



# Maine Motorcycle Crashes: Causes and Injury Outcomes

A report prepared  
by the  
Maine Health Information Center  
For the  
Maine CODES Advisory Committee

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## **About the Maine Crash Outcome Data Evaluation System**

This study was conducted by the Maine Health Information Center as part of the Maine Crash Outcome Data Evaluation System (CODES). The Maine CODES project is a cooperative agreement with the National Highway Traffic Safety Administration. The project links statewide police-reported motor vehicle crash data to statewide hospital inpatient and hospital emergency department data. For more information about Maine CODES refer to [www.mhic.org/CODES/](http://www.mhic.org/CODES/).

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## **About the Study**

This study was conducted by the Maine Health Information Center (MHIC) at the request of members of the Maine CODES Advisory Committee. Maine CODES has conducted studies on the outcomes from motor vehicle crashes in Maine on a wide variety of topics including: young drivers, older drivers, children, safety belt use, motorcycles, bicycles, vehicles that ran off the road, and speeding and other unsafe driving behavior. This study is the second study of motorcycle crashes conducted by the Maine CODES project.

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## EXECUTIVE SUMMARY

Using Maine Crash Outcome Data Evaluation System (CODES) data, the causes of motorcycle crashes and the injury outcomes are described. Single-vehicle crashes (did not involve another vehicle) were distinguished from motorcycles in collision with another vehicle. Road location, time of crash, operator age, gender, pre-accident actions, contributing factors, license status, and alcohol or drug impairment were evaluated. For collisions with another vehicle, the driver of the other vehicle's age, gender, pre-accident actions, contributing factors, license status, and alcohol or drug impairment were also evaluated. The study was based on 2003-2006 Maine crashes.<sup>‡</sup> Injury outcomes were determined from linked hospital data.

### Overall Findings for Maine Motorcycle Crashes:

- During 2003-2006, 2,340 motorcycle operators and 288 passengers were involved in motorcycle crashes in Maine
- During 2003-2006, 1,103 (47%) of motorcycle crashes were single-vehicle (did not involve another vehicle) and 1,237 (53%) were motorcycles in collision with another vehicle.

### *Single-Vehicle Motorcycle Crashes*

- Based on police-reported light conditions, 208 (19%) of single-vehicle and 96 (8%) of motorcycle collisions with another vehicle took place when it was dark.
- Overall, 33 percent of single-vehicle motorcycle crashes had some reported operator violation. Operator illegal or unsafe speed was a factor in 318 (29%) of single-vehicle motorcycle crashes.
- Among the 1,103 single-vehicle crashes, 472 (43%) took place at a curve in the road and illegal or unsafe speed was a factor in 38 percent of these crashes.
- Driver inattention (27%) and operator inexperience (27%) were also factors in single-vehicle crashes. Motorcycle operator inexperience (7%) was less likely to be reported in collisions with another vehicle than in single-vehicle crashes (27%).
- Among operators in single vehicle crashes 32 (3%) were operating with a suspended license and 290 (26%) did not have a motorcycle permission based on police report.

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<sup>‡</sup> This study was based on Maine Crash Outcome Data Evaluation System (CODES) data. The police-reported crash data was provided early in 2008 to the CODES project. Since the MCRS or other data sources may be revised over time, counts provided in this report may not match exactly to counts of motorcycle crashes provided in other reports generated by other state agencies.

- In single-vehicle motorcycle crashes, operators without a motorcycle endorsement were more than twice as likely to have driver inexperience reported compared with operators with an endorsement (47% vs. 19%).
- Operator impairment (alcohol or drugs) was more likely to be a factor in single-vehicle crashes. Among the 1,103 operators in single-vehicle crashes, 128 (12%) were reported as impaired compared to 27 (2%) in collisions with another vehicle.
- Operators in single-vehicle crashes were more likely to be younger than operators in collisions with another vehicle.

#### *Motorcycles in Collision with Other Vehicles*

- Among the 1,237 collisions with another vehicle 512 (41%) took place at an intersection and 261 (21%) took place at a driveway intersecting with the road.
- In 1,237 collisions with another vehicle, 338 (27%) of the drivers of the other vehicle were making a left turn.
- In collisions with another vehicle, 29 percent of the motorcyclists and 45 percent of the drivers of the other vehicle had a least one violation. For drivers of the other vehicle, failure to yield right of way, was reported for 325 (26%) of the crashes.
- Among operators in collisions with another vehicle 274 (22%) did not have a motorcycle permission.

#### *Injury Outcomes for Motorcycle Riders*

- Motorcycle riders represented 1 percent of all persons involved in crashes and 10 percent of persons requiring hospital care based on the linked data.
- Of 2,628 motorcycle riders and passengers, 398 (15%) were linked to an inpatient hospitalization and 1,044 (40%) were linked to an outpatient emergency department but were not hospitalized.
- Riders with hospital care sustained 2,530 injuries to different body regions indicating that riders in motorcycle crashes frequently sustained multiple injuries.
- The average charge for an outpatient emergency department visit was \$1,761 and the average charge for an inpatient hospitalization was \$40,844. The average hospital stay was 7.0 days.
- Injured riders discharged to a rehabilitation facility (61) had the highest average charges (\$92,417). While they accounted for only 4 percent of the

riders linked to hospital care these riders incurred one-third of the hospital charges and patient days.

- Riders in single-vehicle crashes incurred \$8.4 million in hospital charges and 1,262 inpatient days while riders in collision with another vehicle incurred \$9.7 million and 1,507 inpatient days.
- Compared with riders without a head injury, hospitalized motorcycle riders with a head injury stayed longer (9.2 vs. 5.8 days) and incurred higher charges (\$56,783 vs. \$32,477).<sup>¶</sup>
- Controlling for other crash factors, use of a motorcycle helmet reduced the risk of hospital care or death for any head injury by 41 percent (margin of error 23% to 55%) and reduced the risk of hospital care or death for a serious head injury by 53 percent (margin of error 29% to 69%).

#### **Limitations:**

This study evaluated the causes of crashes for motorcycle operators and operators of other vehicles colliding with motorcycles. The results of this study cannot be used to make any inferences about operators of motorcycles in general since it does not include any information about operators who were not involved in crashes. The hospital charges reported here do not represent the full cost impact of motorcycle crash injuries but only the charges for initial hospital care following the crash.

#### **Conclusions:**

Causes of Maine motorcycle crashes are consistent with previous studies of motorcycle crashes going back as far as 1981.<sup>2</sup> About half of the motorcycle crashes were single-vehicle (did not involve another vehicle) and half were motorcycles in collision with another vehicle. Road speed limit, a curve in the road, riding at night, younger operators, operator inexperience, illegal or unsafe speed, alcohol or drugs, lack of motorcycle license permission were associated with motorcycle crashes. Drivers of other vehicles in collisions with a motorcycle were often very young or very old, in violation, failing to yield right of way, making a left turn, or with driver distraction or inattention reported. Motorcycle riders sustained significant injury and often multiple injuries. Helmets reduced the risk of a head injury. These findings suggest the value of:

- enforcement efforts to reduce speeding and other violations;
- rider education and motorcycle permission endorsement;
- improved visibility by use of headlamps or high visibility clothing;
- increased efforts with the general driving population to improve awareness of motorcycles on the road; and,
- use of helmets and other protective gear.

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<sup>¶</sup> These charges represent only the initial cost of care for these patients and do not reflect additional medical and other costs that may occur during the months and years after discharge from the hospital. For some patients with severe injuries, the long-term cost of treatment may ultimately be covered by Medicaid (MaineCare).

## INTRODUCTION

Traffic Safety Facts published by the National Highway Traffic Safety Administration (NHTSA) indicate that fatalities from motorcycle crashes have more than doubled within the past decade.<sup>1</sup> In addition, the NHTSA statistics indicate:

- motorcyclists accounted for 11 percent of total traffic fatalities;
- per vehicle mile traveled, motorcyclists were about 37 times more likely than passenger car occupants to die in a traffic crash;
- 51 percent of all motorcycles involved in fatal crashes collided with another vehicle; and,
- one out of four motorcycle operators in fatal crashes were operating with an invalid license

Although motorcycle crashes are common, there have been surprisingly few studies of the causes. From the first major study by Hurt in 1981 and subsequent studies, factors that contribute to motorcycle crashes and crash fatalities can be identified.<sup>1,2,3,4,5,6,7</sup> These include:

- crashes with another vehicle;
- intersections;
- the other vehicle is turning left;
- driver of the other vehicle violated motorcyclist's right of way, did not see the motorcyclist, or may have been obstructed by other vehicles;
- driver of the other vehicle misjudged motorcyclist speed and distance;
- an object or hazard in the road;
- motorcyclist riding at night;
- motorcycle rider lacked basic riding skills and experience;
- motorcycle rider failure to countersteer on curves;
- motorcycle rider over-braking;
- excessive speed, particularly with younger riders;
- rider with no license, license suspended, or no motorcycle license; and
- rider with high blood alcohol concentrations (BAC).

These crash factors drive many of the recommendations and programs of NHTSA, state and local highway safety departments, and other organizations such as the Motorcycle Safety Foundation<sup>¶</sup> programs to improve safety for and by motorcyclists.

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<sup>¶</sup> The Motorcycle Safety Foundation® is the internationally recognized developer of the comprehensive, research-based, Rider Education and Training System (MSF RETS). RETS curricula promotes lifelong-learning for motorcyclists and continuous professional development for certified RiderCoaches and other trainers. MSF also actively participates in government relations, safety research, public awareness

These include efforts to make other drivers more aware of motorcyclists on the road, education and training programs for motorcyclists to improve operation and defensive driving skills, rider visibility, and use of protective clothing including helmets. One publication describes an experienced motorcyclist's recommendation to a new motorcyclist, "assume you are invisible to the motorist and operate your motorcycle accordingly".<sup>7</sup>

## Maine Motorcycle Laws and Safety Education

Title 29-A of Maine statutes cover license endorsement, rider education, rules of the road for operation, and protective headgear. These statutes are provided in detail in Appendix 1 of this report.

Operation of a motorcycle in Maine requires a motorcycle license endorsement. A motorcycle instruction permit, license or endorsement requires a certificate of successful completion of a motorcycle driver education program and examination approved by the Secretary of State. Maine's motorcycle rider education was updated from the Motorcycle Safety Foundation's Basic Rider Course curriculum which made the classroom portion "learner based" with class participation in exercises; previously the classroom was lecture based. As Maine's 8 hour classroom course is based on the MSF BRC, there was a similar change to that curriculum

The two avenues to motorcycle endorsement are:

- 2-days, 15 hours (5 hours classroom, 10 on bike on a range including 17 exercises with the final exercise being the evaluation. Under this option a road test is not required.
- 8 hours classroom only resulting in a permit valid for 2 years. The permit is for daylight operation only without passengers. This is followed by a road test.

Due to Maine's relatively short riding season, the validity period for the instruction permit was extended from one to two years in 2008 to allow more practice time.

Maine's motorcycle helmet law passed in 1967 and was repealed in 1977. During the period of this study, helmets were required for riders under 15 and operators on an instruction permit and operators and passengers within one year of endorsement. In 2009, legislation was enacted that increased the aged based requirement to riders under 18.

## Motorcycle Endorsements and Registrations

Table 1 provides motorcycle license endorsement and registration data collected by the Maine Bureau of Motor Vehicles. During the decade 1998-2007, the number of

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campaigns and the provision of technical assistance to state training and licensing programs.  
<http://www.msf-usa.org/>

motorcycle and moped registrations increased by 82 percent from 26,979 to 49,103. The number of Maine residents endorsed to operate motorcycles was 96,998 during 2007. The higher number of endorsements than registrations reflects the fact that many Maine residents who are endorsed to ride a motorcycle may not be actively riding. Motorcycle registrations are often used in studies by NHTSA as a denominator to generate rates for analyses.

**Table 1. Maine Motorcycle License Endorsements and Registrations, 1998-2007**

| Year | Total Motorcycle Endorsements* | Motorcycle and Moped Registrations | Motorcycle Registrations | Special Motorcycle Registrations** | Moped Registrations |
|------|--------------------------------|------------------------------------|--------------------------|------------------------------------|---------------------|
| 1998 | 104,195                        | 26,979                             | 25,604                   | 0                                  | 1,375               |
| 1999 | 104,598                        | 27,650                             | 26,415                   | 0                                  | 1,235               |
| 2000 | 106,001                        | 28,892                             | 27,535                   | 0                                  | 1,357               |
| 2001 | 108,047                        | 31,115                             | 29,760                   | 0                                  | 1,355               |
| 2002 | 110,743                        | 33,549                             | 32,037                   | 243                                | 1,269               |
| 2003 | 114,274                        | 35,468                             | 33,810                   | 264                                | 1,394               |
| 2004 | 117,821                        | 37,561                             | 35,751                   | 326                                | 1,484               |
| 2005 | 92,519                         | 39,939                             | 37,802                   | 382                                | 1,755               |
| 2006 | 94,331                         | 43,622                             | 41,119                   | 478                                | 2,025               |
| 2007 | 96,998                         | 49,103                             | 46,033                   | 653                                | 2,417               |

Source: State of Maine Bureau of Motor Vehicles. Commonly Requested Statistics. Registration and License Information. <http://www.maine.gov/sos/bmv/stats/>

\*Motorcycle endorsements drop in 2005 due to a migration to new BMV computer system and the purging of old records

\*\*Special motorcycle registrations include: antique motorcycle, handicapped motorcycle, municipal motorcycle, Purple Heart motorcycle, special veteran motorcycle

Motorcycle riding has increased dramatically throughout the U.S. and in Maine as evidenced by the increase in registered motorcycles during the past decade. The number of motorcycle crashes in Maine increased by 45% from 446 during 1998 to 648 during 2007.

A previous Maine CODES study of 1995-1996 motorcycle crashes identified young age of operator, speeding, inexperience, alcohol, driver of other vehicle failed to yield or making left turn as important factors in motorcycle crashes.<sup>8</sup> In that study, helmets were found to reduce the risk of brain injury.

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## Overview and Purpose of Report

This study was conducted by the Maine Health Information Center (MHIC) at the request of members of the Maine CODES Advisory Committee. Maine CODES has conducted studies on the outcomes from motor vehicle crashes in Maine on a wide variety of topics including: young drivers, older drivers, children, safety belt use, motorcycles, bicycles, vehicles that ran off the road, and speeding and other unsafe driving behavior.

This study was requested by members of the Maine CODES Advisory Committee. The purpose of the study was to describe the causes of motorcycle crashes in Maine and the injury outcomes associated with the riders. The study provides a more detailed and up-to-date description of the causes and injury outcomes for motorcycle crashes in Maine. The study goals were to evaluate:

- distribution of crashes by age and gender of operators;
- geographical location of crashes;
- causes of single-vehicle motorcycle crashes;
- causes of crashes involving collision with another vehicle; and,
- injury outcomes and the effect of helmet use.

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## Data Sources and Methods

The study utilized police-reported crash data for 2003-2006. The crash data was supplied to CODES by the Maine Department of Transportation and is from the Maine Crash Reporting System (MCRS). Maine Health Data Organization (MHDO) provides the inpatient and outpatient emergency department hospital data. All source agencies for data used in CODES are represented on the Maine CODES Advisory Committee.

This study was based on Maine police-reported 2003-2006 crashes on public roads where an injury occurred or there was \$1,000 or more in property damage. The study included motorcycles, motorbikes, or mopeds. Maine operators and non-Maine operators in Maine crashes were included.

The evaluation of injury outcomes for these motorcyclists used linked data. The methods of linkage and analysis include the use of imputation of missing data consistent with NHTSA methods developed for all states participating in the NHTSA CODES project. NHTSA CODES methods are described in Appendix 2.

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## Interpretation of Results and Limitations

This study is based solely on the police-reported crash data and linked hospital data. The causes of motorcycle crashes may be complex.

Since a large number of motorcyclists operate without crash, it cannot be determined to what degree behaviors are more likely to result in a crash. From this study, the behavior of motorcycle operators who were not involved in crashes cannot be determined. For example, while illegal or unsafe speed was a factor in many motorcycle crashes, it cannot be determined from this study, how many

motorcyclists use illegal or unsafe speed and do not crash. Therefore, this study is descriptive of motorcyclists in crashes only and cannot be used to generalize about all motorcycle operators.

# RESULTS

## Motorcycle Study Population and Type of Crash

During 2003-2006, 2,340 motorcycle operators and 288 passengers were involved in motorcycle crashes in Maine.<sup>†</sup> Of the 2,340 motorcyclists, 2,058 (88%) were Maine licensed and the remaining 282 were from out-of-state, primarily New Hampshire (82), Massachusetts (44), and Canadian Provinces (45). Operators on mopeds (56) were retained in the study.

Figure 1 summarizes motorcycle crashes by month. The highest volume of crashes took place in the warmer months, peaking in July (n=492).

**Figure 1. Motorcyclist crashes in Maine by Month of Crash. 2003-2006  
Maine CODES.**

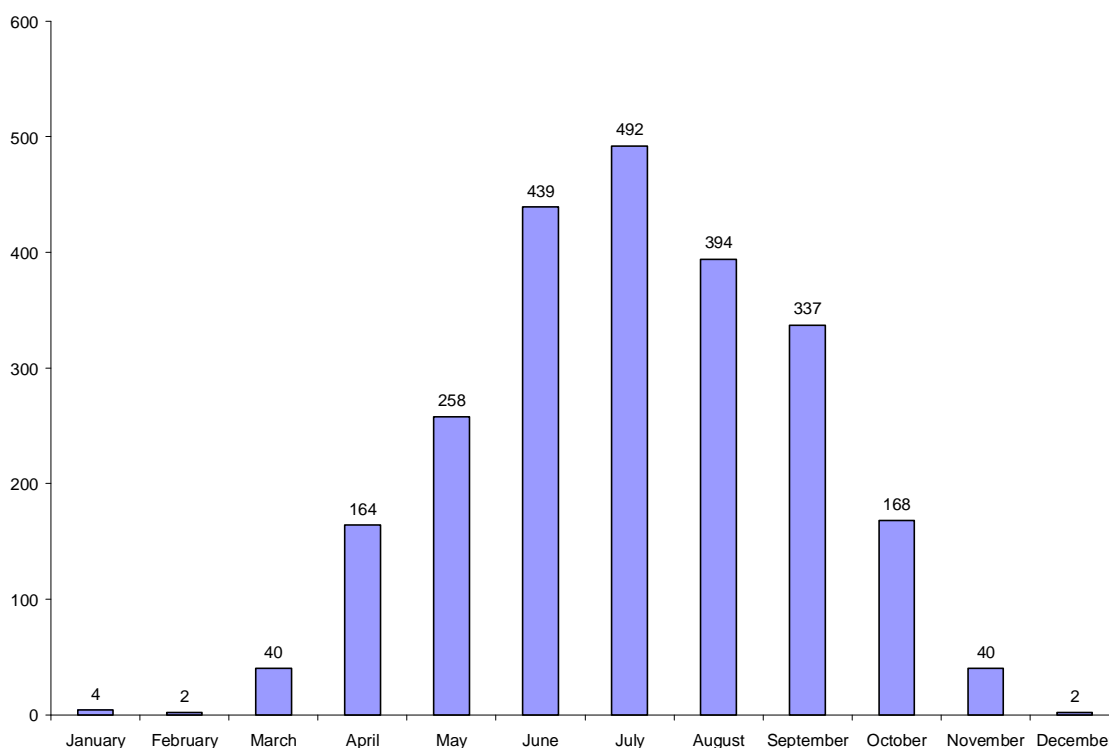
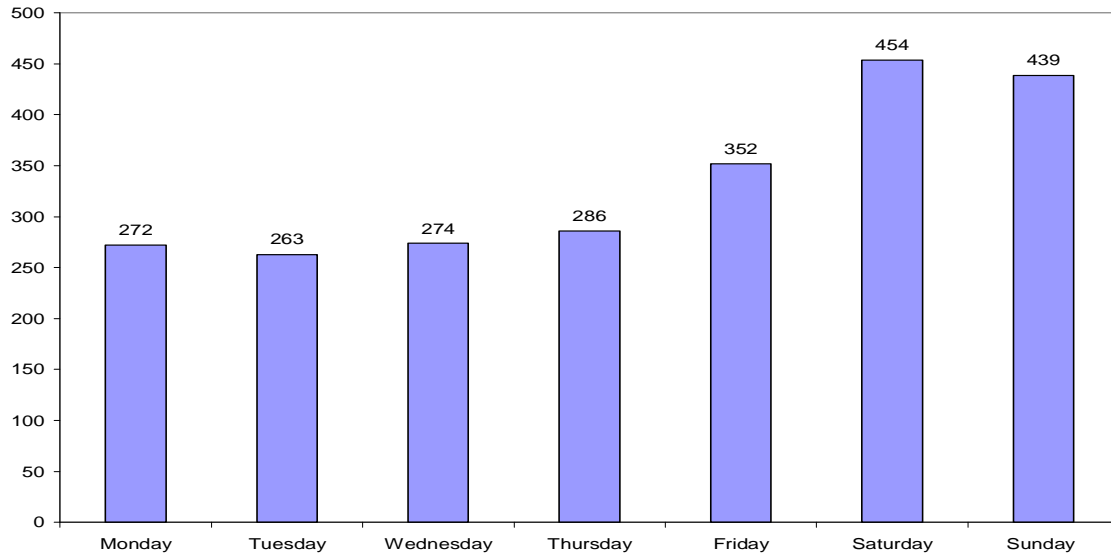


Figure 2 summarizes crashes by day of week of the crash. Motorcycle crashes peaked on Friday (352), Saturday (454), and Sunday (439) reflecting the recreational use of motorcycles on weekends.

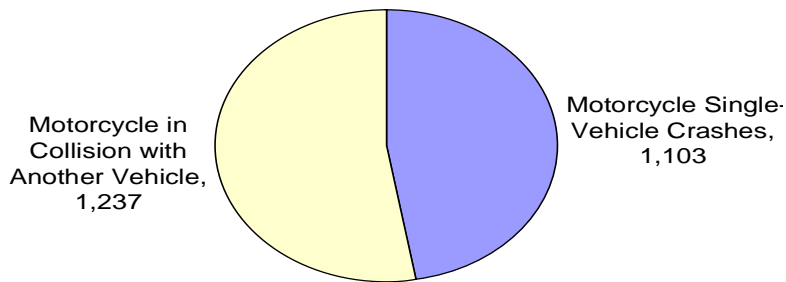
<sup>†</sup> This study included vehicles identified in from the MCRS UNITTYPE as 14=motorcycle (n=2,242) 15=moped (n=56), and 16=motor bike (n=42).

**Figure 2. Motorcyclist Crashes by Day of Week. 2003-2006 Maine CODES.**



The crash data indicated that there were two major types of motorcycle crashes; single-vehicle crashes (did not involve another vehicle) and crashes involving collision with another vehicle. During 2003-2006, 1,103 (47%) of motorcycle crashes were single-vehicle (did not involve another vehicle) and 1,237 (53%) were motorcycles in collision with another vehicle. These results are consistent with other studies which suggest that about half of motorcycle crashes are with other vehicles.

**Figure 3. Motorcyclist Crashes in Maine by Type of Crash. 2003-2006 Maine CODES.**



Because the causes of single-vehicle motorcycle collisions may be very different from the causes of motorcycles in collision with other vehicles, the evaluation of causes in the remainder of this section of the report will distinguish these two types of crashes.

### **Causes of Motorcycle Crashes by Road Location, Accident Type, and Time of Day**

Table 2 summarizes motorcycle crashes by rural location. Rural location is defined based on Maine police-reported designation of the crash as rural or urban. A second definition of rural is based on the FHWA Highway Performance Monitoring System (HPMS) definition of rural as the population of the town of the crash location is less than 5,000.

Based on police-report, among 1,103 single-vehicle crashes, 768 (70%) took place in a rural location, while among 1,237 collisions with another vehicle, 682 (55%) took place in an urban location.

Based on FHWA HPMS definition only 420 (34%) of motorcycle collisions with another vehicle took place in a rural community.

**Table 2. Motorcyclist Crashes in Maine by Location of Crash and Type of Crash. 2003-2006 Maine CODES.**

|   | Motorcycle Single- Vehicle Crashes |      | Motorcycle in Collision with Another Vehicle |      |
|---|------------------------------------|------|--|------|
|   | Number                             | %    | Number                                       | %    |
| <b>Total</b>                            | 1,103                              | 100% | 1,237  | 100% |
| <b>Rural/Urban Reported in MCRS*</b>    |                                    |      |  |      |
| Rural Location                          | 768                                | 70%  | 555  | 45%  |
| Urban Location                          | 335                                | 30%  | 682  | 55%  |
| <b>Rural/Urban FHWA HPMS Definition</b> |                                    |      |  |      |
| Rural Location (<5,000 population)      | 581                                | 53%  | 420  | 34%  |
| Urban Location (>=5,000 population)     | 522                                | 47%  | 817  | 66%  |

\*Urban compact municipalities in MCRS reporting are those in which the population according to census exceeds 7,500 with some exceptions as defined in Maine Revised Statutes, Title 23, Part 1 Chapter 13, Subchapter 2, section 754.

Table 3 summarizes motorcycle crashes by county of crash location. Cumberland, York, Penobscot, Androscoggin, and Kennebec counties have the largest populations in Maine and had the highest volume of motorcycle crashes.

Crashes in Androscoggin, York, Cumberland, Hancock, and Sagadahoc counties were more likely to involve another vehicle, while crashes in Piscataquis, Aroostook, Franklin, and Waldo counties were more likely to be single-vehicle crashes.

**Table 3. Motorcyclist Crashes in Maine by County of Crash Location and Type of Crash. 2003-2006 Maine CODES.**

|              | Motorcycle Single- Vehicle Crashes |      | Motorcycle in Collision with Another Vehicle |      |
|--------------|------------------------------------|------|--|------|
|              | Number                             | %    | Number                                       | %    |
| <b>Total</b> | 1,103                              | 100% | 1,237  | 100% |
| Androscoggin | 92                                 | 8%   | 136  | 11%  |
| Aroostook    | 68                                 | 6%   | 37   | 3%   |
| Cumberland   | 216                                | 20%  | 282  | 23%  |
| Franklin     | 43                                 | 4%   | 25   | 2%   |
| Hancock      | 56                                 | 5%   | 72   | 6%   |
| Kennebec     | 96                                 | 9%   | 105  | 8%   |
| Knox         | 34                                 | 3%   | 27   | 2%   |
| Lincoln      | 32                                 | 3%   | 30   | 2%   |
| Oxford       | 57                                 | 5%   | 50   | 4%   |
| Penobscot    | 124                                | 11%  | 126  | 10%  |
| Piscataquis  | 14                                 | 1%   | 4  | 0%   |
| Sagadahoc    | 26                                 | 2%   | 30   | 2%   |
| Somerset     | 36                                 | 3%   | 38   | 3%   |
| Waldo        | 29                                 | 3%   | 17   | 1%   |
| Washington   | 15                                 | 1%   | 16   | 1%   |
| York         | 165                                | 15%  | 242  | 20%  |

Table 4 summarizes motorcyclist crashes by the speed limit and location on the road where the crash took place. Single-vehicle motorcycle crashes were more likely to take place on a road with a higher speed limit than collisions with another vehicle. Among single-vehicle crashes 501 (45%) took place on roads with speed limit of 45 m.p.h. or greater compared with 340 (27%) of the motorcyclists in collision with another vehicle.

Among the 1,103 single-vehicle crashes, 472 (43%) took place at a curve in the road and illegal or unsafe speed was a factor in 38 percent of these crashes. Among the 1,237 collisions with another vehicle 512 (41%) took place at an intersection and 261 (21%) took place at a driveway intersecting with the road.

A relatively small number of crashes were impacted by weather or road conditions. Based on police-reported road surface condition, 6 percent of single-vehicle and 5 percent of collisions with another vehicle took place on wet road conditions. For single-vehicle crashes, 23 (2%), debris was reported in the road.

**Table 4. Motorcyclist Crashes in Maine by Road Speed Limit, Location on Road, and Type of Crash. 2003-2006 Maine CODES.**

|                    | Motorcycle Single- Vehicle Crashes |      | Motorcycle in Collision with Another Vehicle |      |
|--------------------|------------------------------------|------|--|------|
|                    | Number                             | %    | Number                                       | %    |
| <b>Total</b>       | 1,103                              | 100% | 1,237  | 100% |
| <b>Speed Limit</b> |                                    |      |  |      |
| 25*                | 195                                | 18%  | 357  | 29%  |
| 30                 | 59                                 | 5%   | 122  | 10%  |
| 35                 | 215                                | 19%  | 272  | 22%  |
| 40                 | 75                                 | 7%   | 82   | 7%   |
| 45*                | 311                                | 28%  | 156  | 13%  |
| 50                 | 104                                | 9%   | 105  | 8%   |
| 55                 | 61                                 | 6%   | 68   | 5%   |
| 65                 | 25                                 | 2%   | 10   | 1%   |
| <b>Location</b>    |                                    |      |  |      |
| Straight Road      | 398                                | 36%  | 326  | 26%  |
| Curved Road        | 472                                | 43%  | 104  | 8%   |
| Intersections      | 157                                | 14%  | 512  | 41%  |
| Driveways          | 40                                 | 4%   | 261  | 21%  |
| Bridges            | 2                                  | 0%   | 4  | 0%   |
| Interchanges       | 18                                 | 2%   | 7  | 1%   |
| Other              | 16                                 | 1%   | 23   | 2%   |

\*Crashes on roads in urban areas where the speed limit is not posted are assigned in police crash reports to a speed limit of 25 m.p.h. and crashes in rural areas where the speed limit is not posted are assigned in police crash reports to a speed limit of 45 m.p.h. 5% invalid/missing speed limit not shown.

Table 5 summarizes motorcyclist crashes by the police-reported “type of accident”. In single-vehicle motorcycle crashes, 113 (10%) involved an animal in the road and 51 (5%) involved some other object in the road.

**Table 5. Motorcyclist Crashes in Maine by Police-Reported Type of Accident and Type of Crash. 2003-2006 Maine CODES.**

| Type of Accident     | Motorcycle Single- Vehicle Crashes |      | Motorcycle in Collision with Another Vehicle |      |
|----------------------|------------------------------------|------|--|------|
|                      | Number                             | %    | Number                                       | %    |
| <b>Total</b>         | 1,103                              | 100% | 1,237  | 100% |
| Object in Road       | 51                                 | 5%   | 15   | 1%   |
| Rear End / Sideswipe | 11                                 | 1%   | 475  | 38%  |
| Head-on / Sideswipe  | 4                                  | 0%   | 104  | 8%   |

| Type of Accident      | Motorcycle Single-Vehicle Crashes |     | Motorcycle in Collision with Another Vehicle |     |
|-----------------------|-----------------------------------|-----|--|-----|
|                       | Number                            | %   | Number                                       | %   |
| Intersection Movement | 32                                | 3%  | 497  | 40% |
| Ran Off Road          | 635                               | 58% | 58   | 5%  |
| All Other Animal      | 35                                | 3%  | 0  | 0%  |
| Rollover              | 79                                | 7%  | 13   | 1%  |
| Deer                  | 62                                | 6%  | 1  | 0%  |
| Moose                 | 16                                | 1%  | 2  | 0%  |
| Other                 | 171                               | 16% | 53   | 4%  |

\*9 crashes reported with pedestrians, 16 reported with a bike

Table 6 summarizes motorcyclist crashes by time of day and light conditions. Single-vehicle crashes were more likely to take place at night than crashes involving collision with another vehicle. Among single-vehicle crashes 162 (15%) took place between the hours of 9PM and 6AM (21:00 – 05:59) compared to 68 (5%) of motorcyclist collisions with another vehicle. Based on police-reported light conditions, 208 (19%) of single-vehicle and 96 (8%) of motorcycle collisions with another vehicle took place when it was dark.

**Table 6. Motorcyclist Crashes in Maine by Time of Day, Light Conditions, and Type of Crash. 2003-2006 Maine CODES.**

| Military Time of Day      | Motorcycle Single-Vehicle Crashes |     | Motorcycle in Collision with Another Vehicle |     |
|---------------------------|-----------------------------------|-----|--|-----|
|                           | Number                            | %   | Number                                       | %   |
| 00:00-02:59               | 45                                | 4%  | 12   | 1%  |
| 03:00-05:59               | 24                                | 2%  | 3  | 0%  |
| 06:00-08:59               | 72                                | 7%  | 62   | 5%  |
| 09:00-11:59               | 123                               | 11% | 193  | 16% |
| 12:00-14:59               | 224                               | 20% | 350  | 28% |
| 15:00-17:59               | 288                               | 26% | 397  | 32% |
| 18:00-20:59               | 230                               | 21% | 167  | 14% |
| 21:00-23:59               | 93                                | 8%  | 53   | 4%  |
| <b>Light Conditions</b>   |                                   |     |  |     |
| Dark (Street Lights Only) | 87                                | 8%  | 69   | 6%  |
| Dark (No Street Lights)   | 119                               | 11% | 25   | 2%  |
| Dark (Street Lights Off)  | 2                                 | 0%  | 2  | 0%  |

## Causes of Motorcycle Crashes Operator and Other Vehicle Driver Factors

Single-vehicle motorcycle crashes were influenced by the operating behavior of the motorcyclist. Motorcycle crashes in collision with another vehicle were influenced by the operating behavior of the motorcyclists or the behavior of the driver of the other vehicle or both. Table 7 provides the age and gender distribution of motorcycle operators and the drivers of other vehicles. Operators in single-vehicle crashes were more likely to be younger than operators in collisions with another vehicle. Among single-vehicle crash operators, 408 (37%) were under age 30 compared to 322 (26%) of motorcycle operators in collision with another vehicle.

Males were more likely to be the motorcycle operator in both single-vehicle and collisions with another vehicle. The proportion of female operators in single-vehicle crashes was 12 percent and in collisions with another vehicle was 8 percent.

In motorcycle collisions with another vehicle, the driver of the other vehicle's age was evaluated. The age distribution was representative of the demographics of the driving population involved in all motor vehicle crashes. Young drivers, age 16-24, of the other vehicle accounted for 255 of the crashes and had a higher representation in colliding with a motorcycle than middle-aged drivers. Older drivers, age 65 and over, represented 160 of the drivers in collision with a motorcycle.

**Table 7. Motorcyclist Crashes in Maine by Operator/Driver Age and Gender and Type of Crash. 2003-2006 Maine CODES.**

|               | Motorcycle Operator in Single-Vehicle Crash |      | Motorcycle Operator in Collision with Another Vehicle |      | Driver of Other Vehicle in Collision with Motorcyclist |      |
|---------------|---|------|---|------|--|------|
|               | Number                                      | %    | Number  | %    | Number   | %    |
| <b>Age</b>    |   |      |   |      |  |      |
| Total         | 1,103                                       | 100% | 1,237   | 100% | 1,237  | 100% |
| 16-19         | 87  | 8%   | 65  | 5%   | 131  | 11%  |
| 20-24         | 194   | 18%  | 143   | 12%  | 122  | 10%  |
| 25-29         | 127   | 12%  | 114   | 9%   | 74   | 6%   |
| 30-34         | 89  | 8%   | 120   | 10%  | 113  | 9%   |
| 35-39         | 96  | 9%   | 124   | 10%  | 103  | 8%   |
| 40-44         | 131   | 12%  | 157   | 13%  | 115  | 9%   |
| 45-49         | 126   | 11%  | 159   | 13%  | 124  | 10%  |
| 50-54         | 104   | 9%   | 150   | 12%  | 85   | 7%   |
| 55-59         | 74  | 7%   | 108   | 9%   | 90   | 7%   |
| 60-64         | 38  | 3%   | 35  | 3%   | 61   | 5%   |
| 65 and older  | 37  | 3%   | 53  | 4%   | 160  | 13%  |
| <b>Gender</b> |   |      |   |      |  |      |
| Male          | 965   | 87%  | 1135  | 92%  | 723  | 58%  |
| Female        | 137   | 12%  | 102   | 8%   | 458  | 37%  |

Of the 1,237 crashes involving other vehicles 1,138 (92%) were in collision with a single other vehicle and 99 (8%) were in collision with multiple vehicles (3 or more vehicles in the crash). Of the 1,237 drivers of other vehicles in collision with the motorcyclist, 140 (11%) were other motorcyclists.

Table 8 summarizes results for the operator and other vehicle driver pre-accident actions from the police report. For most motorcyclists, the police reported pre-accident action was “following the roadway”.

In 1,237 collisions with another vehicle, 338 (27%) of the drivers of the other vehicle were making a left turn. In collisions with another vehicle, the motorcyclists was more likely to be passing (7%) than the drivers of the other vehicle (2%).

**Table 8. Motorcyclist Crashes in Maine by Operator/Driver Pre-Accident Actions and Type of Crash. 2003-2006 Maine CODES.**

|   | Motorcycle Operator in Single-Vehicle Crash |    | Motorcycle Operator in Collision with Another Vehicle |    | Driver of Other Vehicle in Collision with Motorcyclist |     |
|---|---|----|---|----|--|-----|
|   | Number                                      | %  | Number  | %  | Number   | %   |
| Total   | 1,103                                       |    | 1,237   |    | 1,237  |     |
| Wrong way into opposing traffic                         | 2   | 0% | 16  | 1% | 9  | 1%  |
| Making right turn                                       | 36  | 3% | 31  | 3% | 56   | 5%  |
| Making left turn  | 48  | 4% | 45  | 4% | 338  | 27% |
| Making U turn   | 3   | 0% | 6   | 0% | 15   | 1%  |
| Starting from parked                                    | 10  | 1% | 4   | 0% | 17   | 1%  |
| Starting in traffic                                     | 4   | 0% | 20  | 2% | 87   | 7%  |
| Slowing in traffic                                      | 14  | 1% | 48  | 4% | 70   | 6%  |
| Stopped in traffic                                      | 2   | 0% | 88  | 7% | 110  | 9%  |
| Avoiding Vehicle, Object, Pedestrian, Animal in Roadway | 82  | 7% | 70  | 6% | 20   | 2%  |
| Skidding  | 104   | 9% | 65  | 5% | 16   | 1%  |
| Changing Lanes  | 10  | 1% | 11  | 1% | 23   | 2%  |
| Overtaking Passing                                      | 15  | 1% | 83  | 7% | 26   | 2%  |
| Merging   | 7   | 1% | 4   | 0% | 8  | 1%  |
| Backing   | 0   | 0% | 1   | 0% | 29   | 2%  |

For 1,103 single-vehicle crashes, police reported 720 (65%) were “following the roadway” and for 1,237 collisions with another vehicle, police reported 705 (57%) were “following the roadway”. Other pre-accident actions with small volume included right turn of red (1), entering parked position (2), parked legally (13), crossing with signal (4), and emerging from behind parked car (1).

The police crash reports contain both a primary and secondary contributing factor for the crash. Table 9 provides the frequency of either a primary or secondary contributing factor. Resulting number will add to more than the totals.

Operator illegal or unsafe speed was a factor in 318 (29%) of single-vehicle motorcycle crashes. Overall, 33 percent of single-vehicle motorcycle crashes had some reported operator violation. Operator inattention (27%) and operator

inexperience (27%) were also factors in single-vehicle crashes. Motorcycle vehicle defects accounted for 6 percent of single-vehicle motorcycle crashes.

In motorcycle collisions with another vehicle both motorcycle operators and drivers of the other vehicle had violations. In collisions with another vehicle, 29 percent of the motorcyclists and 45 percent of the drivers of the other vehicle had a least one violation. For drivers of the other vehicle, failure to yield right of way, was reported for 325 (26%) of the crashes. Although the numbers were relatively small, the motorcyclist was more likely to be reported with illegal or unsafe speed (8%), following too close (9%), or improper passing or overtaking (5%) than the driver of the other vehicle.

In motorcycle collisions with another vehicle, inattention or distraction by the driver of the other vehicle (28%) was more likely than for the operator of the motorcycle (17%). Motorcycle operator inexperience (7%) was less likely to be reported in collisions with another vehicle than in single-vehicle crashes (27%).

**Table 9. Motorcyclist Crashes in Maine by Operator/Driver Contributing Factors and Type of Crash. 2003-2006 Maine CODES.**

| Contributing Factors                     | Motorcycle Operator in Single- Vehicle Crash |     | Motorcycle Operator in Collision with Another Vehicle |     | Driver of Other Vehicle in Collision with Motorcyclist |     |
|--|--|-----|---|-----|--|-----|
|  | Number                                       | %   | Number  | %   | Number   | %   |
| Total                                    | 1,103  |     | 1,237   |     | 1,237  |     |
| Failure to Yield Right of Way            | 2  | 0%  | 50  | 4%  | 325  | 26% |
| Illegal Unsafe Speed                     | 318  | 29% | 105   | 8%  | 30   | 2%  |
| Following Too Close                      | 21   | 2%  | 115   | 9%  | 68   | 5%* |
| Disregard Traffic Control Device         | 6  | 1%  | 13  | 1%  | 18   | 1%  |
| Driving Left of Center Not Passing       | 6  | 1%  | 24  | 2%  | 12   | 1%  |
| Improper Passing, Overtaking             | 5  | 0%  | 59  | 5%  | 21   | 2%  |
| Improper Unsafe Lane Change              | 3  | 0%  | 12  | 1%  | 30   | 2%  |
| Improper Parking Start, Stop             | 7  | 1%  | 7   | 1%  | 11   | 1%  |
| Improper Turn                            | 11   | 1%  | 14  | 1%  | 45   | 4%  |
| Unsafe Backing                           | 0  | 0%  | 0   | 0%  | 19   | 2%  |
| No Signal or Improper Signal             | 0  | 0%  | 6   | 0%  | 19   | 2%  |
| Impeding Traffic                         | 1  | 0%  | 2   | 0%  | 5  | 0%  |
| <i>Any Violation</i>                     | 366  | 33% | 357   | 29% | 553  | 45% |
| Operator/Driver Inattention, Distraction | 297  | 27% | 209   | 17% | 351  | 28% |

| Contributing Factors         | Motorcycle Operator in Single- Vehicle Crash |     | Motorcycle Operator in Collision with Another Vehicle |    | Driver of Other Vehicle in Collision with Motorcyclist |    |
|------------------------------|--|-----|---|----|--|----|
|                              | Number                                       | %   | Number  | %  | Number   | %  |
| Operator/Driver Inexperience | 294  | 27% | 89  | 7% | 27   | 2% |
| Physical Impairment          | 38   | 3%  | 10  | 1% | 7  | 1% |
| Vision Obscured              | 15   | 1%  | 21  | 2% | 64   | 5% |
| Vehicle Defects              | 66   | 6%  | 15  | 1% | 18   | 1% |

\* For the 1,237 motorcycle collisions with another vehicle, in 79 crashes both operator and driver of the other vehicle had a violation, in 278 crashes the motorcycle operator had a violation but the operator of the other vehicle did not, in 474 crashes the motorcycle operator did not have a violation but the driver of the other vehicle had a violation, and in 406 crashes neither the motorcycle operator or the driver of the other vehicle had a violation. Of the 68 drivers of other vehicles reported as "following too close", 29 were other motorcycle operators.

Table 10 summarizes operator or other vehicle driver license status and impairment as reported by police. Impairment was defined from the police crash report as under the influence, had been drinking, or had been using drugs. Blood alcohol content (BAC) was not available in the police-reported data used in CODES. Among operators in single vehicle crashes 32 (3%) were operating with a suspended license and 290 (26%) did not have a motorcycle permission. Among operators in collisions with another vehicle 274 (22%) did not have a motorcycle permission. Operator impairment (alcohol or drugs) was more likely to be a factor in single-vehicle crashes. Among the 1,103 operators in single-vehicle crashes, 128 (12%) were reported as impaired compared to 27 (2%) in collisions with another vehicle.

**Table 10. Motorcyclist Crashes in Maine by License Status, Driver Physical Condition, and Type of Crash. 2003-2006 Maine CODES.**

|   | Motorcycle Operator in Single- Vehicle Crash |     | Motorcycle Operator in Collision with Another Vehicle |     | Driver of Other Vehicle in Collision with Motorcyclist |    |
|---|--|-----|---|-----|--|----|
|   | Number                                       | %   | Number  | %   | Number   | %  |
| Totals                                  | 1,103  |     | 1,237   |     | 1,237  |    |
| <b>License Status and MC Permission</b> |  |     |   |     |  |    |
| No License                              | 11   | 1%  | 15  | 1%  | 3  | 0% |
| Permit                                  | 28   | 3%  | 27  | 2%  | 4  | 0% |
| Suspended                               | 32   | 3%  | 12  | 1%  | 10   | 1% |
| MC Permission                           | 813  | 74% | 963   | 78% | NA   | NA |
| No MC Permission                        | 290  | 26% | 274   | 22% | NA   | NA |
| <b>Physical Condition</b>               |  |     |   |     |  |    |
| Impaired (alcohol or drugs)             | 128  | 12% | 27  | 2%  | 27   | 2% |

## Single-Vehicle Motorcycle Crashes

The previous section identified several factors that were common in single-vehicle motorcycle crashes compared with motorcycle crashes in collision with another vehicle. These included rural location, curve in road, speed limit 45 m.p.h. or greater, riding at night, young operator (age 16-24), illegal or unsafe speed, driver inexperience, lack of motorcycle license endorsement, and impairment. These factors were evaluated for single-vehicle crashes in more detail and the results of this analysis are provided in Table 11.

Younger operators (age 16-24) were more likely to have inexperience, illegal or unsafe speed reported and less likely to have a motorcycle license permission. In single-vehicle motorcycle crashes, among 281 young operators, 110 (39%) had illegal or unsafe speed reported as a factor compared with 208 (25%) among operators age 25 and older. In single-vehicle motorcycle crashes, among 281 young operators, 113 (40%) did not have a motorcycle endorsement compared with 176 (21%) among older operators. In single-vehicle motorcycle crashes, operators without a motorcycle endorsement were more than twice as likely to have driver inexperience reported compared with operators with an endorsement (47% vs. 19%). A large proportion of single-vehicle crashes (472) took place at a curve in the road and illegal or unsafe speed was a factor in 38 percent of these crashes.

Impairment was defined from police crash reports as under the influence, had been drinking, or had been using drugs. Operators in single-vehicle crashes at night were more likely to be impaired compared with operators in crashes during the daytime.

**Table 11. Key Factors for Single-Vehicle Motorcycle Crashes in Maine. 2003-2006 Maine CODES.**

|                           | Total | Illegal or Unsafe Speed     | % with Factor |
|---------------------------|-------|-----------------------------|---------------|
| Operator Age 16-24        | 281   | 110                         | 39%           |
| Operator Age 25 and Older | 822   | 208                         | 25%           |
|                           | Total | No MC License Permission    |               |
| Operator Age 16-24        | 281   | 113                         | 40%           |
| Operator Age 25 and Older | 822   | 176                         | 21%           |
|                           | Total | Driver Inexperience         |               |
| No MC License Permission  | 289   | 137                         | 47%           |
| MC License Permission     | 813   | 157                         | 19%           |
|                           | Total | Illegal or Unsafe Speed     |               |
| Curved Road               | 472   | 177                         | 38%           |
| Straight Road/Other       | 631   | 141                         | 22%           |
|                           | Total | Impaired (alcohol or drugs) |               |
| Operating at Night        | 207   | 70                          | 34%           |
| Not Operating at Night    | 893   | 58                          | 6%            |

## Summary of Key Factors Associated with Motorcycle Crashes

The previous sections of this report describe in detail factors associated with motorcycle crashes in Maine. In this section, key factors are summarized graphically for single-vehicle motorcycle crashes and for motorcycles in collision with another vehicle.

Figure 4 summarizes key factors for single vehicle crashes. Single-vehicle crashes were more likely in rural locations, at a curve in the road, at night, involve younger operators, operator inexperience, illegal or unsafe speed, impairment with alcohol or drugs, and the operator was less likely to have a motorcycle license permission.

**Figure 4. Key Factors in Single-Vehicle Motorcycle Crashes in Maine. 2003-2006 Maine CODES.**

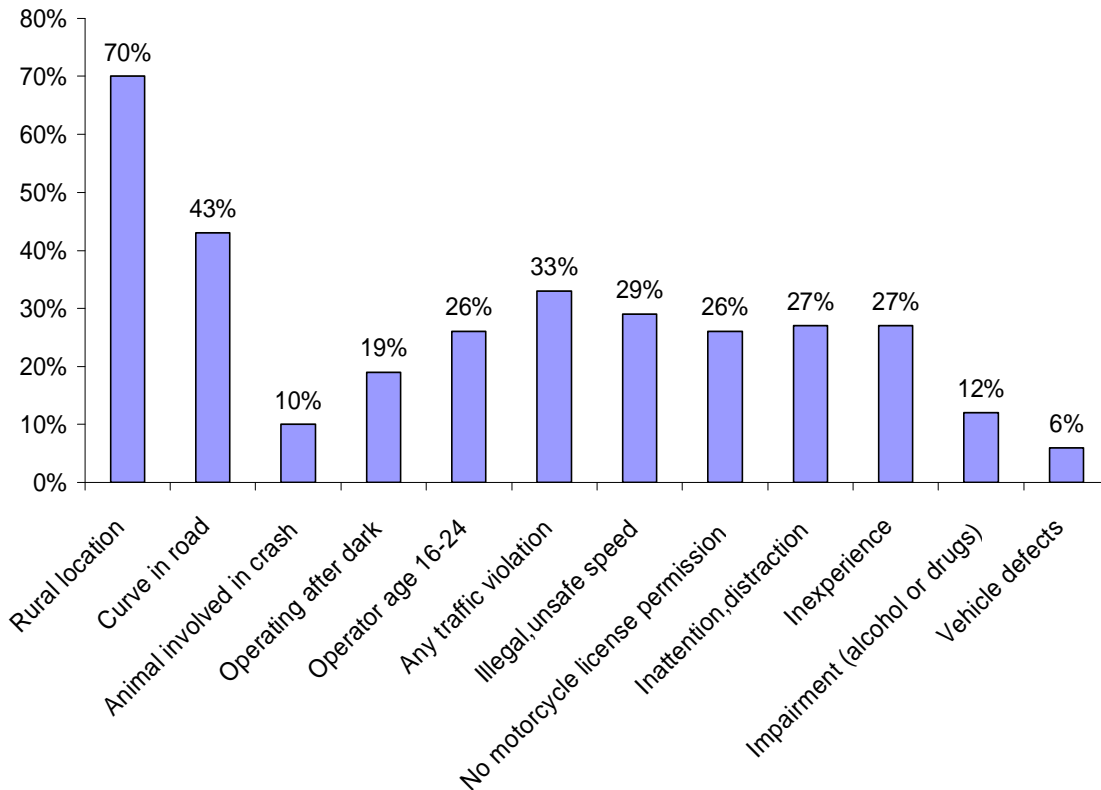
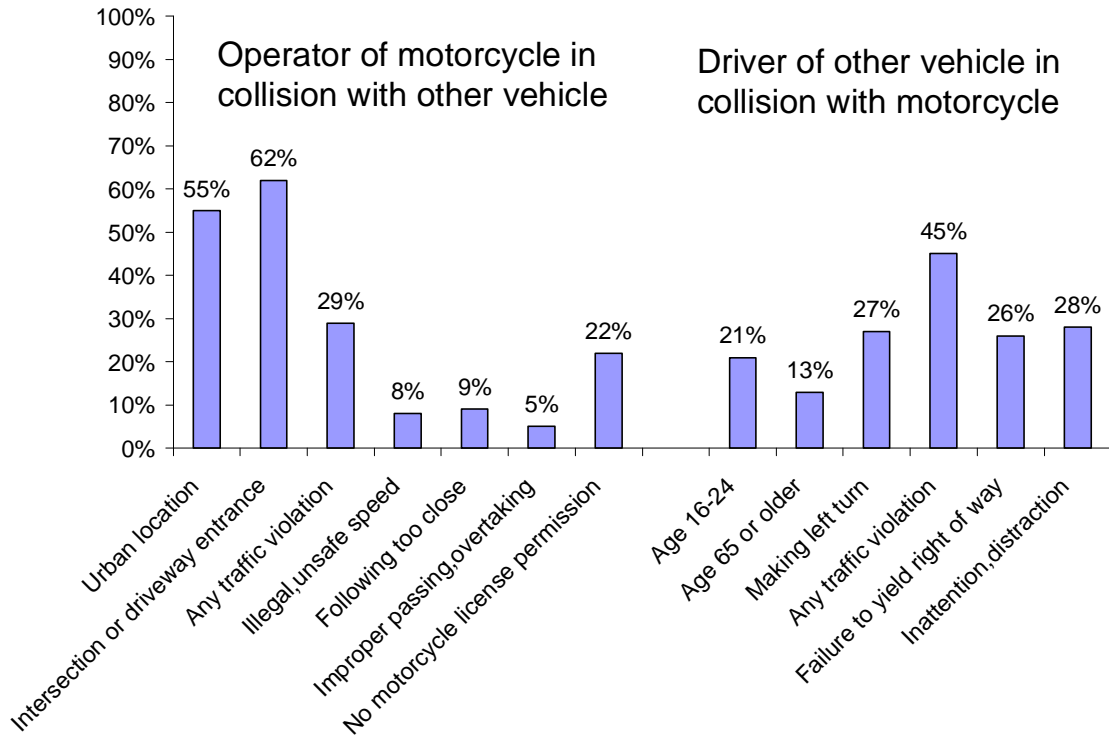


Figure 5 summarizes key factors for motorcycle collisions with another vehicle. For these crashes key factors for both the motorcycle operator and the driver of the other vehicle are displayed. Motorcycles in collision with another vehicle were more likely in urban locations, at an intersection or driveway entrance. Drivers of the other vehicle were more likely to be young (16-24) or older drivers (65 and older). The driver of the other vehicle was often making a left turn. A traffic violation was more likely to be reported for the driver of the other vehicle with failure to yield the most common violation.

**Figure 5. Key Factors in Motorcycle Collisions with Another Vehicle in Maine. 2003-2006 Maine CODES.**



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## **Injury Outcomes and the Impact of Helmet Use**

### *CODES Injury Identification and Classification Methods*

Motorcycle operators and passenger injuries were evaluated using hospital data linked by Maine CODES for the crashes during 2003-2006. The CODES projects make use of clinical injury grouping software, ICDMAP-90, to assign body region and severity of injuries based on ICD-9-CM clinical coding in the hospital records.<sup>9</sup> The ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) is based on the World Health Organization's Ninth Revision, International Classification of Diseases (ICD-9). ICD-9-CM is the official system of assigning codes to diagnoses and procedures associated with hospital utilization in the United States. The clinical ICD-9-CM codes identify the specific types of injuries that patients have. For each patient multiple injuries (up to 10) can be identified and reported on from the hospital data.

An injury grouping software (ICDMAP-90) is often used in studies of injuries, is currently used by states participating in CODES for analyses, and has been used in other studies published by NHTSA.<sup>1,9</sup> The software classifies injuries based on body area and severity of injury. The Abbreviated Injury Score (AIS) is an anatomical scoring system. ICD-9-CM clinical diagnosis in the hospital data are used to assigned AIS scores for up to 9 body regions. A maximum abbreviated injury score (MAIS) is then assigned over all body regions injured for the patient. Below are examples of AIS severity classification of selected ICD-9-CM codes for the head body region:

- Critical: 801.25 Fracture of base of skull, closed with subarachnoid, subdural, and extradural hemorrhage, with prolonged (more than 24 hours) loss of consciousness without return to pre-existing conscious level
- Severe: 852.21 Subdural hemorrhage following injury without mention of open intracranial wound, with no loss of consciousness
- Serious: 801.01 Fracture of base on skull, closed without mention of intracranial injury, with no loss of consciousness
- Moderate: 850.0 Concussion with no loss of consciousness
- Minor: 873.0 Open wound of scalp without mention of complication

The classification system represents a significant enhancement over police-reported data in clinical validity, ability to track multiple injuries per patient, and ability to assign the relative severity level of injury.

### *Hospital Care – CODES Linkage Results*

Results of the linkage to hospital data are reported by the highest level of care in Table 12. A total of 2,628 (2,340 motorcycle operators and 288 passengers) were evaluated.

Of 2,628 motorcycle riders and passengers, 398 (15%) were linked to an inpatient hospitalization and 1,044 (40%) were linked to an outpatient emergency department

but were not hospitalized. Based on police-reported injury degree, only 80 percent of riders in a reported crash sustained a “possible” injury or higher level of injury.

**Table 12. Motorcycle Operator and Passenger Injuries by Police-Reported Injury Degree and CODES Hospital Linkage Results. 2003-2006 Maine CODES.**

| Police-Reported Level of Injury |                             | Total Riders ( Operators and Passengers) | Riders Linked to an Inpatient Hospitalization | Riders Linked to Outpatient Emergency Department Visit but not Hospitalized |
|---------------------------------|-----------------------------|--|---|---|
|                                 | Total                       | 2,628                                    | 398   | 1,044   |
| 1                               | Killed                      | 82                                       | 16  | 18  |
| 2                               | Injury – Incapacitating     | 420                                      | 232   | 139   |
| 3                               | Injury – Not Incapacitating | 1,014                                    | 100   | 521   |
| 4                               | Injury – Possible           | 599                                      | 46  | 318   |
| 5                               | Injury – None               | 509                                      | 4   | 46  |

\*Riders reported by police as killed that did not link to a hospital record were likely to be dead at the scene and not transported to a hospital.

Table 13 provides hospital injury outcome information for the motorcycle riders. Of 1,442 riders linked to hospital record, 1,383 had an injury level assigned by the clinical grouping software. The 59 records not assigned included patients in observation at the hospital and patients for which no injury was clinically defined.

Riders with hospital care sustained 2,530 injuries to different body regions indicating that riders in motorcycle crashes frequently sustained multiple injuries. The most common areas injured were lower extremities (633), upper extremities (549), and external injuries (400). The most common external injuries were abrasions or friction burns. Head injuries (208) accounted for the largest number injuries classified as severe or critical.

The 1,422 motorcycle riders incurred \$1.8 million in outpatient emergency department charges, \$16.3 million in inpatient hospital charges, and 2,769 in inpatient hospital days. The average charge for an outpatient emergency department visit was \$1,761 and the average charge for an inpatient hospitalization was \$40,844. The average hospital stay was 7.0 days.

The average outpatient emergency department charge, inpatient charge, and length of hospital stay increased with severity of injuries. For example, the average inpatient charge for a rider with severe injuries (MAIS=4) increased to \$72,439.

These charges represent only the initial cost of immediate care for these patients and do not reflect additional medical and other costs that may occur during the months and years following the injury.

**Table 13. Motorcycle Operator and Passenger Injuries by Injury Severity and Body Region. 2003-2006 Maine CODES.**

*Note: Of 1,442 operators and passengers linked to hospital records 58 (<1%) were not assigned an injury severity level and are not shown in this table.*

|  | Injury Scale |            |           |          |            | Total    |
|--|--------------|------------|-----------|----------|------------|----------|
|  | 1=Minor      | 2=Moderate | 3=Serious | 4=Severe | 5=Critical |          |
| <b>Maximum Abbreviated Injury Scale (MAIS) Over All Body Regions</b> | 688          | 449        | 148       | 67       | 31         | 1,384*   |
| <b>Injuries and Severity by Body Region</b>                          |              |            |           |          |            |          |
| Head   | 31           | 82         | 27        | 47       | 19         | 208      |
| Face   | 200          | 33         | 0         | 0        | 0          | 233      |
| Thorax   | 77           | 40         | 77        | 14       | 0          | 211      |
| Abdomen  | 61           | 24         | 5         | 14       | 11         | 131      |
| Spine  | 75           | 79         | 2         | 2        | 2          | 161      |
| Upper Extremities  | 272          | 266        | 11        | 0        | 0          | 549      |
| Lower Extremities  | 327          | 205        | 98        | 3        | 0          | 633      |
| External   | 400          | 0          | 0         | 0        | 0          | 400      |
| <b>Hospital Charges and Inpatient Length of Stay</b>                 |              |            |           |          |            |          |
| Outpatient ED Average Charge   | \$1,370      | \$2,374    | \$4,488   | **       | **         | \$1,761  |
| Inpatient Average Charge   | \$14,013     | \$22,089   | \$41,526  | \$72,446 | \$75,323   | \$40,844 |
| Inpatient Average Length of Stay                                     | 4.1          | 4.1        | 6.9       | 12.9     | 9.9        | 7.0      |

\*1 patient with hospital care assigned by ICDMAP-90 as “unsurvivable” (MAIS=6). By body region columns may not add to total because a small number (2%) of patients had a body region assigned but an MAIS severity level was not assigned. \*\*Insufficient data to report charges and length of stay reliably n<5; patients with emergency department care only rarely have severe or critical injuries.

Table 14 provides information from the linked hospital data on hospital charges and length of stay by the expected source of payment for the care and the hospital discharge status. Private-commercial insurance (including employer-sponsored health plans) represented the largest number (1,052) of riders, hospital charges (\$12.8 million), and inpatient days (1,908); about 70 percent of total. Riders with Medicaid (MaineCare) and riders without health insurance accounted for most of the remaining charges and length of stay.

Based on hospital-reported discharge status, most riders (1,310) were discharged to home. Injured riders discharged to a rehabilitation facility (61) had the highest average charges (\$92,417). While they accounted for only 4 percent of the riders linked to hospital care these riders incurred one-third of the hospital charges and patient days.

These charges represent only the initial cost of care for these patients and do not reflect additional medical and other costs that may occur during the months and years after discharge from the hospital. For some patients with severe injuries, the long-term cost of treatment may ultimately be covered by Medicaid (MaineCare).

**Table 14. Motorcycle Operator and Passenger Hospital Care by Expected Source of Payment and Discharge Status. 2003-2006 Maine CODES**

|  | Riders Linked to Hospital Care | Hospital Charges (millions) | Inpatient Days |
|--|--------------------------------|-----------------------------|----------------|
| <b><i>Expected Source of Payment</i></b>         |                                |                             |                |
| Total  | 1,442                          | \$18.1                      | 2,769          |
| Public Payer                                     | 192                            | \$4.1                       | 693            |
| Medicare   | 53                             | \$0.9                       | 114            |
| Medicaid (MaineCare)                             | 109                            | \$2.8                       | 508            |
| Military (TRICARE CHAMPUS)                       | 30                             | \$0.4                       | 71             |
| Private-Commercial                               | 1,052                          | \$12.8                      | 1,908          |
| Uninsured  | 183                            | \$1.1                       | 163            |
| Other  | 14                             | \$0.1                       | 5              |
| <b><i>Hospital Reported Discharge Status</i></b> |                                |                             |                |
| Discharged to another facility                   | 31                             | \$0.7                       | 117            |
| Left Against Medical Advice                      | 4                              | \$0.1                       | 5              |
| Died at hospital                                 | 27                             | \$1.1                       | 81             |
| Discharged long-term care facility               | 9                              | \$1.4                       | 303            |
| Discharged to a rehab facility                   | 61                             | \$5.6                       | 880            |
| Discharged home                                  | 1,310                          | \$9.2                       | 1,383          |

\*Riders reported by police as killed that did not link to a hospital record were likely to be dead at the scene and not transported to a hospital.

Table 15 provides information on average charge and length of stay for head injury. Care for head injuries was more expensive and resulted in longer length of stay than other injury types. Compared with riders without a head injury, hospitalized motorcycle riders with a head injury stayed longer (9.2 vs. 5.8 days) and incurred higher charges (\$56,783 vs. \$32,477). Two-thirds of riders with a head injury required inpatient hospitalization.

**Table 15. Motorcyclist Operator and Passengers by Head Injury Identified in Hospital Records Linked. 2003-2006 Maine CODES**

| Highest Level of Care           | Average Charge |                | Average Length of Stay |                |
|---------------------------------|----------------|----------------|------------------------|----------------|
|                                 | Head Injury    | No Head Injury | Head Injury            | No Head Injury |
| Outpatient Emergency Department | \$3,683        | \$1,621        | NA                     | NA             |
| Inpatient                       | \$56,783       | \$32,477       | 9.2                    | 5.8            |

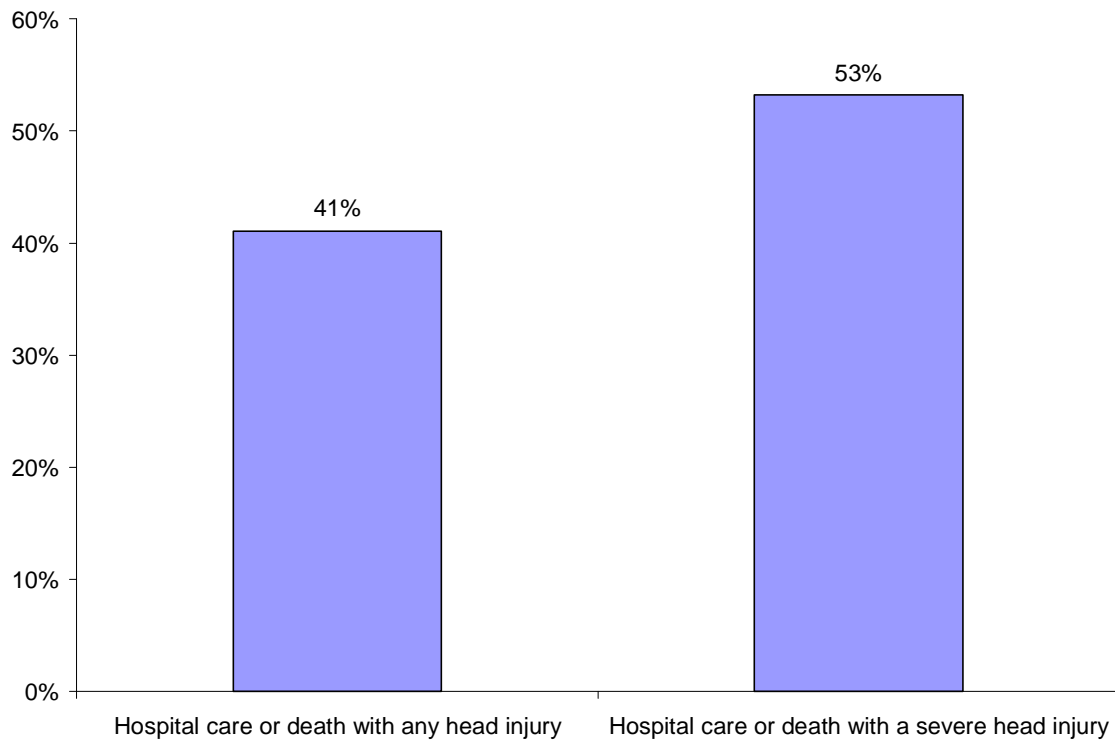
### *Impact of Helmet Use on Injury Outcomes*

The impact of motorcycle helmet use on the injury outcomes for motorcycle riders was evaluated using the 2003-2006 linked CODES data. This analysis controlled for demographic and other crash factors using methods consistent with NHTSA CODES models.

The impact of helmet use on risk of injury was evaluated at cut-points: hospital care or death with a head injury or hospital care or death with a severe head injury. Specific types of helmets worn were not available in the police-reported crash data. Results are reported in Figure 6 for motorcycle riders in 2003-2006 crashes.

**Figure 6. Reduction in Risk of Injury When a Helmet Reported as Used. 2003-2006 Maine CODES.**

The analysis of helmet use was based on a multivariate model that controlled for demographic and other crash factors including: age of rider, gender of rider, operator or passenger, road speed limit, intersection crash location, operating with illegal or unsafe speed, impaired operator (alcohol or drugs), single-vehicle compared with collision with another vehicle, operation during night hours. All results were statistically significant.



Controlling for other crash factors, use of a motorcycle helmet reduced the risk of hospital care or death for any head injury by 41 percent (margin of error 23% to 55%) and reduced the risk of hospital care or death for a serious head injury by 53 percent (margin of error 29% to 69%).

The current rate of helmet use in Maine is unknown. An informal (non-scientific) observation study during September, 2008 estimated that 51 percent of Maine motorcycle riders were wearing helmets.‡

Controlling for other crash factors head injury was also associated with night-time operation, impaired operator (alcohol or drugs), higher road speed limit, and illegal, unsafe speed also increased the likelihood of hospital care or death from a head injury.

A statistical model predicting lower extremity (e.g. leg, ankle) injuries indicated a slightly higher risk when the motorcyclist was in collision with another vehicle.

### *Injury Outcomes by Type of Crash*

Table 16 summarizes the level of injury care by type of crash using the linked CODES hospital data. There were slightly more riders and passengers in collisions with another vehicle (1,410) than in single-vehicle crashes (1,218). The proportion of riders killed or hospitalized was not significantly different in the two crash types. Collisions with another vehicle accounted for more deaths (47) than single-vehicle crashes (35).

Motorcycle riders in single-vehicle crashes were more likely to require outpatient emergency department care than motorcycle riders in collisions with another vehicle. Single vehicle riders were more likely have an injury classified as moderate level of severity (e.g. concussion with no loss of consciousness).

Riders in single-vehicle crashes incurred \$8.4 million in hospital charges and 1,262 inpatient days while riders in collision with another vehicle incurred \$9.7 million and 1,507 inpatient days.

**Table 16. Motorcycle Operator and Passenger Injuries by Type of Crash. 2003-2006 Maine CODES.**

|  | Motorcycle in Single-Vehicle Crash |      | Motorcycle in Collision with Another Vehicle |      |
|--|------------------------------------|------|--|------|
|  | Number                             | %    | Number                                       | %    |
| Total Operators                              | 1,103                              |      | 1,237  |      |
| Total Operators and Passengers               | 1,218                              | 100% | 1,410  | 100% |
| Killed                                       | 35                                 | 3%   | 47   | 3%   |
| Linked to Inpatient                          | 198                                | 16%  | 200  | 14%  |
| Linked to Outpatient<br>Emergency Department | 531                                | 44%  | 513  | 36%  |

‡ An informal (non-scientific) observational survey of motorcyclists was conducted by staff at Maine Health Information Center. Seven staff contributed observations during the first three weeks of September, 2008 including the following locations: Portland, South Portland, Lisbon, Brunswick, Augusta, West Gardiner, Lewiston, Farmingdale, Richmond, Wiscasset, Fryeburg, Gorham, Buxton, I-295 and I-95 (Augusta to NH border). Of 224 observed 114 (51%) were wearing a helmet. These results are biased to the southern areas of Maine and daytime operation only.

|   | Motorcycle in Single-Vehicle Crash |     | Motorcycle in Collision with Another Vehicle |     |
|---|------------------------------------|-----|--|-----|
|   | Number                             | %   | Number                                       | %   |
| <b>Maximum Abbreviated Injury Scale (MAIS) Over All Body Regions for Riders Linked to Hospital Data</b> |                                    |     |  |     |
| 1=Minor   | 326                                | 27% | 362  | 26% |
| 2=Moderate  | 263                                | 22% | 186  | 13% |
| 3=Serious   | 62                                 | 5%  | 86   | 6%  |
| 4=Severe  | 43                                 | 4%  | 24   | 2%  |
| 5=Critical  | 11                                 | 1%  | 20   | 1%  |
| Linked to hospital reported as not injured or injury level unspecified                                  | 23                                 | 2%  | 35   | 2%  |
| <b>Hospital Charges and Inpatient Days</b>  |                                    |     |  |     |
| Total Hospital Charges (million)  | \$8.4                              |     | \$9.7  |     |
| Total Hospital Inpatient Days   | 1,262                              |     | 1,507  |     |

\* 1 rider in single-vehicle crash linked to hospital reported as “unsurvivable” MAIS=6 not shown in table.

Motorcycle riders were compared to all other persons involved in police-reported crashes during 2003-2006. Motorcycle riders represented 1 percent of all persons involved in crashes and 10 percent of persons requiring hospital care based on the linked data.

## DISCUSSION AND POLICY IMPLICATIONS

This Maine CODES study described motorcycle crashes in Maine and associated injury outcomes in greater detail than previous studies. However, many of the findings concerning causes of motorcycle crashes are consistent with previous studies. In fact, some of the common causes of motorcycle crashes that this study identifies were also identified in the Hurt study published more than 25 years ago.<sup>2</sup>

During 2003-2006, 47 percent of motorcycle crashes in Maine were single-vehicle (did not involve another vehicle) and 53 percent were motorcycles in collision with another vehicle. This finding is consistent with other motorcycle studies.

### *Single-Vehicle Motorcycle Crashes*

Single-vehicle crashes were more likely to take place in rural locations, on a road with higher speed limit, at a curve in the road, at night, involve younger operators, operator inexperience, illegal or unsafe speed, impairment with alcohol or drugs, and the operator was less likely to have a motorcycle license permission. Illegal or unsafe speed was a factor in 29 percent of single-vehicle crashes. This was higher than the rate (10%) for drivers of passenger cars and pickup trucks reported in a recent CODES study of speeding.<sup>10</sup> These findings for single vehicle crashes suggest the potential value of:

- enforcement efforts to reduce speeding and other violations; and,
- rider education and motorcycle permission endorsement.

### *Motorcycles in Collision with Other Vehicles*

In collisions with another vehicle, 29 percent of the motorcyclists and 45 percent of the drivers of the other vehicle had a least one violation reported. For drivers of the other vehicle, failure to yield right of way, was reported for 26 percent of the crashes and making a left turn was frequently reported. About two-thirds of these crashes take place at an intersection or driveway entrance. Drivers of the other vehicle were often young drivers (16-19) or older drivers (65 and older). Driver inattention or distraction was a factor for 28 percent of the other drivers. These results for motorcyclist collision with other vehicles suggest the potential value of:

- improved visibility by use of headlamps or high visibility clothing;
- rider education particularly for intersections and areas with many driveways; and,
- increased efforts with the general driving population to improve awareness of motorcycles on the road.

### *Injury Outcomes for Motorcycle Riders*

Of 2,628 motorcycle riders and passengers, 398 (15%) were linked to an inpatient hospitalization and 1,044 (40%) were linked to an outpatient emergency department but were not hospitalized. Based on the hospital data:

- Motorcycle riders represented 1 percent of all persons involved in crashes and 10 percent of persons requiring hospital care based on the linked data.
- Injured motorcycle riders frequently had injuries to multiple body areas.
- Injuries to the lower extremities (e.g. leg, ankle) were the most common type of injury.
- Based on expected source of payment, riders with commercial-private insurance (including employer-sponsored plans) accounted for the largest number of riders followed by Medicaid (MaineCare) and riders with no health insurance.
- The hospital length of stay and charges were higher for riders with head injuries and helmets reduced the risk of hospital care or death for a serious head injury by 53 percent (margin of error 29% to 69%).

This study indicates opportunities to reduce injuries and medical costs for motorcyclists on Maine roads.

# APPENDICES

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## Appendix 1: Maine Statutes for Motorcycles

Maine Revised Statutes

Title 29-A: MOTOR VEHICLES:

*<http://janus.state.me.us/legis/statutes/29-A/title29-Asec1254.html>*

Chapter 11: DRIVER'S LICENSE

Subchapter 1: GENERAL PROVISIONS

§1254. Special licenses

1. Motorcycles. The Secretary of State may issue a license specifically endorsed for the operation of a motorcycle with the same requirements as a motor vehicle license. A motor vehicle license does not authorize operation of a motorcycle unless the license is endorsed for that vehicle.
2. Moped license. The Secretary of State may issue a license to operate a moped. An applicant must have attained 16 years of age and must pass an examination on qualifications to operate a moped. The examination fee and license fee for a moped license is the same as for a Class C license.
3. Motorized bicycle, tricycle or scooter operator. A motorized bicycle or tricycle or motorized scooter may only be operated by a person who possesses a valid license of any class, an instruction permit or a license endorsed for a motorcycle or moped. The Secretary of State may not require the operator of a motorized bicycle or tricycle or motorized scooter to obtain a license endorsed for a motorcycle or moped

*<http://janus.state.me.us/legis/statutes/29-A/title29-Asec1352.html>*

Chapter 11: DRIVER'S LICENSE

Subchapter 3: DRIVER EDUCATION

§1352. Motorcycle driver education

1. Motorcycle driver education required. Notwithstanding any other provision of law, a motorcycle instruction permit, license or endorsement may not be issued to a person, unless that person presents a certificate of successful completion of a motorcycle driver education program and examination approved by the Secretary of State, except as provided in this subsection.
2. Education program. The following provisions apply to motorcycle driver education programs.
  - A. A motorcycle driver education program must consist of an 8-hour block of instruction directly related to the actual operation of motorcycles, emphasizing safety measures designed to ensure greater awareness of careful and skillful operation of motorcycles
  - B. The program may be offered by a public secondary school, a private secondary school approved for attendance purposes by the Commissioner of Education, a career and technical education center or career and technical education region or adult education program conducted under Title 20-A, chapter 316.
  - C. A motorcycle program offered independently of an approved driver education course may not be offered for credit toward a high school diploma.
  - D. A program may include instruction and riding experience on a motorcycle driving range.

- E. The Secretary of State must approve a motorcycle driver education program.
3. Instructors. The following provisions apply to the certification of instructors.
- A. A person may not conduct a motorcycle driver education program unless certified by the Secretary of State as a qualified instructor.
- B. The Secretary of State shall:
- (1) Conduct, or authorize other qualified persons to conduct, certification courses; and
- (2) Establish reasonable qualification standards and requirements for certification. The requirements must include a provision to demonstrate proficiency in operating a motorcycle.
4. Instructor availability. When a certified instructor is not available in a geographic area, the Secretary of State may assign a qualified instructor for the program subject to the following provisions.
- A. The requesting authority must ensure a minimum class size of 6 students.
- B. The Secretary of State shall charge a program fee comparable to other motorcycle driver education programs
- C. An instructor is not a "teacher" within the meaning of Title 5, section 17001, subsection 42 or Title 20-A.
5. Completion certificates. An instructor shall issue a completion certificate to a student who has successfully completed the course.
6. Waiver of examination. The Secretary of State may waive the required:
- A. Written examination on receipt of a completion certificate; and
- B. Road examination for the holder of a valid motor vehicle operator's license on receipt of a certificate demonstrating successful completion of the Basic Rider Course or other hands-on motorcycle rider course approved by the Secretary of State. An endorsement issued pursuant to this paragraph prohibits the holder from carrying a passenger for a period of 60 days following the date of issuance of the endorsement.
7. Suspension and revocation. The Secretary of State may suspend, revoke or deny a certificate of completion or an instructor's certificate for just cause in accordance with the Maine Administrative Procedure Act

*<http://janus.state.me.us/legis/statutes/29-A/title29-Asec2062.html>*

Title 29-A: MOTOR VEHICLES:

Chapter 19: OPERATION:

Subchapter 1: RULES OF THE ROAD:

§2062. Motorcycles

1. Seating. Seating on a motorcycle is as follows.
- A. A person operating a motorcycle may ride only on the permanent and regular seat attached.
- B. More than 2 persons may not ride on a motorcycle.
- C. The number of passengers in a sidecar attached to a motorcycle may not exceed the number of permanent seats for which the sidecar has been designed, to a maximum of 2 persons.
- D. A passenger may only ride on permanent seating with no more than one passenger occupying each seat.
2. Headlight. When the motorcycle is on a public way, the motorcycle's headlight must be on.

3. Handlebars. A person may not operate on a public way a motorcycle equipped with handlebars whose handgrips are higher than the shoulder level of the operator.
4. Lane use; motorcycles and mopeds. Lane use by motorcycles and mopeds is restricted as follows.
  - A. An operator of a motorcycle other than a moped may fully use a lane. [2003, c.
  - B. More than 2 motorcycles may not be operated abreast within the same lane.
  - C. A motor vehicle may not be driven in such a manner as to deprive a motorcycle of the full use of a lane.
  - D. A moped may be operated only in single file and as far as practicable to the right side of the way at all times, except when making a left turn.
5. Passing. A motorcycle operator may not overtake or pass in the lane occupied by the vehicle being overtaken, except for passing a bicycle. This subsection does not apply to a law enforcement officer performing an officer's duties.
6. Between lines. A person may not operate a motorcycle between lanes of traffic or between adjacent lines or rows of vehicles.
7. Raising wheel. A person may not intentionally or knowingly raise the front wheel of a motorcycle off the surface when operating it on a public way or any place where public traffic may reasonably be anticipated.

*NOTE: During the period of this study, helmets were required for riders under 15 and operators on an instruction permit and operators and passengers within one year of endorsement. In 2009, legislation was enacted that increased the aged based requirement to riders under 18. The law cited below reflects the law at the time (2003-2006) of the crashes under study.*

<http://janus.state.me.us/legis/statutes/29-A/title29-Asec2083.html>

#### §2083. Protective headgear

1. Requirement. The following persons must wear protective headgear:
  - A. If under 15 years of age, a passenger on a motorcycle or in an attached side car;
  - B. If under 15 years of age, an operator of an off-road motorcycle;
  - C. An operator of a motorcycle, operating under a learner's permit or within one year of successfully completing a driving test;
  - D. A passenger of an operator required to wear headgear
2. Compliance. An operator of a motorcycle, parent or guardian may not allow a passenger under the age of 15 years to ride in violation of this section.
3. Standard. Protective headgear must conform with minimum standards of construction and performance as prescribed by the American National Standards Institute specifications Z 90.1 or by the Federal Motor Vehicle Safety Standard No. 218.
4. Public program. In furtherance of reasonable protective public policy, the Department of Public Safety, Bureau of Highway Safety must develop and implement a public information and education program designed to encourage helmet utilization by all motorcycle and moped riders.
5. Violation. Violation of this section is a traffic infraction.

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## Appendix 2. What is CODES. Linkage and Reporting Methods

What is the Crash Outcome Data Evaluation System (CODES)?

CODES, a NHTSA sponsored program, provides software and technical assistance to states to generate population-based crash outcome data that are complete, comprehensive and representative of all crashes reported statewide. CODES evolved from a congressional mandate to report on the benefits of safety belts and motorcycle helmets in terms of reductions in mortality, morbidity, injury severity and health care costs. To date, the National Highway Traffic Safety Administration has funded 30 states to implement CODES.

Background: Crash data are the major source of population-based information about the persons and vehicles involved in crashes statewide. Thus, they are crucial for traffic safety decision-making. But they are not comprehensive or complete. As with all routinely collected state data used for administrative purposes, they are limited by the reporting threshold and include missing or inaccurate information. In addition, because the impact of the crash on the occupants of the vehicles involved is not usually known at the scene, crash data do not include the outcome information traffic safety needs to evaluate effectiveness in terms of decreased mortality, morbidity, injury severity and hospital costs.

Traffic safety must target its limited resources where they will have the most impact. To do this effectively, additional information is needed to identify which specific characteristics of the person, vehicle, and/or event are likely to result in death, or to prevent death but result in severe injury, or prevent severe injury but result in long term disability, or allow the Vic Tim of a crash to walk away with a minor injury or unharmed. Medical records collected during treatment at the scene, en route, at the emergency department, as a hospital inpatient and/or as an outpatient include data about the type and severity of the injury and the subsequent costs (billed charges) related to that injury. Although this information is included in the billing data set used to merge medical data statewide for public health purposes, routine access by traffic safety is restricted because of privacy regulations, non-uniform data release policies, and, most important, inconsistent documentation of motor vehicle crash as the cause. Thus, traffic safety could make decisions based on injury outcome data that are incomplete and unrepresentative.

What does CODES provide that other crash data sets cannot? CODES linked crash outcome data are a unique resource because they identify crash characteristics for both the injured and the non-injured. Analyses are less likely to be biased when data include characteristics of persons involved in crashes who have unexpected outcomes: persons who are injured in spite of using safety equipment and persons who are not injured in spite of not using safety equipment.

CODES enhances the state data without the expense of additional data collection. The crash outcome linkage provides EMS and hospitals with time of the crash, a time earlier than time of the call that is needed to calculate total time to the hospital, a measure of the responsiveness of the trauma system. Roadway

inventories are enhanced with the inclusion of injury type and severity by location. Licensing data are enhanced when driver information is linked to the injury severity and health care costs caused by driving under the influence, aggressive driving, or speeding.

CODES promotes collaboration between the traffic safety and health communities. Owners of the crash and injury data are required to serve as a Board of Directors. They are responsible for ensuring that state data are available for linkage and for developing the policies that control release of the linked data in compliance with state privacy legislation/regulations. The success of these proactive partnerships spills over into other areas of traffic safety, which also depend upon a collaborative approach to improve crash outcome. This collaborative approach is consistent with the NHTSA's Program Guidelines and the Data Improvement Grants. CODES states found they met the guidelines for traffic records assessments and had already established much of the structure required for Data Improvement funding.

CODES is useful to promote safety legislation. Because the CODES crash outcome data are state-specific, they are more likely to convince state legislators about the value of supporting primary belt laws or the cost of repealing helmet use legislation. The ability to compare state-specific results to national estimates provides further clarification about the need for immediate action.

How does CODES generate the linked crash outcome data? Each state links person-specific crash records to the statewide EMS, emergency department, hospital inpatient and death certificate records, all of which are also person-specific. Few states have unique identifiers, such as social security numbers, available in the records to be linked. Instead, indirect identifiers that discriminate among the events and the persons involved are matched. Some states augment the person-specific crash outcome data with driver specific data from the state licensing files, vehicle specific data from the state registration data files, and roadway specific data from the roadway inventory data files.

The linkage is a sophisticated process. In the real world, we cannot know for certain which crash and injury records are true matches. A lack of unique identifiers, records (crash or injury) missing for occupants known to have been injured, in addition to the expected problems of missing, and/or inaccurate data all contribute uncertainty. After evaluating the completeness and quality of the state data to determine if what is expected to be there actually is, CODES grantees implement advanced methods of linkage and probabilities using CODES2000 software, which estimates the probability that a possible record pair is a valid match.

How does CODES handle missing links? Not all valid matches have high probabilities. This occurs when either the crash or injury record is missing or when the identifiers are unable to discriminate among the crashes and the persons involved because of missing, inaccurate or inconsistent values. Conclusions based only on high probability linked pairs cannot be presented as representative of the population. Linked pairs, excluded because of low probabilities caused by incomplete data, may in fact be valid. To compensate for the imperfect data, linkage

imputation techniques are implemented to include representative low probability links as well as high probability links in outcome studies.

CODES constructs ("imputes") multiple sets of data that can be used to statistically summarize estimates about the crash population. These estimates are representative of the population from which they were derived, just as a scientifically selected survey sample is representative of the population from which it was drawn.

How are imputed datasets analyzed? Once the missing links have been found, routine techniques are used to handle missing values and analyze the resulting datasets. These techniques provide margins of error that accurately reflect the variability in the process.

Thus, by first imputing the missing links, and then handling missing values, CODES provides complete, representative data for traffic safety analyses.

The Crash Outcome Data Evaluation System (CODES) links crash reports to injury outcome records such as emergency medical services (EMS) ambulance run reports or hospital discharge records in order to evaluate injuries and medical charges associated with crashes. In addition, other traffic safety datasets including roadway inventory, vehicle registration, driver licensing and citations, and insurance claims may also be linked to provide a more comprehensive picture. Most CODES datasets do not have common unique identifiers. Consequently, CODES applies a statistical methodology to link the datasets. The probability that two records are a true link is determined by comparing all event characteristics (e.g. date and place) and all person characteristics (e.g. age and sex) that are common to both records. These characteristics are called quasi-identifiers.

### LINKAGE METHODOLOGY

CODES record linkage is conducted using CODES2000, commercially available software that implements an extension of Fellegi and Sunter's statistical theory of record linkage (Fellegi and Sunter, 1969; McGlinchey, 2004 and 2006). CODES2000 determines the posterior odds for a true link by applying Bayes' rule for odds (Gelman et al., 2004, pg. 9), "the posterior odds are equal to the prior odds multiplied by the likelihood ratio." Parameters of the linkage model are determined using Markov Chain Monte Carlo data augmentation (Schafer, 1997, pg. 72). CODES linkage concepts are summarized in Table 1.

| <b>CODES Linkage Concepts (Pr X means Probability of X)</b> |   |   |
|---|---|---|
| <b>Concept</b>  | <b>Definition</b>   | <b>Calculation</b>  |
| Probabilistic Record Linkage                                | Bayes' Rule for Odds applied to record linkage: Posterior odds for a true match equal the prior odds multiplied by the likelihood ratio | Posterior Odds = (M / U) X (m / u)                                    |
| Prior Odds for a True Match                                 | Odds for a true match estimated from prior information. Posterior odds after comparing one match field become prior odds for next.      | M / U = Estimated # of Matched Pairs / Estimated # of Unmatched Pairs |

| CODES Linkage Concepts (Pr X means Probability of X) |   |  |
|--|---|--|
| Concept  | Definition  | Calculation  |
| m Probability  | Conditional probability for a comparison result (agreement, disagreement, or missing) for true matched pairs        | m Agreement = Pr(Reported) X Pr(Correct) X Pr(Field has Given Value for Matched Population)<br>...   |
| u Probability  | Conditional probability for a comparison result (agreement, disagreement, or missing) for true unmatched pairs      | u Agreement = Pr(Reported) X Pr(Correct) X Pr(Field has Given Value for Crash Population) X Pr(Field has Given Value for Hospital Population)<br>... |
| Likelihood Ratio for a True Match                    | Likelihood for comparison result for true matched pairs / Likelihood for comparison result for true unmatched pairs | Likelihood Ratio Agreement = (m Agreement / Pr(Agreement)) / (u Agreement / Pr(Agreement)) = m Agreement / u Agreement<br>...                        |

Missing values and reporting errors in the data collection processes may lead to low probabilities being assigned to many true matches. If only high-probability links are selected then low-probability false negatives can make selected links unrepresentative of the total population of true linked pairs. To be able to include these low-probability matches in outcome studies, CODES2000 completes five linkage imputations; that is, missing links are determined five times resulting in five complete datasets. (Note that multiple imputation does not attempt to identify each missing link but instead constructs samples representative of the distribution of low to high probability links. As a result, analyses yield valid statistical inferences that reflect the uncertainty associated with having low-probability true links.) Standard statistical analyses are performed on each of the five datasets and then combined to produce final results using procedures in SAS.

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