Bicycle Helmet Laws Are Associated with a Lower Fatality Rate from Bicycle–Motor Vehicle Collisions

William P. Meehan, III, MD[1,2,3,4], Lois K. Lee, MD, MPH[4], Christopher M. Fischer, MD[5], and Rebekah C. Mannix, MD, MPH[3,4]

Objective To assess the association between bicycle helmet legislation and bicycle-related deaths sustained by children involved in bicycle–motor vehicle collisions.

Study design We conducted a cross-sectional study of all bicyclists aged 0-16 years included in the Fatality Analysis Reporting System who died between January 1999 and December 2010. We compared fatality rates in age-specific state populations between states with helmet laws and those without helmet laws. We used a clustered Poisson multivariate regression model to adjust for factors previously associated with rates of motor vehicle fatalities: elderly driver licensure laws, legal blood alcohol limit (<0.08% vs ≥0.08%), and household income.

Results A total of 1612 bicycle-related fatalities sustained by children aged <16 years were evaluated. There were no statistically significant differences in median household income, the proportion of states with elderly licensure laws, or the proportion of states with a blood alcohol limit of >0.08% between states with helmet laws and those without helmet laws. The mean unadjusted fatality rate was lower in states with helmet laws (2.0/1 000 000 vs 2.5/1 000 000; P = .03). After adjusting for potential confounding factors, lower fatality rates persisted in states with mandatory helmet laws (adjusted incidence rate ratio, 0.84; 95% CI, 0.70-0.98).

Conclusion Bicycle helmet safety laws are associated with a lower incidence of fatalities in child cyclists involved in bicycle–motor vehicle collisions. *(J Pediatr 2013; ■: ■-■).*

In the US, approximately 900 people annually die in bicycle crashes, three-quarters of them from head injuries.[1] Bicycle helmets were introduced more than 30 years ago in an attempt to decrease this fatality rate.[2] Over the last 20 years, several case-controlled and epidemiologic studies have demonstrated the efficacy of bicycle helmets, reporting a lower risk of injury and death for cyclists wearing helmets compared with unhelmeted cyclists.[3-10] Thompson et al[9] found that riders wearing bicycle helmets had an 88% lower risk of brain injury compared with riders without helmets. In a meta-analysis of case-control studies examining the efficacy of bicycle helmets in cyclists involved in crashes or falls, which included more than 11 000 subjects, helmets were shown to provide a 63%-88% reduction in the risk of head, brain, and severe brain injury in cyclists of all ages.[1] The American Academy of Pediatrics recommends that all cyclists wear a properly fitted bicycle helmet for every ride, and encourages legislation requiring helmet use by all cyclists.[11]

Initially, educational and promotional campaigns were developed to increase bicycle helmet use among riders.[12] Such campaigns were expensive and demonstrated only limited success.[12] Given the documented benefits of helmets, mandatory helmet laws were introduced as an easy-to-implement means of increasing helmet usage.[12] Legislators across the US enacted laws mandating the use of bicycle helmets, but often limited the requirement to children under 16 years old. Several investigators have studied the effect of bicycle helmet laws on helmet use[4,13,14] and on the rates of bicycle-related head injuries and death on a local level,[4,15,16] but the effect of such legislation on the national rates of injury remained unexamined.

We sought to assess the effect of bicycle helmet legislation nationally, by examining the association between helmet laws and deaths due to bicycle–motor vehicle crashes sustained by children aged <16 years using a large national database.

Methods

We conducted a cross-sectional study using data obtained from the Fatality Analysis Reporting System (FARS). The FARS is a census compiled by the National Highway Traffic Safety Administration (NHTSA) that includes data from all motor vehicle crashes occurring on a traffic way customarily open to the public and result in the death of a motorist or nonmotorist within 30 days of the crash. The FARS contains detailed information on the vehicles, cyclists, drivers, occupants, and nonoccupants involved in each crash, as well as details regarding helmet use of adults and children. The FARS data are derived from a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico.

FARS	Fatality Analysis Reporting System
NHTSA	National Highway Traffic Safety Administration

From the [1]Micheli Center for Sports Injury Prevention, Waltham, MA; [2]Sports Concussion Clinic, Division of Sports Medicine, [3]Brain Injury Center, and [4]Division of Emergency Medicine, Boston Children's Hospital; and [5]Department of Emergency Medicine, Beth Israel Deaconess Medical Center, Boston, MA

W.M. is supported by National Institutes of Health (T32 HD040128-06A1). The authors declare no conflicts of interest.

 http://dx.doi.org/10.1016/j.jpeds.2013.03.073

The NHTSA has a cooperative agreement with an agency within each state government to provide specific information in a standard format on crashes that result in a fatality in that state. All FARS data on fatal motor vehicle traffic crashes are gathered from the states' own source documents, coded on standard FARS forms, and checked for consistency by NHTSA. A detailed coding manual is produced annually and is augmented by FARS classes and an annual system-wide FARS meeting designed to reinforce uniform coding practices.[17]

Most state laws regarding the use of bicycle helmets apply only to children, usually under age 16 years. Thus, we identified all bicycle–motor vehicle related fatalities sustained by children aged <16 years between January 1999 and December 2010 and included in the FARS database. All US states and the District of Columbia were included in the analysis. We adjusted for the following factors that have been previously associated with motor vehicle fatalities and could potentially affect bicycle injuries: age-based elderly licensure laws, legal blood alcohol limit (<0.08% vs ≥0.08%), and median state household income.[18-24] Because pediatric bicyclist–motor vehicle collisions are uncommon on highways, we did not adjust for legislation regarding speed limits. We calculated the number of state-years that helmet use laws were in effect by multiplying the number of states with the helmet law by the number of years that the law was in effect during the study period. Date of helmet law passage and enactment were obtained from several sources, including the Insurance Institute for Highway Safety and the Governor's Highway Safety Administration. Our primary outcome measure was death.

We compared fatality rates in states with helmet laws and states without helmet laws. All states that passed helmet laws during the study period did so within a short time interval, at the start of our study period. Thus, to keep our estimates conservative, we considered these states to have a law. To determine fatality rates, we used the total number of deaths divided by age-specific state populations obtained from the US Census Bureau.[25] We created a multivariate model to account for other legislative and economic factors previously associated with motor vehicle fatalities. We used a clustered Poisson multivariate regression model adjusted for maximum legal blood alcohol limit, median household income, and age-based elderly licensure laws. We defined age-based elderly licensure laws as those laws that had specific age-based renewal procedures; that is, at a given age, the state may reduce the time interval between license renewal, restrict the ability to obtain license renewal by mail, require on-road testing, require a physician's report, and/or require specific vision, traffic law, and sign knowledge. To account for state-level effects not included in our model, we used state-level clustering in the multivariate model. All of the data analyses were performed using Stata SE, version 11 (StataCorp, College Station, Texas). As all FARS data is de-identified and publicly available, the study was considered exempt from review by the institutional review board of Boston Children's Hospital.

Table I. Number of state-years that laws were in effect

Law	No. of state-years (n = 561)
Helmet laws	219
Maximum highway speed limit ≤65 mph	209
Age-based licensure law	341
Blood alcohol level ≥0.08%	437

Results

More than 200 state-years of mandatory helmet legislation were recorded during the study period (Table I), with 16 states having already enacted laws regarding helmet use by the start of the study period. The overall rate of bicycle-related fatalities in the US in 1999 was 4.0/1 000 000 children. Although there were no statistical differences in median household income, proportion of states with age-based licensure laws, or proportion of states with a legal blood alcohol limit of ≥0.08% between those states with helmet laws and those without helmet laws, the rate of bicycle-related fatalities was significantly lower in states with mandatory helmet legislation (Table II).

During the 12-year study period, a total of 1612 bicycle–motor vehicle related fatalities were sustained by children aged <16 years. The mean unadjusted fatality rate in children aged <16 years was significantly lower in states with helmet laws compared with states without helmet laws (2.0/1 000 000 children vs 2.5/1 000 000 children; $P = .03$), yielding an incidence rate ratio of 0.83 (95% CI, 0.69-0.99).

When we adjusted for other motor vehicle legislation and economic factors in the multivariate analysis, helmet laws continued to be associated with a lower risk of fatalities (adjusted incidence rate ratio, 0.84; 95% CI, 0.70-0.98).

Discussion

Our findings show that US bicycle helmet safety laws are associated with a lower national incidence of fatalities among bicyclists aged <16 years who suffer collisions involving a motor vehicle. In 1999, only 16 states had bicycle helmet laws, and the fatality rates were lower in those states than in the 35 states without helmet laws. After adjusting for other motor vehicle legislation and state-specific economic factors, states with helmet laws demonstrated a 20% decrease in the rate of bicycle–motor vehicle related deaths and injuries compared with states without helmet laws.

Our findings are in contrast with a recent review of pediatric trauma patients in Los Angeles County that concluded that the statewide helmet law had no significant effect on helmet use or on the proportion of pediatric head injury patients who were helmeted.[26] Other previous studies have reached conclusions similar to ours, however. In an analysis of a trauma registry in San Diego County, California, Ji et al showed that helmet use increased after the introduction of legislation, and the that helmet use by patients with bicycle-related trauma was associated with a decreased

Table II. State-level statistics in 1999 (50 states and the District of Columbia; n = 51)

	States with helmet laws (n = 16)	States without helmet laws (n = 35)
Bicycle fatalities in children aged <16 years per 1 000 000 children, mean (SD)*	2.7 (2.3)	4.5 (4.6)
Annual household income, $, median (IQR)	52 739 (48 599-59 298)	50 543 (42 767-59 757)
Other state laws, no. of states (%)		
Age-based licensure laws	8 (50)	23 (66)
Blood alcohol level ≥0.08%	6 (38)	15 (43)

*$P < .05$.

odds of suffering a serious head injury.[4] Similarly, a study using the discharge records of all California public hospitals found that an 18% decrease in the proportion of traumatic brain injuries sustained by youth bicyclists after the advent of bicycle safety helmet legislation.[15] In addition, an examination of bicycle-related mortality rates in Ontario, Canada, by Wesson et al[16] revealed a significantly reduced rate after the introduction of a law mandating helmets in all bicyclists aged <18 years when riding on a public way.

As with many of the foregoing studies that found a decrease in the risk of serious head injury after the introduction of mandatory bicycle helmet laws, our study shows that on a national level, states with mandatory pediatric bicycle helmet laws have a lower incidence of fatalities after collisions involving cyclists and motor vehicles. Our findings support the legislation of mandatory bicycle helmet use by children.

In this information age, when parents can be inundated with injury prevention information concerning their children, legislation can be an important factor in helping parents adhere to best practice guidelines. This phenomenon has been seen in other mandatory safety laws, such as the use of booster seats by children. In one study about booster seat use, many parents commented that they looked to the law to guide them in appropriate car seat use for their children.[27] Similarly, a statewide survey of parents found that 70% of part-time booster seat users said they used them because they believed it was the law, and more than 90% of part-time users and nonusers reported that it would be easier for them to use a booster seat if there were a law.[28] For children aged 4-7 years, booster seat laws have led to an increase in booster seat use and to a decreased risk of suffering a fatality during a motor vehicle collision.[29]

Our results must be interpreted in light of several limitations. The FARS database is limited to injuries sustained during a motor vehicle collision that resulted in the death of at least 1 person within 30 days of the collision. As a result, our findings likely underestimate the effects of the mandatory helmet laws, because we did not capture all pediatric bicycle-related injuries. Indeed, previous authors have shown the benefit of bicycle helmet usage and mandatory helmet legislation in reducing head injuries and death.[1,3,4,6,15,16] Second, little is known about the degree of helmet law enforcement by states, the independent effect of which can be difficult to assess, although previous studies have suggested that mandatory helmet laws are enforced in certain circumstances and communitites[30,31] and have founds an increase in helmet use after the introduction of legislation.[4,12-14] Finally, some authors argue that mandatory helmet laws decrease bicycle ridership, and thus the benefits of helmets preventing head injuries may be offset by the medical problems that arise from a decreased number of cyclists.[32,33] The present study did not address the effect of helmet laws on ridership. ■

Submitted for publication Jan 18, 2013; last revision received Feb 19, 2013; accepted Mar 26, 2013.

Reprint requests: William P. Meehan, MD, Sports Concussion Clinic, Division of Sports Medicine, Boston Children's Hospital, 319 Longwood Ave, Floor 6, Boston, MA 02115. E-mail: concussion.sportsmed@childrens.harvard.edu

References

1. Thompson DC, Rivara F, Thompson R. Helmets for preventing head and facial injuries in bicyclists. Cochrane Database Syst Rev 2000;167.
2. Rivara FP, Thompson DC, Thompson RS. Bicycle helmets: it's time to use them. BMJ 2000;321:1035-6.
3. Attewell RG, Glase K, McFadden M. Bicycle helmet efficacy: a meta-analysis. Accid Anal Prev 2001;33:345-52.
4. Ji M, Gilchick RA, Bender SJ. Trends in helmet use and head injuries in San Diego County: the effect of bicycle helmet legislation. Accid Anal Prev 2006;38:128-34.
5. Maimaris C, Summers CL, Browning C, Palmer CR. Injury patterns in cyclists attending an accident and emergency department: a comparison of helmet wearers and non-wearers. BMJ 1994;308:1537-40.
6. McDermott FT, Lane JC, Brazenor GA, Debney EA. The effectiveness of bicyclist helmets: a study of 1710 casualties. J Trauma 1993;34:834-44.
7. Sosin DM, Sacks JJ, Webb KW. Pediatric head injuries and deaths from bicycling in the United States. Pediatrics 1996;98:868-70.
8. Thomas S, Acton C, Nixon J, Battistutta D, Pitt WR, Clark R. Effectiveness of bicycle helmets in preventing head injury in children: case-control study. BMJ 1994;308:173-6.
9. Thompson RS, Rivara FP, Thompson DC. A case-control study of the effectiveness of bicycle safety helmets. N Engl J Med 1989;320:1361-7.
10. Thompson DC, Rivara FP, Thompson RS. Effectiveness of bicycle safety helmets in preventing head injuries: a case-control study. JAMA 1996;276:1968-73.
11. American Academy of Pediatrics Council on Injury and Poison Prevention. Bicycle helmets. Pediatrics 2001;108:1030-2.
12. Graitcer PL, Kellermann AL, Christoffel T. A review of educational and legislative strategies to promote bicycle helmets. Inj Prev 1995;1:122-9.
13. Dellinger AM, Kresnow MJ. Bicycle helmet use among children in the United States: the effects of legislation, personal and household factors. J Safety Res 2010;41:375-80.
14. Karkhaneh M, Rowe BH, Saunders LD, Voaklander D, Hagel B. Bicycle helmet use after the introduction of all-ages helmet legislation in an urban community in Alberta, Canada. Can J Public Health 2011;102:134-8.

15. Lee BH, Schofer JL, Koppelman FS. Bicycle safety helmet legislation and bicycle-related non-fatal injuries in California. Accid Anal Prev 2005;37: 93-102.
16. Wesson DE, Stephens D, Lam K, Parsons D, Spence L, Parkin PC. Trends in pediatric and adult bicycling deaths before and after passage of a bicycle helmet law. Pediatrics 2008;122:605-10.
17. Fatality Analysis reporting system coding and validation manual. US Department of Transportation, National Highway Traffic Safety Administration. Washington, DC: 2011.
18. Males MA. Poverty as a determinant of young drivers' fatal crash risks. J Safety Res 2009;40:443-8.
19. Whitlock G, Norton R, Clark T, Pledger M, Jackson R, MacMahon S. Motor vehicle driver injury and socioeconomic status: a cohort study with prospective and retrospective driver injuries. J Epidemiol Community Health 2003;57:512-6.
20. Brady JE, Li G. Prevalence of alcohol and other drugs in fatally injured drivers. Addiction 2013;108:104-14.
21. Taylor B, Rehm J. The relationship between alcohol consumption and fatal motor vehicle injury: high risk at low alcohol levels. Alcohol Clin Exp Res 2012;36:1827-34.
22. Morrisey MA, Grabowski DC. State motor vehicle laws and older drivers. Health Econ 2005;14:407-19.
23. Lyman S, Ferguson SA, Braver ER, Williams AF. Older driver involvements in police reported crashes and fatal crashes: trends and projections. Inj Prev 2002;8:116-20.
24. Grabowski DC, Campbell CM, Morrisey MA. Elderly licensure laws and motor vehicle fatalities. JAMA 2004;291:2840-6.
25. United States Census Bureau. Available from: www.census.gov. Accessed January 28, 2012.
26. Castle SL, Burke RV, Arbogast H, Upperman JS. Bicycle helmet legislation and injury patterns in trauma patients under age 18. J Surg Res 2012; 173:327-31.
27. Simpson EM, Moll EK, Kassam-Adams N, Miller GJ, Winston FK. Barriers to booster seat use and strategies to increase their use. Pediatrics 2002;110:729-36.
28. Bingham CR, Eby DW, Hockanson HM, Greenspan AI. Factors influencing the use of booster seats: a state-wide survey of parents. Accid Anal Prev 2006;38:1028-37.
29. Mannix R, Fleegler E, Meehan WP 3rd, Schutzman SA, Hennelly K, Nigrovic L, Lee LK. Booster seat laws and fatalities in children 4 to 7 years of age. Pediatrics 2012;130:996-1002.
30. LeBlanc JC, Beattie TL, Cillgian C. Effect of legislation on the use of bicycle helmets. CMAJ 2002;166:592-5.
31. Gilchrist J, Schieber RA, Leadbetter S, Davidson SC. Police enforcement as part of a comprehensive bicycle helmet program. Pediatrics 2000;106: 6-9.
32. de Jong P. The health impact of mandatory bicycle helmet laws. Risk Anal 2012;32:782-90.
33. Robinson DL. Head injuries and bicycle helmet laws. Accid Anal Prev 1996;28:463-75.