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EFFECTS OF NON-USE OF HELMETS ON THE SEVERITY OF INJURIES AND ACUTE CARE COSTS AMONG MARYLAND MOTORCYCLE DRIVERS

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16. Abstract A comprehensive study was conducted throughout the state of Maryland of all motorcycle crashes occurring during the period of July, 1988, through June, 1989. All available medical and cost data were manually linked with the driver's driving records and police crash, ambulance, and coroner's reports. During the study period, 1900 motorcycle drivers (of whom 52 died) and their 362 passengers, and 40 struck pedestrians, were involved in motorcycle crashes. The Maryland motorcycle helmet use law, passed in 1968, was repealed in 1979, and has not yet (1990) been reinstated. The data of this study indicated that 1) driver helmet usage was 35 percent overall, 30 percent among fatally injured drivers, and only 16 percent among drivers with a history of drug/alcohol conviction. 2) Unhelmeted drivers seen at an emergency department were almost twice as likely to have sustained head injury (40 percent) as helmeted drivers (21 percent). (Fifty five percent of hospitalized drivers who crashed without helmets sustained head injuries, whereas this dropped to 38 percent of those who had worn helmets). 3) Acute care costs, including physician costs, for unhelmeted drivers ($30,365) were three times those of helmeted drivers. 4) The public through taxation for public assistance pays $16,200 toward the acute care costs of each motorcycle driver who has no insurance and is injured without a helmet, and the insurance companies (and hence the public with insurance) pay $23,150 toward the acute care costs of insured motorcycle drivers who are injured without a helmet. The formats of the data collection forms and the tape of the linked data, with personal identifiers removed, are presented.

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EFFECTS OF NON-USE OF HELMETS ON THE SEVERITY OF INJURIES AND ACUTE CARE COSTS AMONG MARYLAND MOTORCYCLE DRIVERS

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This is one of three parts of the Final Report of this statewide Maryland Motorcycle Crash Study. The other two parts, "A Study of Alcohol Use Among 165 Injured Motorcycle Drivers Treated at Maryland Trauma Centers: Clinical and Crash Perspectives Including Crash Culpability, "Carl Soderstrom, Patricia Dischinger, Shiu Man Ho, and Belavadi Shankar, and "Maryland Motorcycle Injury Study: A Methodology for linking Crash reports with Medical data", "Belavadi Shankar, Patricia Dischinger, and Ameen Ramzy, both dated September, 1990, are in press.

THE CONSEQUENCES of non-use of helmets by motorcyclists involved in highway crashes have been the subject of considerable research in recent years. Most of these studies concern fatal crashes. Some investigators have reported on the impact of non-use of helmets on injuries and medical outcome of motorcyclists in non-fatal crashes. Most of these studies, however, include only those who were admitted to a trauma hospital. Population-based studies are rare.

The effect of helmet use in reducing death has been well established. In 1967, a federal standard for state highway safety programs was issued. According to this standard, states without mandatory helmet use laws would lose certain federal funds designated for highway safety. By 1969, just 2 years after the standards were issued, 37 states enacted laws concerning the use of helmets; by 1975, all but three states had laws requiring the use of helmets by all motorcyclists. These laws remained in effect until 1976, when the U.S. Congress removed the linkage of federal funds to helmet laws. Within 2 years of this change in the federal standards, 26 states repealed or weakened their helmet use laws.

Watson et al. (1980) studied the effects of changes in these laws on motorcyclist fatality rates during 1975 and 1978. They concluded that "the mortality rate among unhelmeted riders is almost twice as high as that among helmeted riders." In another study, Watson et al. (1981) reported, "If helmeted and non-helmeted riders have similar crashes..., when helmets are not worn head injury deaths are twice as frequent as deaths due to other causes." By studying the injured motorcyclists who were seen at a major trauma center, Luna et al. (1981) reported that "the chance of sustaining a severe head injury was significantly higher in the no helmet group, and the incidence of long-term neurological deficit was three times greater in the no helmet group" as compared with the helmeted group. Chenier and Evans (1987) also studied the effect of the repeal of mandatory helmet use laws on motorcyclist fatalities and concluded that "repeals of mandatory helmet wearing laws for motorcyclists were followed by substantial increases in motorcyclist fatalities." In a special study conducted in Kansas before and after repeal of the state law in 1976, McSwain and Lummis (1980) reported that "the impact of repeal of mandatory motorcycle helmet usage is significant in terms of injuries, fatalities and accident rate; a 63.3 percent increase in fatalities per 1,000 accidents during study; a 95 percent increase in fatalities per 1,000 motorcycle registrations during study; a 51 percent increase in the incidence of head injury per 1,000 accidents during study; a 19.4 percent increase in the crude accident rate - accidents per 1,000 registrations - during study; and a decrease in helmet usage from 95 to 50 percent." The state of Louisiana re-enacted mandatory helmet legislation, which became effective January 1, 1982. McSwain, Willey, and Janke (1985) conducted a special study to compare rates before and after this change in the state law and reported that helmet usage increased from 50% to 95%, fatalities decreased from 3.63 to 1.07 per 100 accidents, crashes resulting in injury decreased from 84% to 74%, the rate of head injury decreased from 60% to 40%, and the average medical care cost per patient was reduced from $2,071.78 to $835.40.

McSwain and Petrucelli (1984) reported the results of an in-depth study done in four states. They concluded that helmet use is significantly less where use is not mandatory; helmets significantly decrease head injury death and disability; head injury death and disability increase when the laws are repealed; the crash rate is higher when helmets are not worn; the cost of medical care for a nonhelmeted rider is more than twice that of a helmeted rider; and the amount of permanent disability is significantly increased when helmets are not worn.

Several investigators have studied the patterns of injury among motorcyclists. Bachulis et al. (1988) reported that 105 of 235 (44.7%) unhelmeted motorcyclists suffered brain injury and that 31 (30%) of these brain injuries were severe. The corresponding

figures for helmeted motorcyclists, in their study, were 24.2% and 9.3%, respectively. In a New Zealand study, Civil (1986) reported that "motorcyclists had the highest rates of extremity fracture but presumably because of mandatory helmet regulations, the lowest rate of head and facial injuries."

In a case-control study of hospitalized motorcyclists, Carr et al. (1981) reported that 1) non-helmeted riders tended to have a higher percentage of serious and critical head injuries than helmeted riders, 2) non-helmeted riders are twice as likely to suffer a minor head injury and approximately five times as likely to suffer a severe or critical head injury, and 3) an unhelmeted rider is approximately six times as likely to die of a head injury than is a helmeted rider. They also concluded that "when all types of cervical spine injuries were combined, there was no association between helmet use and cervical spine injuries."

Reviewing the massive amount of data available on this subject, Trunkey (1981) concluded that "the data supporting the use of safety helmets by motorcyclists seem overwhelming. Clearly, helmets reduce death and head injuries. For those who continue to oppose mandatory motorcycle helmet laws, a fundamental question must be answered: when do social rights become more important than individual rights? The answer seems self-evident." Bull (1988) commented that "the latest annual figures (1985) show that 626 motorcycle riders were killed and 12,212 seriously injured on the 839,000 machines registered. One death per 1340 and a serious injury per 68 represents one of the most severe current exposures to risk of injury; it is certainly far in excess of any 'acceptable' occupational hazard. Most of the casualties are young, with peak incidence at 17 or 18 years."

Discussing the cost of hospitalization for injured motorcyclists, Mortimer and Petrucelli (1984) reported that injuries to the head produced substantially higher hospital charges. Considering that the use of helmets significantly reduces the head injury rate, they estimated that "a potential savings in medical expenses of about $52 million (annually) could result if all motorcyclists in Illinois wore helmets" and that savings to taxpayers would be $13 million. Bried et al. (1987) also found the cost of hospitalization for a head-injured motorcyclist to be significantly higher than the cost for those without head injury. They also reported that "patients sustaining a head injury were less likely to return to baseline functioning." Rivara et al. (1988) studied the public cost of motorcycle trauma by examining the records of 105 patients admitted to Harborview Medical Center at Seattle. They reported that "the direct costs for these 105 patients, followed up for a mean of 20 months, were more than $2.7 million. Only 60% of the direct costs were accounted for by the initial hospital care ...." The majority (63.4%) of care was paid for by public funds ...."

PURPOSES OF THIS STUDY

This report of a special study, conducted in Maryland, included all motorcycle traffic collisions during a 12-month period (July 1987 to June 1988). The main purpose of this study was to link relevant medical and cost data with police crash reports to facilitate analyses of factors related to injuries sustained by these motorcycle riders. Since Maryland has a centrally coordinated system of trauma and emergency medical services (Ramzy, 1988), certain data are available to make this linkage possible. However, since these databases did not contain a common identifier, the initial linkage had to be performed manually. To optimize the data collection for this project it was necessary to obtain cooperation from all agencies involved. A letter requesting the cooperation was sent to the Maryland Hospital Association (MHA), the Maryland Chapter of the American College of Emergency Physicians (MACEP), the Maryland State Police, and the state Emergency Medical Services (EMS) director. Included in this letter was a commitment to protect the confidentiality of the patients as well as the hospitals that treated them. Individual letters requesting cooperation were sent (by name, to each of the emergency physicians in all acute care hospitals) by the heads of the participating agencies. A similar letter was sent by the project director to all hospital emergency physicians and copied to the medical director and the chief executive officer of the respective hospitals. The project staff also visited some hospitals where there were some questions concerning the study. Forty-five of the 50 hospitals in the state agreed to participate. Each of the hospitals designated a contact person so that further interaction between the hospital and the project staff was possible. This report, one of several to be produced from the study, discusses the medical outcome and acute care cost as related to the use of helmets by injured motorcycle drivers.

MATERIALS AND METHODS

All traffic crashes involving a motorcycle as identified by police during a 12-month period (July 1987 through June 1988) were included. Hard copies of the crash reports were obtained and injured motorcyclists who were transported to a hospital were identified. From these hospitals, emergency department information concerning injuries and patient disposition was obtained. Eligible for this study were drivers and passengers of motorcycles and pedestrians struck by a motorcycle. Only traffic crashes with a police report were included. Motorized two- or three-wheelers other than registered motorcycles were excluded. All possible records that were linked for each case are shown in Figure 1, starting with police crash reports. The detailed methodology as well as the process of record linkage has been reported elsewhere (Shankar, in press).

Fig. 1 - Data Systems Used in the Study

NOTE: MAARS - Maryland Automated Accident Reporting System
MAIS - Maryland Ambulance Information System
HSCRC - Health Services Cost Review Commission

MAARS - Through the Maryland Automated Accident Reporting System (MAARS), traffic police in all jurisdictions use a uniform crash reporting form (Appendix I), which is sent to state police headquarters for processing. While reviewing these forms prior to data entry, police headquarters staff made copies of those related to crashes involving motorcycles and sent them to the project office. The project staff reviewed the MAARS copies thoroughly to determine whether the crash met the criteria for inclusion. About 17% of these forms had to be excluded: 12% because vehicles other than motorcycles were coded erroneously as motorcycles and the rest because an unoccupied parked motorcycle was involved in the crash, a non-traffic collision was being reported, the crash was a "hit and run" (and therefore incomplete information was available), or the vehicle was a moped or other two-or three-wheeled conveyance. The state police also provided the project with a computer tape of the MAARS data. Upon reviewing this tape, it was found that about 15% of the reports listed as involving motorcycles on the tape did not have hard copies in the project office. The copies of these reports were received retrospectively from the state police. Thus, every effort was made to collect reports for all motorcycle crashes occurring during the period studied. These reports were received prospectively on a weekly basis, and selected items of data were entered onto a "Log" file. This file included the name, date of birth (age), and sex of all eligible persons; date, time, and place (county) of crash; whether the individual was transported to a hospital; and the name of the hospital. Since crash report numbers are not individual-specific (i.e., there is one number for each crash regardless of the number of persons involved), a unique number was devised to include the

crash number (first seven digits), vehicle unit number (eighth digit), and the occupant seating position number (ninth digit). For pedestrians, the eighth digit was zero, and for drivers the ninth digit was zero. This number was included in all prehospital and hospital data and other records such as autopsy records and trauma registry data.

Hospital Emergency Departments - For each case indicated as transported to a hospital, an emergency department survey was generated by the computer and mailed to the respective hospital. The top half of this form contained the name, age, and sex of the injured motorcyclist and the date, time, and county of the crash. The hospital was requested to complete the bottom portion (Appendix II), giving the vital signs, injury description, and disposition. A self-addressed stamped envelope was provided. Upon receipt of these forms, the injuries were coded into ICD.9.CM and all information (including the nine-digit individual identifying number) was entered into an emergency department file. If forms were not received within 2 weeks, a second copy of the survey was mailed.

MAIS - The Maryland Ambulance Information System collects prehospital care data from both ground and air transportation crews. Maryland prehospital care providers use a uniform, optically scanned runsheet (Appendix III) in all jurisdictions with the exception of two counties. These forms are sent to the state EMS office for processing. During the routine of editing these forms prior to scanning, those pertaining to the victims of motorcycle crashes were pulled and a copy provided to the project staff. These forms were then matched with the police crash reports using the location (county as well as road intersections), date, and time of the crash and the name (if available) of the injured person. All available information was abstracted and a MAIS file was created, including the nine-digit identification number. Hard copies of the ambulance runsheet were requested from the two counties that do not use the standard optical scan sheet; however, this effort was not successful.

Trauma Registry - As required by Maryland's statewide system, all designated trauma hospitals provide data pertaining to trauma cases on a standardized form (Appendix IV), which are computerized at the state EMS office. This file was linked with crash reports of patients known to have been admitted to the trauma hospitals (based on emergency department information).

HSCRC - The Maryland Health Services Cost Review Commission (HSCRC) is a state agency responsible for regulating hospital costs. By law all hospitals are required to provide to HSCRC discharge summary data for all inpatients treated in nonfederal acute care facilities. This data file is provided to the Maryland Institute for Emergency Medical Services Systems to be used in connection with coordination, education, and evaluation of the statewide trauma/EMS system. This data file was linked with the crash reports for cases known to have been admitted as inpatients. The

linkage was made utilizing the hospital number and the medical record number within each hospital (as provided on the emergency department survey sheet by the hospital).

Driver History - For the motorcycle drivers who had a Maryland driver's license, driving history during the 60 months prior to (and including) the crash under study was obtained from the Motor Vehicle Administration (MVA). Since these files are textual and therefore not suitable for statistical analysis, the data from these records had to be abstracted and computerized, including the nine-digit identification number.

Autopsy - For all motorcyclists and pedestrians struck by motorcycles, who were identified by police as being killed in crashes, autopsy information was abstracted using a standard form (Appendix V). The chief medical examiner of the state receives and maintains autopsy/inspection records for all deaths from all jurisdictions. However, this information is not computerized. Manual search of the records was necessary to identify the reports related to these fatal cases. While the injury descriptions were abstracted, they were also AIS coded. This was then computerized onto a separate file, including the identification number. These records were linked by using the case identification number. But, for the hospital discharge data, the linkage was done using the medical record number.

After all appropriate records were linked for each individual in the study, three master files were created: one for drivers (Appendix A), another for passengers, and a third for pedestrians. These master files contain completely "sanitized" data so that no record from them can be traced back to the individual. The sanitization procedures are described elsewhere (Shankar, in press).

The number and types of cases included in the study are shown in Figure 2. The immediate outcome of injuries among the drivers (the subject of this report) is presented in Figure 3.

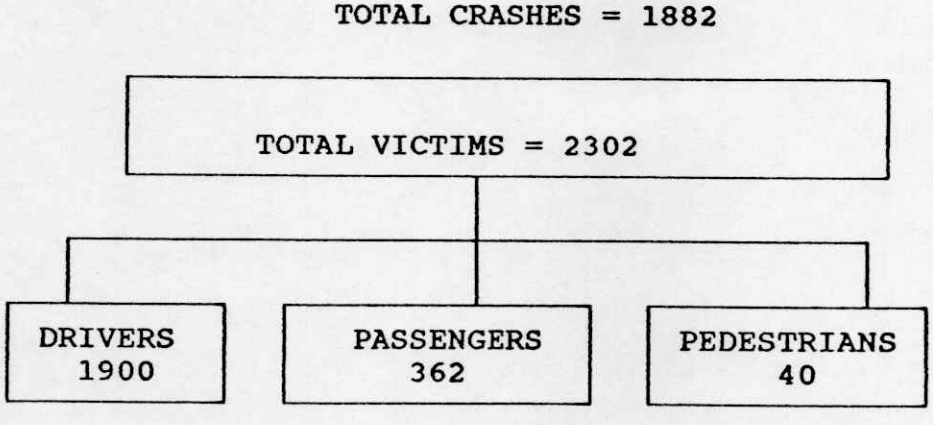

Fig. 2 - Study Population

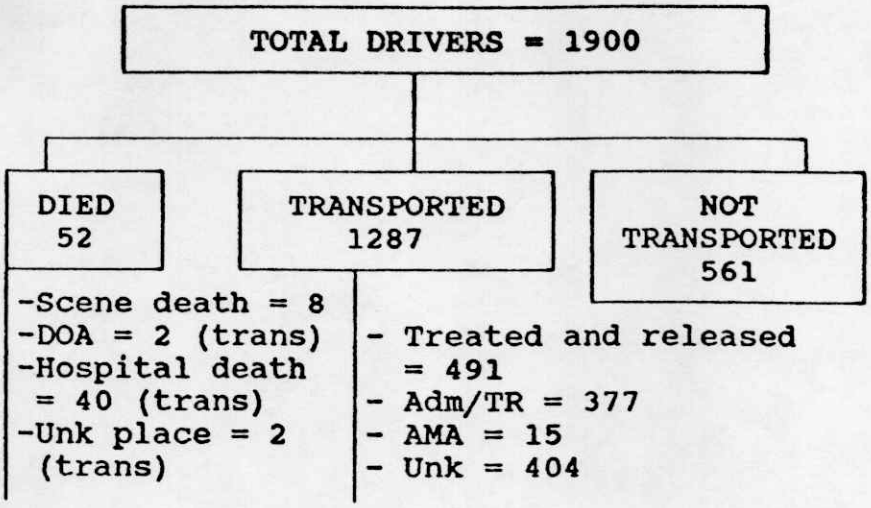

Fig. 3 - Disposition of Drivers

The data were analyzed using Statistical Analysis System (SAS) software package, and chi-square test was performed where applicable.

RESULTS

During the study period, 1882 crashes involving motorcycles occurred, which produced 2302 eligible cases. Of them, 1900 were motorcycle drivers, 362 motorcycle passengers, and 40 pedestrians struck by a motorcycle (Figure 2). The results presented here pertain to the drivers only. Among them, 52 (2.74%) died as a result of crash injuries; 1287 (67.7%) were transported by ambulance/helicopter to hospitals (201 of them had no transport recorded on the police report); and the rest, 561 (29.5%), were not transported from the scene of the crash (Figure 3). Information following the transport was available for 883 drivers. The reasons for unknown follow-up information have been discussed in another report (Shankar, in press). More than half (55.6%) of the drivers with known follow-up information were treated and released from the emergency department, 42.7% were either admitted at the first hospital or transferred to another facility (usually to a trauma center) where they were admitted as inpatients, and the rest (1.7%) refused treatment and were discharged against medical advice (AMA).

Crash Pattern (Table 1) - As expected, the highest number of crashes occurred during the summer (42.6%) and spring (31.3%). Night crashes (6 pm - 6 am) represented almost the same percentage as day crashes (48.2% and 51.5%, respectively). Proportionately more crashes occurred during the weekend: 42.5% occurred during 60 hours of weekend compared with 57.3% during the 108 hours of the rest of the week. Very few collisions occurred in rural counties of Western Maryland and eastern shore, a combined 19.3%. A majority of crashes involved other motor vehicles in transit. Almost 1 in 5 (23.1%) motorcyclists hit a fixed object, and 1 in

10 (9.9%) resulted in an overturn as the first harmful event. In more than a third of the crashes (37.0%) a motorcycle was the only vehicle involved. Among the 1114 multiple vehicle crashes, front-to-front impact (whether head-on or angle) was reported in 585 instances (52.5%). Surprisingly, a majority of crashes (61.2%) occurred on roads with posted speed limits of ≤ 35 MPH.

Driver Characteristics (Table 2) - A majority of the drivers were young (median age, about 25 years). Ninety-eight percent were males. Most of them had a Maryland driver's license. Less than a third (29.6%) were cited for traffic violations for the crash under study. However, 39.4% had a history of speeding and 8% had been cited for the use of drugs/alcohol in the past. Slightly more than a third (35.5%) of the drivers were reported to have used a helmet at the time of crash. More than half (57.2%) were not wearing a helmet. They included those who had "Eye Protection Only". This category of 'eye protection only' was included under 'other' protection in a previous paper (Shankar et al., October, 1990). As expected, a majority of the drivers were ejected from their vehicle. Only a small number (0.6%) were trapped.

The data from police crash reports indicate that 1) a great majority of these crashes occurred during spring and summer times (74%) and during day times (74%), 2) front impact (including head-on (5.5%) and angle (25.3%) was noted in almost a third of the crashes, 3) a motorcycle was the only vehicle in 37% of the crashes, 4) only 14% of the crashes occurred on highways with posted speed limits ≥ 50 MPH, 5) 60 hours of weekend (6 pm Friday to 6 am Monday) produced 42.5% of the crashes, and 6) less than 20% of the crashes occurred in rural counties.

As shown in Figure 3, 377 drivers were admitted to a hospital, 203 of them to a trauma center. A blood alcohol level (BAL) was available for 165 of them, and both BAL and helmet usage were available for 111. These data indicated that 1) positive BAL was found in 53.3% of these drivers and 2) only 21% of drivers with positive BAL were helmeted.

Table 1 - Crash Pattern (N = 1900)

	Number of Drivers	%
Season		
Summer	810	42.6
Fall	331	17.4
Winter	164	8.6
Spring	595	31.3
Time of Day		
Midnight - 6am	247	13.0
6am - Noon	248	13.1
Noon - 6pm	730	38.4
6pm - Midnight	669	35.2
Unknown	6	0.3
Day of Week		
Weekend (6pm Friday-6am Monday)	808	42.5
Weekdays	1088	57.3
Unknown	4	0.2
Geographic Region		
Western Maryland	162	8.5
Central Maryland (includes Baltimore SMSA)	958	50.4
Eastern Shore	205	10.8
Southern Maryland (includes Washington SMSA)	575	30.3
First Harmful Event		
Other motor vehicle	1114	58.6
Fixed object (include parked vehicle)	438	23.1
Pedestrians (include cycles, animals)	61	3.2
Overturned	189	9.9
Other non collision	98	5.2
Type of Collision		
Head-on	105	5.5
Rear-end	246	12.9
Side-swipe	80	4.2
Angle (front impact)	480	25.3
Single vehicle	703	37.0
Other	284	14.9
Unknown	2	0.1
Posted Speed Limit		
≤ 35 MPH	1162	61.2
40 - 45 MPH	312	16.4
≥ 50 MPH	268	14.1
Unknown	158	8.3

Table 2 - Driver Characteristics

	Number of Drivers	%
Age-Group		
≤ 24	912	48.0
25 - 34	655	34.5
35 - 44	241	12.7
≥ 45	78	4.1
Unknown	14	0.7
State of Driver's License		
Maryland	1568	82.5
Out-of-state	270	14.2
Unknown	62	3.3
Charges by Police		
Not charged	1337	70.4
Charged	563	29.6
# Violations Due to Speeding During Past 60 Months		
None	562	29.6
One	322	16.9
Two or more	428	22.5
Unknown	256	13.5
Not applicable	332	17.5
# Violations Due to Drug/Alcohol During Past 60 Months		
None	1159	61.0
One	105	5.5
Two or more	48	2.5
Unknown	256	13.5
Not applicable	332	17.5
Helmet Use		
Not used	1087	57.2
Used	674	35.5
Mis-coding	42	2.2
Unknown	97	5.1
Ejection Status		
Not ejected	648	34.1
Ejected	1212	63.8
Trapped	11	0.6
Unknown	29	1.5

Patterns of Helmet Use (Table 3) - Overall, only 35.5% of the drivers were reported to have used a helmet at the time of crash. However, the frequency of helmet use was significantly less under special circumstances. For example, only 16.3% of the drivers with

special circumstances. For example, only 16.3% of the drivers with a history of drug/alcohol violations were helmeted. Among those who crashed between midnight and 6 am, only 24.7% were wearing a helmet. Weekend riders used helmets less frequently. Drivers with a history of "other" violations (other than speeding and drug/alcohol) used helmets less frequently. Those who hit fixed objects also wore helmets less frequently. Highway (≥ 50 MPH) drivers wore helmets more frequently. Drivers in the age-group 25 to 34 were less frequently helmeted. These differences are statistically significant.

Table 3 - Patterns of Helmet Use

Category	Percent Helmeted	p
Summer/other seasons	32.6/37.6	<0.03
Midnight-6am/other times	24.7/37.6	<0.001
Weekend/weekdays	30.6/39.1	<0.001
Central MD/other regions	28.6/42.5	<0.001
Hit fixed object/other	31.2/36.7	<0.05
Age 25-34/other ages	31.4/37.6	<0.01
Posted speed <50/≥50	33.1/49.6	<0.001
Record of drug or alcohol/no record	16.3/37.2	<0.001
MD driver/out-of-state	34.2/43.0	<0.005
Past record of other violation/no violation	30.6/38.9	<0.001

Patterns of Crash Fatality (Table 4) - As mentioned earlier, 52 of the 1900 drivers died as a result of crash injuries, which brings the overall fatality rate to 2.74%. The highest death rate occurred in head-on collisions. Although statistically not significant ($p=0.06$), crashes occurring between midnight and 6 am produced a higher fatality rate (4.05%) than during other times of the day (2.54%). Because of the problem of "miscoding" and "unknown" use of helmets, the driver population was grouped in two ways: 1) the drivers with the specific code of helmet not being used vs the rest and 2) the drivers with the specific code of helmet being used vs the rest. From both comparisons, it is clear that when helmets are worn the probability of death decreases (not statistically significant).

Table 4 - Patterns of Crash and Fatality

Category	Percent Died	p
Midnight-6am/other times	4.05/2.54	NS
Hit fixed object/other	4.61/2.29	<0.02
Head-on/other collision	6.67/2.51	<0.01
Ejected/not ejected	4.04/0.44	<0.001
Posted speed ≥ 50MPH/<50	4.85/2.39	<0.05
Past violation of speed/none	4.66/2.34	<0.05
Helmet not used/other	3.12/2.22	NS
Helmet used/other	2.37/2.94	NS

Patterns of Injuries Among Drivers Seen at Emergency Departments - Information from the emergency department records was available for 897 drivers. Overall, 31.3% were found to have head injury. The proportion of head injury was twice as high among unhelmeted drivers (39.9%) as among helmeted drivers (20.6%) ($p<.001$). Unhelmeted drivers suffered head injury more frequently than helmeted drivers (27.1% vs 11.5%, respectively) (Table 5). The incidence of extremity injury was analyzed along with that of head injury because of the medical consequences and cost of care for such a combination of injuries (discussed later).

Table 5 - Head and Lower Extremity Injuries Sustained by Drivers Seen in Emergency Departments

Injury Status (Head/Extremity Only)	Helmet Use: No	Helmet Use: Yes
Total drivers	505	329
No head/No extremity injury	224	185
No head injury but: Extremity injury	86	76
Head injury only	150	55
Head injury with: Extremity injury	45	13
Total with head injury	195 (38.6%)	68 (20.7%)

Patterns of Injuries Among Hospitalized Drivers - Of 377 drivers admitted to hospitals, information was available for 345. Although the injury classification from the emergency department data was based on the preliminary assessment by the physicians in the admitting area, the final diagnosis as recorded on the discharge summary was obtained for the drivers who were admitted. Overall 49.9% had a diagnosis of head injury. Unhelmeted drivers had a significantly higher (54.6%) incidence of head injury than helmeted drivers (38.5%) (Table 6).

Table 6 - Head and Lower Extremity Injuries Sustained by Drivers Admitted to Hospitals

Injury Status	Helmet Use	
	No	Yes
Total Drivers	203	109
No head/No extremity inj.	33	24
No head injury but: Extremity inj.	56	43
Head injury only	69	35
Head injury with: Extremity inj.	45	7
Total with head injury	114 (56.2%)	42 (38.5%)

Acute Care Cost (Tables 7-10) - Hospital records were obtained for 345 drivers who were admitted to any of the participating hospitals in the state. From these records, final diagnosis, length of stay, disposition, and hospital charges were available. From the statewide level I trauma center, where one-third of these drivers were admitted, physicians' fees specific to length of stay, disposition (dead/live discharge), and the severity of injury were computed. Using these data, physicians' fees were estimated for patients admitted to other hospitals. Data presented in Tables 7-8 therefore represent total acute care charges (hospital charges + professional fees) during hospitalization. From these data the following results were obtained: Overall cost of acute care was $21,500 per driver. This cost was three times higher for unhelmeted drivers (mean costs of $30,365 and $10,442, respectively) as for helmeted drivers (Table 7). Although the proportion of unhelmeted drivers without insurance was the same (30.6%) as that of helmeted drivers (29.3%), their acute care cost was more than twice ($18,789) that of helmeted ($7,546) in the "no insurance" group (Table 8). A slightly higher proportion (15.3%) of unhelmeted drivers as helmeted drivers (12.9%) was covered by public assistance (all government insurance). However, even in this group, cost of care per unhelmeted driver was more than twice ($47,785) that per helmeted driver ($21,678). The difference in this cost between helmeted and unhelmeted drivers is even more significant among those carrying commercial health insurance. The average cost per unhelmeted driver ($32,000) was almost four times

that per helmeted driver ($8,855). These differences in cost may be largely explained by the presence/absence of head and extremity injuries, which are by far the costliest conditions to treat. Utilizing the experiences of helmeted drivers within each major insurance category, the expected costs, if all drivers had worn helmets, were calculated for unhelmeted drivers. Subtracting this from the actual cost gave the "excess" cost in each category (Table 9). These data indicated that 1) the public must subsidize $16,200 in acute care cost alone per driver per incidence of injury for non-use of a helmet and 2) even the commercial insurance companies must pay an extra $23,150 in acute care cost alone per unhelmeted driver per incidence of injury.

Table 7 - Acute Care Cost for Hospitalized Drivers

Helmet	N	Cost
Used	116	$1,211,214
Not used	170	$5,162,057
Unknown	59	$1,043,935
Total	345	$7,417,206

Table 8 - Insurance Status, Cost, and Use of Helmet (Drivers)

Insurance Status	Helmet Use		
	No	Yes	Unknown
No insurance	$976,564 (52)	$256,566 (34)	$251,556 (20)
Public assistance	$1,242,400 (26)	$325,173 (15)	$160,175 (7)
Commercial	$2,944,416 (92)	$593,261 (67)	$565,949 (32)

Note: The figures in parentheses are the numbers of drivers.

Table 9 - Expected Cost and Excess Cost of Acute Care for Nonhelmeted Drivers Based on the Experience of Helmeted Drivers

Insurance Status (N)	Expected Cost	Excess Cost
No insurance (52)	$392,395	$584,169
Public assistance (26)	$563,633	$678,767
Subtotal (Cost to taxpayer)		$1,262,936
Commercial insurance (92)	$814,627	$2,129,789

Acute Care Cost for Head and Lower Extremity Injury - Acute care costs per driver per episode of hospitalization are shown in Table 10 specific to the use of helmets and the presence of head/extremity injuries. Consistently, the cost was less within each injury type if helmets were worn. The cost was more than 10 times ($56,200) when both head and lower extremity injuries were present and helmets were not worn compared with $4,964 for those who had head injury but no extremity injury and were wearing helmets. The acute care cost was positively correlated with mean ISS ($r=0.822$, $p=0.012$) . Head injury was more severe (higher mean ISS) among unhelmeted drivers regardless of the presence or absence of lower extremity injury.

Table 10 - Acute Care Cost by Pattern and Severity of Injury among Hospitalized Drivers

Injury Pattern	Helmet Used	Mean ISS	Hosp Chrg	Prof Fee
No head injury and no lower extremity injury	No	8.4	6208	3562
	Yes	12.9	8967	4956
Head injury but no lower extremity injury	No	16.3	8732	4113
	Yes	10.4	3597	1367
No head injury but lower extremity injury	No	9.6	11405	9765
	Yes	8.8	7946	3540
Head injury and lower extremity injury	No	22.9	39554	16646
	Yes	11.6	5395	2260

DISCUSSION

Laws requiring motorcyclists to use helmets reduce deaths by approximately 24-30 percent (Watson, et al. 1980, 1981; Robertson, 1984; Hartumian et al., 1983).

Few studies of non-fatal injuries have been reported, but a report by McSwain and Lummis (1980) indicated that the increase in such injuries after repeal of a helmet law was similar to the analogous increase in deaths. Our study shows that the increase in head injury, if helmets were not used, may be as high as 42% among hospitalized drivers (Table 5), and even higher (100%) among those seen at an emergency department (Table 4). The true impact of non-use of helmets, then, both in terms of financial burden as well as human suffering, is reflected more realistically by these costs of non-fatal injuries, since the overall fatality rate was only 2.74%.

The helmet law was passed in Maryland in 1968 and repealed in 1979. Before repeal, 96% of motorcyclists were wearing helmets, as contrasted to only 50% in 1982. As indicated, usage among drivers in our study was 35.5%. Of the total group of admitted patients with head injuries, 52% also had lower extremity injuries (Table 5). This pattern of injuries has increasingly been recognized as an especially serious combination, as reflected by the injury severity scores and costs presented in Table 9. The effectiveness of the helmet is particularly apparent for the group of patients with both head and lower extremity injuries. Although the samples of patients are small, the group with helmets had a mean ISS score equal to half that of the non-helmeted and one-tenth hospital costs. Hospital charges incurred in the present study are similar to those reported in a 1988 paper by Rivara et al.; however, that report did not relate charges to helmet use or to the pattern of injuries.

The true long-term costs of this devastating types of injuries, is reflected in a paper by MacKenzie et al. (1988). Those investigators showed that even after 1 year, only 57% of patients had returned to work.

These findings are reinforced by more recent data (Siegel et al., 1990) indicating that "femoral fractures which markedly impair mobility, or pelvic fractures which may induce both morbidity and gait-related problems, imposed a substantial increase in the need for acute inpatient rehabilitation in the highest GCS groups when compared to brain injury alone.

Given the significantly higher incidence of non-fatal injuries, the estimated savings attributable to helmet use are staggering. Furthermore, this reduction in cost is particularly important because it could greatly reduce public expenditures. Approximately 37% of the estimated excess cost incurred by the 170 non-helmeted drivers in this study was born by taxpayers. This translates into an excess cost, born by the public, of

$16,000 per acute traumatic episode.

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