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Report to Congressional Requesters

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HIGHWAY SAFETY

Motorcycle Helmet Laws Save Lives and Reduce Costs to Society

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The Honorable Daniel P. Moynihan
Chairman, Subcommittee on Water Resources,
Transportation and Infrastructure
The Honorable John H. Chafee
Ranking Minority Member
Committee on Environment and Public Works
United States Senate

In response to your April 20, 1990, letter, this report evaluates studies on motorcycle helmet laws. As agreed with Subcommittee staff, we have summarized these studies' findings on (1) the effectiveness of helmets in preventing deaths and serious injuries, (2) the effect of helmet laws on helmet use and fatality rates, and (3) the costs that society incurs when motorcyclists who do not wear helmets are involved in accidents. We are suggesting that the Congress consider encouraging states to enact or keep in place universal helmet laws.

We are sending copies of this report to the appropriate congressional committees; the Secretary of Transportation; the Administrator, National Highway Traffic Safety Administration; and other interested parties. We will make copies available to others upon request.

This work was performed under the direction of Kenneth M. Mead, Director, Transportation Issues, (202) 275-1000. Other major contributors are listed in appendix II.

J. Dexter Peach
Assistant Comptroller General

Executive Summary

Purpose

In 1990, over 3,000 motorcycle riders were killed in traffic accidents in the United States. The National Highway Traffic Safety Administration (NHTSA) has reported that about 55 percent were not wearing protective helmets. In addition, some riders who survived accidents will remain disabled or impaired.

The Congress, as part of the federal highway safety program reauthorization, has been considering bills that would use either penalties or incentives to encourage states to enact helmet laws. Helmet laws have been a subject of continuing debate, with opponents arguing that such laws are an unwarranted infringement of personal liberty. The Chairman, Subcommittee on Water Resources, Transportation and Infrastructure, Senate Committee on Environment and Public Works, and the Ranking Minority Member of the Committee asked GAO to evaluate existing studies on motorcycle helmet laws and summarize their findings on (1) the effectiveness of helmets in preventing deaths and serious injuries, (2) the effect of helmet laws on helmet use and fatality rates, and (3) the costs that society incurs when motorcyclists who do not wear helmets are involved in accidents.

GAO conducted a broad search for published and unpublished studies on motorcycle helmets and helmet laws and assembled a review panel with experience in research methodology to assist in evaluating studies and formulating conclusions. GAO's conclusions were drawn from 46 studies that contained original data or original analyses and met minimum criteria for methodological soundness.

Background

Motorcycle registrations in the United States increased dramatically from less than 600,000 in 1960 to about 5.7 million in 1980 and later declined to about 4.4 million by 1989. Concurrently, the number of rider fatalities rose from about 800 in 1960 to over 5,000 in 1980 and then declined to about 3,200 in 1990. The trend in motorcycle registrations reflected a similar trend in the male population aged 18 to 24, as well as changes in the prices of motorcycles and gasoline.

The Department of Transportation (DOT), acting under the Highway Safety Act of 1966, issued standards for state highway safety programs in 1967, including one requiring states to adopt motorcycle helmet laws. By 1975, all but three states (California, Illinois, and Utah) had complied. DOT attempted to enforce the requirement; however, the enforcement process was interrupted when the Congress amended the act in 1976 to rescind the helmet law requirement and limit DOT's authority to

use funding sanctions for state noncompliance with safety program standards. Subsequently, 29 states repealed their laws or limited them to young riders (usually those under age 18).

Since 1982, six states have enacted helmet laws applying to all riders. California's action in May 1991 brought to 24 the number of states (plus the District of Columbia and Puerto Rico) with universal laws requiring all riders to wear helmets. Twenty-three states still had only limited laws, requiring some riders to wear helmets, and three (Colorado, Illinois, and Iowa) had no helmet requirement.

Results in Brief

Although the studies evaluated differed in the specific questions addressed and the methodologies used, they were consistent in pointing to a safety benefit from helmet use. The studies that compared helmeted with nonhelmeted accident victims all found that helmeted riders had lower fatality rates. Rates ranged from 28 to 73 percent lower, depending on how researchers defined their study population. Studies that addressed injury severity showed that surviving helmeted riders suffered fewer serious and critical injuries than nonhelmeted riders because they had a lower incidence of head injuries.

The studies reported that under universal helmet laws (those applying to all riders), nearly all riders wore helmets, compared with roughly 50 percent under limited laws or no law. When universal helmet laws have been in effect, fatality rates have generally been 20 to 40 percent lower than during periods before enactment or after repeal. If applied to the states not having universal helmet laws in 1990, and assuming that motorcyclists in those states were similar to their counterparts in states with universal laws, a 20- to 40-percent reduction would have meant a total of about 350 to 700 fewer deaths in those states in 1990.

The data on the cost of motorcycle accidents were less complete, but the available studies did indicate that nonhelmeted riders were more extensive users of medical services and long-term care, and were more likely to lose earning capacity through disability.

Principal Findings

Helmet Use Reduces Fatality Rates and Injury Severity

Eleven of the 46 studies compared the fatality rates of helmeted and nonhelmeted riders. All found lower fatality rates for helmeted riders. The rates were from 28 to 73 percent lower, depending on the rider population studied (for example, all riders in accidents or only injured riders). Eleven studies that compared the severity of injuries between helmeted and nonhelmeted riders all indicated that helmet use reduced the severity of nonfatal injuries. These studies reported that helmet use reduced the incidence of severe, serious, and critical head injuries by 46 to 85 percent.

Universal Helmet Laws Increase Helmet Use and Reduce Fatality Rates

Nine studies included data on observed helmet use and/or helmet use by riders involved in motorcycle accidents. They reported that helmet use under universal laws ranged from 92 to 100 percent, while without a law or under a limited law, helmet use generally ranged from 42 to 59 percent. These data also indicated low helmet use among young riders in states with limited helmet laws.

Twenty studies compared motorcycle fatality rates under universal helmet laws with rates during periods before enactment or after repeal of the laws. These studies consistently showed that fatality rates were lower when universal helmet laws were in effect; most rates ranged from 20 to 40 percent lower. Several of these studies compared periods before a helmet law was enacted, while it was in effect, and after it was repealed. They showed that the decreases in fatality rates when laws were enacted were matched by comparable increases when the laws were repealed.

Public Bears Higher Costs for Nonhelmeted Riders

Thirteen studies had data on some aspect of the societal cost of motorcycle accidents. These studies indicated that nonhelmeted riders were more likely to (1) need ambulance service, (2) be admitted to a hospital as an inpatient, (3) have higher hospital charges, (4) need neurosurgery and intensive care, (5) need rehabilitation, and (6) be permanently impaired and need long-term care.

The magnitude of the cost to care for injured motorcycle riders was unclear because little information was available on costs such as physician and surgeon fees, rehospitalization and rehabilitation, and extended

care. However, two other studies of long-term accident costs (not among our 46 motorcycle studies) indicated that costs may approach $100,000 for persons with serious head injuries and $300,000 for critical head injuries.

The studies evaluated showed that nonhelmeted riders were more likely to die or lose earning capacity through disability. One study attempted to estimate the cost of lost years of productive life for 516 riders—the number the authors calculated had died in 1980 because of helmet law repeals. Their estimate, updated to 1990 dollars, was nearly $250 million, or about $480,000 per death.

Matters for Congressional Consideration

Because there is convincing evidence that helmets save lives and reduce society's burden of caring for injured riders, the Congress may wish to consider encouraging states to enact and retain universal helmet laws. The Congress could return to the use of penalties (e.g., withholding highway funds for noncompliance), use incentives (e.g., making additional funds available to states that have universal laws), or use a combination of penalties and incentives.

Agency Comments

As agreed, GAO did not obtain written agency comments on this report. GAO shared the draft report with senior program officials at NHTSA, who said they found the results consistent with their work.

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Abbreviations

AIS	Abbreviated Injury Scale
DOT	Department of Transportation
FARS	Fatal Accident Reporting System
GAO	General Accounting Office
ISS	Injury Severity Scores
NASS	National Accident Sampling System
NHTSA	National Highway Traffic Safety Administration

Introduction

In 1990, 3,238 motorcycle riders died in traffic accidents. The National Highway Traffic Safety Administration (NHTSA) has reported that about 55 percent were not wearing protective helmets (of the 3,017 for whom helmet use was known). Many other riders suffered serious, in some cases disabling, head injuries. California's action in May 1991 brought to 24 the number of states (plus the District of Columbia and Puerto Rico) with universal helmet laws, i.e., laws requiring all riders to wear helmets. Twenty-three states have limited laws which require some riders (usually those under age 18) to wear helmets; while 3 states (Colorado, Iowa, and Illinois) have no helmet requirement.

Legislative History

In 1966, the Congress passed the Highway Safety Act (P.L. 89-564), which required the Secretary of Transportation[1] to prescribe uniform standards for state highway safety programs. The Secretary was to approve each state's program. If a state failed to implement an approved program, the law required withholding highway safety grant funds and 10 percent of federal highway construction funds. The Secretary was authorized, however, to suspend the latter sanction.

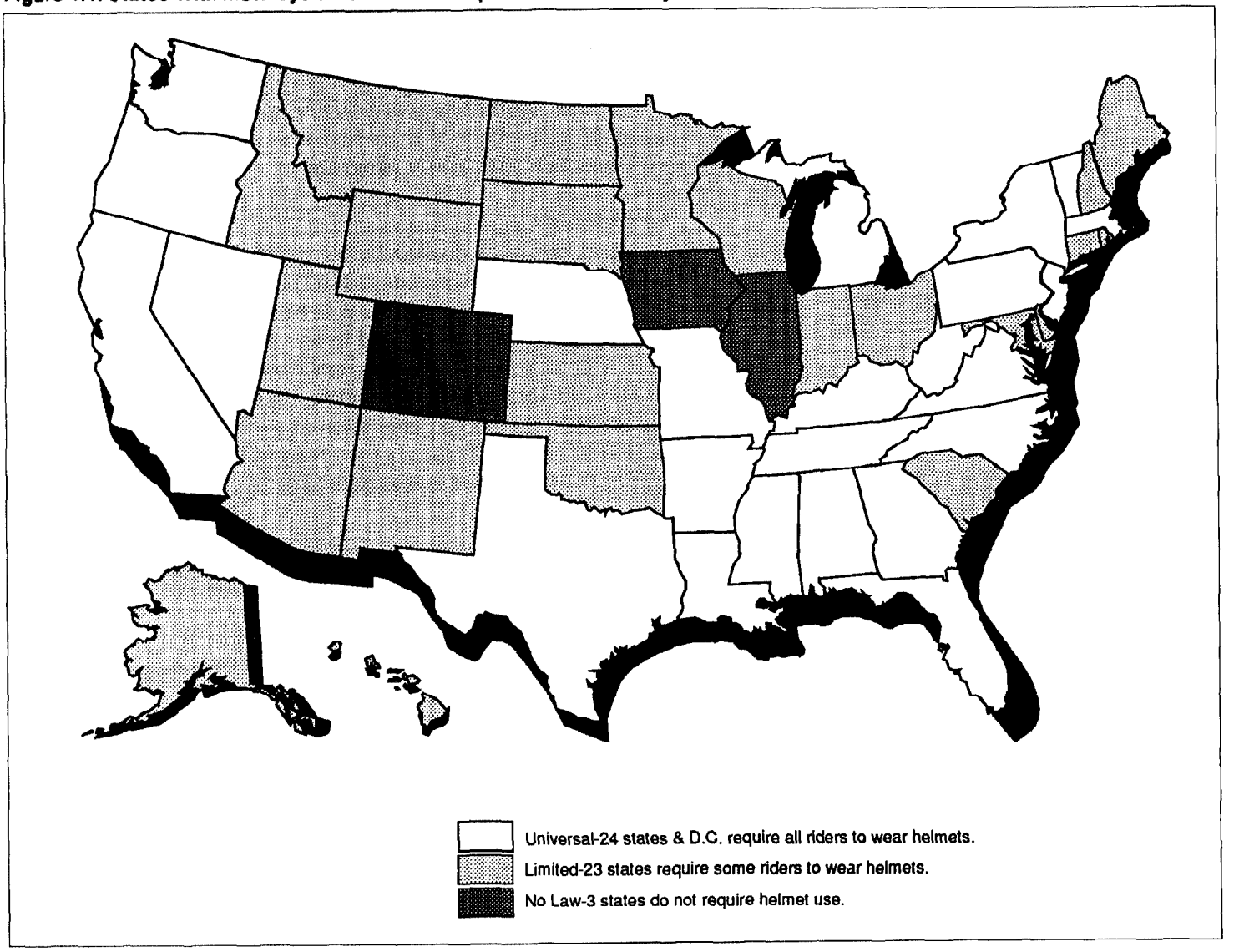
NHTSA[2] was charged with issuing most of the state safety program standards. Among the standards NHTSA issued in 1967, one covered motorcycle safety and required, among other things, that states adopt universal helmet laws. By 1975, 47 states and the District of Columbia had complied with the helmet standard, and the Secretary prepared to apply funding sanctions to the 3 states (California, Illinois, and Utah) not in compliance. In 1976, the Congress amended the Highway Safety Act, prohibiting the Secretary from requiring states to have universal helmet laws. The same amendments removed the 10-percent sanction for state noncompliance with safety program standards and gave the Secretary discretion in enforcing the other standards. Beginning in 1976, 29 states repealed or limited their helmet laws.

In 1982, Louisiana became the first state to reenact a universal helmet law. Nebraska and Oregon reenacted laws in 1988, Texas in 1989, and Washington in 1990, and California enacted a universal law in 1991. Figure 1.1 shows the status of helmet laws as of May 1991.

[1]The legislation actually referred to the Secretary of Commerce, but these responsibilities were transferred to the then newly created Secretary of Transportation in 1967.

[2]The agency was originally called the National Highway Safety Bureau.

Figure 1.1: States With Motorcycle Helmet Use Requirements as of May 1991



Source: NHTSA.

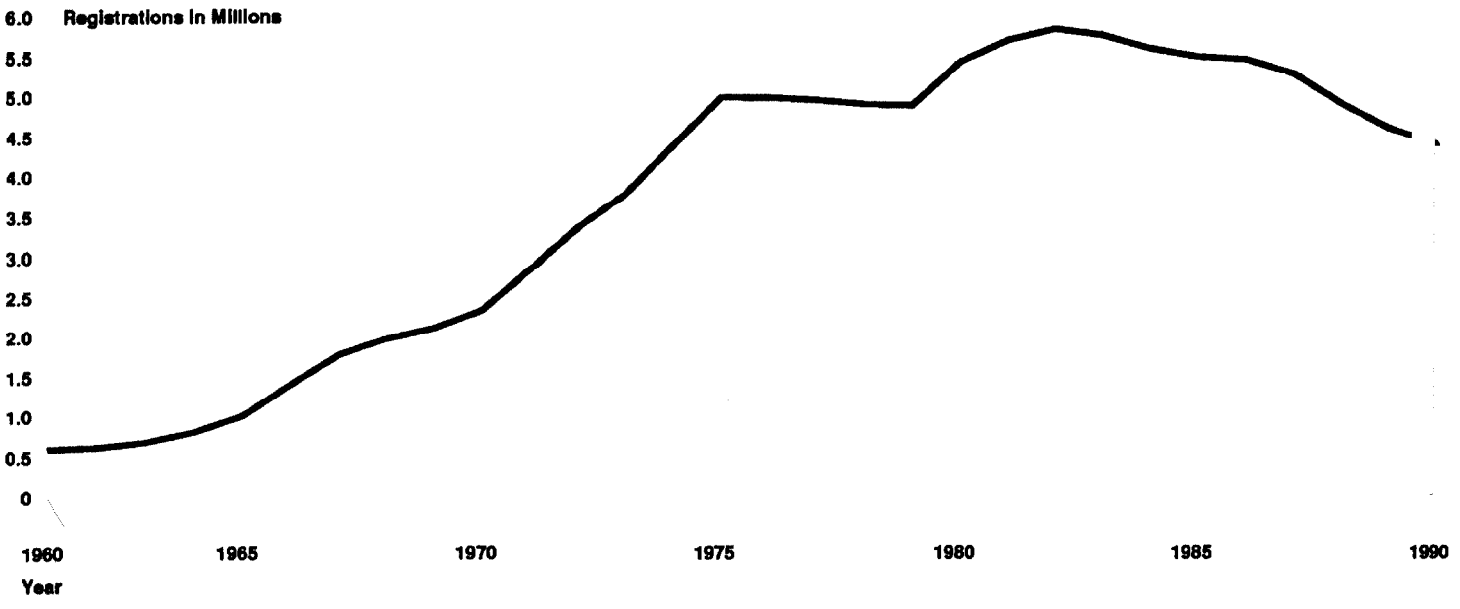
In recent years, bills have been introduced in the Congress to encourage states to adopt universal helmet laws. Hearings were held in 1989 on a bill that would have withheld 10 percent of federal highway construction funds from states not having universal helmet laws and passenger vehicle safety belt laws. The bill would also have provided incentive grants for the enforcement of the laws. In 1991, the Department of Transportation proposed legislation to create bonus grants that states

could earn by taking various highway safety actions. Motorcycle safety programs would count as 1 of a possible 12 "credits" that would determine the amount of each state's grant. Also, the Senate has approved S. 965, the Surface Transportation Efficiency Act of 1991, which would require states with no mandatory seat belt and motorcycle helmet laws by 1994 to earmark 1.5 percent of their highway aid money (3 percent for each succeeding year) for safety programs.

Trends in Motorcycle Riding and Fatalities

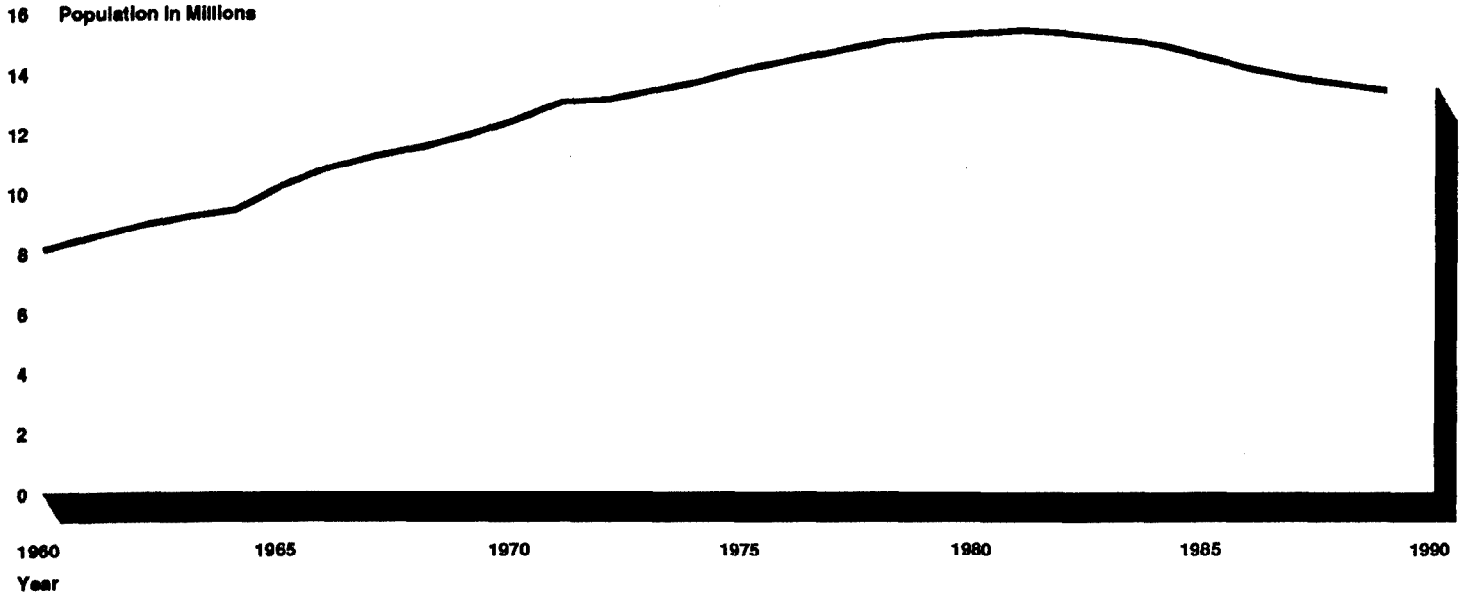
Motorcycle registrations have declined after dramatic increases. Fewer than 600,000 motorcycles were registered in the United States in 1960. As shown in figure 1.2, however, motorcycle registrations began rising in the 1960s, and the growth accelerated in the 1970s until reaching a peak of nearly 6 million in 1981. Factors contributing to this were the availability of smaller, less expensive motorcycles, rising gasoline costs, and the arrival of the baby boom generation at the prime motorcycle riding ages of 18-24. Figure 1.3 shows the trend of the male population aged 18-24. About 90 percent of motorcycle riders are males.

Figure 1.2: Motorcycle Registrations, 1960-89



Source: Federal Highway Administration.

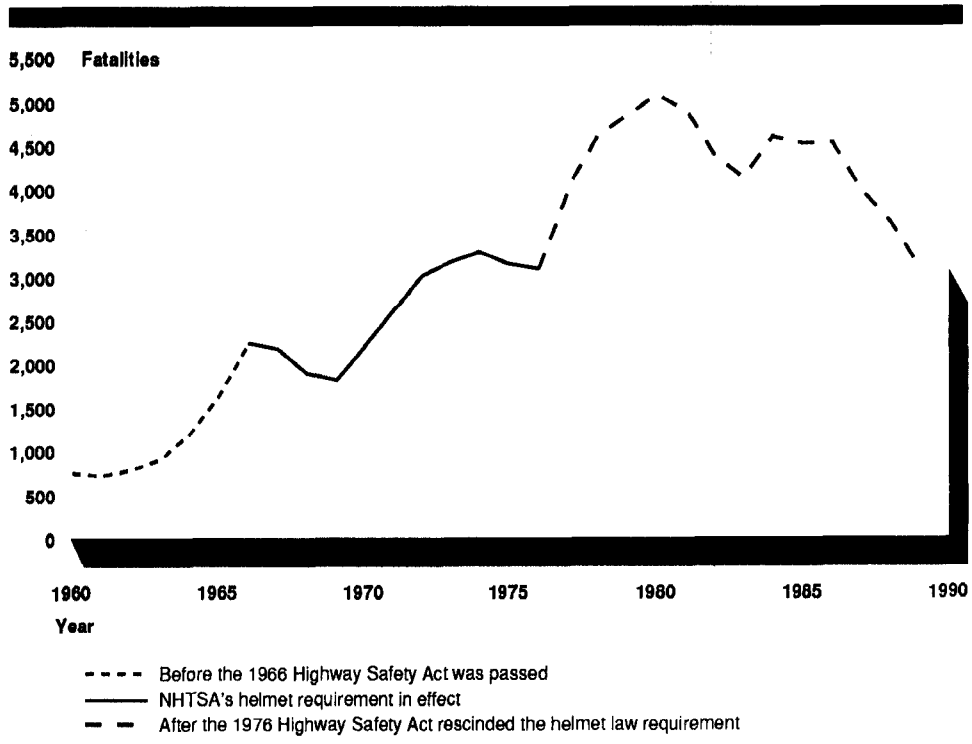
Figure 1.3: U.S. Male Population Aged 18-24



Source: U.S. Bureau of the Census.

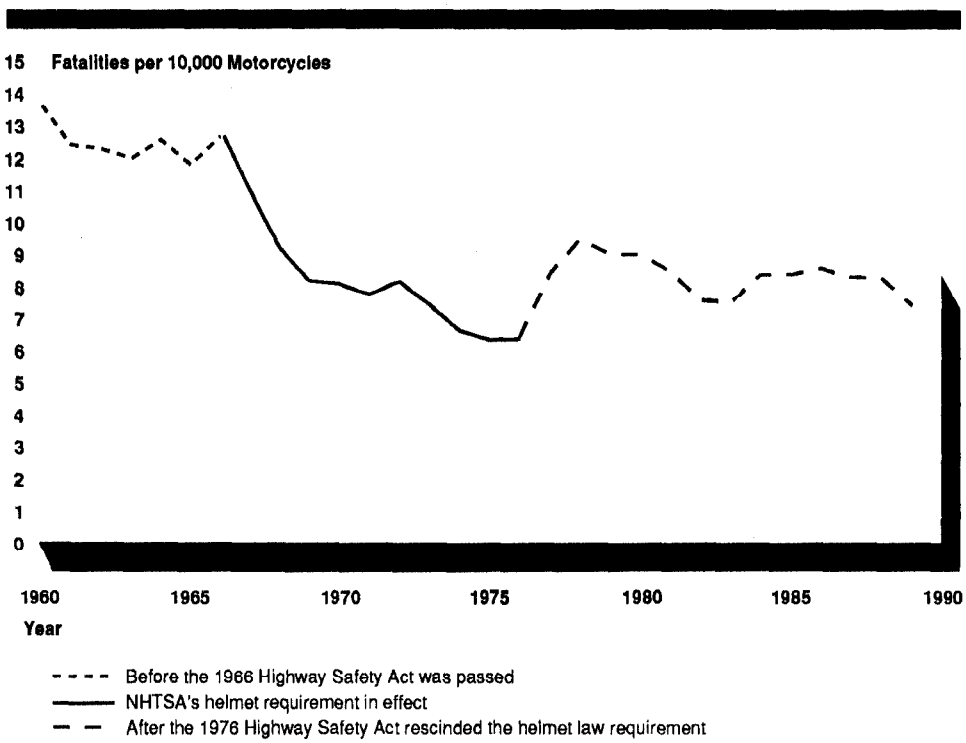
From 1981 to 1989, motorcycle registrations declined 25 percent to about 4.4 million, while the population of males aged 18-24 declined 13 percent. Motorcycle fatalities have also declined since peaking at 5,144 in 1980. (See fig. 1.4.) As shown in figure 1.5, the fatality rate relative to motorcycle registrations was noticeably lower during the 1967-76 period when NHTSA's helmet law requirement was in effect. After rising sharply in the late 1970s, the fatality rate was relatively stable from 1981 through 1988, then declined in 1989.

Figure 1.4: Motorcycle Fatalities, 1960-89



Note: Includes moped riders.
Source: NHTSA.

Figure 1.5: Motorcycle Fatality Rate, 1960-89



Note: Includes moped riders.
Source: NHTSA.

Motorcycle Safety Research Is Limited by Data Shortcomings

Several factors make it difficult to study the impact of policy initiatives such as motorcycle helmet laws. One problem is the lack of reliable data at a national or even state level on nonfatal accidents and injuries. States vary considerably in their criteria for recording accidents in their data bases, making state-to-state comparisons difficult. Also, linking accident reports with medical data is a painstaking process. While death is an unmistakable outcome, a nonfatal injury may range from minor to critical. (The Abbreviated Injury Scale—AIS—which grades injuries as minor, moderate, severe, serious, critical, or unsurvivable, is used by many researchers.) Police officers may record their judgments in accident reports, but their assessments of the seriousness of injuries cannot be considered as authoritative as those of an examining physician.

Since 1975, NHTSA has collected standardized data on fatal traffic accidents through the Fatal Accident Reporting System (FARS). These data are readily available and considered quite reliable, but fatal accidents are less than 1 percent of all traffic accidents.

Exposure to Risk: An Elusive Concept

Exposure to accident risk is a critical variable for studying the effect of safety programs, but it is often difficult to define and measure, especially for state-to-state comparisons. Unfortunately, good risk exposure data for motorcycle riding are not available. Some studies have used the number of accidents as an indicator of exposure to the risk of injury. These studies are of some value in assessing the protective effects of helmets, but they are dependent on accident reporting. If accident reporting is not consistent between study periods or study groups, fatality and injury rates based on the number of accidents will not be comparable.

Many studies have used the number of registered motorcycles as a measure of exposure. But registration data are not necessarily valid indicators of mileage traveled. This is especially true for motorcycles because of the influence of climate on the riding season. States with virtually year-round riding seasons will generally have more accidents per 10,000 registered motorcycles than states with limited riding seasons. Studies based on registration data are more useful if done in a single state, since differences in climate and traffic conditions are minimized. Even in a single state, however, annual variations in the riding season can occur, so it is important to control for annual variations in any time series analysis.

Objectives, Scope, and Methodology

The Chairman, Subcommittee on Water Resources, Transportation and Infrastructure, Senate Committee on Environment and Public Works, and the Ranking Minority Member of the Committee asked us to do an evaluation synthesis of existing research on the effectiveness of motorcycle helmets and helmet laws. In cooperation with Subcommittee staff, we focused our review on three major questions:

- What is the effectiveness of helmets in preventing fatalities and serious injuries?
- What is the impact of motorcycle helmet laws on helmet usage and fatality rates?
- What are the societal costs of helmet nonuse?

In order to identify studies for evaluation, we

- conducted computerized literature searches;
- reviewed files at the Office of Traffic Safety Programs, NHTSA;
- reviewed several bibliographies, including one compiled by the Motorcycle Safety Foundation of the Motorcycle Industry Council;

- noted the references in studies we obtained; and
- wrote to all the Governors' Safety Representatives to obtain copies of studies done in their states.

These efforts identified over 900 citations to reports, articles, editorials, etc. In order to put some reasonable limits on the body of research we would review, we decided to consider only studies published in 1975 or later and only those using data from the United States. We chose 1975 because it was the year before states began repealing their helmet laws and we wanted to include all the studies done on the effect of repeals. We eliminated studies using foreign data because we believed that the legal and traffic situations in other countries were sufficiently different from those in the United States that questions could be raised about the applicability of the studies.

In our initial screening of abstracts, we also found that (1) many were duplicate citations or interim reports superceded by final reports, (2) often the same research had been published in different places, and (3) some documents were clearly editorial in nature rather than research-oriented.

Our initial screening eliminated all but 113 citations. In examining these, we eliminated many because they did not address our specific questions or they did not contain original data or analyses. We also eliminated a few that gave so little explanation of their sources of data that we could not assess their significance. We decided that 49 studies met our criteria for review and assessment.

We were assisted in our evaluation of these studies by a three-member panel composed of two GAO specialists in methodology and data analysis (see app. II), and a consultant, Robert P. Lillis, who has extensive experience in highway safety research. Our panel evaluated each of the studies. Some of these studies addressed more than one of our questions and/or used more than one different analysis technique to address one or more of our questions. In its deliberations, the panel considered, but did not accept, 3 of the 49 studies and some of the different analyses in the remaining 46 studies because of serious methodological deficiencies. Our evaluation of the remaining 46 is summarized below.

- Nineteen studies addressed helmet effectiveness with some type of comparison between helmeted and nonhelmeted riders involved in accidents. The panel assisted with these.
- Nine studies had data on helmet usage. The panel assisted with these.

- Twenty studies analyzed fatality rate changes when helmet laws were enacted or repealed. The panel assisted with these.
- Thirteen studies had data on the cost to society of helmet nonuse. A GAO staff economist assisted with this information.
- Three studies addressed the effect of helmet use on hearing or field of vision. Our audit staff reviewed these studies.

After reviewing studies, the panel members helped formulate a summary of each study's approach, principal findings, limitations, and significance. The panel considered the quality of the research, the scope of the study, and the adequacy of its methodological explanation. The individual summaries are compiled in appendix I.

The review panel also discussed an overall interpretation of the research reported in the various studies, and considered whether there was a consensus in the research. Individual studies may have limitations of scope, missing data, large margins of error, or other uncertainties. However, as we pointed out in a 1983 paper on evaluation synthesis, "A series of independently conducted case studies consistent in their findings may yield a stronger vote of confidence than would any study taken individually."[3] Thus, to the extent that studies of varying scope and analytical technique reach consistently similar conclusions, their collective value for answering a question is greatly enhanced.

To aid in comparing study results, we used data in some of the studies to calculate percentages or rates that could be compared with results of other studies. These calculations were available to the panel to assess the extent of consistency among the various studies.

We performed our work from May 1990 through April 1991 in accordance with generally accepted government auditing standards. Because we were not reviewing a current federal program, we did not obtain official agency comments on this report. We discussed the report's contents with NHTSA officials, who said they found our results consistent with their work.

[3]The Evaluation Synthesis. GAO/Institute for Program Evaluation, Apr. 1983, p. 34.

Helmets Are Effective in Preventing Deaths and Reducing Injury Severity in Motorcycle Accidents

The studies that compared helmeted and nonhelmeted motorcycle riders varied in scope, data sources, and methodological approach, but they were consistent in pointing to a safety benefit from helmet use. They indicated that helmet use prevents deaths and reduces injury among motorcycle accident victims. Although helmet law opponents have raised various concerns about the adverse effects of helmets, we found no basis for these concerns in the studies evaluated.

Helmets Are Effective in Reducing Motorcycle Fatalities

Eleven studies compared fatality rates between helmeted and nonhelmeted motorcycle accident victims. As shown in table 2.1, all indicated a lower incidence of deaths among helmeted riders, ranging from 28 to 73 percent lower, depending on the rider population studied. The studies are arranged in the table according to the definition of their study populations, with the most broadly based studies in the first group. The first group, based on all reported accidents in a study area, probably provided the most useful comparisons. (Note that some studies had more than one level of data analysis and thus appear in two groups.)

The data may be summarized as follows:

- Six studies reported that the fatality rates of helmeted riders involved in accidents were 32 to 73 percent lower than for nonhelmeted riders.
- Five studies reported that fatality rates among injured helmeted riders were 39 to 73 percent lower than for nonhelmeted riders.
- Two studies of injured riders brought to specific trauma centers reported that helmeted riders had 45 to 50 percent lower fatality rates than nonhelmeted riders.
- Two studies of accidents in which a driver and passenger were riding on the same motorcycle and at least one was killed estimated that helmet use reduced the chance of death by 28 to 29 percent.

Table 2.1: Death Rates of Helmeted and Nonhelmeted Riders Involved in Accidents

Studies of riders involved in reported accidents	Percent that died[a]		Percent that helmeted deaths were lower than nonhelmeted deaths
	No helmet	Helmet	
Wisconsin DOT	3.8	2.6	32
Struckman-Johnson, et al. (S. Dak.)	3.3	2.1	36
Krane and Winterfield (Colo.)	3.0	1.2	60
Heilman, et al. (N. Dak.)	2.5	0.8	68
Lummis and Dugger (Kans.)	4.4	1.2	73
Dorris and Purswell (Okla.)	7.7	2.1	73
Studies of riders injured in reported accidents			
Struckman-Johnson, et al. (S. Dak.)	6.7	4.1	39
Krane and Winterfield (Colo.)	4.6	2.1	54
Hurt, et al. (Los Angeles)	7.1	3.2	55
Lummis and Dugger (Kans.)	8.5	2.8	67
Dorris and Purswell (Okla.)	10.7	2.9	73
Studies of riders at specific hospitals			
Bachulis, et al. (Portland—trauma center)	9.7	5.3	45
Lloyd, et al. (Austin—trauma center)	16.3	8.2	50
Studies of fatal accidents involving passengers			
Evans and Frick (FARS data)	[b]	[b]	28
Wilson (FARS data)	[b]	[b]	29

[a]GAO calculated some of the rates from data presented in studies.

[b]Not reported in this way.

Helmets Reduce Injury Severity in Motorcycle Accidents

The studies we evaluated showed that helmet use reduced the incidence of nonfatal serious and critical injuries.[1] Eleven studies compared the severity of head injuries between helmeted and nonhelmeted riders, and all indicated that helmet use reduced severity. As shown in table 2.2, the reported incidence of severe, serious, and critical head injuries was 46 to 85 percent lower for helmeted riders. In addition, six of the studies also made general comparisons of injury severity. These showed that helmeted riders suffered fewer serious and critical injuries than nonhelmeted riders. This lower overall injury severity among helmeted riders may be attributed to the lower incidence of severe or worse head injuries.

[1]Most researchers used the Abbreviated Injury Scale (AIS), which grades injuries as minor, moderate, severe, serious, critical, and unsurvivable.

According to FARS data, at least 1,666 nonhelmeted riders died in 1989. As noted in chapter 1, injury data are more difficult to assemble than fatality data, and were less available in the studies we evaluated. However, a comparison of studies appearing in both tables 1.1 and 1.2 suggests that for every nonhelmeted rider that died, at least as many survived with severe, serious, or critical head injuries (assuming that many of the fatalities in table 1.1 are also counted in table 1.2).

Table 2.2: Percentage of Injured Riders With Severe, Serious, or Critical Head Injuries

Studies of riders injured in reported accidents	Percent with severe or worse head injuries		Percent that helmeted injuries were lower than nonhelmeted
	No Helmet	Helmet	
Lummis and Dugger (Kans.)	13	6	54
Struckman-Johnson, et al. (S. Dak.)	16	7	56
Goodnow (Amarillo, Austin, Corpus Christi, San Antonio)	13	5	62
Hurt, et al. (Los Angeles)	11	4	64
Dorris and Purswell (Okla.)	15	5	67
Krane and Winterfield (Colo.)	16	3	81
Studies of riders at specific hospitals			
Lloyd, et al. (Austin—trauma center)	26	14	46
Carr, et al. (Minneapolis/St. Paul—7 hospitals)	28	10	64
Luna, et al. (Seattle—trauma center)	31	11	65
Peterson, et al. (Iowa—8 hospitals)	15	3	80
Bachulis, et al. (Portland—trauma center)	13	2	85

Note: Most researchers used AIS. Bachulis, et al., presented data on major brain injuries.

Objections by Helmet Law Opponents Were Not Supported by the Studies Evaluated

Opponents of helmet laws have raised several questions regarding the effectiveness of helmets, but we did not find valid evidence to support those objections.

During the early debates over helmet laws, questions were raised as to whether helmets presented a hazard by degrading a rider's hearing or field of vision. None of the studies we reviewed suggested that hearing or vision restrictions from helmets contributed to accidents. Hurt and associates (see app. I, No. 20) reported that in the 900 motorcycle accidents they investigated in Los Angeles, in which 40 percent of the riders were helmeted, none were influenced by hearing or vision restrictions.

NHTSA conducted tests in 1975 to determine the extent to which various helmets restricted a rider's field of vision.[2] The horizontal field restriction (with the rider's head facing forward) ranged from less than 1 percent to 22 percent, depending on the type of helmet. For the most popular helmets, the restriction was about 3 to 7 percent. The helmets evaluated provided from 182 to 232 degrees of horizontal field of vision, compared with 233 degrees without a helmet.

Both NHTSA and the University of Utah issued reports on the effect of helmets on a rider's ability to hear warning sounds.[3] Both concluded that ambient noise was a rider's greatest obstacle to hearing warning sounds, and that if a sound was loud enough to penetrate the noise of the wind and motorcycle, it would be heard by both a helmeted and nonhelmeted rider. The Utah study concluded that helmets actually improved a rider's ability to hear warning sounds by reducing the masking effect of wind noise.

As discussed below, two of the three studies that our review panel considered, but did not accept because of methodological concerns, raised objections to mandatory helmet use. One author contended that although helmet use reduces the severity of head injuries, it increases the likelihood of severe neck injury. However, this author's conclusion was based on only four cases of severe neck injury among helmeted riders. (See app. I, No. 48.) We found no other evidence to support this author's position. The five other studies with data on severe neck injuries indicated that they were much less common in motorcycle accidents than severe head injuries. Moreover, the five studies all reported a higher incidence of severe neck injuries among nonhelmeted riders.

Another author addressed the question of whether wearing a helmet affected a rider's behavior and contended that helmeted riders are more likely to have accidents. The author suggested, without supporting data, that wearing a helmet may lead a rider to take more risks.[4] (See app. I, No. 47.) We found no evidence to support this theory. Moreover, in some

[2]Gordon, Stephen, and James Prince, Field of View With and Without Helmets (Washington: National Highway Traffic Safety Administration, Oct. 1975), pp. 13, 20, 23.

[3]Henderson, Robert L., Effect of Safety Helmets on Auditory Capability (Washington: National Highway Traffic Safety Administration, Sept. 1975), pp. 2, 11, 15 and Van Moorhem, W.K., K.P. Shepherd, Tom D. Magleby, and Guy E. Torian, The Effect of Motorcycle Helmets on Hearing and the Detection of Warning Signals (Salt Lake City: University of Utah, Mar. 1977), pp. 13, 14.

[4]This risk-compensation hypothesis was presented by Sam Peltzman in "The Effects of Automobile Safety Legislation," Journal of Political Economy, Vol. 8, No. 3, 1975, pp. 667-725.

of the reviewed studies the nonuse of helmets was associated with risky riding behavior. Six studies indicated that nonhelmeted riders were more likely to contribute to accidents than helmeted riders. These studies also reported that nonhelmeted riders were more likely to ride after drinking alcoholic beverages.

In the motorcycle studies we evaluated, nonhelmeted riders had higher accident rates than helmeted riders. Also, of the eight studies that compared motorcycle accident rates before and after helmet law changes, seven reported that accident rates increased after universal laws were repealed. Several factors can influence accident rates, thus this change in accident rates does not necessarily contradict this author's hypothesis. However, the net result of all factors was an increase in accident rates after repeal.

Universal Helmet Laws Increase Helmet Use and Reduce Fatality Rates

The studies evaluated showed that most motorcycle riders wore helmets in those states with universal helmet laws. In states with no law or limited laws, roughly half of all the riders wore helmets. Studies of the impact of helmet laws showed substantially lower fatality rates when universal laws were in effect, with most of the results falling in a range of 20 to 40 percent lower.

Universal Helmet Laws Substantially Increase Helmet Use

Nine studies contained data on helmet use from roadside observational surveys or from accident reports (some studies had both kinds of data). As shown in table 3.1, helmet use under universal laws ranged from 92 to 100 percent. Under limited laws, helmet use was similar to use without a law, with most reported rates falling in a range from 42 to 59 percent.

Only four studies had helmet use data for young riders covered by limited laws. In one state, use was still high after the change to a limited law, but appeared to be declining. The other studies showed that use by young riders was not very different from use by riders not covered by the law. This may indicate the impracticality of enforcing a helmet law that applies to only young riders.

Table 3.1: Helmet Use Under Different Requirements

Studies using roadside observations	Area	Years	Percent helmeted: Universal laws	Limited laws	No law
Dorris and Purswell	Okla.	1977		52	
Goodell-Grivas, Inc.	19 cities	1988	92	44	74[a]
		1989	98	46	21[a]
Hurt, et al.	Los Angeles	1978–79			49
Krane and Winterfield	Colo.	1976			
		1977			58
		1978	100		49
Lund, et al.	Tex.	1989[b]	93	42	
McSwain and Willey	La.	1982	96		
Struckman-Johnson	S. Dak.	1976			
		1977		58	
		1978	100	50	
Studies using accident reports					
Dorris and Purswell	Okla.	1976		59	
		1977		55	
Heilman, et al.	N. Dak.	1977		55	
		1978		46	
		1979		28	
		1980		28	
Hurt, et al.	Los Angeles	1976–77			42 40[c]
Krane and Winterfield	Colo.	1976			
		1977	93		37
Lummis and Dugger	Kans.	1975			
		1976	95		42
Struckman-Johnson	S. Dak.	1976			
		1977		50	
		1978	95	43	

[a]Chicago only. The 1988 data appeared to reflect only cold weather riding. Three times as many observations were made in 1989.

[b]Universal law reinstated Sept. 1, 1989.

[c]Accidents investigated by study team.

Fatality Rates Have Been Consistently Lower Under Universal Helmet Laws

Twenty studies compared fatality rates under universal helmet laws with rates either before enactment of the laws or after they were repealed. These studies varied considerably in the length of time studied, number of states included, and ways of controlling for the influence of factors other than the laws. Nonetheless, every study documented lower fatality rates when universal laws were in effect.

As shown in tables 3.2 through 3.4, the great majority of fatality rates fell in a range 20 to 40 percent lower when universal helmet laws were

in effect. This was a significant degree of consistency for studies differing in scope and analytical technique. If applied to the states which did not have universal helmet laws in 1990, and assuming that motorcyclists in those states were similar to their counterparts in states with universal laws, a 20- to 40-percent reduction in fatalities would have meant a total of about 350 to 700 fewer deaths in those states in 1990.

Although all of the studies had weaknesses (summarized in app. I), when taken together, the consistency of results considerably enhanced the confidence we could place in this body of data. Several studies covered long enough periods to allow a comparison of fatality rates before, during, and after the enforcement of a universal helmet law. These studies showed that declines in fatality rates when universal laws were enacted were matched by similar increases when the laws were repealed.

Table 3.2 shows results from the seven studies that used data from FARS. They produced estimates ranging from a 12- to 28-percent reduction in fatalities attributed to universal helmet laws. These studies addressed the period after 1975, when many states repealed or limited their helmet laws. The authors generally compared the experience of repeal states with that of states not changing their laws, but used different analytical approaches. A drawback for these studies was the unavailability of FARS data before 1975, which meant that prerepeal data were limited for many states.

Table 3.2: Studies Comparing Fatalities in States Retaining Universal Helmet Laws With States Repealing Laws

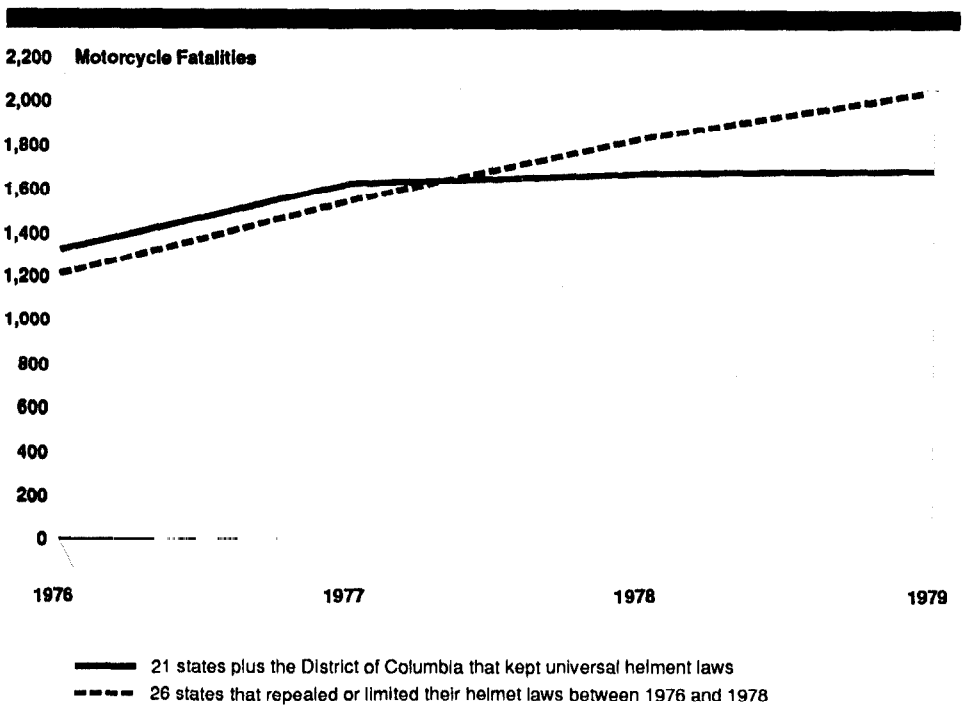
Studies using FARS data	Period studied	Percent that fatalities remained lower under universal laws
Hertz	1975–88	17
de Wolfe	1975–84	18
Chenier and Evans	1975–82	20–22
Graham and Lee	1975–84	12–22
Berkowitz and Johnson	1976–79	23[a]
Hartunian, et al.	1975–80	24
Watson, et al.	1975–78	28

[a]GAO calculated this figure from data presented by the authors.

Figure 3.1 shows data reported in one of the these studies on the number of fatalities in states that kept their universal helmet laws compared with those that repealed or limited their laws during the years 1976 through 1978. Although motorcycle registrations were still

increasing somewhat during these years, the universal law states were leveling off in the number of fatalities while the repeal states had a steady increase.

Figure 3.1: Fatality Trends Reported in a Multi-State Study



Source: Berkowitz and Johnson. (See app. I.)

Table 3.3 shows results from 13 studies that used data from state accident reports to compare fatality rates under universal helmet laws with fatality rates before and/or after the laws were in effect. These studies, which used motorcycle registrations as a measure of accident risk, found fatality rates under universal laws ranging 12 to 62 percent lower than comparison periods. Although mileage traveled would be a better measure of exposure, it is not reliably available for motorcycles. Registration data are available, and are more consistent over time than accident data, which are subject to reporting variabilty.

Table 3.3: Universal Law Periods Compared With Prelaw and/or Post-Repeal Periods Using Fatality Rates per 10,000 Registered Motorcycles

Studies using state accident data	Period studied	Percent universal law period was lower than: Prelaw period	Post-repeal period
Struckman-Johnson, et. al. (S. Dak.)	1976–78		12
Wisconsin DOT	1975–80		18
Krane and Winterfield (Colo.)	1964–78	24	23
Scholten and Glover (Ind.)	1962–73 1974–81[a]	29	30
Berenguel (Iowa)	1974–77	35	30
Hatton (Ariz.)	1969–85		30
Williams and Cleary (Minn.)	1970–80		32–40
Carr, et al. (Minn.)	1970–80		31
Hill (Tex.)	1956–87	31	35
Robertson (16 states)	1968–72	35	
McHugh and Raymond (S.C.)	1965–84	20	36
Lummis and Dugger (Kans.)	1965–78	38	39
Kim and Willey (Hawaii)	1962–87	58	62

Note: GAO calculated some of these results from data presented by the authors.
[a]These authors divided their study period at the introduction of the 55 mph speed limit.

Table 3.4 shows results from 5 studies that compared fatality rates per 100 motorcycle accidents between periods. The universal law periods in these studies had fatality rates ranging from 4 to 41 percent lower than during periods before enactment or after repeal. While these results were further evidence that helmet laws reduce fatality rates, they may have underestimated the effect of the laws. Fatality rates based on reported accidents can be misleading if accident reporting changes between two time periods. A number of studies indicated that reported accidents increased when helmet laws were repealed, possibly because injuries increased. This would make a fatality rate per 100 accidents appear lower during the post-repeal period.

Table 3.4: Universal Law Periods Compared With Prelaw and/or Post-Repeal Periods Using Fatality Rates per 100 Motorcycle Accidents[a]

Studies using state accident data	Period studied	Percent universal law period was lower than: Prelaw period	Post-repeal period
Struckman-Johnson, et al. (S. Dak.)	1976–78		5
Wisconsin DOT	1975–80		24
Krane and Winterfield (Colo.)	1976–78		26
Scholten and Glover (Ind.)	1962–73 1974–81[b]	4	27
Hill (Tex.)	1956–87		41

[a]GAO calculated some of these results from data presented by the authors.

[b]These authors divided their study period at the introduction of the 55 mph speed limit.

Helmet Nonuse Increases the Societal Cost of Motorcycle Accidents

The additional deaths and serious head injuries resulting from the nonuse of helmets impose a substantial cost burden on society. Society bears direct costs related to the treatment and rehabilitation of accident victims and indirect costs consisting primarily of lost or reduced productivity. The studies we evaluated showed that nonhelmeted riders were more extensive users of medical services and long-term care, and were more likely to die or lose earning capacity through disability. In one sense, the care of accident victims represents a claim on society's resources regardless of how payment is made. The studies we evaluated also indicated, however, that much of the actual payment for care is made by society through tax-supported programs or insurance premiums.

Nonuse of Helmets Increases the Cost of Caring for Injured Riders

Available data on the cost of medical services rendered to motorcycle accident victims were incomplete. Much of them came from hospital-based studies, which showed considerable variability in the magnitude of costs. This variance depended in part on whether the patients studied included those treated and released or only those admitted, and whether the hospitals were trauma centers or less-specialized facilities. Nonetheless, the studies consistently showed that nonhelmeted riders were more extensive users of medical services. In particular, they were more likely to

- need ambulance service,
- be admitted to a hospital as an inpatient,
- have higher hospital charges,
- need neurosurgery and intensive care,
- need rehabilitation, and
- be permanently impaired and need long-term care.

The magnitude of costs to care for injured riders was unclear because very little information was available for motorcyclists on costs such as surgeons' fees, rehospitalization and rehabilitation, and extended care. However, two other studies of long-term accident costs (not among our 46 motorcycle studies) indicated that costs can be very large for serious and critical head injuries. A study of surviving trauma victims (not only motorcyclists) at two Maryland hospitals found average first-year costs[1] of about $92,000 for serious head injuries and $171,000 for critical head injuries. Many of these patients were still convalescing 1 year after their

[1]All cost figures cited in this report have been updated to 1990 dollars.

accidents.[2] A recent study that used data from NHTSA's National Accident Sampling System and workman's compensation claims estimated long-term medical costs of motor vehicle accident victims at about $84,000 for those with serious head injuries and $291,000 for those who survived critical head injuries.[3]

Indirect Costs of Motorcycle Accidents Can Be Very High

Indirect costs, primarily the reduction in the potential output of society due to disability or premature death, can be quite substantial and would likely exceed direct costs in cases of fatality and the most severe injuries. Many years of productive life may be lost as a result of accidents, and motorcycle accidents are especially costly because the rider population is generally young. According to NHTSA, the average age of riders killed in accidents is 22.

Only one of the studies of helmet laws attempted to estimate indirect costs. The authors calculated that 516 additional riders had died in 1980 as a result of helmet law repeals; they used demographic characteristics of motorcyclists to estimate the potential earnings lost due to premature death. Their estimate was nearly $250 million, or about $480,000 per death. Another recent estimate of indirect costs from motor vehicle fatalities was about $457,000 per death.[4]

Payment for Motorcycle Accidents Falls Mainly on the Public

Several studies addressed the source of payment for hospital charges. They showed that roughly half of the nonhelmeted riders were covered by medical insurance, somewhat less than for helmeted riders. Public assistance programs were reported in two studies to have covered about one-fourth of the charges, while the remaining one-fourth were considered self-pay. The self-pay category may be misleading, however. One study which investigated this further found that public programs paid a much higher percentage and that riders and their families actually paid only about 1 percent of the total costs. Presumably, some of the cost was absorbed by the hospitals.

[2]Ellen J. McKenzie, et al., "The Economic Impact of Traumatic Injuries," Journal of the American Medical Association, Vol. 260, No. 22, Dec. 1988, pp. 3290, 3294, 3296.

[3]Ted R. Miller, et al., "Motor Vehicle Injury Costs by Body Region and Severity," Proceedings, Association for the Advancement of Automotive Medicine, Oct. 1990, pp. 97-98, 101, 103.

[4]Ted R. Miller, "Crash Costs and Safety Investment," Presented to the Association for the Advancement of Automotive Medicine, Sept. 1988, p. 4.

Although insurance, either medical insurance or motorists' liability insurance, covered a portion of the costs of caring for injured riders, it should be recognized that insurance costs are borne by employers and individuals who pay premiums. The cost of higher insurance claims is thus spread over a broad public.

Some costs are shifted to society when accident victims survive but are unable to work either temporarily or permanently. Although little information was available on the extended effects of motorcycle accidents, three studies that reported on riders with long-term disability found nearly all had been nonhelmeted. Another study reported that nonhelmeted riders had lost more days of work than helmeted riders. Unfortunately, none of the studies captured information on the level of income-replacement benefits such as sick leave, disability benefits, or welfare benefits provided to injured riders or their families.

Conclusions and Matters for Consideration by the Congress

Conclusions

Although none of the studies we evaluated would have been adequate by itself to justify an unqualified conclusion, the consistency among the results made it possible for us to put considerable confidence in the collective evidence they represented. The studies showed that helmet use provides a considerable amount of protection to motorcycle riders involved in accidents, and does not increase the likelihood of having an accident. Helmet use reduces fatality rates and reduces injury severity among survivors of motorcycle accidents, because it sharply reduces the number of severe, serious, and critical head injuries.

The studies we evaluated showed that universal helmet laws have been very effective in increasing helmet use, virtually doubling use compared with experience without a law or with a limited law applying only to young riders. Under universal helmet laws, most states experienced 20 to 40 percent lower fatality rates than during periods without laws or under limited laws.

In the case of helmet laws, as in many matters before the Congress, individual rights must be weighed against those of society. On one hand, some individuals consider requiring all motorcycle riders to wear helmets to be an unwarranted infringement of personal liberty. On the other hand, the studies we evaluated showed that society bears the cost, through tax-supported programs as well as insurance premiums, for the additional deaths and serious injuries resulting when motorcycle riders do not use helmets.

Matters for Consideration by the Congress

Because there is convincing evidence that helmets save lives and reduce society's burden of caring for injured riders, the Congress may wish to consider encouraging states to enact and retain universal helmet laws. The Congress could return to the use of penalties (e.g., withholding of highway funds for noncompliance), use incentives (e.g., making additional funds available to states that have universal laws), or use a combination of penalties and incentives.

Agency Comments

As agreed, we did not obtain written agency comments. We shared the draft report with senior program officials at NHTSA, who said they found our results consistent with their work.

Summaries of Studies

Studies Evaluated by Reviewers

1. Bachulis, Ben L. MD, William Sangster, MD, Guy W. Gorrell, MD, and William B. Long, MD. "Patterns of Injury in Helmeted and Nonhelmeted Motorcyclists." American Journal of Surgery, Vol. 155, May 1988, pp. 708-711.

Approach

The authors reviewed the records of all 367 motorcycle accident victims admitted to Emanuel Hospital in Portland, Oregon, from January 1983 through May 1987.

Principal Findings

How is helmet use related to fatality and severe injury in motorcycle accidents? The helmeted cyclists in this patient population appeared to have had more serious accidents, since they had a higher rate of major injuries overall, especially orthopedic injuries. However, 9.7 percent of the nonhelmeted riders died, compared with 5.3 percent of the helmeted riders. This difference was almost entirely due to brain injuries suffered by nonhelmeted riders. Among these injured riders, 13.2 percent of the nonhelmeted riders compared with 2.3 percent of the helmeted riders suffered major brain injury.

Motorcycle riders made up 20 percent of the motor vehicle accident victims admitted to this hospital, and 64 percent were nonhelmeted. Out of 42 riders requiring neurosurgery, 36 were nonhelmeted.

How is helmet use related to the need for care and services after the period of initial hospitalization? Of the 18 riders who survived major brain injuries, the authors judged all to be long-term disabled. Seventeen had not worn helmets.

Limitations of the Data or Analysis

The study population was rather small and did not represent accident-involved riders in general, but rather those admitted to a trauma center emergency room. The authors did not use the Abbreviated Injury Scale (AIS), so comparison to other studies was more difficult. It was unclear whether only riders admitted as inpatients were included or whether outpatients were also counted. It was not clear whether cases where helmet use was unknown were excluded from the study or how many there were.

Significance of Findings

The study's limitation to a single trauma center and the lack of comparabilty to other studies reduced its value, although it did cover a 4-

year period. The study illustrated the high incidence of serious head injury among nonhelmeted motorcycle accident victims and the significant resources required to care for them.

2. Berenguel, Aurora P. Iowa Motorcycle Crash Study: 1974-1976. Iowa Governor's Highway Safety Office, 1977.

Approach

Iowa's helmet law was in effect for only 10 months—September 1975 through June 1976. The author presented data from accident reports showing the fatalities during the period the law was in effect as well as during September-June periods in the year before and the year after its repeal. Data were also compiled on the primary injuries causing death, apparently from the judgments of investigating police officers.

Principal Findings

What changes in motorcycle fatality rates have been associated with enactment and repeal of universal helmet laws? Fatalities per 10,000 registered motorcyles were similar in the before and after periods. However, while the helmet law was in effect, the fatality rate was 35 percent lower than during the "before" period and 30 percent lower than during the "after" period. The cause of death analysis indicated that the lower fatality rate during the law period appeared to be due almost entirely to a reduction in fatal head injuries.

Limitations of the Data or Analysis

The periods available for comparison were short, and altogether they accounted for only 126 fatalities. The high-fatality months of July and August had to be excluded because they were never covered by the helmet law. Police reports are also questionable sources for determining the location of fatal injuries. Data cited within the study were not always consistent from table to table.

Significance of Findings

Despite the limited period of study, the similarity in the two periods without a law and the clear difference from the law period were interesting. It was also noteworthy that the difference in fatalities was similar to the difference in fatal head injuries.

3. Berkowitz, A. Evaluation of State Motorcycle Helmet Laws Using the National Electronic Injury Surveillance System. Washington: National Highway Traffic Safety Administration, 1981.

Approach

The author used data gathered by the Consumer Product Safety Commission from 70 hospital emergency rooms in 34 states. While the data came from the period October 1978 through December 1980, reporting periods by individual hospitals varied from 1 to 27 months. Emergency room personnel reported the location of the most severe injury and graded its severity according to an 8-point scale. The author compared injuries to motorcycle riders in states with universal helmet laws with those in states with limited or no helmet laws. Actual helmet use by the injured riders was unknown.

Principal Findings

What changes in injury severity have been associated with repeal of universal helmet laws or change to limited laws? Injured riders in states without universal helmet laws had a 45-percent higher incidence of injuries to the head and facial region than riders in states with universal laws. They also had a higher incidence of neck injuries. The incidence of serious head injuries (4 or higher on 8-point scale) was twice as high in the states without universal helmet laws.

Limitations of the Data or Analysis

There was no discussion of data quality, missing data, or the reasons for the varying reporting periods among hospitals. No information was given on how the hospital sample was chosen. The data were dependent on severity judgments by a large number of personnel among the various hospitals.

Significance of Findings

Without a complete discussion of the data sources, little judgment could be made about the meaningfulness of the data. The study provided one more piece of evidence that serious head injuries increase in the absence of a helmet law and that neck injuries are both infrequent and unrelated to helmet use.

4. Berkowitz, A. and P. Johnson. Motorcycle Fatality Experience Based on Fatal Accident Reporting System Data 1976-1979. Washington: National Highway Traffic Safety Administration, Mar. 1981.

Approach

Using data from the Fatal Accident Reporting System (FARS), the authors compared motorcycle fatality increases from 1976 to 1979 in (1) states that did not change their universal helmet laws, (2) states that did not have helmet laws, and (3) states that repealed or limited their laws during the study period.

Principal Findings

What changes in fatality rates have been associated with repeal of universal helmet laws or change to limited laws? States repealing their helmet laws accounted for 48 percent of the motorcycle fatalities in 1976 and 55 percent in 1979.

From data compiled by the authors, we calculated that fatalities in 1979 were 70 percent higher than in 1976 in the states that repealed or limited their laws. This compared with a 28-percent increase in states that did not change their laws and a 34-percent increase in the three states that had no laws. Thus, in comparison to the fatality trend in the states that did not have a law change, the states changing their laws had 31 percent more fatalities. This is equivalent to saying they would have had 23 percent fewer fatalities had they not repealed or relaxed their helmet laws and experienced the same fatality trend as states not changing their laws.

Limitations of the Data or Analysis

The time period used was quite limited. No attempt was made to account for other factors that might have influenced the fatality rates.

Significance of Findings

The use of all states in the analysis, including those that never had helmet laws, was a positive factor in this analysis. Limitation to the transition period of helmet law repeal was a limiting factor.

5. Bried, James M., MD, Frank A. Cordasco, MD, and Robert G. Volz, MD. "Medical and Economic Parameters of Motorcycle-induced Trauma." Clinical Orthopedics and Related Research, No. 223, Oct. 1987, pp. 252-256.

Approach

The authors studied the medical records (paramedic reports, emergency department reports, and inpatient histories) of the 71 injured motorcycle riders admitted to the Arizona Health Sciences Center in Tucson from July 1, 1984, through June 30, 1985.

Principal Findings

How do initial hospitalization costs compare for helmeted and nonhelmeted riders involved in motorcycle accidents? In this population of 71 hospitalized riders, 53 (75 percent) had not been wearing helmets. Nonhelmeted riders incurred an average of $17,120 in hospital costs compared with $13,368 for helmeted riders. This difference was reflected in the high cost of treating the 30 head-injured riders, 27 of whom were nonhelmeted. Head-injured riders averaged $21,945 in hospital costs compared with $11,941 for those without head injuries.

How is helmet use related to the need for care and services after the period of initial hospitalization? Twelve riders did not recover from their injuries: 1 died, 1 was quadriplegic, 1 was paraplegic, and 9 were severely mentally impaired from head injuries. None of the 12 were wearing a helmet. The remaining riders returned to baseline functioning in periods ranging from 1 to 64 weeks (average 23 weeks).

Limitations of the Data or Analysis

The study population was small and limited to riders injured seriously enough to be admitted to a major hospital. Thus, the findings would not apply to all riders involved in accidents. The data-gathering methodology was not well explained. In particular, it was not clear how the authors were able to ascertain helmet use for all 71 riders without police reports.

Significance of Findings

The small study population and limited scope prevented a higher rating. Helmeted riders incurred 22 percent lower average charges than nonhelmeted riders. The high figures reported reflect the inclusion of physician and surgeon fees, which can be very substantial in treating head injuries. Although the study indicated that a number of nonhelmeted riders needed long-term care, no data were available on long-term costs.

6. Carr, W. Peter, Donald Brandt, MD, and Kathryn Swanson. "Injury Patterns and Helmet Effectiveness Among Hospitalized Motorcyclists." Minnesota Medicine, Vol. 64, Sept. 1981, pp. 521-527.

Approach

The authors studied the medical records of 397 motorcycle riders admitted to seven hospitals in the Minneapolis-St. Paul area from May through October, 1979. The hospitals were chosen for geographic representation and emergency department volume. Victims' injuries were assessed using AIS. A search was also made to match injured victims with police accident reports, which was successful for 237 cases. The authors also compiled data from Minnesota registration and accident statistics from 1970 through 1980.

Principal Findings

How is helmet use related to injury severity in motorcycle accidents? Nearly 50 percent of these hospitalized riders had head injuries, with 18 percent suffering severe or worse head injuries. Head injuries accounted for 67 percent of the critical or fatal injuries received.

Helmet use was known for 69 percent of the riders. Severe or worse head injuries were suffered by 28 percent of the nonhelmeted riders compared with 10 percent of the helmeted riders. Critical or fatal head injuries were suffered by 9 percent of the nonhelmeted and 4 percent of the helmeted riders.

Less than 4 percent of the riders suffered neck injuries. The authors found no significant relationship between neck injury and helmet use.

What changes in fatality rates and injury severity have been associated with repeal of universal helmet laws or change to a limited law? Minnesota amended its helmet law on April 7, 1977, to apply only to riders under age 18. In the 7 years before the change, fatalities averaged 4.81 per 10,000 registered motorcycles, 31 percent less than the average of 6.96 in the 3 years following the change. Injuries per 10,000 registered motorcycles averaged 11 percent lower when the universal law was in effect.

Limitations of the Data or Analysis

By definition, these were the more seriously injured riders, since all were admitted to hospitals. The representativeness of the hospitals in the study was not demonstrated. Helmet use was unknown for 31 percent of the riders.

Significance of Findings

The scope limitations and amount of missing data reduced the significance of the injury data, which were confined largely to head and neck

injuries. The historical data showed a fairly clear increase in fatality and injury rates when Minnesota changed to a limited helmet law.

7. Chang, Chia-Juch, PhD, PE. "A Cross-Classification Analysis of the Effectiveness of Safety Helmets in Motorcycle Accident Injuries." ITE Journal, Sept. 1981, pp. 17-25.

Approach

The author analyzed 751 motorcycle accidents selected with an interval sample from 10,729 accidents reported in Wisconsin from 1977 through 1979. Using data from police accident reports, he classified accidents by speed intervals, the angle of impact, helmet use, and the incidence of head injury. Apparently, the author did not include about 320 additional cases sampled because of incomplete information. (Note: Wisconsin changed from a universal to a limited helmet law in March 1978.)

Principal Findings

How is helmet use related to fatality and injury severity in motorcycle accidents? Usable cases involved 888 riders, of whom 45 percent were helmeted. The author found an incidence of head injury 1.7 times greater (49 percent to 29 percent) among nonhelmeted riders than among helmeted riders. He found that the probability of head injury increased with impact speed and that helmet use reduced the probability of head injury above 25 miles per hour. Helmet use also reduced the probability of head injury for all accident scenarios except head-on collisions.

The author did not compare helmet use with injury severity but did compile data showing that the presence of head injury was strongly associated with fatality and severe injury.

Limitations of the Data or Analysis

Police accident data are often used because alternative efforts to assemble data on a large number of accidents are very time-consuming and difficult. But police reports are of questionable reliability with regard to injury location and severity, and often have a problem with missing data.

This study overlapped the pre- and post-repeal periods in Wisconsin, but was not a before/after study. It would have been better not to combine the periods in a helmet/no helmet study. The author's analysis of speeds

and impact angles was interesting, but many of the data cells contained small numbers.

Significance of Findings

The sample was fairly large, but data quality was questionable and the reported findings were limited. The study indicated that even at higher speeds, helmets provide protection against head injury. However, the author did not compare head injury severity or overall injury severity with helmet use.

8. Chenier, Thomas C. and Leonard Evans. "Motorcycle Fatalities and the Repeal of Mandatory Helmet Wearing Laws." Accident Analysis and Prevention, Vol. 19, No. 2, 1987, pp. 133-139.

Approach

Using data from FARS from 1975 through 1982, the authors compared fatality trends in states that did not change their helmet laws (including those with no laws) with those that repealed or limited their laws. The states not changing their laws thus served as a control group in lieu of using control variables in the analysis. The authors used monthly data and excluded transitional months (3 months before and 3 months after repeal). Oklahoma and Iowa were excluded because their situations had changed in 1975, the base year. Louisiana was analyzed separately because it reinstated its law in 1982.

Principal Findings

What changes in motorcycle fatality rates have been associated with repeal of universal helmet laws or change to a limited helmet law? The authors calculated that the repeal of helmet laws led to an average increase in fatalities of 25 percent (standard error: ±3 percent). The authors had earlier estimated an increase of 28 percent (standard error: ±4 percent), but modified this by converting individual state results to their natural logarithms before computing a weighted average. As a test of their results, the authors performed simple regression analyses using the region of country and change in young male population as independent variables. These variables did not significantly influence the results.

The finding of a 25-percent increase would correspond to 20 percent fewer fatalities if helmet laws had not been repealed. A 28-percent increase would correspond to 22 percent fewer fatalities.

Limitations of the Data or Analysis

The authors reported their individual state results but did not adequately explain their procedure for computing a weighted average among these results.

The period before repeal was very short for many states because FARS data were not available prior to 1975.

Significance of Findings

This study used the experience of the states that did not change their laws as a control in lieu of using some measure of motorcycle usage, such as registered motorcycles. It assumed that the number of states in each group would be large enough to make usage trends comparable. The short prerepeal periods may not have been very representative of the prerepeal experience.

9. De Wolfe, Virginia A. The Effect of Helmet Law Repeal on Motorcycle Fatalities. Washington: National Highway Traffic Safety Adminitration, Dec. 1986.

Approach

The author used annual data from FARS, 1975 through 1984, and accident statistics compiled from the states by the Motorcycle Safety Foundation, to compare trends in states that did or did not repeal helmet laws and estimate the effect of repeals on the fatality rate per accident. Regression equations were constructed to control for changes in motorcycle registrations and to measure the effect of the repeal variable on the fatality rate. Any state that did not maintain a universal helmet law was treated in the analysis as having repealed its law.

Principal Findings

What changes in motorcycle fatality rates have been associated with repeal of universal helmet laws or change to a limited helmet law? The author calculated that states repealing (or limiting) their helmet laws experienced a 21.3-percent increase (95-percent confidence intervals: 10.4 to 33.3 percent) in fatalities per accident as a result of repeal. Stated differently, if the states had not changed their laws, and had experienced the same fatality trend as states not changing their laws, their fatality rates would have been 18 percent (9.4 to 25 percent) lower.

Limitations of the Data or Analysis

Although the author believed that fatalities per accident was the best available measure of exposure, accident data are in fact subject to much variation in reporting practices from state to state and over time within states. Also, a number of studies have indicated that the repeal of a helmet law increases the number of reported accidents. Whether this happens because more accidents occur or because more are reported, it changes the denominator for computing fatalities per accident and overstates the rate in helmet law states compared with no-law states. It would cause an analysis such as this to underestimate the effect of repealing a helmet law.

Significance of Findings

The author used data from nearly all states and from a 10-year period. The analysis showed a statistically significant increase in the fatality rate per accident associated with the repeal of helmet laws, but the magnitude was somewhat lower than estimates using other exposure variables. The author failed to recognize that repeal could also increase the number of reported accidents and thus disguise some of the increase in fatality rates.

10. Dorris, Alan L. and Jerry L. Purswell. Impact of Motorcycle Helmet Usage in Oklahoma. Norman, Okla. (University of Oklahoma), 1978. (Sponsored by the National Highway Traffic Safety Admin., Wash., D.C.)

Approach

From June through September 1977, 3,300 motorcycle, moped, and minibike drivers and 595 passengers were observed at 73 urban and rural locations selected to be representative of Oklahoma traffic.

Police reports of 987 motorcycle accidents were collected from 4 urban police departments and the Oklahoma Highway Patrol for periods of July through September in 1976 and 1977. Medical records were obtained for the 613 injured riders who could be located and gave consent, and a physician coded them according to AIS.

Principal Findings

What levels of helmet use are associated with limited helmet laws? The roadside observations, done more than 1 year after Oklahoma changed

its helmet law to apply only to riders under age 18, found that 53.8 percent of the drivers and 44.7 percent of the passengers were wearing helmets. Helmet use was highest on interstate highways and higher in rural areas than urban areas.

How is helmet use related to fatality and severe injury in motorcycle accidents? For riders with known injury and helmet data, 67 percent of the helmeted and 72 percent of the nonhelmeted riders were injured. Injury severity rates riders involved in accidents, using overall AIS scores, were as follows: for helmeted riders, 2.1 percent fatal, 1.5 percent nonfatal critical, 3.2 percent serious, and 12.4 percent severe; for nonhelmeted riders, 7.7 percent fatal, 3.1 percent nonfatal critical, 4.9 percent serious, and 18 percent severe.

Among injured riders, the severity rates were as follows: for helmeted riders, 3.2 percent fatal, 2.2 percent nonfatal critical, 4.8 percent serious, and 18.5 percent severe; for nonhelmeted riders, 10.7 percent fatal, 4.4 percent nonfatal critical, 6.7 percent serious, and 25 percent severe.

Comparing head and neck injuries between injured riders, 15 percent of the nonhelmeted riders and 5 percent of the helmeted riders received severe or worse head injuries, while 2 percent of the nonhelmeted and 1 percent of the helmeted riders received severe or worse neck injuries.

Limitations of the Data or Analysis

The data represented a limited geographic area and time period. In particular, only 37 fatalities were included in the analysis. Also, injury status could not be ascertained for about 28 percent of the riders. Rural areas were overrepresented in the helmet use survey, and the averages cited were unweighted. Thus, the averages probably overstated helmet use.

Significance of Findings

Despite missing data, the study population was relatively large and was based on all reported accidents in the areas studied. The comparison of helmeted and nonhelmeted riders showed that the difference in injury severity was almost entirely due to head injuries. The study gave no support to the contention that helmet use increases the risk of severe neck injury. The observation data may have overstated helmet use.

11. Evans, Leonard, and Michael C. Frick. "Helmet Effectiveness in Preventing Motorcycle Driver and Passenger Fatalities." Accident Analysis and Prevention, Vol. 20, No. 6, 1988, pp. 447-458.

Approach

Using data from FARS from 1975 through 1986 and a method called "double pair comparison," the authors studied motorcycle accidents involving drivers and passengers, at least one of whom was killed. Only accidents in which the driver and passenger were within 3 years of each other's age were included. In a minority of the accidents, one of the riders was helmeted and one was not, and these accidents were critical to the analysis. The authors constructed equations to combine all the possible combinations of helmeted and nonhelmeted riders, and calculated the ratios of driver-to-passenger fatalities under the different scenarios.

Principal Findings

How is helmet use related to fatality and severe injury in motorcycle accidents? The authors calculated that helmets reduced the chance of fatal injury among motorcycle drivers by 26.5 percent (standard error ±8.5 percent) and among passengers by 30.2 percent (standard error ±8.2 percent). Combined, helmets reduced the chance of fatal injury by 28.4 percent (standard error ±8.2 percent).

The overall result was influenced by the lower survivability of female passengers. Calculations using only male riders showed a much higher helmet effectiveness. This is important because males account for most motorcycle fatalities (92 percent in 1989).

Limitations of the Data or Analysis

This analysis relied on a small and specialized subset of motorcycle accidents: those involving both a driver and passenger in which at least one died. As the authors recognized, one cannot assume that the conditions and kinetics of such accidents are the same as for single-rider accidents.

Significance of Findings

The matched-pairs technique tries to focus on accidents in which a helmeted and nonhelmeted rider are exposed to the same severity of crash circumstances. However, the specialized type of accidents studied (two riders, at least one of whom was killed), the overrepresentation of females in the analysis, and the small cell sizes in several of the categories reduced the applicability of the findings.

12. Goodell-Grivas, Inc. Restraint System Usage in the Traffic Population: 1988 and 1989 Annual Reports. Washington: National Highway Traffic Safety Administration, 1989, 1990.

Approach

Traffic was observed for about 6 hours per day for about 30 days each in 1988 and 1989 in 19 cities covering 6 geographical regions of the United States. Observation sites were essentially the same as those used in previous studies dating back to 1974. They were chosen by a stratified random-sampling procedure to represent freeway exits (30 percent) and arterial road intersections (70 percent) in each city, with some additional observations made at shopping centers.

Principal Findings

What levels of helmet use are associated with universal helmet laws and limited or no helmet laws? Overall, 18,234 motorcycle drivers and 2,012 passengers were observed in 1988, and 16,821 drivers and 2,252 passengers in 1989. The percentage of observed helmet use is summarized below:

Table I.1: Observed Helmet Use, 1988-89

	Drivers		Passengers		Combined	
Type of city	**1988**	**1989**	**1988**	**1989**	**1988**	**1989**
Cities in states with universal helmet laws	94	98	76	98	92	98
Cities in states without universal helmet laws	46	44	36	31	45	43

Limitations of the Data or Analysis

Site selections had been made for the purpose of observing seat belt use, with motorcycle helmet observation being a secondary activity. Seasonal variation appears to have affected the distribution of motorcycle observations among cities, and the number of observations in successive years for some of the cities. Rural areas and small cities, where voluntary helmet use is often higher, were not represented in these studies.

Significance of Findings

Despite their limitations, these observational studies indicate that a universal helmet law achieves nearly total compliance, while voluntary helmet use in the absence of such a law is likely to approximate 50 percent.

13. Goodnow, Robert K. Injury Severity, Medical Costs and Associated Factors for Helmeted and Unhelmeted Motorcyclist Crash Cases Transported to Hospitals in Amarillo, Austin, Corpus Christi, and San Antonio, Texas. Austin: Texas Department of Public Safety, unpublished.

Approach

The author used the Texas Department of Public Safety Accident Files to identify motorcycle accidents occuring in nine counties from September 1, 1986, through December 31, 1987. A search was made for medical records of identified victims at 17 participating hospitals in Amarillo, Austin, Corpus Christi, and San Antonio. Medical records were retrieved for 763 of 945 riders reported as being taken to a hospital. A medical student assigned AIS scores.

Principal Findings

What levels of helmet use are associated with limited helmet laws? Helmet use was known for 742 of the 763 injured riders, and 32 percent of them wore helmets. Although Texas required riders under age 18 to wear helmets, only 29 percent of the underage riders in this study were wearing helmets.

How is helmet use related to fatality and injury severity in motorcycle accidents? The injury severity of helmeted and nonhelmeted riders was compared only for head injuries or cervical spine injuries. Head injuries were suffered by 12.6 percent of the helmeted and 24.2 percent of the nonhelmeted riders. Severe or worse head injuries were suffered by 4.5 percent of the helmeted and 12.9 percent of the nonhelmeted riders. Of 30 riders with cervical spine injuries, 10 were helmeted (about the same proportion as the overall study population). The two severe or worse cervical injuries occurred to nonhelmeted riders.

How do initial hospitalization costs compare for helmeted and nonhelmeted riders involved in accidents? The authors reported that hospital costs were higher for head-injured riders than for those without head injuries, and costs among head-injured riders were higher for nonhelmeted riders. A substantial number of cases lacked cost information. Among the head-injured riders, 40 percent of the nonhelmeted riders were treated in intensive care units, compared with 23 percent of the helmeted riders.

How is helmet use related to the need for care and services after the period of initial hospitalization? Of eight riders sent to rehabilitation

centers, seven were nonhelmeted riders with head injuries and one was a rider with spinal cord injuries.

Limitations of the Data or Analysis

Only larger hospitals were included (those receiving 10 or more riders). In general, the authors were quite clear about accounting for cases with missing data and giving significance test results.

Significance of Findings

The study population was fairly large but was drawn only from larger hospitals. The study did not compare overall injury severity or fatality among helmeted and nonhelmeted riders.

The nonuse of helmets added substantially to the hospital costs of riders with head injuries, even without including physician and surgeon charges. The study indicated that some riders incurred costs after hospital discharge, but information was not obtained on such costs as those for rehabilitation, chronic care, or income support.

The large percentage of riders under age 18 who were nonhelmeted indicated that Texas' law was ineffective in achieving helmet use by young riders. (Texas reenacted a universal helmet law in 1989.)

14. Graham, John D. and Younghee Lee. "Behavioral Response to Safety Regulation: The Case of Motorcycle Helmet-Wearing Legislation." Policy Sciences, Vol. 19, 1986, pp. 253-273.

Approach

The authors used data from FARS from 1975 through 1984, to estimate the effect of helmet laws on motorcycle fatalities and the fatality rate per 1,000 registered motorcycles. Regression models were constructed to control for differences in motorcycle registrations, differences among states, and annual fluctuations. Any state that did not maintain a universal helmet law was treated in the analysis as having repealed its law.

Principal Findings

What changes in motorcycle fatality rates have been associated with repeal of universal helmet laws or change to a limited helmet law? The authors tried 5 versions of their regression model, including 2 in which only the 40 largest states were included. The version with the highest correlation coefficient produced an estimate of a 22-percent fatality reduction from universal helmet laws. This formulation explained 96

percent of the variance. The other formulations, which achieved less explanation of variance, estimated 12- to 14-percent reductions in fatalities per 1,000 registered motorcycles.

The authors also believed their data indicated that fatalities began to decline in repeal states following the initial increase. They speculated that riders may compensate for the absence of a helmet law with less risky driving behavior.

Limitations of the Data or Analysis

Like other analyses using FARS, this one was weakened by the short period of prerepeal experience in many states.

Regression analyses can be sophisticated tools for measuring the effects of independent variables, but only if the variables are quantifiable and reasonably representative. Otherwise, such analyses are useful primarily for showing the direction of influence and distinguishing stronger variables from weak ones. In highway safety research, the compromises that must be made to specify variables for the equations can render multiple regression analyses subject to much uncertainty. (See discussion on pp. 13 and 14.)

Significance of Findings

The authors used data from all states and from a 10-year period. The analysis showed a statistically significant effect of helmet laws on motorcycle fatalities. The authors did a good job of explaining their procedures and the reasons for them.

15. Hartunian, Nelson S., Charles N. Smart, Thomas R. Willemain, and Paul L. Zador. "The Economics of Safety Deregulation: Lives and Dollars Lost due to Repeal of Motorcycle Helmet Laws." Journal of Health Politics, Policy and Law, Vol. 8, No. 1, spring 1983, pp. 76-98.

Approach

The authors used monthly fatality data from FARS from 1975 through 1980 (about 25,000 motorcycle fatalities). Using a log-linear modeling approach, they compared fatality trends in states that repealed or limited their helmet laws with those that maintained their laws or had not had universal laws. The number of additional deaths attributed to helmet law changes were estimated by age group and sex. The authors used various procedures to test their estimates for the effects of

regional variations, seasonal riding differences, and annual variations (such as riding increases related to fuel prices).

Cost-to-society estimates were made by age group and sex, using values from various sources for direct costs such as emergency services, hospital care, legal costs, and funeral costs. Lost productivity (earnings) was also estimated using survival, employment, and wage rates by age and sex, plus an estimate of the value of homemaker services.

Principal Findings

What changes in motorcycle fatality rates have been associated with repeal of universal helmet laws or change to limited helmet laws? The authors estimated that 516 deaths in 1980 were attributable to the repeal or change of helmet laws. This was 24 percent of the fatalities in states that changed their laws.

The impact was most noticeable on women, who are most often passengers. The model estimated that 43 percent of their deaths in the repeal states would have been prevented if universal helmet laws had been continued. In general, the impact was greatest on riders aged 20-29.

The authors estimated that the additional deaths in 1980 generated about $5.4 million (1980 dollars) in direct costs and about $171 million in lost productivity.

Limitations of the Data or Analysis

The period studied (1975-80) was somewhat brief for a time series analysis, especially when separate estimates by sex and age group were needed to make the economic loss estimates. While the use of these variables was interesting, they resulted in a number of very small data cells. Our panel felt the authors gave a rather cursory explanation of their modeling approach.

Significance of Findings

The authors used sophisticated statistical techniques to estimate fatality changes, but their explanation of the techniques and the basis for their data adjustments were obscure.

These cost estimates related only to riders who died, leaving out all the costs associated with nonfatal injuries. While the calculation of large social costs due to loss of life is not uncommon, it should be recognized that not all conceptual issues in this approach have been resolved.

16. Hatton, Roger L., P.E. A Study of Motorcycle Accidents in Arizona. Arizona Department of Transportation, Jan. 1987.

Approach

After requiring all motorcycle riders to wear helmets from 1969 through May 27, 1976, Arizona changed its law to apply only to riders under age 18. The author used a simple linear regression to determine the relationship of rider fatalities to registered motorcycles from 1969 through 1976, then projected this experience through 1985 as an estimate of the number of deaths that would have occurred had the helmet law remained unchanged.

Principal Findings

What changes in motorcycle fatality rates have been associated with repeal of a helmet law or change to a limited law? The author estimated that actual rider fatalities over the 9-year period 1977-85 were 289 higher than would have occurred had the helmet law not been repealed. By this calculation, the continuation of the universal helmet law would have reduced fatalities by 30 percent.

Limitations of the Data or Analysis

The data were representative only of Arizona, a sparsely populated state, although the author did note that 80 percent of Arizona's motorcycle accidents occurred in urban areas.

Significance of Findings

The analysis covered a fairly long period, although it did not extend to the period before Arizona enacted its helmet law. The author's calculation assumed that all of the excess deaths were the result of changing the helmet law, although it is possible that other factors contributed.

17. Heilman, Don R., Jonathon B. Weisbuch, Richard W. Blair, and Larry L. Graf. "Motorcycle-Related Trauma and Helmet Usage in North Dakota." Annals of Emergency Medicine, Vol. 11: 12, Dec. 1982, pp. 659-654.

Approach

North Dakota amended its helmet law effective July 1, 1977, to apply only to riders under age 18. The authors used a variety of sources to collect data on motorcycle accidents occuring in North Dakota from 1977 through 1980. Several of these sources were forms specifically required for motorcycle accidents by the state highway department and

the state health department, such as the motorcycle injury reporting forms required of hospitals and physicians, and the highway patrol supplemental motorcycle accident report. Helmet usage was known for 89 percent of the involved cyclists, but helmet use and injury severity were known for 71 percent of the injury cases.

Principal Findings

What levels of helmet use are associated with limited helmet laws? Helmet use by riders involved in accidents declined throughout the 4-year period: 55 percent in 1977, 46 percent in 1978, 28 percent in 1979, and 28 percent in 1980. Among motorcycle drivers aged 17 who were involved in accidents, helmet use declined from 63 percent in 1977 to 44 percent in 1980.

How is helmet use related to fatality and injury severity in motorcycle accidents? Among riders involved in accidents, 63 percent of the helmeted riders were injured compared with 69 percent of the nonhemeted ones. Fatalities per 100 involved riders were 0.8 for helmeted and 2.5 for nonhelmeted riders. Nonfatal critical injuries per 100 involved riders were 0.5 for helmeted and 1.2 for nonhelmeted riders.

Head, neck, or face injury was cited as the cause of death for 82 percent of the nonhelmeted fatalities.

Limitations of the Data or Analysis

North Dakota is a sparsely populated state, so the findings cannot be assumed to be representative of more urban states. It was not clear whether AIS scoring was used for injury severity. Also, since the severity of injury was determined by treating physicians, consistency might be questionable. Unknown helmet use increased in the later years of the study.

This study identified a large number of minor-injury accidents that were not reported to police. Hence, the rates of fatal and critical injury per 100 riders were somewhat lower compared with other studies.

Significance of Findings

Although done in a sparsely populated state, the effort to identify a comprehensive data base of accidents over a 4-year period enhanced the value of this study. Unfortunately, injury severity was not clearly reported in AIS terms nor was the severity of head injury given. The effect of unknown cases on injury severity data was also unclear.

The data indicated deteriorating rates of voluntary helmet use in the years following the change of the law, and also the ineffectiveness of partial helmet requirements based on a rider's age.

18. Hertz, Ellen S. The Effect of Helmet Law Repeal on Motorcycle Fatalities: A Four Year Update. Washington: National Highway Traffic Safety Administration, Sept. 1989.

Approach

The author used FARS data and repeated the regression analysis used by de Wolfe (National Highway Traffic Safety Administration, 1986) to estimate the increase in fatalities per motorcycle accident attributable to repeals of helmet laws, but extended the data base 4 years through 1988. This analysis thus covered the period 1975 through 1988.

Principal Findings

What changes in motorcycle fatality rates have been associated with repeal of universal helmet laws or change to a limited helmet law? The author estimated that states which repealed or limited helmet laws experienced about a 20-percent (95-percent confidence interval: 9 to 31 percent) increase in fatalities per accident compared with states which did not change their laws. This was close to de Wolfe's earlier estimate of about 21 percent (10 to 33 percent). A 20-percent increase would correspond to 17 percent fewer fatalities had the laws not been changed.

Including the states which had not had helmet laws to begin the period, the author used her finding and de Wolfe's to estimate that in the 5-year period, 1984 through 1988, between 2,276 and 2,520 persons lost their lives because of the absence of universal helmet laws.

Limitations of the Data or Analysis

As with de Wolfe's analysis, this study was subject to the vagaries of state accident-reporting practices. This author also failed to acknowledge that repeal of helmet laws can increase the number of reported accidents, which would affect the fatality rate per accident.

Significance of Findings

This study extended the period studied by de Wolfe (although the prerepeal data remained limited). The relatively low estimate of fatality rate increase reflected the author's assumption (with de Wolfe's) that accident frequency does not change when helmet laws are repealed.

19. Hill, Kim Quaile. Motorcycle Helmet Laws and Accidental Deaths and Injuries in Texas. College Station, Texas: Public Administration Research Group, Texas A&M University, May, 1989.

Approach

The author used data from police-reported accident statistics to perform an interrupted time-series analysis focusing on three periods: 1956-67 (before Texas' helmet law took effect), 1968-76 (when Texas required all riders to wear helmets), and 1978-87 (when only riders under 18 were required to wear helmets). Fatality rates per 10,000 registered motorcycles were calculated for all 3 periods, through 1986. Fatality rates per 100 accidents could be calculated for the periods 1969-76 and 1978-87.

The author also calculated injury rates per 1,000 accidents for 1971-76 and 1978-87. (The year 1977 was left out of all calculations because the law changed in mid-year.)

Principal Findings

What changes in motorcycle fatality rates have been associated with enactment of a universal helmet law? Using a linear regression procedure, the authors calculated the death rate before enactment of the helmet law at 10.9 per 10,000 registered motorcycles. This dropped 31 percent to 7.5 per 10,000 when the universal law was in effect.

What changes in motorcycle fatality rates and injury severity have been associated with change from a universal helmet law to a limited law? The calculated death rate per 10,000 registered motorcycles rose to 11.5 in the 9 years following change to a limited helmet law, a level comparable to the rate before the helmet law was adopted. The universal law period rate had been 35 percent lower.

The author also calculated a fatality rate of 1.64 per 100 motorcycle accidents during the universal law period, which was 41 percent lower than the rate of 2.76 in the following 10 years. The author estimated that continuation of the law would have saved 1,420 to 1,450 lives from 1978 through 1988.

Injuries per 1,000 reported accidents were 16.6 percent lower under the universal law compared with the period afterward. No data on injury severity were presented.

Limitations of the Data or Analysis

The author did not discuss any changes that may have occurred in registration definitions or accident-reporting practices, which can affect time series analyses such as these.

The author did a good job of providing standard errors and tests of significance for the findings. She did not, however, report the raw data on which the death rates were calculated, and the procedures were somewhat unclear.

Significance of Findings

This analysis covered 31 years, and was the longest time series we reviewed. Although done in a single state, Texas is a large and varied study area. All the calculated effects met tests of statistical significance. The clear discontinuities in fatality rates coinciding with law changes were evident when the data were presented graphically. There was also a similarity in the fatality rate changes when calculated with alternative exposure measures: registered motorcycles and accidents.

20. Hurt, H.H., Jr., J.V. Ouellet, and D.R. Thom. Motorcycle Accident Cause Factors and Identification of Countermeasures, Vol. I: Technical Report. Los Angeles: University of Southern California Traffic Safety Center, 1981. (Sponsored by the National Highway Traffic Safety Administration, Wash., D.C.)

Approach

A multidisciplinary team conducted in-depth investigations of 900 accidents in Los Angeles in 1976 and 1977. Accidents were identified primarily by monitoring the ambulance communications of the Los Angeles Fire Department. Notifications were also received from telephone operators at the Los Angeles Police Department. The coroner's office was called daily to identify motorcycle fatalities. For comparison purposes, police accident reports were collected and compared with the investigated accidents.

Injured riders were interviewed whenever possible, and two pathologists working for the project consulted medical records and attending physicians to evaluate injuries. Autopsy reports were obtained for all fatalities.

Of the 900 accidents investigated, a stratified random sample of 505 sites was revisited 2 years later at the same time and on the same day to

observe motorcycle traffic for 1 hour. Riders were interviewed or sent questionnaires.

Principal Findings

What levels of helmet use are associated with no helmet law? Helmet use was recorded for 2,168 motorcycle drivers observed and 410 passengers. Fifty-two percent of the drivers and 32 percent of the passengers wore helemets. Combined usage was 49 percent.

Of the drivers for whom age was determined, helmet use increased significantly with age. Helmet use was also higher among better educated drivers, white collar drivers, and more experienced drivers.

Are helmet users or nonusers overrepresented among motorcycle accident victims? While 48 percent of the drivers observed passing accident scenes were nonhelmeted, 60 percent of the drivers in the accidents were nonhelmeted. However, the comparabilty of the observation and accident data is questionable, given the 2-year lag before observations were made.

Does helmet use degrade a rider's ability to avoid accidents? Investigators found no cases where accidents were partially attributable to a motorcycle driver's fatigue, failure to hear traffic sounds, or restricted field of vision.

How is helmet use related to fatality and injury severity in motorcycle accidents? Nonhelmeted drivers and passengers accounted for 78 percent of all fatalities, and 59 percent of these nonhelmeted riders suffered critical or fatal head injuries.

Among injured riders, 3.2 percent of the helmeted and 7.1 percent of the nonhelmeted ones died. Nonfatal critical injuries were suffered by 1.1 percent of the helmeted and 1.9 percent of the nonhelmeted riders. Serious injuries were suffered by 6.7 percent of the helmeted and 4.7 percent of the nonhelmeted riders.

Head injuries were prominent among accident victims, second only to the extremities (arms and legs) as regions of the most severe injury. Among helmeted drivers, 3.8 percent suffered severe or worse head injuries, compared with 10.8 percent of the nonhelmeted drivers. Severe or worse neck injuries were suffered by 1.2 percent of the helmeted drivers compared with 2.1 percent of the nonhelmeted drivers.

The authors reviewed the cases of the nine critical and fatal neck injuries in the study (three helmeted, six nonhelmeted) and concluded that helmet use or nonuse was unrelated to the severity of the injuries. The authors were able to identify only four cases of minor face or neck injury attributable to helmets, and in all cases, the helmets appeared to have prevented severe or worse head injury.

Limitations of the Data or Analysis

The data represented urban Los Angeles and may differ from conditions in other cities or more rural settings. The accidents investigated represented about 20 percent of all accidents reported in Los Angeles during the 2 years. Selection was based on the project team's ability to identify and respond to accidents. The heavy reliance on ambulance dispatch communications appears to have left the bulk of the noninjury accidents out of the sample. The authors compared their sample with 3,600 accident reports collected from police departments, and found a close correlation for such factors as the time of day, day of week, number of vehicles involved, and driver responsible.

The 2-year delay in the collection of the observational data diminished their value for comparison to accident data. Although estimates of speed and alcohol use were made, they were not used as control variables with helmet use.

Significance of Findings

Accident investigation was very thorough and the study population relatively large. However, noninjury accidents were largely left out, and the authors generally did not do tests of significance on their data.

There was no evidence that helmets increase the likelihood of having an accident. Nonhelmeted riders were overrepresented among accident victims, and substantially overrepresented among critically and fatally injured riders. The study demonstrated that nonhelmeted riders are more vulnerable to severe or worse head injuries, while being no more vulnerable to severe neck injuries. In general, severe neck injuries were relatively rare in the accidents investigated.

21. Kelly, Patrick, MD, Tracy Sanson, MD, Gary Strange, MD, and Elizabeth Orsay, MD. "A Prospective Study of the Impact of Helmet Usage on Motorcycle Trauma." Chicago: University of Illinois Affiliated Hospitals Emergency Medicine Residency, 1989.

Approach

From April through October 1988, the research team followed motorcycle riders brought to eight Illinois hospitals serving urban, suburban, and rural areas. Injury Severity Scores (ISS) were computed for each, and cost data were compiled for emergency room charges, inpatient services, and rehabilitation services.

Principal Findings

How is helmet use related to fatality rates and injury severity in motorcycle accidents? Nonhelmeted riders predominated: they were 85 percent of the 398 riders brought to the hospitals and 96 percent of those who died.

Although a higher proportion of the helmeted riders were traveling over 40 miles per hour, 9 percent had severe or worse injuries compared with 18 percent of the nonhelmeted riders.

There was a 24-percent incidence of head and neck injury among helmeted riders compared with a 42-percent incidence among nonhelmeted riders.

How do hospital admission rates compare for helmeted and nonhelmeted riders involved in accidents? Ambulance transport was required for 46 percent of the helmeted riders compared with 63 percent of the nonhelmeted riders. Hospital admission rates were 33 percent for helmeted and 40 percent for nonhelmeted riders.

How do initial hospitalization costs compare for helmeted and nonhelmeted riders involved in accidents? The average costs to care for nonhelmeted riders were 23 percent higher than for helmeted riders, but the sampling error was too large for this to be statisically significant.

How is helmet use related to the need for care and services after the period of initial hospitalization? Of seven patients transferred to long-term care facilities, six were nonhelmeted. This was comparable to the overall breakdown of helmeted and nonhelmeted riders.

How much of the hospital costs of nonhelmeted injured motorcyclists is paid by insurance? Insurance payment was available for 44 percent of the nonhelmeted riders and 56 percent of the helmeted riders. The amount paid was not reported.

Limitations of the Data or Analysis

The study population represented injured riders seen at these eight hospitals. No indication was given of the number of riders excluded for the lack of helmet use information.

Illinois is a state which has gone more than 20 years without a helmet law, and this seems to be reflected in the low level of helmet use. The small number of helmeted riders in the sample made the differences fail most statistical tests of significance (there was only one helmeted fatality, for example).

Significance of Findings

Although the authors attempted to achieve a diverse sample by using eight hospitals, the predominance of nonhelmeted riders reduced the value of comparisons. The prospective nature of the study probably enhanced data consistency. Helmeted riders appeared to be underrepresented among the accident victims, perhaps because they are less likely to be injured in low-speed accidents.

The cost figures cited in the study did not include physician fees beyond the emergency rooms, and did not include any long-term costs other than hospital-based rehabilitation. Significant additional costs could be expected for the most seriously injured riders.

22. Kim, Karl E. PhD, and Mark R. Willey. Motorcycle Safety in Hawaii. University of Hawaii at Manoa: Department of Urban and Regional Planning, 1990.

Approach

The authors compiled data from Hawaii's motor vehicle accident and registration statistics from 1962 through 1987. They also carried out a telephone survey of motorcycle operators. However, because of the unrepresentative nature of the sample and survey design weaknesses, the survey results are not summarized here.

Principal Findings

How is helmet use related to the likelihood of having an accident?

Hawaii's universal helmet law was in effect from May 1968 through June 1977. In the 3 years following repeal, Hawaii experienced a 37-percent increase in motorcycle accidents per 10,000 registered motorcycles, compared with the accident rate during the last 3 years before repeal. Comparison to earlier years was not made because of changes in accident reporting.

What changes in motorcycle fatality rates have been associated with enactment and repeal of universal helmet laws? The periods 1962-67 (before helmet law enactment) and 1978-87 (after change to a law applying only to riders under age 18) were remarkably similar in fatalities per 10,000 registered motorcycles (13.1 and 14.5). While the universal helmet law was in effect, annual fatalities per 10,000 registrations (5.5) were 58 percent lower than before the law and 62 percent lower than during the post-law period.

Limitations of the Data or Analysis

Hawaii is a small state, and the number of fatalities never exceeded 23 in a single year. Only 51 fatalities occurred throughout the entire period the universal helmet law was in effect. Some discontinuities occurred during the period in the recording of accident and registration data.

Significance of Findings

The small numbers involved limited the significance of the percentages noted. However, an interrupted time series such as this which produces two very similar nonlaw periods, both clearly different from the period the law was in effect, is evidence that a helmet law substantially reduces fatality rates.

23. Krane, S.W. and L.A. Winterfield. Impact of Motorcycle Helmet Usage in Colorado: A Three Year Study. Denver: Colorado Division of Highway Safety, 1980. (Sponsored by the National Highway Traffic Safety Admin., Wash., D.C.)

Approach

From July through September 1976, while Colorado's helmet law was still in effect, and for the same periods in 1977 and 1978 after the law was repealed, accident data were collected from reports by the Colorado State Patrol and the police departments of Denver, Boulder, Fort Collins, and Grand Junction. About 80 percent of Colorado's motorcycle accidents were covered by this procedure. For the 1978 period, data were not collected on the majority of noninjury accidents. Medical records were analyzed by a professor of surgery who was chairman of the Colorado Committee on Trauma. He assigned AIS scores to the three most severe injuries of each rider.

Helmet use was observed during the 3 periods at 97 urban and rural locations in 1976, 95 locations in 1977, and 78 locations in 1978. Altogether, nearly 60,000 drivers and passengers were observed.

Principal Findings

What levels of helmet use are associated with universal helmet laws and no helmet law? Observed helmet use by drivers declined from virtually 100 percent to 57 and 49 percent in the 2 years following repeal of the law. Observed use by passengers declined from 99 percent to 63 and 53 percent. The biggest declines were in urban areas, while use on rural freeways remained relatively high. Use also declined much more rapidly among Colorado riders than among out-of-state riders. Among riders injured in accidents, reported helmet use declined from 93 percent before repeal to 37 percent after repeal.

How is helmet use related to the likelihood of having an accident? In the specific areas studied, the number of motorcycle accidents increased 48 percent in the period following repeal of the helmet law. This may have been partly due to increased rider activity in 1977, as suggested by the roadside observation part of the study.

What changes in fatality rates and injury severity have been associated with repeal of universal helmet laws? From the author's compilation of Colorado historical statistics, we calculated that while the helmet law was in effect, fatalities per 10,000 registered motorcycles averaged 4.71, compared with 6.18 before the law took effect and 6.08 in the 2 years following repeal.

Helmet use was known for 95 percent of the riders involved in accidents in 1976 and 97 percent in 1977. Among these riders, 57 percent were injured in 1976 compared with 62 percent in 1977. Severe injuries increased from 8.1 to 11 percent of involved riders, serious injuries from 2.3 to 3.7 percent, nonfatal critical injuries from 0.4 to 1.9 percent, and fatalities from 1.4 to 2.3 percent.

Among injured riders, injury severity increased significantly after the helmet law was repealed. Fatalities increased from 2.6 percent in 1976 to 3.7 percent in 1977 and 4.9 percent in 1978. Severe injuries increased from 14.3 percent in 1976 to 17.8 percent in 1977 and 19.4 percent in 1978, serious injuries from 4.1 to 6.0 and 6.4 percent, and nonfatal critical injuries from 0.8 to 3.1 and 2.6 percent.

How is helmet use related to fatality and severe injury in motorcycle accidents? Only the 1977 data were suitable for calculating the following comparisons. Among riders involved in accidents, 58 percent of the helmeted riders were reported injured compared with 64 percent of the nonhelmeted riders. The injury severity breakdown among involved helmeted riders (using overall AIS scores) was as follows: 10 percent

severe, 3.2 percent serious, 1 percent nonfatal critical, and 1.2 percent fatal. Among nonhelmeted riders, the breakdown was: 11.7 percent severe, 4.1 percent serious, 2.5 percent nonfatal critical, and 3 percent fatal.

Considering only injured riders, the injury severity breakdown was as follows: for helmeted riders, 17.1 percent severe, 5.4 percent serious, 1.7 percent nonfatal critical, and 2.1 percent fatal; for nonhelmeted riders, 18.2 percent severe, 6.3 percent serious, 3.9 percent nonfatal critical, and 4.6 percent fatal. Among injured riders, 3.3 percent of the helmeted suffered severe or worse head injuries compared with 16.1 percent of the nonhelmeted riders. Severe or worse neck injuries were suffered by 0.8 percent of the helmeted and 1.2 percent of the nonhelmeted riders.

The authors compared injury severity for six different speed intervals, but only the 1977 data were meaningful. While helmeted riders overall were traveling somewhat faster than nonhelmeted riders, they had a lower probability of severe or worse injury at virtually all speed levels. The differences were dramatic below 15 and above 45 miles per hour. Among riders traveling faster than 45 mph, 1.4 percent of the helmeted and 5.4 percent of the nonhelmeted riders were killed.

Limitations of the Data or Analysis

The representativeness of the observational data was doubtful, since it was conducted in daylight only and appeared to underrepresent urban areas, which had lower helmet use.

Large amounts of missing data on noninjury accidents limited the usefulness of the 1978 injury data for helmet/no helmet comparisons.

The availability of only 3 years for a time series analysis limits its value, especially in a state where climate can cause annual fluctuations in the riding season.

Significance of Findings

Although limited to a single state and three riding seasons, it represented a very considerable effort to link accident reports with medical records, and few injury cases were left with missing data. The findings of injury severity were consistent whether based on reported accidents or injured riders. The increased rates of severe, serious, critical, and fatal injuries were associated with increased rates of head injury.

The study lent no support to the contention that helmet use increases the risk of severe neck injury, or the risk of having an accident.

24. Lloyd, Linda E., Mary M. Lauderdale, Lorrie J. Laing, Stella Wang, Cindy Knox, Kenneth W. Holt, and Philip L. Graitcer. A Comparison of Helmeted and Unhelmeted Motorcyclists Admitted to a Community Trauma Center. Austin: Texas Department of Health, 1987.

Approach

The authors used the trauma registry of Brackinridge Hospital in Austin, Texas, to identify 255 motorcycle drivers and passengers treated for injuries between February 1985 and August 1986. They examined medical records to determine injury severity scores for each patient's three most severe injuries, and hospital records to determine the costs of initial hospitalization. An effort was made to link the victims to accident reports on file at the Texas Department of Public Safety. Reports were found for 81 percent of the cases.

Principal Findings

How is helmet use related to fatality and severe injury in motorcycle accidents? Helmet use was known for 202 of the 255 victims, and 70 percent were nonhelmeted. The nonhelmeted riders accounted for 82 percent of the fatalities and 80 percent of the severe or critical head injuries.

While 14 percent of the helmeted riders had severe or worse head injuries, 26 percent of the nonhelmeted riders had such injuries. Eight percent of the helmeted victims died, compared with 16 percent of the nonhelmeted victims. (The study did not include victims dead at the scene who were not transported to the hospital.)

How do initial hospitalization costs compare for helmeted and nonhelmeted riders involved in accidents? Hospital charge data were available for 95 percent of those for whom helmet use was known. Even though 13 nonhelmeted riders died in the hospital (compared with 2 helmeted riders), nonhelmeted riders averaged 3 days longer in the hospital and incurred an average of $12,032 in hospital bills, compared with $9,032 for helmeted riders.

How much of the hospital costs of nonhelmeted injured motorcyclists is paid by insurance? In total, hospital charges exceeded $2 million. Riders with no health insurance incurred $734,000 in bills, of which 82 percent

was for nonhelmeted riders. Forty-five percent of the nonhelmeted riders lacked hospital insurance, compared with 23 percent of the helmeted riders.

Is helmet use or nonuse associated with high-risk riding behavior? On the basis of accident reports, nonhelmeted riders more often contributed to the accidents than helmeted riders. Although excessive speed was more often noted for helmeted riders, alcohol consumption was cited as a contributing factor for 28 percent of the nonhelmeted drivers' accidents, compared with 8 percent for helmeted drivers.

Limitations of the Data or Analysis

The scope of the study is small: a single trauma center in a small city. Only injured riders are represented, and possibly the more seriously injured, since this was a level I trauma center. It was unclear whether only riders admitted as inpatients were analyzed or whether the data included riders treated and released.

Significance of Findings

The scope was very limited and somewhat confusing. The study suggested that in states without universal helmet laws, nonhelmeted riders consume a disproportionate share of public resources for medical care. This study addressed only initial hospital costs, and did not attempt to capture such longer term costs as outpatient care, rehabilitation, sick leave, or disability benefits.

25. Lummis, Michael L. and Christopher Dugger. Impact of the Repeal of the Kansas Motorcycle Helmet Law: 1975-78. University of Kansas College of Health Sciences, 1980. (Sponsored by the National Highway Traffic Safety Admin., Wash., D.C.)

Approach

Kansas repealed its helmet law on July 1, 1976. This study collected data from motorcycle accident reports for the periods of July through September 1975, 1976, 1977, and 1978. The areas covered were the counties including and surrounding Kansas City, Topeka, and Wichita. Emergency room logs were also reviewed to identify unreported accident victims. The area was 90-percent urban and accounted for about 33 percent of the registered motorcycles in Kansas. Medical records were analyzed by paramedics trained and assisted by two surgeons. They assigned AIS scores to the three most severe injuries of each rider.

Principal Findings

How is helmet use related to the likelihood of having a motorcycle accident? Despite a decline in motorcycle registrations, the number of reported motorcycle accidents in the 3 study periods following repeal of the helmet law averaged 15 percent more than in the 1975 period. Statewide statistics also indicated that reported accidents per 10,000 registrations increased after the helmet law was repealed.

What changes in fatality rates and injury severity have been associated with repeal of universal helmet laws? From the author's compilation of Kansas statistics, we calculated that while the helmet law was in effect, fatalities per 10,000 registered motorcycles averaged 3.97, compared with 6.39 before the law took effect and 6.49 in the 2 years following repeal.

In the specific areas studied, 36 percent of the riders involved in reported accidents were injured in 1975, compared with 44 percent in the following 3 years. The fatality rate per 100 involved riders rose from 1.5 to 2.1 percent.

Injury severity data for 1977 and 1978 were not comparable to the previous two study periods because of large amounts of missing data. Severe injuries (AIS score of most severe injury) increased from 7.5 percent of the involved riders in 1975 to 8.4 percent in 1976, serious injuries from 0.9 to 1.8 percent, nonfatal critical injuries from zero to 0.3 percent and fatalities from 1.7 to 3.1 percent.

Among injured riders, fatalities increased from 4.4 percent in 1975 to 6.3 in 1976. Severe injuries decreased from 19.1 to 17.4 percent, but serious injuries rose from 2.2 to 3.7 percent, and nonfatal critical injuries from zero to 0.5 percent.

How is helmet use related to fatality and injury severity in motorcycle accidents? Most of the 1977 and 1978 data were not reliable because helmet use data were missing for nearly 50 percent of the riders involved in accidents. Helmet use was known for all fatalities, however. Nonhelmeted riders accounted for 82 percent of the fatalities in the 3 years following repeal.

In 1976, for which 84 percent of helmet use was known, 44 percent of the helmeted riders involved in accidents were reported injured compared with 52 percent of the nonhelmeted riders. Injury severity among involved riders (AIS scores for most severe injury) was as follows: for helmeted riders, 11 percent severe, 1.8 percent serious, zero percent

nonfatal critical, and 1.2 percent fatal; for nonhelmeted riders, 6.6 percent severe, 1.8 percent serious, 0.4 percent nonfatal critical, and 4.4 percent fatal.

Among injured riders, severity was as follows: for helmeted riders, 25 percent severe, 4.2 percent serious, zero percent nonfatal critical, and 2.8 percent fatal; for nonhelmeted riders, 12.7 percent severe, 3.4 percent serious, 0.8 percent nonfatal critical, and 8.5 percent fatal. Severe or worse head injuries were suffered by 13 percent of the nonhelmeted and 6 percent of the helmeted riders, while 8 percent of the nonhelmeted and none of the helmeted riders received severe or worse neck injuries.

Limitations of the Data or Analysis

Although the authors presented data from 1977 and 1978 that were similar to the 1976 data, we did not use the injury severity data because too many cases were missing. Helmet use data were not consistently reported in 1977 and 1978, and the authors excluded from most of their data tables all riders for whom helmet use was not known.

It would have been preferable for physicians to assign the AIS scores rather than paramedics.

The data largely reflected urban traffic conditions and so probably underrepresented high-speed crashes. The numbers were also somewhat small for representing trends, especially the fatalities (32 in 4 years).

Significance of Findings

The data from Kansas statistics and the comparison of prerepeal and post-repeal study periods were more useful than the helmet/nonhelmet comparisons. The latter were hindered by the large amounts of missing data, so that only the 1976 period (391 riders) could be used.

26. Luna, G.K., MD, M.K. Kopass, MD, M.R. Oreskovich, MD, and C.J. Carrico, MD. "The Role of Helmets in Reducing Head Injuries From Motorcycle Accidents: A Political or Medical Issue? Western Journal of Medicine, Vol. 135, Aug. 1981, pp. 89-92.

Approach

The authors reviewed the emergency room records of all 311 motorcycle accident victims seen at the Harborview Medical Center in Seattle during a 17-month period in 1978 and 1979. They assigned AIS scores to all injuries.

Principal Findings

How is helmet use related to fatality and injury severity in motorcycle accidents? Helmet use was known for 85 percent of the victims. Of those for whom helmet use was known, nonhelmeted riders were 62 percent of those seen at the hospital, 73 percent of those who died, and 82 percent of those with severe head injuries. Among helmeted riders, 11 percent had severe or worse head injuries, compared with 31 percent of the nonhelmeted riders. Of the 19 riders who died, 18 had a major head injury. There were five riders with cervical spine (neck) injuries, of whom four were not wearing helmets.

How do hospital admission rates compare for helmeted and nonhelmeted riders? Among the riders brought to the emergency room, 59 percent of the nonhelmeted riders required admission for inpatient care, compared with 47 percent of the helmeted ones.

Limitations of the Data or Analysis

The study population represented the injured riders seen at a major trauma center, not all accident-involved riders. The numbers were too small for a comparison of fatality rates.

Significance of Findings

The scope involved a single trauma center, which could be expected to receive the more seriously injured riders. The study showed the vulnerability of nonhelmeted riders to disabling and fatal head injuries. The study did not support the contention that helmeted riders are vulnerable to severe neck injury.

27. Lund, Adrian K., Allan F. Williams, and Katie N. Womack. Motorcycle Helmet Use in Texas. Arlington, Va.: Insurance Institute for Highway Safety, 1989.

Approach

Texas restored its helmet law for all riders on September 1, 1989, after 12 years of requiring use only by riders under age 18. In this study, a series of observational surveys of helmet use were made at 6-month intervals from June 1987 to June 1989, and in August, September, and November 1989. The surveys were done in 18 Texas cities, 12 sites in each city.

Principal Findings

What levels of helmet use are associated with limited helmet laws and universal helmet laws? Because the data prior to August 1989 included

moped and scooter riders, we have not cited those data. The level of observed helmet usage by motorcyclists in August 1989 was 42 percent. In September 1989, it jumped to 90 percent and in November to 97 percent, with a combined percentage of 93. Driver usage was higher than passenger usage in all periods.

Limitations of the Data or Analysis

Observations were not done in rural areas, where usage has generally been observed to be higher. The sampling procedure was designed to obtain seat belt observations, with motorcycle observation being a secondary activity. September 1989 could be considered as a transition month when some cyclists may not yet have obtained a helmet.

Significance of Findings

In general, the authors did a reasonable job of detailing their study methods. The study showed an immediate rise in helmet use, approaching universal compliance when the law was reenacted.

28. McHugh, Terrance P., MD, and James I. Raymond, MD. "Safety Helmet Repeal and Motorcycle Fatalities in South Carolina." The Journal of the South Carolina Medical Association, Nov. 1985, pp. 588-590.

Approach

South Carolina's universal helmet law became effective in 1968. On June 17, 1980, the universal law was changed to a limited law which required motorcyclists only under the age of 21 to wear helmets. To examine the effects of this law change, motorcycle accident statistics from 1965 through 1984 were obtained from the Highway Safety Division of the South Carolina Department of Highways and Public Transportation. During this 20-year period, there was a total of 28,045 reported motorcycle accidents and 820 reported deaths.

What changes in motorcycle fatality rates have been associated with the enactment of a universal helmet law? From data compiled by the authors, we calculated that before the mandatory helmet law was in effect (1965-67), the death rate was 14.9 per 10,000 registered motorcycles. While the mandatory helmet law was in effect (1968-79), this rate dropped 20 percent to 11.9.

What changes in motorcycle fatality rates have been associated with the change from a universal helmet law to a limited law? The law period

fatality rate of 11.9 was 36 percent lower than the 18.6-rate during the first 4 years of the limited law (1981-84).

How does helmet use affect the likelihood of having an accident? Although the number of motorcycle registrations remained about the same after repeal of the helmet law, the number of reported accidents increased substantially.

Limitations of the Data or Analysis

The helmet law was enacted in 1967, and may have affected the fatality rate that year, although it was not enforced until 1968. The authors did not disclose whether any changes in registration procedures or accident reporting occurred that might have affected the rates. In general, they gave little explanation of their data sources.

Significance of Findings

The authors presented data but did little analysis. The data alone were interesting. The period of the helmet law was clearly different from both the previous and following periods, strongly suggesting that the law was responsible for lower fatality rates.

29. McLoughlin, Elizabeth, ScD, and Patrick Romano, MD. Final Report: Fatal Injuries to California Motorcyclists, 1987. San Francisco: UCSF Injury Center for Research and Prevention, 1990. (Sponsored by the California Highway Patrol.)

Approach

The authors merged data from FARS with data from death certificates in an attempt to identify the injuries contributing to the deaths of motorcycle riders in California in 1987. A match was obtained for 745 of the 754 riders identified by FARS.

Principal Findings

How is helmet use related to fatality and injury severity in motorcycle accidents? Of those for whom helmet use was known, 72 percent of these fatally injured riders were nonhelmeted. Head injuries were the most frequently reported injury, and nonhelmeted riders were nearly twice as likely to sustain a head injury as helmeted riders.

Is helmet use or nonuse associated with high-risk riding behavior? The nonuse of helmets was associated with riders under age 21 and riders

over age 30, alcohol consumption, prior traffic violations, and riding a Harley-Davidson motorcycle.

Limitations of the Data or Analysis

The data on injuries were dependent on death certificates from throughout California, and thus were susceptible to varying quality of input. Not all coroners are physicians, and autopsies are not always performed. About 39 percent of the certificates did not specify injury locations, and helmet use data were missing for 37 percent of the riders.

Significance of Findings

Although the study population was quite large and included all fatalities in California, the problems of data quality and missing data reduced the value of the analysis. No fatality rates for helmeted and nonhelmeted riders could be derived from this study. Basically, it demonstrated that head injuries are an important cause of fatality among nonhelmeted riders.

30. McSwain, Norman E., Jr., MD, and Anita Belles Willey. Impact of the Re-Enactment of the Motorcycle Helmet Law in Louisiana. New Orleans: Tulane University School of Medicine, 1984. Sponsored by the National Highway Traffic Safety Admin., Wash, D.C.)

Approach

Louisiana had a universal helmet law from 1968 to 1976, then limited it to riders under age 18 from 1976 through 1981. Effective January 1, 1982, Louisiana was the first state to reinstate a universal helmet requirement. The authors used statewide fatal accident reports and coroners' reports to assess the effect of reenactment on motorcycle fatalities. They conducted roadside observational surveys in 1982 in the areas of New Orleans, Lake Charles, and Baton Rouge to determine compliance with the law. They also collected accident reports from the three areas for the periods June-September 1981 and June-September 1982.

Principal Findings

What levels of helmet use are associated with universal helmet laws and limited helmet laws? The observational surveys found helmet use after reenactment ranging from 90 percent in New Orleans to 100 percent in Baton Rouge. Overall, 96 percent of the 1,465 riders observed were wearing helmets.

Accident victims in the three study areas showed an increase in helmet usage from 1981 to 1982 (47 to 74 percent) but did not reflect the high level of usage observed in the general rider population.

What changes in motorcycle fatality rates and injury severity have been associated with enactment of a universal helmet law from a limited law? In the areas studied, accidents increased by 13 percent from 1981 to 1982, but injuries declined by 4 percent and the number of fatalities from 12 to 4.

An analysis of death certificates statewide indicated that head injuries as the primary cause of death declined from 69 percent in 1981 to 49 percent in 1982.

Various data were reported from the three study areas regarding injury severity and hospital costs. However, a large majority of the accident victims were missing from these analyses, and no explanation was given for the missing data or its possible effect on the results.

Limitations of the Data or Analysis

Inconsistencies in data presentation throughout this study made interpretation difficult. The use of a single year before and a single year after reenactment limited the significance of the declines noted because annual fluctuations can affect variables such as fatalities and injuries.

Since coroners' reports do not always involve autopsies, they may not always be reliable regarding the cause of death.

Significance of Findings

This was the only study available of the impact of reenacting a helmet law, but the period available for study was very limited. Injuries and fatalities declined when the helmet law was reenacted. The remaining nonusers of helmets appeared to be overrepresented among accident victims. Unfortunately, the data regarding injury severity and cost could not be used because of the magnitude of missing data and lack of explanation.

31. Mortimer, Rudolf G. and Elaine Petrucelli. "Costs of Hospitalization of Injured Motorcyclists in Illinois: Public Policy Implications." Proceedings of the American Association for Automotive Medicine, 1984, pp. 225-235.

Approach

The authors examined the hospital records of 331 motorcycle riders brought to regional trauma centers in Chicago, Urbana, and Springfield, Illinois, in 1981 and 1982. Information was noted on the injury location, length of hospital stay, disposition, charges (not including surgeon and physician charges), and source of payment. For unexplained reasons, only 43 cases were identified from Chicago. Helmet use by injured riders was not known.

Principal Findings

How do initial hospital costs compare for helmeted and nonhelmeted riders involved in accidents? Although helmet use was not known, the authors found that riders without head injuries averaged 27 percent lower hospital costs than riders with head injuries.

How much of the hospital costs of nonhelmeted injured motorcyclists is paid by insurance, by public sources? Again, helmet use was not known. Overall, 63 percent of the charges were paid by insurance, 25 percent by public aid funds, and 12 percent by individuals.

Limitations of the Data or Analysis

The process of identifying cases was not explained, and no indication was given of how many cases were missing. Apparently, a significant number of cases were not identified at the Chicago hospital. Also, since these were all trauma centers, one would expect that they would receive the more seriously injured accident victims rather than a random sample.

Significance of Findings

Without helmet use data, the study was not of much assistance in addressing our issue questions. However, it did indicate that head injuries were expensive injuries to treat. This might have been even more evident if data on surgeon and physician costs had been collected. Also, no data were available on long-term costs for medical care and income support.

32. Muller, Andreas. "Evaluation of the Costs and Benefits of Motorcycle Helmet Laws." American Journal of Public Health, Vol. 70, No. 6, June 1980, pp. 586-592.

Approach

The author did a cost-benefit calculation by combining data from studies done in Colorado, South Dakota, and Oklahoma when those states

repealed or restricted their helmet laws. From these, he estimated the (1) rider involvement in accidents per 100,000 registered motorcycles and (2) distribution of injury severity for helmeted riders versus nonhelmeted riders and for prerepeal versus post-repeal conditions. To estimate costs and benefits, the author used industry data on average helmet costs and a study of automobile accidents to assign medical and rehabilitation costs to each level of injury severity.

Principal Findings

What are the costs to society of nonuse of helmets? The author estimated that universal helmet use would result in savings of medical and rehabilitation expenditures that would exceed the cost of the helmets by $61 million per year (1979 prices), compared with no helmet use. For the 28 states that repealed or restricted their helmet laws from 1976 through 1980, the author estimated increased medical and rehabilitation costs of $28 million per year, exceeding savings on helmet purchases by $16 million to $18 million (1979 prices).

Limitations of the Data or Analysis

The author's assumptions of injury severity are based on very limited data derived from three rural states. The use of medical cost estimates based on injuries suffered in automobile accidents may understate costs, since unhelmeted motorcyclists suffer a high incidence of head injuries, which are among the most expensive to treat.

Significance of Findings

As the author acknowedged, the analysis does not include potentially significant costs for lost work, long-term custodial care, and income replacement. The author's decision to offset medical cost savings by the cost of helmets was questionable. From society's point of view, the nonuse of helmets results in costs to care for injured riders, reduced only by out-pocket-payments by riders or their families.

33. Peterson, Tim, MD, and Kim Royer. Iowa Cycle Injury Study. Des Moines: Iowa Methodist Medical Center, Dec. 1989. (Sponsored by Iowa Governor's Traffic Safety Bureau.)

Approach

Emergency room personnel at 8 hospitals throughout Iowa recorded accident, injury, and cost data on 268 motorcyclists who came or were brought to the hospitals from April through September 1989. Riders were included only if helmet use could be determined from interviewing

the rider, ambulance staff, or investigating officers. The study coordinator, a registered nurse, used the descriptive injury data to assign AIS scores.

Principal Findings

How is helmet use related to injury severity in motorcycle accidents? Nonhelmeted riders had a higher average ISS than helmeted riders. This was especially true at accident speeds under 20 mph and over 40 mph. Injury severity was comparable at speeds of 20-40 mph.

Among injured riders with known helmet data, injury severity was as follows: for helmeted riders, 1.6 percent fatal, zero percent nonfatal critical, 1.7 percent serious, and 15 percent severe; for nonhelmeted riders, 3.4 percent fatal, 3.9 percent nonfatal critical, 1.9 percent serious, and 13 percent severe.

Head injuries accounted for nearly all of the critical and fatal injuries. Severe or worse head injuries were suffered by 15 percent of the nonhelmeted and 3 percent of the helmeted riders. None of these accident victims suffered neck injuries.

How do hospital admission rates compare for helmeted and nonhelmeted riders involved in accidents? Seventy-two percent of the helmeted riders were treated at the emergency room and released, compared with 62 percent of the nonhelmeted riders. The remaining were hospitalized, except for 3.4 percent of the nonhelmeted and 1.6 percent of the helmeted riders who died in the emergency room.

How do initial hospitalization costs compare for helmeted and nonhelmeted riders involved in accidents? Among those admitted, nonhelmeted riders averaged 12.6 days in hospitals compared with 6.9 days for helmeted riders. The average hospital charge for nonhelmeted riders (admitted or not) was $3,368, compared with $2,438 for helmeted riders. These charges did not include physician and surgeon fees.

How is helmet use related to the need for care and services after the initial period of hospitalization? Permanent disability was suffered by 6.7 percent of the nonhelmeted riders compared with 1.6 percent of the helmeted riders. A higher percentage of the helmeted riders suffered temporary disability than nonhelmeted riders. No data were given on the costs of rehabilitation or long-term care.

How much of the hospital costs of nonhelmeted injured motorcyclists is paid by insurance? Fifty-five percent of the nonhelmeted riders were covered by insurance, compared with 75 percent of the helmeted riders. Costs were not broken down by insurance coverage.

Limitations of the Data or Analysis

One of the hospitals was a major trauma center, but the character of the other facilities was not reported. It was thus impossible to know whether the population studied was representative of all injured riders or only the more severely injured. The group did include a large percentage with minor or moderate injuries.

No data were given on the number of victims not included because of unknown helmet status. The study population was small and included only 61 helmeted riders. About 20 percent of the accidents occurred off-road, and it was not possible to tell how these affected the data.

Significance of Findings

The small size of the study group and uncertainties about what it represented prevented us from giving more weight to the results. However, the study provided further confirmation that nonhelmeted riders are more likely to be injured, hospitalized, and permanently disabled. Their vulnerabilty to head injury was almost entirely responsible for this difference, especially since their average speed was only slightly higher than that of the helmeted riders.

34. Rivara, Frederick P., MD, Barbara G. Dicker, Abraham B. Bergman, MD, Ralph Dacey, MD, and Clifford Herman, MD. Motorcycle Injuries: What Are the Costs and Who Pays? Seattle: Harborview Injury Prevention and Research Center, unpublished.

Approach

The authors reviewed medical records of all injured motorcyclists admitted in 1985 to the Harborview Medical Center, a level I trauma center in Seattle, Washington. AIS scores were assigned as well as ISS, a calculation of overall severity. Glasgow Coma Scores assigned by the treating physicians for head injuries were also noted. Medical charges were obtained from the hospital and physician group. Follow-up rehabilitation costs were from providers, and state personnel searched the records of Medicaid, Vocational Rehabilitation, Supplemental Security Income, and Aid to Families with Dependent Children.

Principal Findings

How do initial hospitalization costs compare for helmeted and nonhelmeted riders involved in accidents? This study did not distinguish helmeted from nonhelmeted riders. Complete financial information was available for 105 of the 111 riders brought to the hospital. They generated an average of $25,283 in total costs, of which about 60 percent was for initial hospitalization. Other major cost categories were rehabilitation, physician fees, readmissions to the hospital, and skilled nursing care. Riders with severe head injuries generated very high hospital charges, an average of $46,936.

How is helmet use related to the need for care and services after the period of initial hospitalization? Seven percent of the riders died, while 17 percent remained vegetative or very disabled. Helmet use was not reported.

How much of the hospital costs of nonhelmeted injured motorcyclists is paid by insurance, other public sources, and hospital absorption? Less than 1 percent of the identified costs was paid by the riders themselves. Insurance paid 22 percent, while Medicaid and other public sources paid over 65 percent.

Limitations of the Data or Analysis

The study population was small and limited to injured riders brought to a trauma center. The absence of helmet use data meant the study gave no direct evidence on how nonuse affects medical costs.

Significance of Findings

Without helmet use data, the study was not of much assistance in addressing our issue questions. It did illustrate the exceptionally high costs that can be incurred in treating head injuries. The authors also found that injured motorcyclists were heavily dependent on public sources to pay for treatment and other services. (Note: Washington reenacted a universal helmet law in June 1990.)

35. Robertson, Leon S. "An Instance of Effective Legal Regulation: Motorcyclist Helmet and Daytime Headlamp Laws." Law and Society, spring 1976, pp. 467-477.

Approach

The author compared fatality rates in eight states that adopted universal helmet laws in the 1968-72 period with eight neighboring states that had not yet adopted laws (one state had adopted a very limited

law). Fatalities per 10,000 registered motorcycles were calculated for 1 year before the laws were adopted, the adoption year, and 1 year after.

Principal Findings

What changes in motorcycle fatality rates have been associated with enactment of universal helmet laws from limited or no laws? Fatalities per 10,000 registered motorcycles declined from about 10.8 to 7 in the states that adopted universal helmet laws. In the comparison states, the average rate increased from about 9.8 to 10.8. Enactment of the laws thus appeared to have reduced fatality rates by at least 35 percent in these 8 states.

Limitations of the Data or Analysis

The choice of comparison states was limited by the fact that relatively few states avoided enacting helmet laws in the late 1960s. The period of study in this analysis was only 3 years, which made the analysis susceptible to annual variations. This limitation remained despite the author's use of analysis of variance with heating degree days (climate) as an independent variable.

Significance of Findings

The two groups of states did have very similar fatality rates prior to the adoption of helmet laws, and they followed distinctly different trends beginning with enactment. But the data base of the study was quite limited.

36. Scholten, Donald J., MD, and John L. Glover, MD. "Increased Mortality Following Repeal of Mandatory Motorcycle Helmet Law." Indiana Medicine, Apr. 1984, pp. 252-255.

Approach

From July 1, 1967, through September 1, 1977, Indiana required all motorcycle riders to wear helmets. The authors used state accident report statistics and motorcycle registration statistics from 1962 through 1981 to compare fatality rates before, during, and after the law was in effect. They also examined data on helmet usage by accident victims gathered by state police officers during May through September 1977 and the same period in 1978. However, we did not use these data because it was not clear what they represented (apparently the data did not include urban areas).

Principal Findings

What changes in fatality rates have been associated with enactment of universal helmet laws? In the 5 years prior to enactment of its helmet law, Indiana averaged 10.12 fatalities per 10,000 registered motorcycles and 2.33 fatalities per 100 accidents. In the 5 years following enactment, fatalities were 7.18 per 10,000 registrations (29 percent lower) and 2.24 per 100 accidents (4 percent lower).

What changes in fatality rates have been associated with repeal of universal helmet laws? In the 3 years preceding repeal of the helmet law, fatalities were 5.98 per 10,000 registrations, or 30 percent lower, and 2.03 per 100 accidents, or 27 percent lower than rates of 8.56 and 2.78 in the 3 years following repeal.

Limitations of the Data or Analysis

The authors did not disclose whether there had been any change in state accident reporting criteria which may have affected the rates per 100 accidents. The effect of the helmet law may have been slightly underestimated because of the way that partial helmet law years were treated in the analysis.

Significance of Findings

Although reflecting a single state's experience, the comparison periods in this study were long enough to represent substantial experience with and without the law. The authors included an interesting factor by breaking their study periods before and after the introduction of the 55 mph speed limit. The helmet law periods each had about 30 percent fewer fatalities per 10,000 registrations than the comparable nonlaw periods.

37. Scott, Robert E. Motorcycle Accidents and Motorcycle Injuries—A Review. Ann Arbor: University of Michigan Transportation Research Institute, 1983.

Approach

The author analyzed 1980 and 1981 data from the National Accident Sampling System (NASS) maintained by the National Highway Traffic Safety Administration (NHTSA). NASS collected data from 50 accident-investigation teams who sample accidents in selected areas across the United States. The 1980 and 1981 files contained data on 796 riders involved in motorcycle accidents.

Principal Findings

How is helmet use related to fatality and injury severity in motorcycle accidents? The distribution of the most severe injuries indicated that nonhelmeted riders were substantially more vulnerable than helmeted riders to head and face injuries and that neck injuries were relatively rare.

Is helmet use or nonuse associated with high-risk riding behavior? Alcohol involvement was reported for 23 percent of the nonhelmeted motorcycle operators but only for 6 percent of the helmeted operators.

How do hospital admission rates compare for helmeted and non-helmeted riders? Thirty-seven percent of the nonhelmeted riders required admission to a hospital for inpatient care, compared with 28 percent of the helmeted riders. Overall, 81 percent of the nonhelmeted riders required medical treatment, compared with 79 percent of the helmeted riders.

How is helmet use related to lost work days from motorcycle accidents? Sixty-three percent of the nonhelmeted riders lost work days, compared with 45 percent of the helmeted riders. Forty-seven percent of the nonhelmeted riders lost 7 days or more and 32 percent lost 14 days or more, compared with 28 percent of the helmeted riders who lost 7 days or more and 22 percent who lost 14 or more.

Limitations of the Data or Analysis

The author did not discuss the limitations of NASS, which has never achieved the coverage planned for it. The NASS sample was designed to represent automobile accidents, which might not be distributed the same as motorcycle accidents. All findings were given as percentages, so the number of helmeted and nonhelmeted riders in various data cells could not be determined. No tests of significance and no confidence intervals for the findings were reported. The number of cases with missing helmet data was not reported.

Significance of Findings

The NASS data are multistate data, but its representativeness is questionable. The study produced an extraordinarily high estimated fatality reduction from helmet use, but gave no indication of the number of fatalities that this was based on. In general, the lack of detail about the data used in the study reduced its usefulness.

38. Shankar, Belavadi, ScD, Patricia C. Dischinger, PhD, Ameen I. Ramzy, MD, Carl A. Soderstrom, MD, and Carl C. Clark, PhD. Helmet Use, Patterns of Injury, and Medical Outcome Among Motorcycle Drivers in Maryland. Baltimore: Maryland Institute for Emergency Medical Services Systems, 1990. (Sponsored by the National Highway Traffic Safety Admin., Wash., D.C.)

Approach

The authors attempted to identify all motorcycle accidents in Maryland from July 1987 through June 1988, and to assemble injury and cost information. They used combined data from Maryland's Automated Accident Reporting System, hospital emergency rooms, the Maryland Ambulance Information System, the state Trauma Registry, autopsy files, and the Maryland Health Services Cost Review Commission (for inpatient hospital and physician costs). Participation of 45 of the 50 hospitals in the state was achieved.

Principal Findings

How is helmet use related to fatality and injury severity in motorcycle accidents? Among 1,900 motorcycle drivers involved in accidents, 52 (2.7 percent) died. While the incidence of injury to the arms and legs was similar for helmeted and nonhelmeted drivers, the incidence of head injury was twice as high (40 to 21 percent) among the nonhelmeted drivers, and 27 percent of the nonhelmeted drivers had only head injuries compared with 12 percent of the helmeted drivers.

How do hospital admission rates compare for helmeted and nonhelmeted riders involved in accidents? Among drivers seen in emergency rooms, 45 percent of the nonhelmeted and 33 percent of the helmeted drivers were admitted as inpatients.

How do initial hospitalization costs compare for helmeted and nonhelmeted riders? Cost information was available for 345 of 377 drivers admitted to hospitals. Hospital charges and professional fees averaged $30,365 for nonhelmeted drivers compared with $10,442 for helmeted drivers.

How much of the hospital costs of nonhelmeted injured motorcyclists is paid by insurance, other public sources, and hospital absorption? Nonhelmeted drivers incurred 81 percent of identified costs. Of this, commercial insurance covered 57 percent, public assistance covered 24 percent, and 19 percent was not covered.

Limitations of the Data or Analysis

Maryland's accident report form left some ambiguity regarding helmet use. Consequently, helmet use was treated as unknown for 26 percent of the involved drivers. Confusion about helmet use caused us to disregard some of the data based on accident reports.

Missing data accumulated as this analysis proceeded to different levels, illustrating the difficulty of assembling a comprehensive analysis. It was not always clear what portion of the population was being analyzed. Injury severity was only analyzed for those admitted to hospitals.

The physician and surgeon charges were derived only from the state's level I trauma center and imputed to the other hospitals. That center would logically treat the most seriously injured victims and have the highest cost structure. This means the average medical cost figures cited are probably inflated.

Significance of Findings

Although done in a single state, the use of a variety of data sources to assemble a comprehensive study population was a useful feature of the study. The significance of the study was reduced by the confusion over helmet use data and the absence of injury severity data. Although the professional fee costs appear inflated, the study does indicate the importance of these costs in caring for head-injured riders. Information was not available on long-term care and support costs.

39. Struckman-Johnson, Cynthia and V.S. Ellingstad. Impact of Motorcycle Helmet Law Repeal in South Dakota 1976-79. Vermillion, S.D.: University of South Dakota, 1980. (Sponsored by the National Highway Traffic Safety Admin., Wash., D.C.)

Approach

South Dakota's helmet law changed on July 1, 1977, to require usage only by riders under age 18. The authors collected data on all police-reported motorcycle accidents for 1 year prior and 2 years following July 1, 1977. Out of 1,847 riders reported involved in accidents, injury data on 908 were obtained from medical records, self reports, and coroners' death certificates. The authors believed this was about 80 percent of the riders who received medical treatment.

From July through September 1976, 15,599 motorcycle drivers and passengers were observed at 96 urban and rural locations selected to be representative of South Dakota traffic. During the same periods in 1977

and 1978, 32,832 drivers and passengers were observed at 118 urban and rural sites. Helmet use by riders involved in accidents was obtained from police reports.

Principal Findings

What levels of helmet use are associated with universal helmet laws and limited helmet laws? Observed helmet use by drivers declined from virtually 100 percent to 54 and 44 percent in the 2 years following change of the law. Use by passengers declined from 99 percent to 56 and 52 percent. The biggest declines were on weekends and on city streets. Among drivers involved in accidents, helmet use declined from 95 percent before repeal to 50 and 43 percent in the 2 years following. Helmet use by drivers 14-17 years old involved in accidents declined from 96 percent to 86 and 80 percent.

What changes in fatality rates and injury severity have been associated with changes from universal to limited helmet laws? Accidents per 10,000 registered motorcycles were 12 percent higher in 1978 than the 1976 level, and fatalities per 10,000 registrations were 19 percent higher. However, South Dakota is popular with out-of-state cyclists, and such visits were especially high in the summer of 1978. According to police reports, riders involved in accidents had a slightly higher chance of being killed (2.5 v. 2.3 percent) in the 2 years following the change in the law.

Considering the overall AIS scores of injured riders, 22.4 percent of the injuries were rated severe in the year before the law changed, compared with 21.3 percent in 1977, and 27.4 percent in 1978. The percentage with serious injuries went from 17.5 in 1976 to 9.9 in 1977 and 15.6 in 1978. Nonfatal critical injuries went from 3.6 percent in 1976 to 6.3 and 2.6 percent, while fatalities rose from 4.2 percent in 1976 to 5.2 and 5.4 percent.

Is helmet use or nonuse associated with high-risk riding behavior? Police citations of motorcycle drivers for improper actions contributing to accidents increased after the helmet law was repealed. Nonhelmeted drivers were cited in 55 percent of their accidents and helmeted drivers in 48 percent. Alcohol impairment was noted or suspected for 22 percent of the nonhelmeted and 4 percent of the helmeted drivers.

How is helmet use related to fatality and injury severity in motorcycle accidents? Comparisons of helmeted and nonhelmeted riders were based on consolidated data from the first year, when 95 percent of the victims

wore helmets, and the following years, when half or less of the victims wore helmets. On the basis of police-reported accidents, the fatality rate among helmeted riders was 2.1 percent, compared with 3.3 percent among nonhelmeted riders.

Among injured helmeted riders, 25.3 percent of the injuries were rated severe, 15.5 percent serious, 3.2 percent nonfatal critical, and 4.1 percent fatal. Among nonhelmeted riders, 21.8 percent of the injuries were rated severe, 20.1 percent serious, 5.8 percent nonfatal critical, and 6.7 percent fatal.

Among injured riders, 7 percent of the helmeted and 16 percent of the nonhelmeted riders had severe or worse head injuries. Among the fatally injured riders, 57 percent of the nonhelmeted riders died of head injuries alone, compared with 23 percent of the helmeted riders.

Limitations of the Data or Analysis

The observational data were fairly representative of South Dakota, except that observations were not made after 8 pm, when helmet use may be lower. Weekend observations seemed to be overrepresented in the final year. Moped and minibike riders were apparently included.

As a sparsely populated state, South Dakota cannot be assumed to be representative of national traffic conditions. On the other hand, the data base included all reported accidents in South Dakota for the 3 years studied.

Although the researchers went to a great deal of effort to acquire injury information, records could not be obtained for 20 percent of the riders reported injured. Also, some of the injury assessments were based only on death certificates or "self-reports." It appears that a physician was not used to assign the AIS scores.

Impact speed was not used as a control variable in comparing injurity severity for helmeted and nonhelmeted riders. However, the average impact speed was reported as 33 miles per hour for helmeted and 34 for nonhelmeted riders.

Significance of Findings

Only 3 years and a total of 45 fatalities were included in the study, which limited its usefulness for a before/after analysis. The reliability of the injury data was questionable. The study indicated, although somewhat less dramatically than other studies, the increased risk of

serious, critical, or fatal injury associated with the nonuse of helmets. Severe head injury was a particular risk for nonhelmeted riders.

40. Watson, Geoffrey S., Paul L. Zador, and Alan Wilks. "The Repeal of Helmet Use Laws and Increased Motorcyclist Mortality in the United States, 1975-78." American Journal of Public Health, Vol. 70, 6, pp. 579-585.

Approach

Using monthly fatality data from FARS from January 1975 through December 1978, the authors compared fatality trends in states that repealed or limited their helmet laws with neighboring states that did not change their laws. They projected the number of fatalities that would have occurred in each state had the laws not been changed, and compared it with the actual number of rider deaths reported.

Principal Findings

What changes in fatality rates have been associated with repeal of universal helmet laws or change to limited helmet laws? For the 26 states that repealed or limited their helmet laws during this period, fatalities increased 38 percent ($\pm$ 13 percent at the 95-percent confidence level) over the number projected, had the laws not been changed. Increases occurred in all states except Maine, Nebraska, and Oklahoma. Stated in other terms, the repeal states would have had 28 percent fewer fatalities had they not changed their laws.

Limitations of Data

This analysis was a rather indirect and complex attempt to compare what happened in states repealing and not repealing their helmet laws. With only 4 years of data, the number of data points would be very small for a time series analysis if annual figures were used. The authors attempted to compensate for this by using monthly data, but the small numbers and wide variation in monthly fatality counts led them to use techniques for "smoothing" the data. Our review panel was not very comfortable with the smoothing techniques used. The authors' methodology also assumed that the neighboring states were in fact comparable, but no prerepeal analysis was shown to establish this.

Of the three states that did not support the general pattern, two should not have been considered repeal states in the first place. Oklahoma did not have a universal helmet law during this period, and Nebraska had

one but had not enforced it. The inclusion of these as repeal states lowered the overall estimate of fatality increase brought by repeal.

Significance of Findings

The approach and statistical techniques were interesting, but the manipulations of the data became somewhat obscure. The findings were worth considering along with those of other studies using different techniques.

41. Williams, John M. and James D. Cleary. Minnesota Motorcycle Fatality Rates and the Motorcycle Helmet Law Repeal. St. Paul: Minnesota House of Representatives Research Department, unpublished.

Approach

Minnesota changed its helmet law on April 7, 1977, to apply only to riders under age 18. These authors used six different models to estimate the effect of this change on motorcycle fatalities in the years 1977 through 1980. Three of the models used prerepeal trends, both annual and monthly data, to project fatalities into the post-repeal period. The other three were regression analyses using different combinations of exposure variables: the number of registered motorcycles, average temperature during the riding season, and number of accidents.

Principal Findings

What changes in motorcycle fatality rates have been associated with changes from universal to limited helmet laws? All of the models showed a sharp discontinuity in fatalities with the change of the helmet law. The model based on monthly data produced an estimate substantially higher than the others. The other five models predicted that if the law had not been changed and fatality experience had continued as it had been under the law, Minnesota would have averaged 33-41 fewer fatalities per year from 1977 through 1980, a decrease of 32-40 percent.

How does helmet use affect the likelihood of having an accident? Annual accident totals averaged 14 percent higher in the 3 years following repeal of the helmet law than they did during the 4 years preceding repeal.

Limitations of the Data or Analysis

The authors gave little information about the construction of their models and none about tests of significance. Data sources were also little explained. Mostly, the authors reported results.

Significance of Findings

Although this study had consistent findings using different analytical approaches, our expert panel felt the authors did not adequately explain their different models or the source data used in them.

42. Wilson, Donna. The Effectiveness of Motorcycle Helmets in Preventing Fatalities. NHTSA Technical Report, Mar. 1989.

Approach

Using data from FARS from 1982 through 1987, the author applied the matched-pairs method used by Evans and Frick to study motorcycle accidents involving both a driver and a passenger on the same vehicle in which at least one was killed. Although a small number of the accidents involved a helmeted and nonhelmeted rider, these accidents had a significant effect on the helmet effectiveness ratios. The author constructed equations for all possible combinations of helmeted and nonhelmeted riders, and calculated the ratios of driver-to-passenger fatality for each scenario. These ratios were calculated for each year (1982-87) individually and for all years combined.

Principal Findings

How is helmet use related to fatality in motorcycle accidents? The author calculated that helmets reduced the chance of fatal injury among motorcycle drivers by 27 percent and among passengers by 30 percent. Overall, helmets reduced the chance of fatal injury by 29 percent.

Limitations of the Data or Analysis

As in the Evans and Frick study, this analysis represents only a small portion of motorcycle accidents: those involving both an operator and passenger on the same vehicle in which at least one died. One cannot assume that the results would be the same for single-rider accidents. This author did not show results separately by sex, and the proportion of females in the analysis was not given. Presumably, these results were affected by the same female survivability bias as was the Evans and Frick analysis.

Standard errors for the estimates were also not given.

Significance of Findings

This analysis had all the limitations of that by Evans and Frick and in addition provided less detail about the cases included.

43. Wisconsin Motorcycle Helmet Law: A Before and After Study of Helmet Law Repeal. Wisconsin Department of Transportation, Accident Data Section, 1981.

Approach

Wisconsin changed its helmet law on March 19, 1978, to apply only to riders under age 18. This study compared injuries per 100 accident-involved riders in the prerepeal years 1975-77 with those in the years 1978-80, as recorded in police accident reports. The data base yielded 11,016 riders in the prerepeal years and 13,531 in the post-repeal years.

Principal Findings

What changes in motorcycle fatality rates and injury severity have been associated with changes from universal to limited helmet laws? From data compiled by the authors, we calculated that fatalities per 100 accidents were 24 percent lower in the 3 years preceding repeal (2.09) than during the 3 years following repeal (2.74). Fatalities per 10,000 registered motorcycles were 18 percent lower in the 3 years before repeal (5.71) than during the 3 years following repeal (6.93).

We also calculated that incapacitating injuries per 100 riders (at least temporary incapacity, as judged by police) were 12 percent lower in the 3 years before repeal. This was attributable to a sharp rise in incapacitating head injuries following repeal.

How is helmet use related to fatality and injury severity in motorcycle accidents? From the authors' data, we calculated that helmeted riders in the post-repeal period had a 32-percent lower rate of fatal injury (2.6 percent v. 3.8 percent), attributable to a much lower rate of fatal head injuries. They had a 13-percent lower rate of incapacitating injury.

Helmeted riders had a 23.6-percent rate of head injury (1.2 percent fatal). Nonhelmeted riders had a 40.6-percent rate of head injury (2.2 percent fatal). The incidence of injury to other parts of the body was essentially the same for helmeted and nonhelmeted riders.

Limitations of the Data or Analysis

Reliance on police reports for injury assessment is questionable, especially for judging the seriousness of injuries to various body locations.

Significance of Findings

This was one of the largest and most comprehensive study populations we encountered for assessing injury rates. Although it relied on police assessments of injury, the consistency of nonhead injury rates lent considerable credence to these assessments. The changes in fatality rates when the helmet law was repealed were similar when accidents or registrations were used as an exposure variable. The study found that head injury rates clearly differentiated helmeted from nonhelmeted riders and the helmet law period from the post-repeal period.

Studies Reviewed by GAO Staff Only

44. Gordon, Stephen, and James Prince. Field of View With and Without Helmets. Washington: National Highway Traffic Safety Administration, Safety Research Laboratory, Oct. 1975.

45. Henderson, Robert L. Effect of Safety Helmets on Auditory Capabilty. Washington: National Highway Traffic Safety Administration, Office of Driver and Pedestrian Research, Sept. 1975.

46. Van Moorhem, W.K., K.P. Shepherd, Tom D. Magleby, and Guy E. Torian. The Effect of Motorcycle Helmets on Hearing and the Detection of Warning Signals. Salt Lake City: University of Utah, Department of Mechanical and Industrial Engineering, Mar. 1977.

Studies Not Accepted for Synthesis

47. Adams, J.G.U. "Public Safety Legislation and the Risk Compensation Hypothesis: The Example of Motorcycle Helmet Legislation." Environment and Planning, Government and Policy, Vol. 1, 1983, pp. 193-203.

Approach

The author criticized the methods used in 1980 studies by NHTSA and Watson, et al., which had reported fatality rate increases coincident with the repeal of universal helmet laws. The author contended that increases were greater in states not repealing their laws. He criticized Watson's study (which had matched up neighboring states) by challenging its conclusions regarding Colorado, Montana, Nevada, Utah, and Wyoming. The author advanced a theory to explain why deaths increase when helmet laws are enacted.

Principal Findings

What changes in motorcycle fatality rates have been associated with repeal of universal helmet laws or change to limited laws? Although he did not present any of the data, the author calculated that states not repealing their helmet laws accounted for more of the increase in fatalities in the 1976-79 period than did states which repealed or limited their laws.

How is helmet use related to the likelihood of having an accident? The author agreed that helmets provide a measure of protection in an accident. He hypothesized that wearing a helmet lowers a rider's perception of risk, leading him to compensate by taking more risks in driving his motorcycle, thus increasing the likelihood of having an accident.

Limitations of the Data or Analysis

The author gave no compilation of the data he used to contradict NHTSA, nor did he explain how he accommodated the different timing of state legislative changes during the 1976-79 period in calculating fatality increases for repeal and nonrepeal states. In criticizing the Watson study, he used only sparsely populated western states with low fatality counts. His focus on Utah as a repeal state was particularly interesting, since Utah never complied with the NHTSA requirement for universal helmet laws and was one of the states NHTSA planned to use sanctions against.

For the risk-compensation theory, the author essentially presented no data, referring to it as "common sense." If the theory is operating, we could find no evidence of it in the studies we evaluated. Nonhelmeted riders were consistently overrepresented among accident victims, and several studies showed that accident rates increased when helmet laws were repealed.

48. Goldstein, Jonathan P. "The Effect of Motorcycle Helmet Use on the Probability of Fatality and the Severity of Head and Neck Injuries." Evaluation Review, 10:3 (1986), pp. 355-375.

Approach

The author used the data base of 900 motorcycle accident investigations compiled by Hurt and associates in Los Angeles in 1976 and 1977. He constructed regression equations to attempt to measure the effect of helmet usage on fatality, as well as severe head and neck injury. In so doing, he hoped to control for such factors as impact speed, alcohol consumption, rider experience, etc.

Principal Findings

How is helmet use related to fatality and injury severity in motorcycle accidents? The author concluded that helmet use does not significantly affect the likelihood of fatality, which instead is related primarily to speed and alcohol consumption. He concluded that helmet use reduces the likelihood of severe head injury but increases the likelihood of severe neck injury. He suggested that this trade-off from helmet use nullifies the beneficial effects of helmet laws.

Limitations of the Data or Analysis

The author eliminated 256 of the 900 cases because they lacked some of the data needed for his regression analysis. From his explanation, it was not possible to determine how this may have affected the results of the analysis. The author did not point out that the original 900 accidents involved only 59 rider fatalities, of which 46 were not wearing helmets (Hurt, p. 236). Thus, there were few helmeted fatalities in the original data base, and presumably even fewer in the author's smaller data base. These numbers were too small to support any finding from a regression analysis.

Even more serious was the author's failure to acknowledge the small cell sizes in his analysis of neck injuries. His conclusion that helmet use increased the likelihood of severe neck injury derived from four cases or less. The original data base of 900 accidents contained only 15 cases of severe, critical, or fatal neck injuries, only 4 of which occurred to helmeted riders (Hurt, p. 303). By contrast, there were 73 severe or worse head injuries, of which only 13 occurred to helmeted riders (Hurt, p. 296). It is difficult to imagine how a trade-off between head and neck injuries could be discovered from these data.

This author's analysis went far beyond the limits of his data. His conclusions were not supported by any other study we reviewed.

49. Motorcycle Helmets: Do They Help? Austin: Texas Department of Public Safety, 1978.

Approach

On August 29, 1977, Texas changed its universal helmet law to a limited law, requiring only riders under the age of 18 to wear helmets. This study compared the number of motorcycle fatalities and injuries that occurred from August 29, 1976, to August 28, 1977 (universal law) with those from August 29, 1977, to August 28, 1978 (limited law).

What changes in motorcycle fatality rates and injury severity have been associated with the change from a universal helmet law to a limited law? In the 12 months after changing from a universal helmet law to a limited law, the total number of motorcycle injuries increased 15 percent compared with the total during the previous 12 months; incapacitating injuries increased 25 percent. and fatalities increased from 213 to 331 (55 percent).

No information was presented on motorcycle registrations, and accident-reporting criteria changed during the period. Among riders reported injured, the fatality rate was 25 percent lower under the universal helmet law (2.4 v. 3.2 percent). The rate of incapacitating injuries was 7 percent lower. The differences were closely associated with a lower rate of head injuries when the helmet law was in effect.

For riders under age 18, the number of fatalities increased from 43 to 66 in the 12 months following the change to a limited law.

What levels of helmet use are associated with universal and limited helmet laws? Helmet use by injured riders decreased from 93 to 46 percent after the change from a universal to a limited law. Among riders under age 18 who were fatally injured, helmet use declined from 77 percent prior to the legislative change to 52 percent in the following 12 months.

Limitations of the Data or Analysis

The period available for study was very brief, and as such was subject to annual fluctuations. Without data on registrations or total accidents, it was difficult to place the changes in perspective. Injury severity data were based on police assessments, which are not as reliable as physicians' assessments. Some of the data used were preliminary rather than final data.

The review panel considered this study too limited and lacking in methodological guidance to be considered in drawing conclusions.

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