Motorcycle Helmet Use and Injury Outcome and Hospitalization Costs from Crashes in Washington State

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Introduction

Motorcycle-related deaths and injuries are an important cause of morbidity and mortality in the United States.1 The injury severity and consequences of a motorcycle crash are far greater than for an automobile crash.2 In Washington State, for example, there were 27.4 motorcycle rider fatalities per 1000 motorcycle crashes in 1989 compared with 5.6 fatalities per 1000 for all other motor vehicle crashes.3 This represents an almost fivefold increase in fatality risk for motorcycle collisions.

Most motorcycle-related deaths involve head injury, and motorcycle helmets significantly reduce the risk of death attributable to head injury.4-8 More recent work has demonstrated the protective effect of helmets during nonfatal crashes.9 Few studies have evaluated the overall impact of helmet use on crash-related motorcycle injuries and associated costs in a statewide population; most previous reports have been case series of admissions to individual hospitals or trauma centers.10-13 These series may overrepresent severely injured, especially head-injured, patients. Patients who have other injuries, but who escape head or facial trauma because of helmet use, often do not require emergency trauma care and thus are not included in these series. Such studies may therefore underestimate the overall impact and cost of motorcycle injuries and the protective effect of helmets.

The present research was undertaken to examine the statewide impact of motorcycle-related trauma and the measurable effects of helmet use under one of the conditions for which helmets were designed—serious crashes. Before passage of the Washington helmet use law in 1990, mandatory helmet use was limited to riders under 18 years of age. By linking 1989 statewide motorcycle crash data from state patrol reports to statewide hospitalization data and vital records death files, we were able to analyze crash-related data, including helmet use, and injury outcome data, including costs of hospitalization, for a statewide population.

Methods

To conduct this retrospective cohort study, we computer-linked statewide crash, hospital, and death records data sets. This linkage permitted assessment of exposure (e.g., motorcycle crashes, helmet use, other crash factors) and incidence of study outcomes (e.g., injuries, deaths, cost) in a statewide population.

Washington State residents who were drivers of a motorcycle, motor scooter, or moped (herein referred to as motorcyclists) and involved in a crash in 1989 were identified from Washington State Patrol data tapes. The patrol collects and maintains data on motor vehicle crashes occurring on public roads in Washington.
State when there is an injury, death, or property damage in excess of $500.

Crash-related information on outcome (fatal—yes or no), age and sex, helmet use (yes or no), posted speed limit (continuous data), type of crash (collision—yes or no), type of road (highway—yes or no), road condition (wet—yes or no), weather (clear—yes or no), visibility (dark—yes or no), and location (rural vs urban) was obtained from Washington State Patrol records for this study.

To obtain data for hospitalized motorcyclists on the type and severity of injuries, length of hospitalization, cost of care, and disposition at discharge, records on motorcyclists involved in crashes were linked to the statewide Comprehensive Hospital Abstract Reporting System. Information from this reporting system is available for individuals hospitalized for at least 1 calendar day in acute-care hospitals in Washington State. This linkage allowed us to combine helmet use and other crash-related data with data on injury outcome and costs. Finally, computerized multiple-cause-of-death records for motorcycle crash fatalities were linked to crash and hospitalization records. For this study, injury outcome data for fatalities that did not involve hospitalization were limited to data on head injury (yes or no, as a contributing cause).

Deterministic linkage of Washington State Patrol records to Comprehensive Hospital Abstract Reporting System records was accomplished by creating an alphanumeric patient identifying code in each data set based on name and birth date. All motorcycle-crash Washington State Patrol records were first linked to Department of Licensing data to obtain additional information (full first name) necessary to formulate the Washington State Patrol patient identifying code. Linked Washington State Patrol and Comprehensive Hospital Abstract Reporting System records were further matched by sex and date of admission to hospital (within 5 days from the crash date) to increase the certainty of appropriate linkage. These linked records represent motorcyclists involved in crashes and hospitalized for injuries in 1989. We obtained injury outcome data for fatally injured motorcyclists who were not hospitalized by linking these records to computerized multiple-cause-of-death files using the name and birth date information available on the driver’s license. These records were further matched by sex and date of death to increase certainty of matches.

Up to five injuries for each hospitalized motorcyclist, coded with the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9 CM), were identified from Comprehensive Hospital Abstract Reporting System records. Head injury data for fatal crashes were identified with ICD-9 CM codes for head injury found in multiple-cause-of-death files (ICD codes 800, 801, 803, 804, and 850–854). For hospitalized motorcyclists, the Abbreviated Injury Scale scores were calculated from the ICD-9 CM codes with the Abbreviated Injury Scale–ICD mapping program. Injury Severity Scores were calculated from the Abbreviated Injury Scale–1985 with the method of Baker et al. Study subjects with maximum head injury Abbreviated Injury Scale scores of 2 through 5 were considered to have a head injury. For the other Abbreviated Injury Scale body regions (face, thorax, abdomen, extremities, and external), any score greater than zero was considered an injury. For this study, Abbreviated Injury Scale [AIS] scores were categorized as follows: AIS 1 = minor, AIS 2 = moderate, AIS 3 = serious, AIS 4 = severe, and AIS 5 = critical. Injury Severity Scores were categorized with a method similar to that of Copes et al. For this study, injury severity scores from 1 through 15 were considered moderate, 16 through 24 were considered serious, and 25 and higher were considered severe or critical. In cases of multiple admissions for follow-up treatment, injuries from the initial admission were used to assess incidence and injury severity (Abbreviated Injury Scale, Injury Severity Score), but all admissions were used to calculate costs.

Although there is a distinction between costs and charges, payer-specific charges were used as a proxy for costs of care. Only charges for hospital care were included. Physician charges; subsequent direct costs for rehabilitation, home care, and subsistence; and indirect costs related to lost productivity and wages were not considered.

Estimates of relative risk (RR; rate ratios) and test-based confidence intervals (CIs) for the following dichotomized outcomes (yes or no) among hospitalized helmeted and unhelmeted motorcyclists were calculated with the Mantel–Haenszel method: all injuries, head injury, severe head injury, serious overall injury, readmission to an acute-care hospital, and death (levels of outcome are described above). Analysis of differences between helmeted and unhelmeted riders with respect to length of hospitalization, cost of hospitalization, and age was done with Student’s t-test and the Wilcoxon rank sum test. Differences in sex and disposition on hospital discharge were tested with chi-square analysis. Relative risk (odds ratios) and confidence bounds for crash-related head injury for the following variables were estimated with logistic regression analysis: helmet use, type of road, crash type, posted speed, visibility, road condition, weather, and locality (levels of exposure are described above). Adjusted odds ratios for variables positively associated with head injury were calculated to explore potential confounding relationships between helmet use and other crash variables.

Data processing and parametric and nonparametric (chi-square, Wilcoxon rank sum) tests of significance were performed with SAS statistical software. Nonparametric test results were used to support parametric results when comparing length of stay and hospital costs for helmeted and unhelmeted motorcyclists, because just a few individuals with very long stays and higher costs can skew results. Logistic regression analysis was performed with EGRET epidemiologic software.

Results

Data Linking

Washington State Patrol records for 1989 show that 2709 motorcyclists (2557 motorcycles, 40 motor scooters, and 112 mopeds) were involved in crashes on public roads, with 59 fatalities. Patient identifying codes could not be formulated for 619 (22.9%) of the Washington State Patrol crash records. Three hundred and eighty-six crash victims did not have a valid driver’s license, and 233 with a valid license were not successfully linked to Department of Licensing data. These records, therefore, could not be linked to hospital discharge records and were excluded from the hospital data analyses (the records could, however, be included in several fatality analyses, as they did not strictly require linkage to hospital discharge data). Information to create patient identifying codes for fatally injured motorcyclists could be obtained from multiple-cause-of-death records.

Patient identifying codes were generated for 2090 Washington State Patrol records. Of these, 399 were linked successfully to hospital records. Ten additional records were added by linking previously
unmatched fatality records to hospital records, bringing the total to 409 records. This was possible because death records could be used to generate patient identifying codes. These fatalities were among the Washington State Patrol records for which no Washington State Patrol patient identifying code could be generated due to lack of a valid driver’s license or unsuccessful computer linkage to the Department of Licensing for information to complete the patient identifying code.

Twenty-three of the 409 records did not have helmet use information and were excluded, yielding 386 hospitalizations for analysis. All 59 fatalities identified from Washington State Patrol records were linked to multiple-cause-of-death files. One nonhospitalized, fatally injured motorcyclist was dropped because there was no helmet use information, yielding 58 fatalities for analysis.

**Hospitalized Crash Victims**

Most hospitalized motorcyclists were male (96%) and their average age was 30 years, which is generally consistent with previous findings5,11,12 (Table 1). Unhelmeted motorcyclists were slightly more likely to be hospitalized when involved in a crash (RR = 1.2; 95% CI = 1.0, 1.5); however, they were nearly three times more likely to be hospitalized with a head injury (RR = 2.9; 95% CI = 2.0, 4.4) and almost four times more likely to have suffered a severe or critical head injury (RR = 3.7; CI = 1.9, 7.3). Unhelmeted drivers were also twice as likely to be seriously injured overall (Injury Severity Score of ≥16) in a crash (RR = 2.0; 95% CI = 1.2, 3.2).

The average length of stay (including readmission days) for helmeted crash victims (10 days) was lower than that for unhelmeted crash victims (12.6 days), but the difference was not statistically significant at the P < .05 level. The total cost for hospital treatment of motorcyclists in this study was $5.7 million in 1989, of which $3.5 million was for unhelmeted riders. The average cost of hospitalization per patient, however, did not prove to be significantly higher for the unhelmeted riders at the P < .05 level.

Most crash victims, helmeted and unhelmeted, were eventually discharged to home in their own or family care. However, nonhelmeted riders were more likely to be referred to a hospital, skilled nursing facility, or intermediate care facility for further care (including rehabilitation). Seventy-two motorcyclists were readmitted to an acute-care hospital for further care of the initial injuries or for complications. Unhelmeted motorcyclists were almost twice as likely to be readmitted (RR = 2.2; 95% CI = 1.4, 3.6).

Although relatively few hospitalized motorcyclists suffered facial injuries (Table 2), the unhelmeted group had a nearly eightfold increase in risk (RR = 7.7; 95% CI = 3.5, 16.8). Injuries to the thorax and abdomen were found with the same frequency in both groups. Injury to an extremity was the most common injury in hospitalized motorcyclists and occurred with identical frequency in helmeted and unhelmeted motorcyclists. Risk of external injuries (e.g., open wounds, contusions, burns) was significantly associated with not wearing a helmet. Eleven percent of all hospitalized motorcyclists suffered neck injuries (not considered a separate Abbreviated Injury Scale body region), but the difference between helmeted and unhelmeted motorcyclists was not significant (RR = 1.1; 95% CI = 0.6, 2.2).

### Table 1—Incidence of Hospitalization and Severe Head and Other Injuries, Length of Stay, Average and Total Costs, and Disposition at Discharge: Hospitalized Motorcyclists, Washington State, 1989

<table>
<thead>
<tr>
<th></th>
<th>Crashes with Helmet (n = 945)</th>
<th>Crashes without Helmet (n = 957)</th>
<th>Relative Risk or P</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of all hospitalizations</td>
<td>18</td>
<td>22</td>
<td>1.2</td>
<td>1.0, 1.5</td>
</tr>
<tr>
<td>% with head injuries (AIS score ≥2)</td>
<td>2.8</td>
<td>8.4</td>
<td>2.9</td>
<td>2.0, 4.4</td>
</tr>
<tr>
<td>% with severe head injury (AIS score ≥4)</td>
<td>1.0</td>
<td>3.6</td>
<td>3.7</td>
<td>1.9, 7.3</td>
</tr>
<tr>
<td>% with ISS ≥16</td>
<td>2.3</td>
<td>4.6</td>
<td>2.0</td>
<td>1.2, 3.2</td>
</tr>
<tr>
<td>% readmitted to hospital</td>
<td>2.3</td>
<td>5.2</td>
<td>2.2</td>
<td>1.4, 3.6</td>
</tr>
<tr>
<td>Hospitalizations</td>
<td>(n = 172)</td>
<td>(n = 214)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% male</td>
<td>95.9</td>
<td>95.8</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td>Mean age (SE)</td>
<td>29.6 y (.91)</td>
<td>30.2 y (.71)</td>
<td>.56</td>
<td></td>
</tr>
<tr>
<td>Average length of stay (SE)</td>
<td>9.9 days (1.0)</td>
<td>12.6 days (1.4)</td>
<td>.14</td>
<td></td>
</tr>
<tr>
<td>Average cost (SE)</td>
<td>$12 689 ($1302)</td>
<td>$16 460 ($1971)</td>
<td>.11</td>
<td></td>
</tr>
</tbody>
</table>

Note. AIS = Abbreviated Injury Scale; ISS = injury severity score.

### Table 2—Number of Injuries* among Hospitalized Motorcyclists, by Body Region

<table>
<thead>
<tr>
<th>AIS Body Region</th>
<th>% Riders with Helmet (n = 945)</th>
<th>% Riders without Helmet (n = 957)</th>
<th>Relative Risk</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>1.4</td>
<td>4.2</td>
<td>2.9</td>
<td>2.0, 4.4</td>
</tr>
<tr>
<td>Face</td>
<td>0.3</td>
<td>2.1</td>
<td>7.7</td>
<td>3.5, 16.8</td>
</tr>
<tr>
<td>Thorax</td>
<td>1.7</td>
<td>1.8</td>
<td>1.1</td>
<td>0.7, 1.7</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1.3</td>
<td>1.2</td>
<td>0.9</td>
<td>0.5, 1.5</td>
</tr>
<tr>
<td>Extremity</td>
<td>6.7</td>
<td>6.9</td>
<td>1.0</td>
<td>0.8, 1.3</td>
</tr>
<tr>
<td>External</td>
<td>3.8</td>
<td>5.7</td>
<td>1.5</td>
<td>1.1, 2.0</td>
</tr>
</tbody>
</table>

*Abbreviated Injury Scale (AIS) score of >1 for head injury; AIS score of >0 for all other body regions.
### Motorcycle Fatalities

The 58 fatal crashes included in this study (all involving motorcycles) represented 2.1% of all \( n = 2709 \) motorcycle, motor scooter, and moped crashes recorded in Washington State in 1989. Unhelmeted motorcyclists were at significantly increased risk for fatal crashes (adjusted \( RR = 1.63; 95\% \ CI = 1.003, 2.64 \)). Males were almost four times more likely to die than females (\( RR = 3.64; 95\% \ CI = 20, 26.59 \)), and the risk of death increased by about 0.7% for each year of age (\( RR = 1.007; 95\% \ CI = 0.983, 1.030 \)).

### Motorcycle Crash Data

Two of the seven crash factors we explored were significantly and independently associated with head injury. Crashes during dark hours (after dusk to predawn) were more likely to involve head injury (\( RR = 1.8; 95\% \ CI = 1.2, 2.6 \)). Crashes in rural areas were also associated with an increased risk of head injury (\( RR = 1.6; 95\% \ CI = 1.1, 2.4 \)). Type of road (highway vs nonhighway), type of crash (collision vs noncollision), posted speed limit, road surface conditions (wet vs dry), and inclement weather (not clear vs clear) were not associated with increased risk of head injury. Adjusted odds ratios for risk of head injury among unhelmeted riders remained significant after controlling for other crash-related variables associated with head injury (Table 3).

### Discussion

This statewide population-based study demonstrates that motorcycle helmet use is strongly and independently associated with reduced likelihood and severity of head injury, reduced overall injury severity, and reduced probability of motorcycle-related hospitalization and death attributable to head injury. Additionally, the results support the hypothesis that increased motorcycle helmet use will decrease the costs for medical care of injured motorcyclists.

Although unhelmeted motorcyclists were only slightly more likely to be hospitalized after a crash for any injury sustained, unhelmeted riders were nearly three times more likely to have sustained head injuries and almost four times more likely to have suffered severe to critical head injuries. Unhelmeted motorcyclists had a 63% higher death rate.

Injuries to the face occurred more often among unhelmeted motorcyclists, whereas the incidence of neck injury was the same in both groups, consistent with the protective benefits of the helmet. This observation supports the direct association between helmet use and reduced likelihood of head injury.

The average per-patient cost of hospitalization was 30% higher for unhelmeted riders in this study, which supports other recent published findings that the cost of medical care among unhelmeted riders is significantly higher. The longer length of stay for unhelmeted vs helmeted motorcyclists in our study also supports recent published findings. The increased hospital stay for unhelmeted riders can be partially explained by the greater number of readmissions to acute-care hospitals for follow-up treatments or complications. This finding shows that the number of hospital days per motorcycle crash event among unhelmeted motorcyclists is higher and helps explain the increased direct costs associated with hospitalizations of unhelmeted motorcyclists.

The lack of statistically significant differences in hospital cost and length of stay between helmeted and unhelmeted motorcyclists is likely due to high variability of the data, given that we used a statewide population that included all moderately and severely injured motorcyclists. However, because of the high number of unhelmeted motorcyclists involved in crashes when no mandatory helmet law was in effect, the difference in total costs between groups was substantial and supports the use of helmets as a method of reducing the economic impact of motorcycle crash-related injury.

This study also demonstrates that the observed differences in the rate and severity of head injury among helmeted and unhelmeted motorcyclists are not explained by differing crash factors such as the age and sex of the rider, type of crash, type of road, posted speed limit, visibility, road surface conditions, weather, and setting (rural vs. urban).

Crash factors not directly studied for this report but associated with the likelihood and severity of trauma-related head injury are alcohol25–28 and speed at impact. Unfortunately, actual speed at impact, blood alcohol concentration, or other reliable, comparable alcohol-related data are not contained on Washington State Patrol records.

Several limitations to this study should be addressed. Sample selection, based on linkage to hospital data, ensured that all hospitalized motorcyclists compared in this study were injured. If helmets are effective in reducing injury, helmeted riders in the sample would be underrepresented. This occurred to the extent that, in some crashes, no severe neck and body injury resulted, and the helmet saved the motorcyclist from a serious head injury that otherwise would have occurred. The beneficial effects of helmets would not have been seen in these cases because the motorcyclist was not hospitalized, implying that the bias is toward an underestimation of the protective effect of helmets.

Incomplete linking of crashes to hospitalizations also led to underestimates of the incidence of injuries and hospitalization costs associated with motorcycle crashes in Washington State. Six hundred nineteen crash victims were not included in the search for matching records in Comprehensive Hospital Abstract Reporting System data because of incomplete linking of crashes to hospitalizations.

### Table 3—Logistic Regression Analysis Predicting Head Injury among Unhelmeted Crash Victims, with Other Crash Factors Controlled for

<table>
<thead>
<tr>
<th>Variable and Level</th>
<th>Odds Ratio for Head Injury</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helmet use: unhelmeted</td>
<td>3.1</td>
<td>2.0, 4.8</td>
</tr>
<tr>
<td><strong>Adjusted odds ratios, by factor controlled</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of road: highway vs local</td>
<td>3.2</td>
<td>2.0, 4.9</td>
</tr>
<tr>
<td>Crash type: collision vs noncollision</td>
<td>3.1</td>
<td>2.0, 4.9</td>
</tr>
<tr>
<td>Posted speed</td>
<td>3.3</td>
<td>2.1, 5.1</td>
</tr>
<tr>
<td>Visibility: dark vs daylight</td>
<td>3.0</td>
<td>1.9, 4.7</td>
</tr>
<tr>
<td>Road condition: wet vs dry</td>
<td>3.1</td>
<td>1.0, 4.8</td>
</tr>
<tr>
<td>Weather: not clear vs clear</td>
<td>3.1</td>
<td>2.0, 4.8</td>
</tr>
<tr>
<td>Locality: rural vs urban</td>
<td>3.1</td>
<td>2.0, 4.8</td>
</tr>
</tbody>
</table>
identification codes could not be generated. Additionally, the number of motorcycle crashes involving injury but not recorded in Washington State Patrol records is not known. More importantly, passengers involved in motorcycle crashes who were hospitalized or died were excluded from this study because personal identification information on passengers is not reported on the crash data tapes. Washington State hospital discharge data for 1989 indicate that there was one passenger hospitalized for every eight motorcycle drivers hospitalized (Washington State Injury Prevention Program, Washington State Department of Health, Olympia, Wash, 1989, unpublished data). The numbers and types of injuries and the costs associated with these unaddressed hospitalizations are not included in this report. Finally, this study does not attempt to estimate other substantial direct costs (e.g., physician charges, skilled nursing or home care, rehabilitation) or the long-term indirect costs (e.g., lost productivity) associated with motorcycle-related trauma.

The findings of this study strongly support the contention that the mandatory motorcycle helmet use law, reinstated in Washington State in 1990, will (1) reduce the incidence and severity of motorcycle-related injuries, particularly head injury; (2) reduce the associated direct and indirect economic costs of motorcycle-related injuries in Washington State; and (3) reduce the physical, psychological, and economic devastation suffered by victims and family of injured motorcyclists, especially where long-term disability due to head injury is involved. The methods used in this study can be used to assess the impact of the mandatory helmet use law reinstated in Washington State in 1990.

References
22. Statistics and Epidemiology Research Corp. EGRET epidemiologic software, version 0.25.01. Seattle, Wash: Statistics and Epidemiology Research Corp; 1990.