyclist autopsy was reviewed. For each fatality the following data were recorded: age, race, sex, date and time of injury, date and time of death, toxicology findings, injury description (including specific diagnoses for head injuries), whether the victim was the driver or a passenger, helmet use, and cause of death.

In order to determine the location of the crash (i.e. urban versus rural) and to confirm helmet usage and type, if available, all motorcyclist *driver* fatalities occurring on Maryland roads during the study period were linked with police report data. Probabilistic linkage methods involve the specification of a predetermined probability cut-off to determine if two observations actually match. Based on weights assigned to each matching variable, the odds of a match are then computed. In this study, autopsy records were matched with records contained in the Maryland Automated Accident Reporting System (MAARS) to obtain the road name and reference intersection of the crash. These records were matched using date of crash, county of crash, gender, age, road where crash occurred, vehicle identification number, vehicle make, model and year. The matched records were geo-coded to determine population per square mile by census tract. For these analyses, an urban region was defined as a location having more than 250 persons per square mile.

#### *Definitions*

'Traumatic brain injury' was defined according to the clinical case definition found in the *Guidelines for Surveillance of Central Nervous System Injury* used by the Centers for Disease Control and Prevention (CDC). A case of TBI is defined as either: (a) an occurrence of injury to the head that is documented in a medical record, with one or more of the following conditions attributed to head injury: observed or self-reported decreased level of consciousness, amnesia, skull fracture, objective neurological or neuropsychological abnormality, or diagnosed intracranial lesion or (b) an occurrence of death resulting from trauma, with head injury listed on the death certificate, autopsy report, or medical examiner's report in the sequence of conditions that resulted in death.

All available documents (i.e., the autopsy report, investigator report, police report, photographs, etc.) were used to determine if the motorcyclist was helmeted or non-helmeted. If two sources disagreed as to whether a helmet was used, or if there was no indication of helmet usage in the records, helmet use was recorded as 'unknown'.

#### *Inclusion/exclusion criteria*

Fatalities used for this analysis occurred between January 1990 and December 1996, and the crash had to have occurred on a Maryland road. For the present analysis

dirtbikes, all terrain vehicles, minibikes, mopeds, and pedestrians struck by a motorcycle were excluded.

### Statistical methods

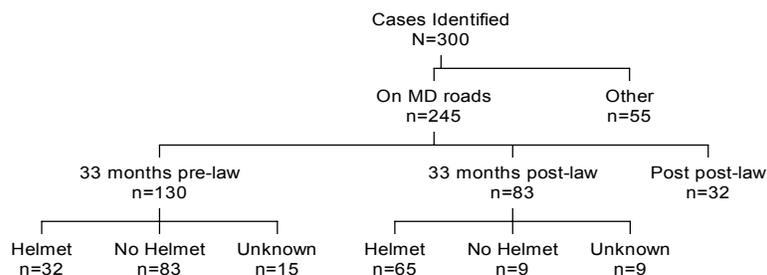
Comparisons of distributions between two groups (i.e., pre-law vs. post-law) were made using Pearson's chi-square statistic. Stratified analyses were also conducted to test if the association between TBI and helmet use in the pre-law period (i.e., stratum 1) was similar to the association between TBI and helmet use in the post-law period (i.e., stratum 2). A statistically significant result of the Breslow-Day test for homogeneity of the odds ratios would indicate that such associations differed between the two strata. A probability value, or p-value, below 0.05 represented a statistically significant result. Where it was important to assess the impact of helmet use among motorcyclist fatalities, odds ratios (OR) and their 95% confidence intervals (CI) were reported in lieu of p-values. All analyses were conducted using PC SAS version 6.12 (Cary, NC).

### Results

For the time frame of January 1990 through December 1996, the OCME for the state of Maryland identified 303 autopsy records where motorcycle or motorbicycle was listed as the type of crash. Of these fatalities, 265 were motorcyclists and 38 were motorbicyclists. Three cases were excluded because they were "late" deaths related to motorcycle crashes occurring in 1984 and 1987. Of the remaining 300 cases, 245 (81.7%) were attributed to motorcycle crashes occurring on Maryland roads. The vast majority of these victims were drivers (89.9%). In an additional 18.8% of the cases, the type of motorcycle was unknown.

Of the 245 fatalities, 130 (53.1%) occurred in the 33 months immediately preceding the law, 83 (33.9%) occurred in the 33 months immediately following the law, and 32 (13.1%) occurred after June 1995, which is considered to be the 'post post-law' period (Figure 1). Of the 213 motorcyclist deaths occurring during the pre- and post-law periods, helmet status could be determined for 189 (88.7%) victims.

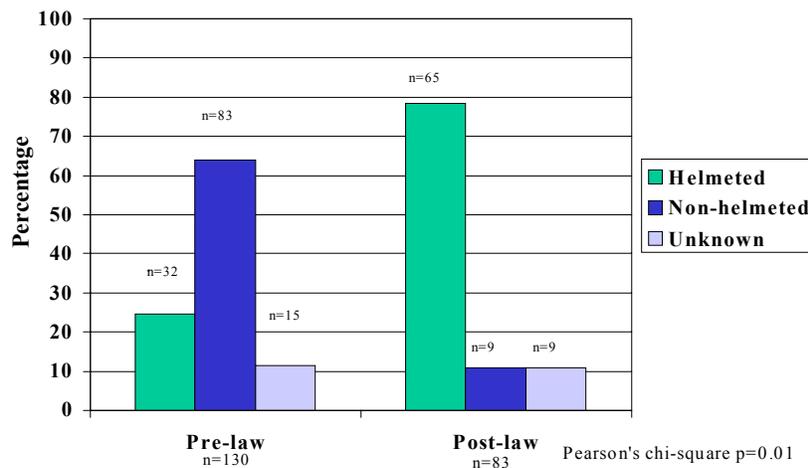
**FIGURE 1.** Overview of all motorcyclist fatalities recorded in Maryland from January 1990 through December 1996 and identified by the Office of the Chief Medical Examiner for the State of Maryland using computerized autopsy records.



*Pre-law vs. post-law*

There was a significant increase in the number of post-law motorcyclists who wore helmets (Figure 2). Prior to the law, 24.6% of the motorcyclists involved in a fatal crash wore helmets compared to 78.3% of fatalities after the law. The proportion of motorcyclists with unknown helmet use remained about 10% during each of the pre- and post-law periods. There were no statistically significant differences between the pre-law and post-law fatalities with respect to age, gender, race, time of week, season of year, alcohol use or geographic region of crash (Table 1). Overall young adults between the ages of 18 and 29 years of age accounted for over one-half of all the motorcyclist fatalities between 1990 and 1996, with the vast majority of the victims being male (94.7%), white (81.6%), and drivers (89.8%). More crashes happened on weekends as opposed to weekdays. Not unexpectedly, approximately 75% of the crashes occurred during the spring and summer months. April through October were the peak months for fatal motorcycle crashes, with more fatal crashes reported in August than in any other month (data not shown). During the post-law period there were fewer crashes late at night and more between 6:00 am and 12:00 noon than during the pre-law period. For the pre- and post-law periods, over 70% of the geo-coded motorcyclist fatalities occurred in urban areas.

**FIGURE 2.** Proportion of helmet use among motorcyclist fatalities occurring on Maryland roads during the 33 months immediately preceding and immediately following enactment of the mandatory helmet use law (n=213)



The trend of motorcyclist fatalities for 1990 through 1996 is exhibited in Figure 3. There was a 36% decline in the number of fatalities occurring in the 33-month period immediately following the law as compared to the 33 months immediately preceding the law (Table 2). For those fatalities occurring immediately after enactment of the law, the proportion with TBI decreased, albeit not significantly (Figure 4).

**TABLE 1.** Association of the 33-month pre- and post-helmet law periods with selected characteristics of motorcyclist fatalities occurring on Maryland roads (N=213)\*.

	Pre-law (n=130)		Post-law (n=83)		p-value**
	n	%	n	%	
Age					
<18	1	0.8	0	0.0	0.61
18-29	68	52.3	50	60.2	
30-34	49	37.7	26	31.3	
≥35	12	9.2	7	8.4	
Sex					
Male	123	94.6	79	95.2	0.86
Female	17	5.4	4	4.8	
Race					
White	112	86.8	65	79.3	0.15
Non-white	17	13.2	17	20.7	
Time of Day					
00:00 – 05:59	27	22.3	19	24.7	0.02
06:00 – 11:59	5	4.1	13	16.9	
12:00 – 17:59	33	27.3	19	24.7	
18:00 – 23:59	56	46.3	26	33.8	
Time of Week†					
Weekday	60	46.2	32	38.6	0.28
Weekend	70	53.8	51	61.4	
Season‡					
Spring	38	29.2	31	37.4	0.20
Summer	65	50.0	31	37.4	
Fall	23	17.7	15	18.1	
Winter	4	3.1	6	7.2	
Alcohol Use					
Yes	64	49.2	39	47.0	0.05
No	52	40.0	42	50.6	
Unknown	14	10.8	2	2.4	
Region§					
Urban	72	72.0	57	79.2	0.28
Rural	28	28.0	15	20.8	

\* The numbers and percentages may vary due to missing data.

\*\* P-value is based on Pearson's chi-square statistic.

† The weekend is Friday 6:00 p.m. until Monday 6:00 a.m.

‡ Season is based on the standard calendar definition of the four seasons.

§ The autopsy records of 180/190 (94.7%) motorcyclist drivers were matched with police report data. Of the 180 matched records, 172 (95.5%) were geo-coded to determine the region of injury.

Due to the differences in seasonal injury rates, and since the study periods encompass different seasons, a further analysis was conducted based on comparable time frames. These results showed a slightly greater decline in the number of fatalities (36.9%). When the most recent 33 months of data were compared to the pre-law period, the decline in motorcyclist fatalities was even more striking, at nearly 48% (Table 2).

Motorcyclist fatality rates per 10,000 registered vehicles are presented in Table 3. Prior to the enactment of the law, the motorcyclist fatality rate ranged from a low of 7.8 to a high of 10.2 per 10,000 registered vehicles. The motorcyclist fatality rate has declined to 4.5 since the enactment of the helmet law despite almost identical numbers of vehicles registered in 1992 and 1996 (46,733 versus 46,708, respectively).

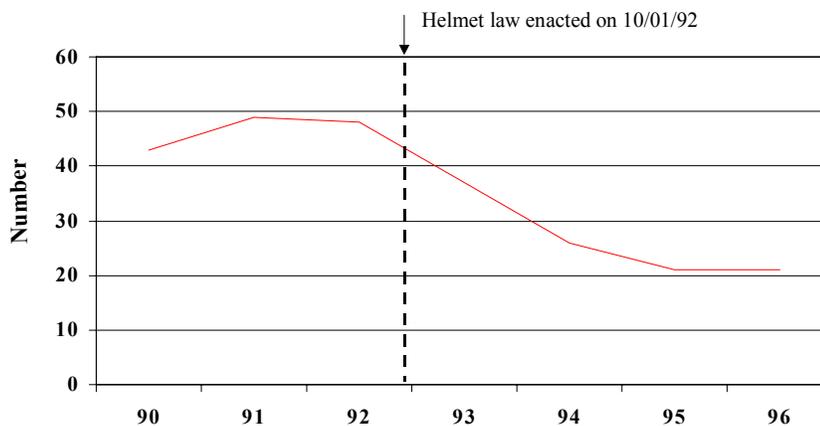
<b>TABLE 2:</b> Percentage decrease in motorcycle fatalities occurring on Maryland roads following the 33 months immediately preceding enactment of the mandatory helmet use law.			
Time Frame	Dates	n	% decrease
33 months pre-law	01/01/90 – 09/30/92	130	Ref.
33 months post-law*			
Immediate	10/01/92 – 06/30/95	83	36.2
Comparable	01/01/93 – 09/30/95	82	36.9
Most recent	04/01/94 – 12/30/96	68	47.7

\* 'Immediate' refers to the 33 months just following the enactment of the helmet law.

'Comparable' covers the same months as the pre-law period.

'Most recent' refers to the 33 months which contain the most current data.

**FIGURE 3.** Trend of motorcyclist fatalities occurring on Maryland roads from January 1990 through December 1996 relative to enactment of the mandatory helmet use law (n=245)



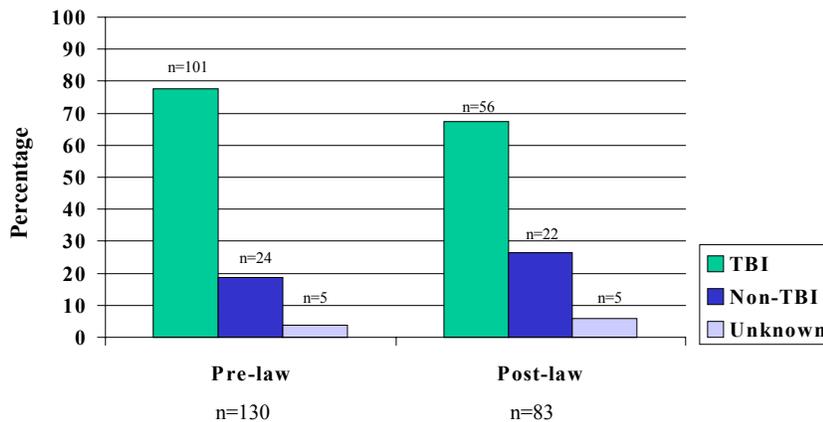
### *Helmeted vs. non-helmeted*

The occurrence of TBI was much less among those wearing helmets than among those not wearing helmets in both the pre-law (65.6% vs. 88.5%) and post-law period (67.2% vs. 88.9%). The similar percentages in both pre-law and post-law periods (Breslow-Day p-value=0.98) indicates that the enactment of the helmet law did not influence the relationship between helmet use and TBI. Because of these findings, fatalities were pooled across study periods to determine if helmets were effective in preventing TBI. Helmeted motorcyclists were significantly less likely to have TBI as compared to non-helmeted motorcyclists (odds ratio (OR)=0.26, 95% CI: 0.12, 0.57).

<b>TABLE 3: Motorcyclist fatality rates per 10,000 registered motorcycles in the state of Maryland from 1990 to 1996</b>			
Year	Registered Vehicles*	Fatalities	Fatality Rate per 10,000 Registered Vehicles
1990	55,068	43	7.8
1991	48,145	49	10.2
1992	46,733	48	10.3
1993	46,839	37	7.9
1994	50,691	26	5.1
1995	47,950	21	4.4
1996	46,708	21	4.5

\* The number of registered vehicles are from Motor Vehicle Administration

**FIGURE 4.** Proportion of traumatic brain injuries among motorcyclist fatalities occurring on Maryland roads during the 33 months immediately preceding and immediately following enactment of the mandatory helmet use law (n=213).



## Discussion

### *Decrease in number of fatalities*

Data from the present study indicate that during the 33 months after the mandatory motorcycle helmet law was enacted, the number of motorcycle fatalities decreased by 36% compared to the 33 months before the law change. This decrease was almost exactly the same (37%) when comparing similar seasons. The results seen here reinforce the public health benefits of mandatory helmet laws and corroborate the similar findings from other states<sup>25, 28-33</sup>.

Although it is easy to assume helmet use is directly responsible for a decrease in fatalities, other factors may have contributed to this decrease. The law change may have

(1) reduced the number of high-risk riders who chose to no longer ride motorcycles, (2) reduced the number of motorcycle sales (by making a motorcycle less attractive and more expensive), (3) decreased the number of miles driven per registered vehicle, or (4) changed the motorcycle rider's risk behavior.

Data from the Motor Vehicle Administration indicated that the number of registered motorcycles in Maryland did fluctuate from 1990 to 1996, but there was no dominant trend of a decrease in the number of registered vehicles after the change in helmet laws. In fact, the number of registered vehicles in the year of the law change (1992) was almost identical to the number of registered vehicles in 1996. However, across this time period, the motorcycle fatality rate per 10,000 registered vehicles steadily decreased 56% from 10.3 in 1992 to 4.5 in 1996. This decrease is consistent with other studies that have reported similar declines by rate. In California, Kraus found a decline in fatalities (per 100,000 registered motorcycles) of 27%<sup>29</sup>, while Louisiana found a decrease of 62%<sup>31</sup>.

This steady decrease in motorcycle fatality rates after enactment of a motorcycle helmet law suggests that not only is there an immediate decrease in fatalities, but the benefit increases with time. This is evident when comparing the 33 months before the law enactment to the last 33 months of available data (4/99 – 12/96). The decline in the number of fatalities was even larger (48%) than the decline in the 33 months immediately following the law change (36%).

#### *Increase in helmet use*

The results of the current study also suggest that a mandatory helmet law is associated with an increase in helmet usage, as the proportion of helmet use among motorcyclist fatalities dramatically increased after the law change from 24.6 to 78.3%. Because helmet use was not always recorded in the available data sources, this percentage of helmet use is most likely underestimated. Other studies report that with a mandatory helmet law, compliance was approximately 90%<sup>9</sup>, and in many cases often approaching 100%<sup>25, 30, 31, 34</sup>. The estimate of 78% is below that of other studies because the study population of the present study consisted of only fatal accident victims that would tend to include more non-helmeted victims. A study from California found similar proportions when only looking at fatal crashes (no law 21.5% versus with law 80.1%)<sup>29</sup>.

There has been additional evidence indicating that helmet laws increase helmet use. A study from Louisiana demonstrated a helmet use decrease, then an increase with the repeal and reinstatement of a similar helmet law (97%→ 50%→95%)<sup>30, 31</sup>.

#### *Helmet use protects against traumatic brain injury, head injury*

Findings from the present study revealed that helmeted motorcyclists sustained fewer traumatic brain injuries than the non-helmeted. This is consistent with a large number of published studies<sup>5, 7-20</sup>. The reported incidence of head/facial/neck injuries among the studied motorcycle riders varies depending on the setting, study population, and case definitions of each individual study.

This study underestimates the protective effect of helmet use since traumatic brain injuries among only fatally injured motorcyclists were examined, encompassing the most

serious crashes. It has been shown that injured motorcyclists who use a helmet have a lower mortality rate than those not wearing a helmet<sup>9, 16</sup>. Since the present study is based on fatal crashes, it stands to reason that this study population is over-represented with non-helmet users. If the analysis was based on patients only seen at an emergency department, those treated and released from a hospital, and those who were only minimally injured and thus sought no medical attention, the discrepancy in traumatic brain injuries between the helmeted and non-helmeted would have been even greater. In addition to preventing head injuries, other studies have shown that helmet use is associated with a shorter hospital stay<sup>12, 16, 19, 25, 30, 31</sup>, fewer hospital readmissions<sup>16</sup>, lower overall injury severity<sup>9, 12, 14, 16, 17, 35</sup>, the need for rehabilitation<sup>19</sup>, and a lower total hospital cost<sup>12, 16, 18-20, 25, 30, 35</sup>.

### *Significance of Data Linkage*

While autopsy records provided information on motorcyclist injuries, police reports provided the only source of data regarding the location of the crash and were essential in the confirmation of helmet use. The match rate among several databases is usually a function of the consistency among data sources and the completeness of reported information within each database. Linkage of autopsy records and police report data in the present study resulted in a 95% match rate of motorcyclist driver fatalities and thus a fairly complete database for analysis.

### *Lack of data on type of helmet used*

An important area which this study does not address is the type of helmet worn. One study which examined the protective effects of full face motorcycle helmets versus non-standard helmets showed that the full face helmet provided was more effective at preventing and mitigating head injuries<sup>36</sup>. In fact, when controlling for variables such as weather, road location, motorcycle type, riding position (driver vs. passenger), age, and gender, the non-standard helmets did not statistically differ from no helmet with respect to head injury<sup>37</sup>. We attempted to address helmet type by examining police reports, autopsy records, and hospital records. However, these data were not analyzed since helmet type was only identified in 5.7% of reviewed cases and there is no code in police report records to capture the type of helmet in use.

## **Conclusion**

In this study of motorcyclist fatalities, we found that in Maryland the enactment of a mandatory motorcycle helmet law in 1992 resulted in an increase in helmet use and a slight decrease in traumatic brain injuries. In addition, helmeted motorcyclists were significantly less likely to have TBI as compared to non-helmeted motorcyclists. Furthermore, the motorcycle fatality rate per 10,000 registered vehicles decreased 56% over a five-year period since the enactment of the helmet law, despite almost identical numbers of vehicles registered. Results presented provide further evidence that controversial helmet laws are an effective public health policy that succeeds in saving lives.

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