



Working Paper

NCAC 2007-W-003

October 2007

Opportunities for Safety Improvements in Motorcycle Crashes in the United States

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This working paper is a compilation of recent efforts and findings intended to solicit feedback on the approach, scenarios analyzed, findings, interpretations, conclusions, and implications for practice resulting from the efforts of the research team. Please forward comments or questions to the authors noted above. These efforts will ultimately be documented and made available to advance research efforts related to this topic and guidance for practice.

OPPORTUNITIES FOR SAFETY IMPROVEMENTS IN MOTORCYCLE CRASHES IN THE UNITED STATES

ABSTRACT

Given the steady growth of the crash problem since the late 1990s, a descriptive analysis of motorcycle crashes on U. S. roads was performed to gain insight into crash causation and investigate opportunities for improving rider safety. Data from the 1992-2004 National Automotive Sampling System/General Estimate System (NASS/GES) were studied relative to crash configuration and rider, motorcycle, and environment characteristics. Data trends pre- and post-1998 were examined. Key findings show that, in addition to the increase in problem size due to exposure, motorcycle crashes are becoming more deadly. Contributing factors to increased severity and higher fatalities rates were: increased roadside departures, vehicles turning into the path of the motorcycle, and head on crashes; lack of awareness of impending crash; speeding for riders under 30, increased alcohol involvement for riders ages 30-49, and decreased helmet use for riders ages under 19 and 40-49; "over 750cc" engine size motorcycles in frontal crashes; riding on roads with higher speed limits; crashes away from a junction, and riders over 40 in dark road conditions. Overall, as compared to all crashes, a rider was about two times more likely to be killed in a roadside departure. Also, riders under age 30 were most vulnerable followed by riders over 50 in all motorcycle crashes. Findings indicate opportunities in safety strategies such as rider education, focused by age groups, relative to speeding, helmet use, and alcohol consumption. Findings also indicate opportunities in countermeasures such as improved lighting, whether for the motorcycle and/or roadway, and improved performance of larger motorcycles in frontal crashes. Findings also highlight the need for a more in depth study of the growing roadside departure motorcycle crash problem.

INTRODUCTION

The number of motorcycle riders killed in traffic crashes on United States (U. S.) roads has increased for eight years in a row and has more than doubled since 1997 [1]. This increase recently overshadowed the decrease in passenger car crash fatalities and has led to an overall increase of traffic fatalities in the U. S. In 2005, 4553 motorcycle riders died in U. S. crashes, accounting for 10.5% of all traffic fatalities.

Given the recent growth of the motorcycle crash problem on U. S. roads, there is a critical need to gain an understanding of the factors contributing to motorcycle crashes. In this paper, results from a nationally representative descriptive analysis of U. S. motorcycle crashes are presented, including assessment of problem size and examination of recent trends. The goal of the research was to gain insight into crash causation and investigate opportunities for improving rider safety.

STUDY POPULATION AND METHODS

Database Selection

In the U. S., there are two national traffic crash databases: the Fatality Analysis Reporting System (FARS) starting in 1975, and the National Automotive Sampling System (NASS) starting in 1988. FARS is a census of all fatal crashes and, as such, includes motorcycle fatalities. NASS is a stratified sample of police reported crashes of all severities and is composed of two systems: the General Estimate System (GES) and the Crashworthiness Data System (CDS). Although CDS includes detailed vehicle, crash scene, and occupant data that allows study of injury mechanisms, only about 5,000 tow-away crashes are investigated per year for four-wheeled vehicles (passenger cars, light trucks, vans, and utility vehicles) and do not include motorcycle specific crash cases. NASS/GES samples around 55,000 cases per year from all police-reported crashes with major property damage, injury, or death. GES includes motorcycle crashes and incorporates pre-event, rider, vehicle, environment, and limited injury data. NASS/GES was the most suitable database for this study. FARS was the source of the overall number of crash fatalities.

Crash Population and Methods

Weighted NASS/GES data from 1992-2004 of crashes with at least one motorcycle, including both driver and passenger, were used for this study. ATVs (all terrain vehicles) were excluded. The study population involved a national estimate of 1,003,665 riders (summarized in Table 1).

Table 1. 1992-2004 NASS/GES Motorcycle Population

All	Un-weighted Sample Size	National Estimates
Single-Vehicle Crash	9,993	437,261
Two-vehicle Crash	9,904	536,857
Multiple Vehicle Crash	631	29,547

Motorcycles made up 2.54% of total vehicle registrations in 2005, with a low of 1.86% in 1998 and a high of 3.9% in 1981 [1]. This leads to motorcycle crashes being a small segment of the police reported crashes sampled by GES. The sparse sample size is accentuated when looking at fatal crashes which occur less frequently. Thus fatal motorcycle crashes are under represented in GES. In the case of motorcycles, GES is more suited to look at trends and problem characterizations using data collected over several years. In this paper, crash configuration, rider, motorcycle, and environment characteristics are investigated by grouping 13 years of weighted GES data from 1992 to 2004 (investigated variables listed in Table 2).

Table 2. GES Variables Investigated

Accident Type	Injury Severity
Speed Limit	Age
Relation to Junction	Safety Equipment Use
Light Condition	Restraint System Use (helmet)
Vision Obstruction	Police Reported Alcohol Involvement
Road Surface Condition	Driver Maneuvered to Avoid
Make	Vehicle Maneuver
Make (engine size)	Corrective Action Attempted
Vehicle Contribution Factor	Speed Related

Color Key: crash configuration related, crash environment related, motorcycle related, rider related

Motorcycle crashes had a downward trend in (1992-1997) followed by an upward trend in (1999-2004) as shown in Figure 1. A trend analysis grouping the two ranges of years was also performed. Crash characteristics were compared between the two ranges of years to study both involvement and severity for motorcycle crashes.

Crash Configuration Groupings - The standard GES crash configuration groups were reassigned (Table 3) to better define the role of the motorcycle. The new assignments specify the crash configuration relative to the motorcycle. For example, in the case of rear-end with a passenger vehicle, the new groups identify if the

motorcycle impacted the rear of the passenger car or visa-versa.

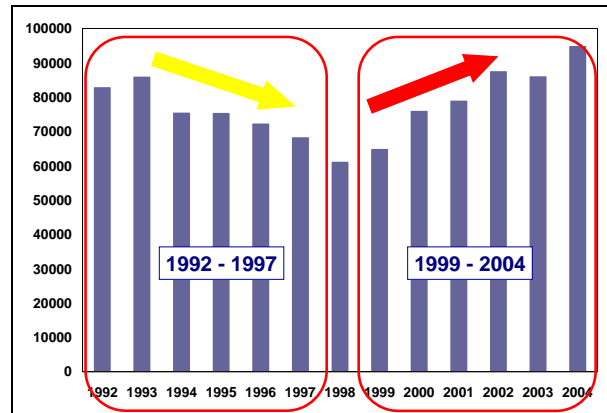


Figure 1. Recent Trends of Motorcycle Crashes (GES)

Table 3.

GES Category	Study Crash Configuration: GES ACCIDENT TYPE Codes
Single-Vehicle Crash	Roadside departure: 01-10 Frontal Impact: 11-16
Pair and Multiple Vehicle Crashes	Frontal Impact: 20, 24, 28, 34, 36, 38, 40, 50-63, 69, 71, 73, 80, 81, 83, 86, 88 Sideswipes: 44-49, 64-67, 76-79 Side: 68, 70, 72, 82, 87, 89 Rollover: 97 Rear: 21, 22, 23, 25, 26, 27, 29, 30, 31, 35, 37, 39, 41 Other: 92,93,98,99,00

Note: GES ACCIDENT TYPE codes [3]

GES cases with Accident Type codes 32, 33, 42, 43, 74, 75, 84, 85, 90, 91 were eliminated, because the specifics were unknown and the role of the motorcycle could not be identified. Most of these were multiple vehicle crashes. This resulted in 18,358 cases lost from 1,003,665 which correspond to less than 2% of the study population.

Injury Severity Groupings - The GES injury severity codes were grouped as non-severe injury, severe injury, and fatal injuries (Table 4):

Table 4. Study Injury Groups

	GES codes
Fatal Injury = K	K : Fatal Injury
Severe Injury = A	A : Incapacitating Injury
Non-Severe Injury = B+C+U	B : Non-incapacitating Injury C : Possible Injury U : Injured, Severity Unknown

OVERALL MOTORCYCLE CRASH TREND AND RISK ASSESSMENT

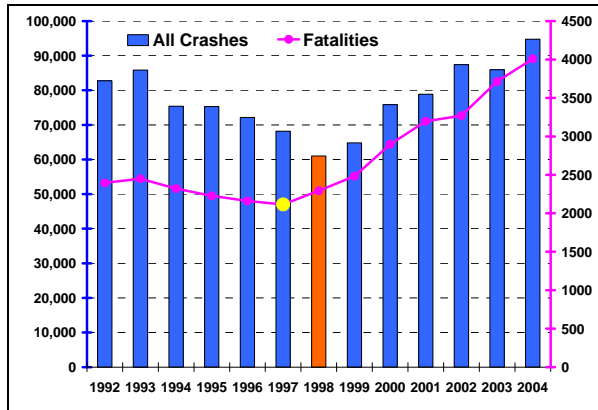


Figure 2. Motorcyclist Crashes and Fatalities Trend. Crashes (weighted GES 1992-2004), Fatalities (FARS).

Motorcycle crashes and resulting rider fatalities have followed a similar trend in the last decade (Figure 2). In fact, since the mid 1980s, both the number of motorcycles on U. S. roads (registrations) and rider fatalities were decreasing until the reversal of trend in the late 1990s (Figure 3). The increase in motorcycle registrations, driven by the rapid increase in sales shown in Figure 3 [2], is a main factor contributing to the increase in motorcycle crashes on U. S. roads.

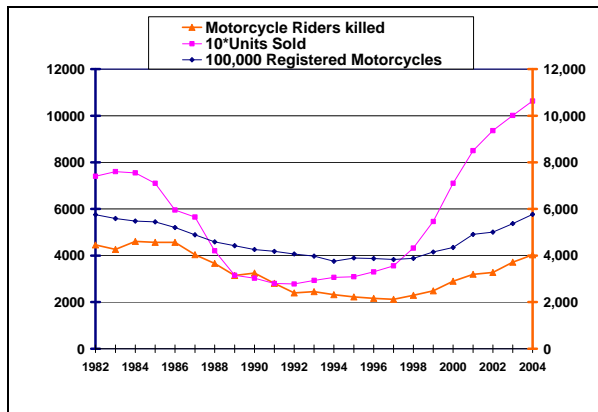


Figure 3. Motorcyclist Fatalities (FARS), Registrations (FHWA), New Unit Sales (Motor Cycle Industry Council (MIC))

However, if we account for the increase in the size of the motorcycle fleet by normalizing with the number of registrations [3] from the Federal Highway Administration (FHWA), we find that motorcycle fatality rates per 100,000 registered vehicles increased from a low of 55 in 1997 to 73 in 2005 (Figure 4). Motorcycle fatality rates have been rising since 1997 while, in comparison, passenger cars fatality rates have

been steadily decreasing. Motorcycle riders represent a very vulnerable segment of road users in the U.S. In 2005, riders were 5.4 times more likely to be killed in motor vehicle traffic crashes per registered vehicle than occupants of passenger cars (who had a fatality rate of 13.6).

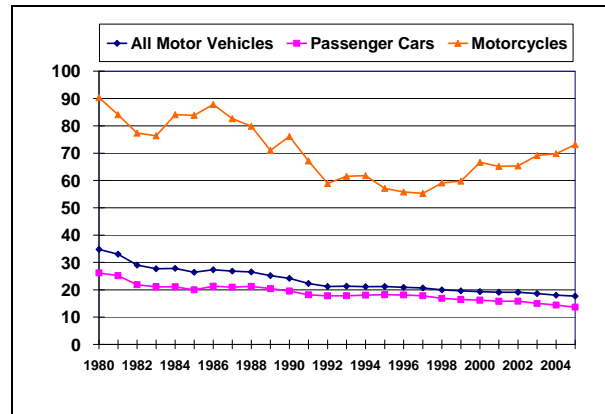


Figure 4. Fatality Rates per 100,000 Registered Vehicles (FARS, FHWA)

Risk Assessment - Are motorcycle crashes just becoming more prevalent and thus resulting in higher fatality rates per registered vehicle or is a motorcycle crash also becoming more dangerous? To obtain some insight into this question, the numbers of motorcycle crashes with a different severity outcome (fatal, severe injury, non-severe injury, and no injury) per 100,000 registered vehicles were used as measures of risk. Fatal risk was the ratio of fatalities from FARS and the injury risks were based on data from GES. The ratio for the total number of crashes was defined as involvement risk.

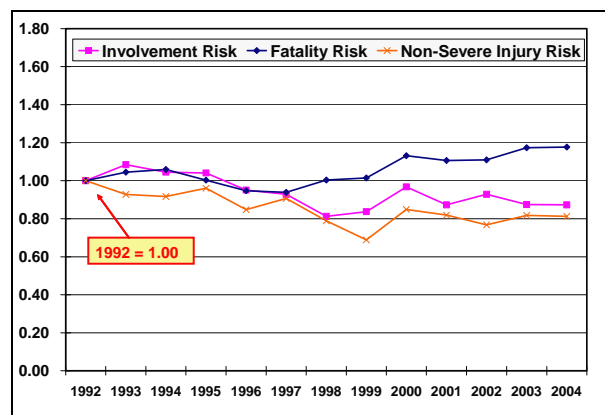


Figure 5. Motorcyclist Crashes and Fatalities Risk Trend

Normalizing to 1992 levels for each measure, the risks for involvement and no-severe injury decreased over twelve years to 0.87 and 0.81 respectively in 2004

while the fatality risk increased to 1.18 in 2004 (Figure 5). This indicates that, although that there seems to be less crashes per registered motorcycle, the crashes tend to be more deadly in recent years.

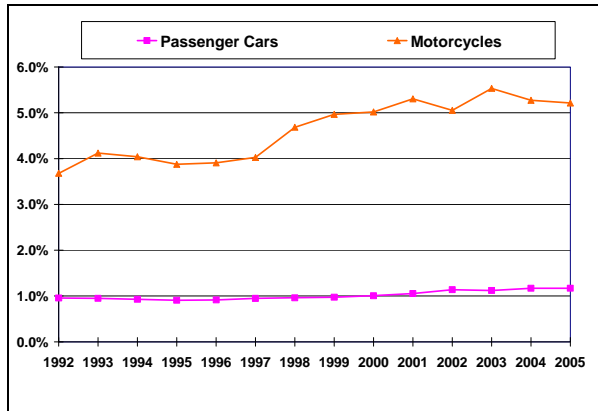


Figure 6. Ratio of People Killed (FARS) to the Number Injured in U. S. Crashes (GES) Trend

As another measure of risk, the ratio of people killed to the number injured people in traffic crashes over the last fourteen years was considered. For motorcycles, this ratio increased from 3.7 to 5.2% from 1992 to 2005 (Figure 6). In contrast, the ratio for passenger cars has more or less stayed in the same range with a relatively small increase (1 to 1.2%). This provides further support that, in addition to becoming more prevalent, motorcycle crashes are becoming more severe or dangerous.

MOTORCYCLE CRASH CHARACTERISTICS

Crash Configuration

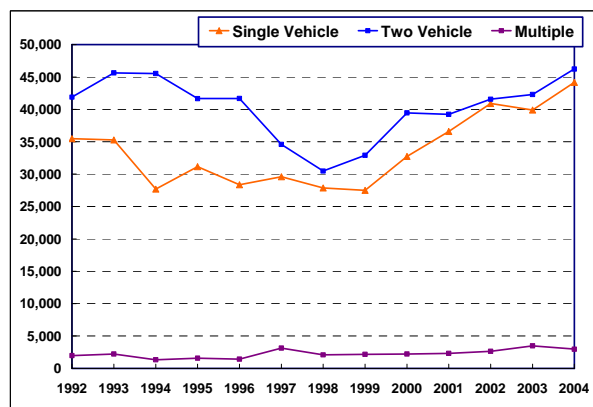


Figure 7. Motorcycle Crash Types (GES)

Single-vehicle crashes, where only the motorcycle was involved, made up 44.2 % of the GES population (1992-2004). Crashes with another vehicle were

52.8% and crashes with multiple vehicles were 3.0%. The percent of single-vehicle crashes has been increasing in recent years (Figure 7) and was 47.5% in 2004.

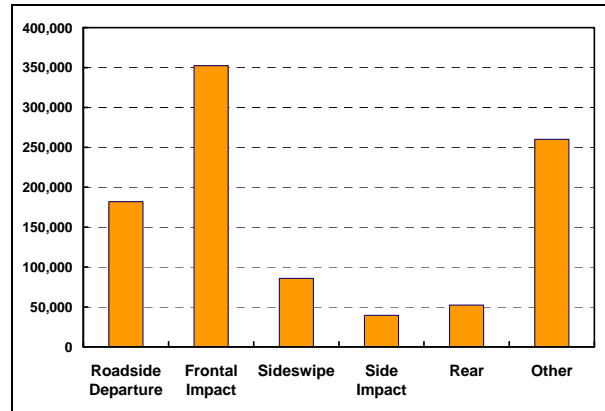


Figure 8. Motorcycle Crash Configurations (GES 1992-2004)

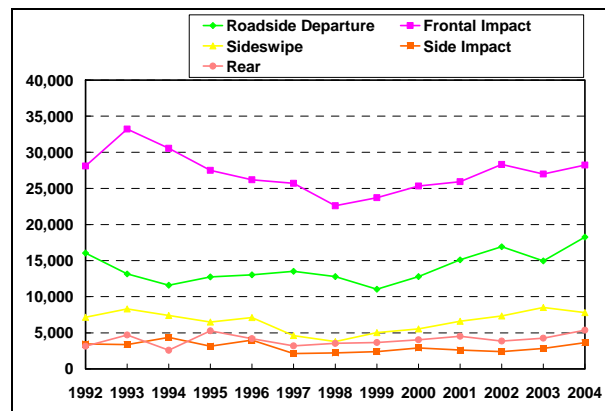


Figure 9. Motorcycles Crash Configurations Trend (GES)

Frontal impact and Roadside Departure are the most common U. S. motorcycle crash configurations and have been increasing in recent years (Figures 8 and 9). They are also the two most dominant configurations for all injury severities, especially fatal crashes, resulting in 75% of motorcycle riders killed from 1992-2004 (Figure 10). Roadside departures were 18.7% of motorcycle crashes but resulted in 36.8% of the fatalities in 1992-2004 GES data (Figures 9 and 10). As compared to all motorcycle crashes, a rider was about two times more likely to be killed in a roadside departure (ratio of 1.97 times). This corresponds to 1675 riders killed from a total of 4553 in 2005 from roadside departures based on FARS. Frontal crashes were 36.3% of the GES crashes and resulted in 39.2% of the fatalities (1784 in 2005 based on FARS).

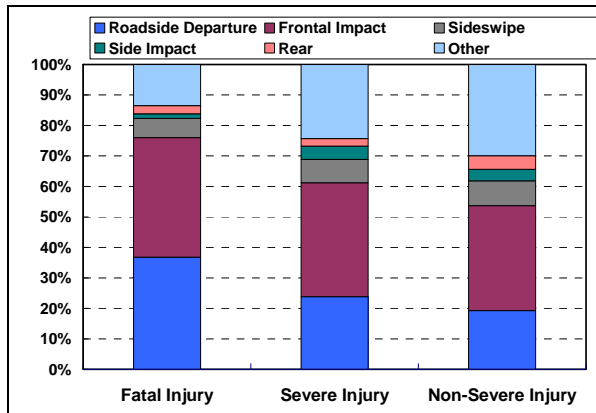


Figure 10. Injury Severity by Crash Configuration (Motorcycle Crashes: GES 1992-2004 weighted)

Table 5. Injury Rates per Involved Rider in Frontal Crashes

	1992-1997 GES	1999-2004 GES
Fatal	2.5%	4.3%
Severe Injury	26.2%	27.7%
Non-Severe Injury	53.2%	48.9%
No Injury	18.1%	19.2%

When comparing injury rates per crash involvement in the two ranges of years (1992-1997) and (1999-2004), GES data shows that both frontal and roadside departure crashes have become more severe in recent years (Table 5 and Table 6). Riders who were killed or severely injured were a bigger percentage of the total crash involved with a trade off in non-severely injured riders in (1999-2004). Roadway departures had a higher fatality rate of 6.5% as compared to 4.3% for frontal crashes in recent years.

Table 6.

Injury Rates per Involved Rider in Roadway Departures

	1992-1997 GES	1999-2004 GES
Fatal	4.5%	6.5%
Severe Injury	28.4%	30.4%
Non-Severe Injury	57.9%	54.5%
No Injury	9.1%	8.6%

Motorcycle Frontal Crashes - For a more in-depth examination, the frontal crash grouping was subdivided into six configurations outlined in Table 7.

“Into Turning-Vehicle” configuration is the most prevalent frontal crash configuration from 1992 through 2004, making up at 48.4% of the total frontal crashes (Table 7). This corresponds to 17% of all GES crashes, 1992-2004. “Into Turning-Vehicle” basically involves another vehicle turning into or across the path of a motorcycle moving straight forward. “Into Rear of Vehicle” and “Into Non-Vehicle” follow at 23.4% and 13.5% of all frontal crashes respectively.

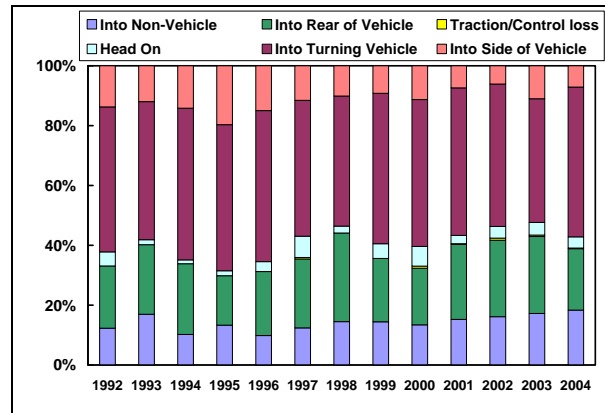


Figure 11. Motorcycle Frontal Crash Configurations

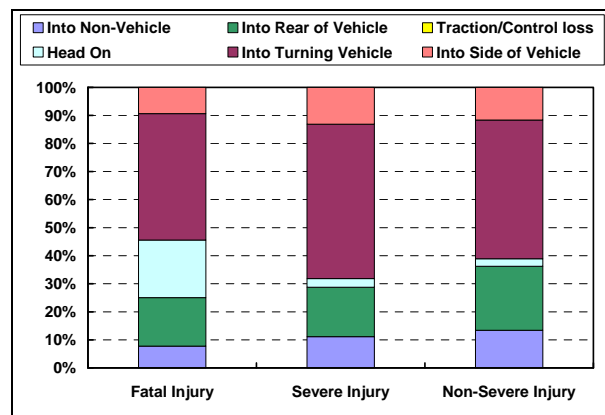


Figure 12. Frontal Crashes by Injury Severity (GES 1992-2004)

The “Into Turning-Vehicle” and “Into Rear of Vehicle” also dominate in injury causing frontal crashes resulting in 45% and 17.3% of the riders killed. However, “Head On” crashes are over represented in the fatalities resulting in 20.5% of the riders killed while making up only 3% of all the frontal crashes (Figure 14). “Into Side of vehicle” resulted in 9.4% of the riders killed in frontal crashes.

Table 7. Frontal Crash Configurations GES (1992-2004)

	% Frontal	% all GES	% Frontal Fatal	% all GES Fatal	Fatality Rate
Into Non-Vehicle	13.5%	4.7%	7.8%	3.0%	1.7%
Into Rear of Vehicle	23.4%	8.2%	17.3%	6.7%	2.2%
Head On	3.1%	1.1%	20.5%	8.0%	19.2%
Into Turning Vehicle	48.4%	17.0%	45.0%	17.6%	2.7%
Into Side of Vehicle	12%	4.1%	9.4%	3.7%	2.4%

“Head On” motorcycle crashes have an exceptionally high fatality rate. 22% of these crashes result in the rider being killed. “Into Turning Vehicle” and “Into Rear of Vehicle” are more prevalent frontal crash modes but only 3.3% and 3.1% of these crashes are fatal.

Rider Related

Rider Age - In 2004, riders ages 20-29, were still the largest segment (28%), of crash involved motorcycles riders; however, there is substantial increase in the proportion of riders age 40 and older since the late 1990s (Figure 13). In 2004, riders ages 40-49 were 23% of the GES crash population. Riders under 30 years old were 36% and riders over 40 were 43% of crash involved riders.

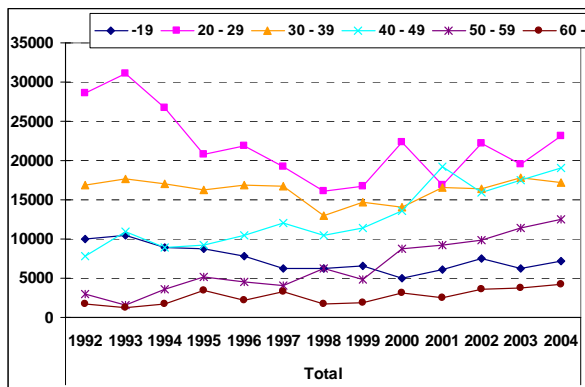


Figure 13. Rider Age in Motorcycle Crashes (GES)

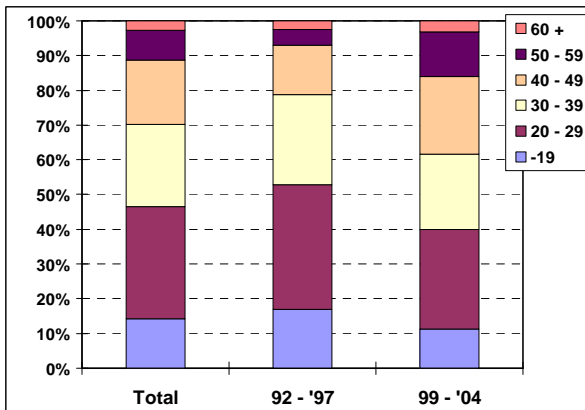


Figure 14. Trend of Frontal Crashes by Rider Age (GES)

Comparing involvement and fatality rates per crash involvement in the two ranges of years (1992-1997) and (1999-2004), rider under 30 years old were 42% of crash population earlier years and 51% of fatalities while riders over 40 were 24% of the crash population

and 23% of the fatalities. In recent years, riders under 30 were 36% of population and 38% of fatalities, and the over 40 increased to 38% of the population and nearly doubled to 40% of the fatalities.

Similar to the overall trend, the proportion of riders ages 40–49 and 50–59 involved and killed has increased in frontal crashes in recent years (Table 8 and Figures 14 and 15). However, while the number of crash involved riders ages 20-29 have decreased, they were a bigger proportion of frontal crash fatalities in later years. Considering the ratio of fatalities to crash involvement, the less than 30 age rider was 1.9 times more likely to be killed in a frontal crash in 1999-2004 as compared to 1992-1997. The over 50 was 1.7 times more likely to be killed in later years.

Table 8. GES Frontal Crashes by Rider Age

Rider Age	All		Fatal		Fatality Rate	
	92-97	92-97	99-04	99-04	92-97	99-04
-19	17%	12%	11%	6%	1.9%	1.8%
20 - 29	36%	28%	29%	37%	2.1%	4.6%
30 - 39	26%	40%	22%	19%	4.1%	3.2%
40 - 49	14%	13%	22%	20%	2.3%	3.2%
50 - 59	4%	2%	13%	13%	1.3%	3.5%
Over 40	21%	19%	38%	38%	2.3%	3.6%

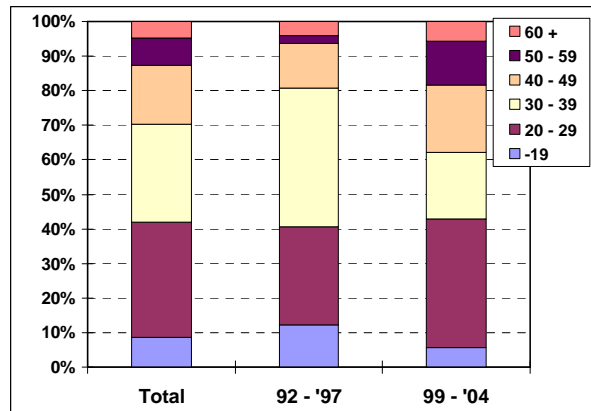


Figure 15. Trend in Fatal Frontal Crashes by Rider Age (GES)

For roadside departures, there were similar trends for 40-49 and 50-59 age riders (Table 9). The less than 30 age rider was also 2 times more likely to be killed in a roadside departure in 1999-2004 as compared to 1992-1997. Riders ages 40-60 were 1.5 more likely to be killed in roadside departures in the later years.

Table 9. GES Roadside Departure by Rider Age

Rider Age	All		Fatal		Fatality Rate	
	92-97	Fatal	99-04	Fatal	92-97	99-04
-19	13%	4%	8%	5%	1.5%	4.0%
20 - 29	38%	36%	29%	36%	4.3%	8.0%
30 - 39	25%	32%	23%	23%	5.9%	6.4%
40 - 49	14%	11%	20%	17%	3.3%	5.5%
50 - 59	6%	9%	14%	18%	6.8%	8.4%
Over 40	24%	27%	39%	35%	5.2%	5.9%

Driver Action - In 55% of recent motorcycle crashes, the rider was going straight prior to impact or prior to realizing an impending harmful event; however, in around 15% of the crashes the rider was negotiating a curve (Figure 16).

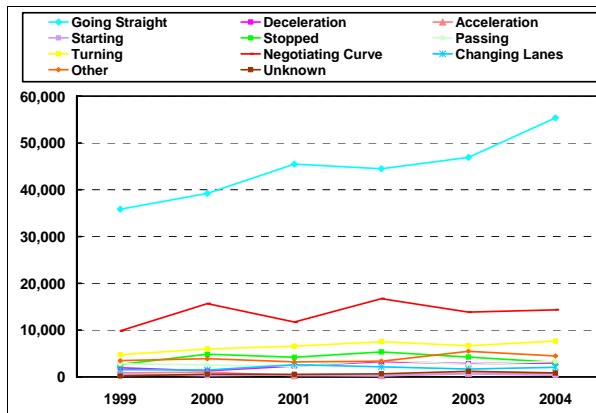


Figure 16. Motorcycle Driver Pre-crash Action (GES)

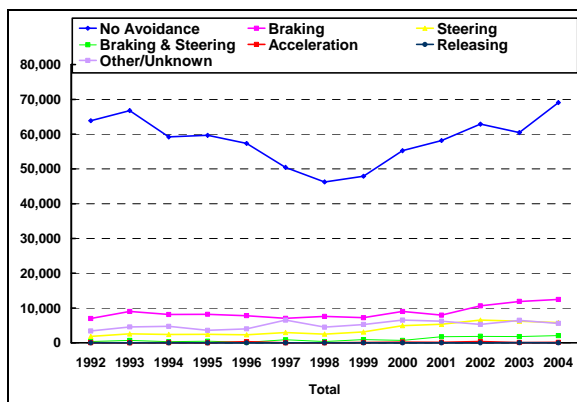


Figure 17. Corrective Action Taken by the Motorcycle Driver (GES)

Relative to corrective action attempted in response to impending danger (prior to first harmful event), the driver did not or could not attempt avoidance maneuver in 80% of the crashes in 1992-1997 (Figure 17). This

decreased to 73% in recent years. The driver attempted to break and/or steer in 20% of the crashes in recent years.

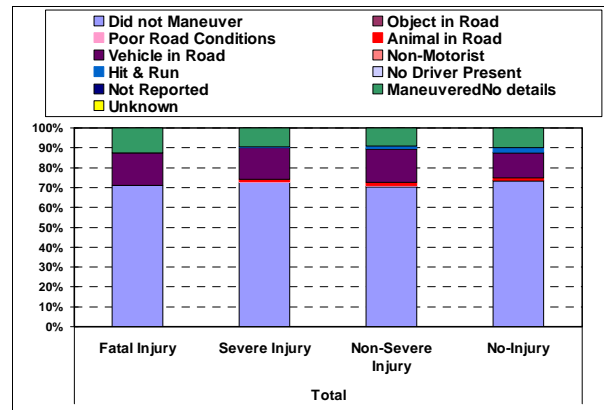


Figure 18. Situation that the Driver Maneuvered to Avoid (GES 1992-2004)

For most crashes, at all severity levels, the rider was not able to or did not attempt any avoidance maneuver (Figure 18). For fatal crashes, 71% of all riders killed did not maneuver. The 50-59 age riders did not attempt to maneuver in 77% of fatal crashes.

Alcohol Involvement - Most riders who were involved in crashes did not drink (Figure 19). However, 22% of all riders who were killed in a crash had been drinking (GES 1999-2004 crashes with known alcohol involvement). This is an increase from 18% in the 1992-1997 and is a conservative estimate due to large proportion of unknown alcohol involvement status as reported by the police in fatal crashes.

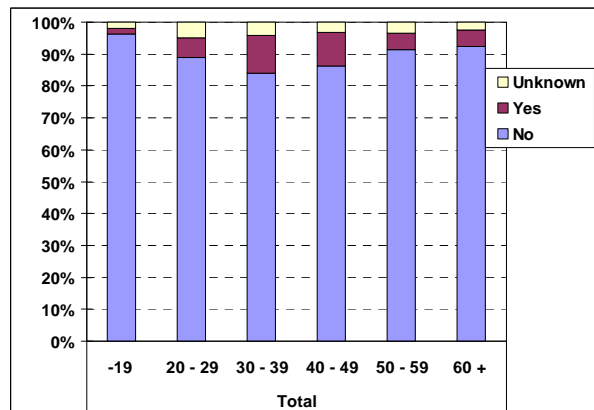


Figure 19. Alcohol Involvement by Age Group (GES 1999-2004)

Looking at GES data with known alcohol involvement, there is marked increase in 30-49 year old riders who were drinking in motorcycle crashes at all severity

levels relative to other riders (fatalities and Severe Injuries shown in Figures 20 and 21).

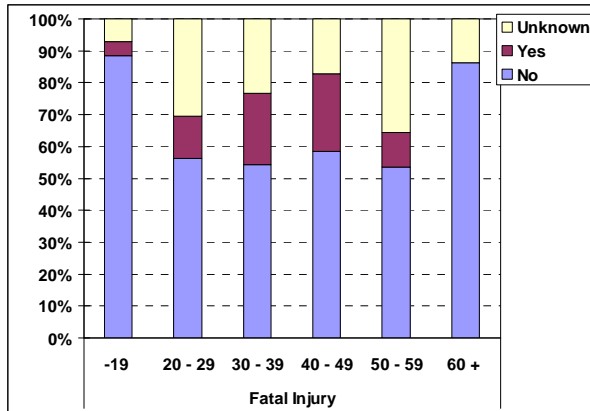


Figure 20. Alcohol Involvement by Age Group for Fatal Motorcycle Crashes (GES 1999-2004)

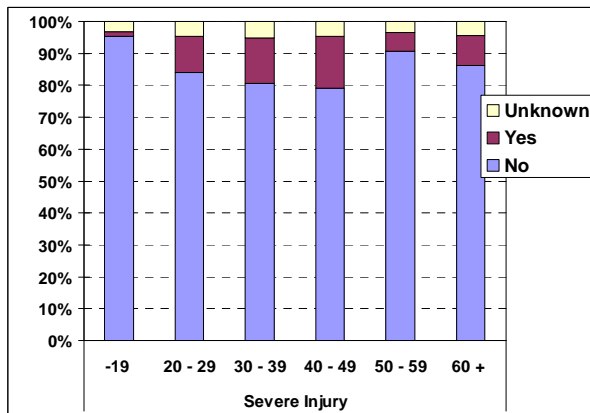


Figure 21. Alcohol Involvement by Age Group for Severe Injury Motorcycle Crashes (GES 1999-2004)

Helmet Use - Crash involved riders in the U. S. who wore a helmet averaged 57% in 1999-2004, an increase 52% in 1992-1997 (Figure 22).

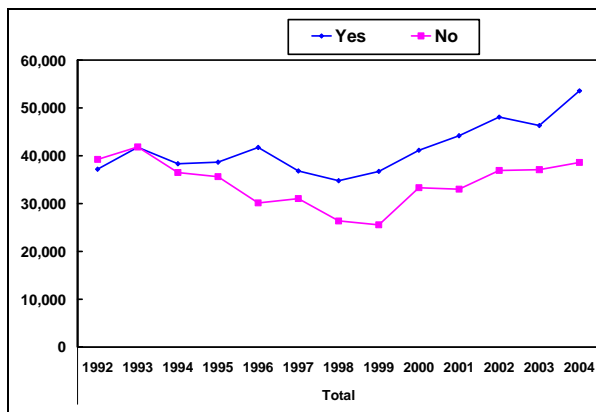


Figure 22. Helmet Use in GES Motorcycle Crashes

Taking a look at fatalities by age group, there is marked decrease of helmet use for the 40-49 and under 19 age groups in recent GES years, and to a lesser degree in the 20-29 age group (Figures 23 and 24). The percent of 40-49 age riders killed in recent years who were not wearing a helmet was 1.34 that of earlier years (61% vs. 45%). The percent under 19 age riders killed who were not wearing their helmet is 1.28 times that of earlier years (54% vs. 42%).

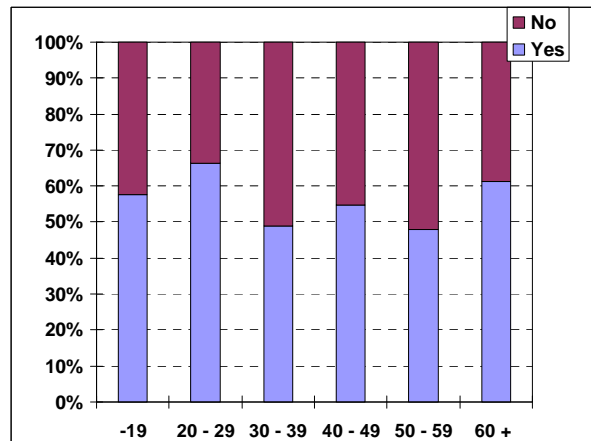


Figure 23. Helmet Use in Fatal GES Crashes (1992-1997)

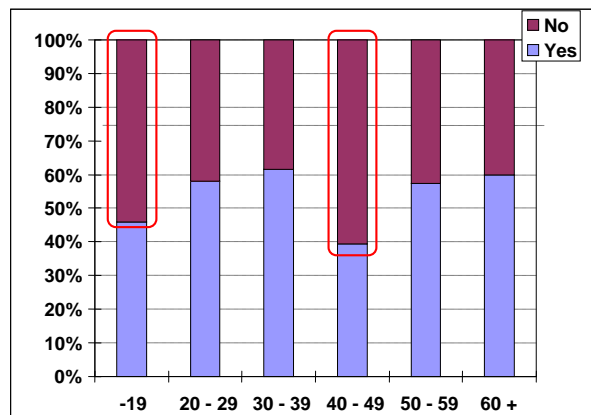


Figure 24. Helmet Use in Fatal GES Crashes (1999-2004)

Speed Relation - A large percentage of fatal motorcycle crashes are speed related as compared with crashes with less severe outcomes: 39.5% of fatal crashes, 27.1% of severe crashes versus 13.7% of no injury crashes are coded by police as speed being a contributing cause of the crash (Figure 25).

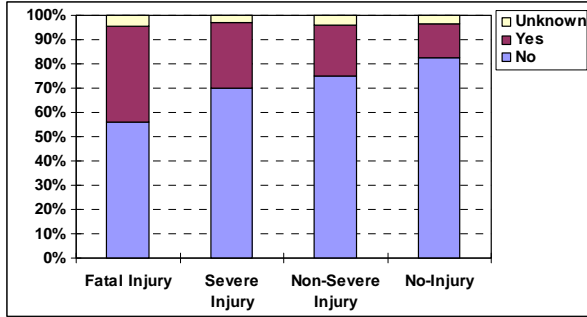


Figure 25. Speed Related Crash Severity (1992-2004) GES)

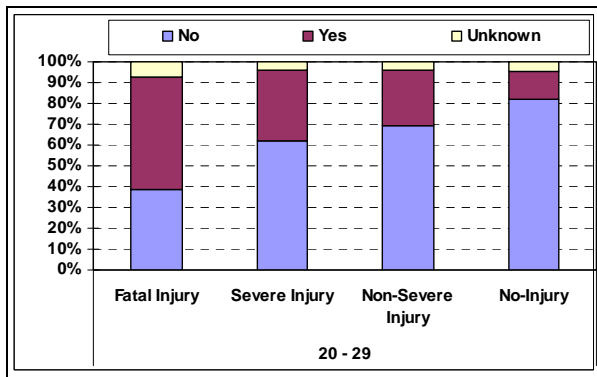


Figure 26. Speed Related Injury Severity for 20-29 year old riders GES (1992-2004)

Taking a look at fatalities by age group, a larger proportion of fatal crashes are speed related for the younger riders (Speed related injury severity for 20-29 and 40-49 age groups are shown in Figures 26 and 27). Actually, 54% of fatal crashes for rider under 30 are coded as speed related in contrast with 26% of fatal crashes for riders over 40 years old.

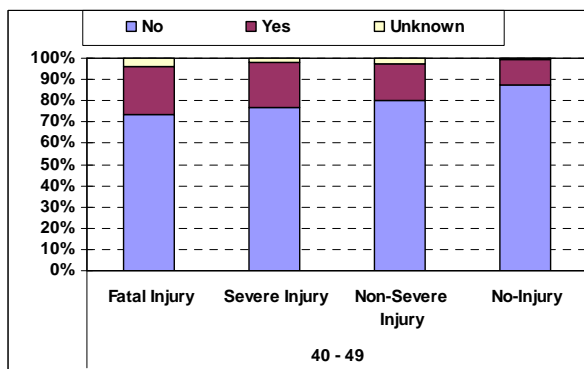


Figure 27. Speed Related Injury Severity for 40-49 year old riders GES (1992-2004)

Motorcycle Related

Motorcycle Engine Displacement - The motorcycle engine displacement in CC (cubic centimeters), an indication of size, was extracted from the vehicle model variable in GES. The engine size was identified for around 2/3 of the GES motorcycle crash population from 1999-2004 but only for 1/4 the population in 1992-1997.

Table 10. Fatal Crashes by Engine Displacement GES (1999-2004)

		% Crash involved		% Total	
		Frontal	Rd Dept	Frontal	Rd Dept
Killed	450 - 749	3.5%	6.4%	22%	25%
	750 & Over	5.2%	6.8%	77%	68%
Severe injury	450 - 749	24%	32%	24%	30%
	750 & Over	29%	31%	67%	66%
Non-Severe injury	450 - 749	51%	57%	28%	31%
	750 & Over	48%	53%	64%	63%
All crashes	450 - 749	-	-	27%	29%
	750 & Over	-	-	64%	64%

The data indicate a relative increase in the large engine size motorcycles in both frontal and roadside departure crashes in recent years (Frontal crashes shown in Figure 28). Motorcycles with engine displacement “over 750cc” were dominant in both frontal impacts and roadside departures at all severity levels (Table 10). The “over 750cc” motorcycles had a higher fatality rate per crash involvement than the 450-749cc in frontal crashes: “over 750cc” riders were 1.5 times more likely to be killed in frontal crashes. Both motorcycle sizes had a similar but high fatality rate in roadside departures (riders of “over 750cc” size where 1.1 times more likely to be killed).

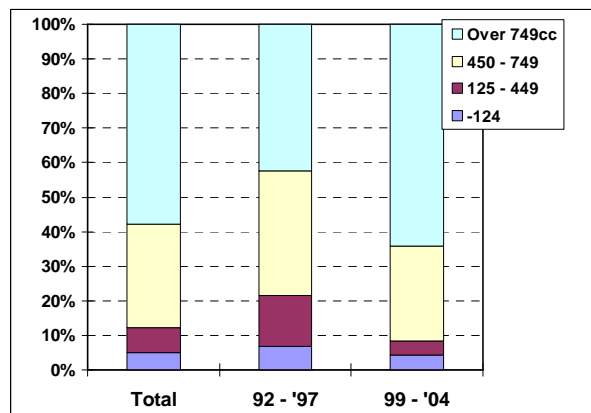


Figure 28. Frontal Crashes by Motorcycle Model (Engine Size in CC)

Motorcycle Contributing Factor - Motorcycle components, listed in Figure 29, did not have any failures and were not a contributing factor in almost all the crashes (Figure 29).

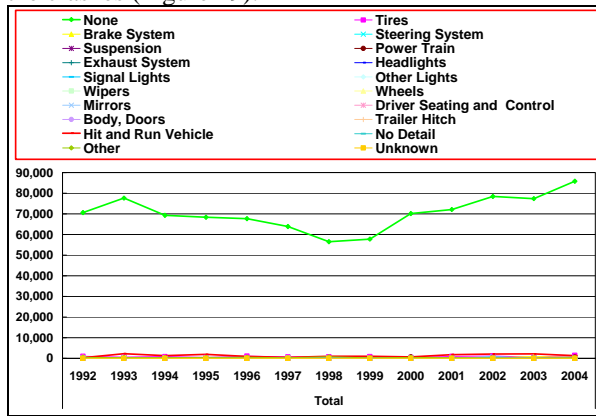


Figure 29. Vehicle Contributing Factor in GES Motorcycle Crashes

Crash Environment Variables

Speed Limit - Motorcycle crashes from 1992-2004 occurred on roads with all speed limits. However, there is recent increase in number of crashes occurring on roads with 65 mph and over speed limits (Figure 30).

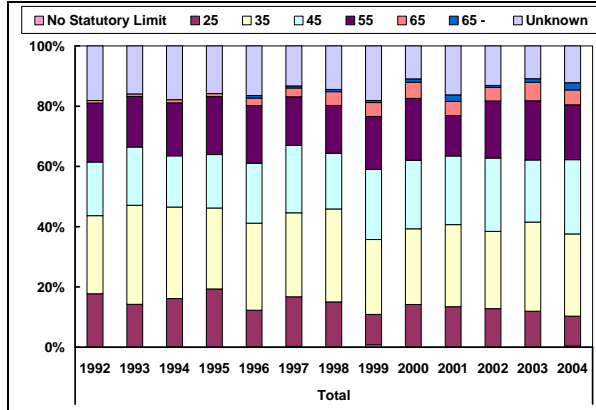


Figure 30. Motorcycle Crashes by Posted Speed Limit in Miles per Hour (mph) (GES)

As expected, there is an increase in crash severity levels on roads with higher speed limits as shown in Table 10). Fatality rates increased from 1.2% in “less than 25 mph” speed limit to 8.1% for “over 66 mph”. Motorcycle crashes on roads with 46-55 mph speed limit were 18% of motorcycle crashes but resulted in 33% of the fatalities on road with known speed limits. Crashes on roads with 45 mph and 35 mph resulted in 27% and 24% of riders killed (Figure 31).

Motorcycles with engine displacement “over 750cc” are dominant at all severity levels with percentages increasing at higher speeds limits. However, the 450-749cc size is over represented at the 55 limit road making up 31% of the crashes and 35% of the fatalities (Figure 32).

Table 11. Crashes per Posted Road Speed Limit (mph)

	- 25	26-35	36-45	46-55	56-65	65 +
% crashes	14%	28%	21%	18%	3%	1%
% fatalities	6.5%	23.5%	26.8%	33.0%	7.5%	2.7%
Fatality Rate	1.2%	2.1%	3.2%	4.6%	5.6%	8.1%
Severe Injury Rate	22%	23%	26%	27%	26%	33%
450-749cc fatality rate	1.4%	2.4%	3.5%	6.0%	4.5%	4.4%
750+ cc fatality rate	1.7%	2.7%	4.8%	4.9%	8.4%	9.1%

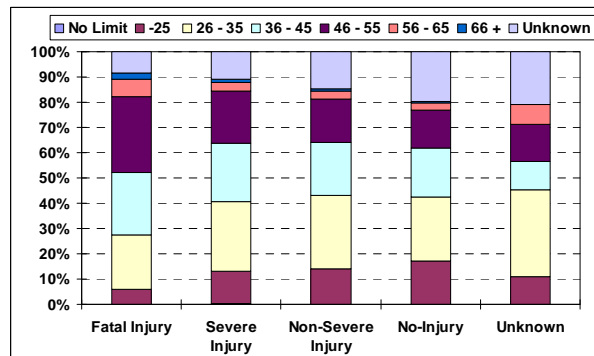


Figure 31. Injury Severity by Speed Limit for GES Motorcycle Crashes (1992-2004)

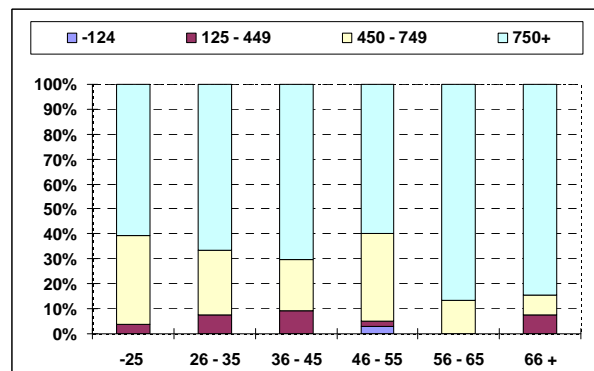


Figure 32. Fatal Crashes by Speed limit and Engine Displacement (GES 1999 - 2004)

Relation to Junction – GES specifies the location of the first harmful event in relation to a road junction. The point of departure is indicated if the first harmful event occurs off the roadway.

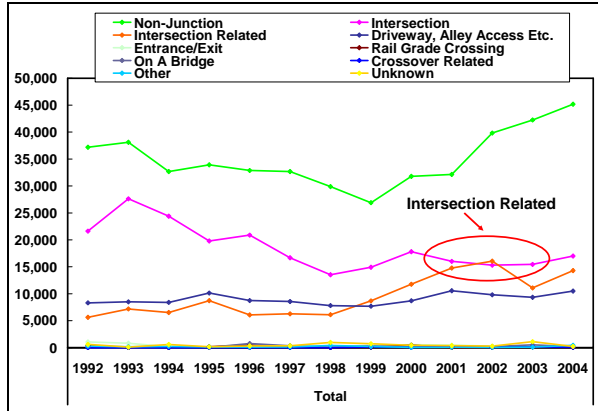


Figure 33. Motorcycle Crashes by Relation to Junction (GES)

From 1992-2004, 48% of motorcycle crashes occurred away from a junction while 38% percent were within an intersection (Figure 33). However, about 64% of the riders are killed in crashes away from a junction as compared to 27% killed in crashes within an intersection (Figure 34). Crashes away from a junction had a fatality rate of 4.3% over 1992-2004, about 1.7 times more fatal than crashes within an intersection which had a 2.5% fatality rate. Crashes away from a junction have also increased steadily in recent years.

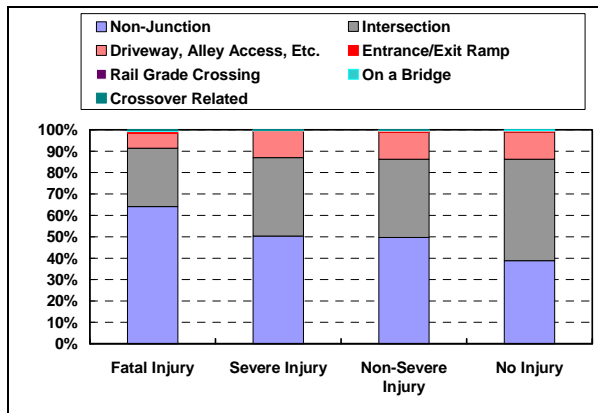


Figure 34. Injury Severity by Relationship to Junction for Motorcycle Crashes (GES 1992-2004)

Road Surface Condition - Overall, the road surface condition at the time of a crash was dry in motorcycle crashes from 1992-2004. As such, the increase in

crashes on dry roads followed the trend of all motorcycle crashes on U. S. roads (Figure 35).

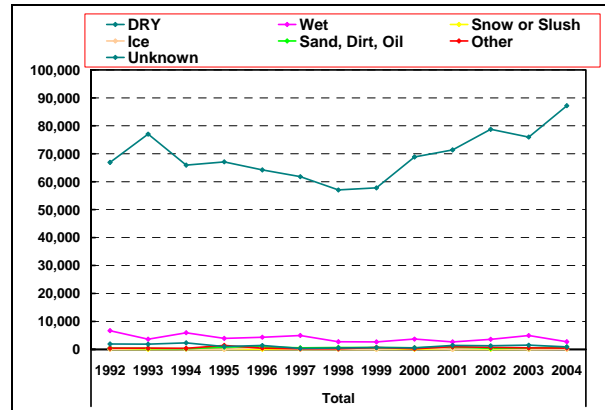


Figure 35. Road Surface Condition for Motorcycle Crashes (GES)

Vision Obstruction and Light Condition – GES identifies visual circumstances that may have contributed to the cause of the crash. There was no vision obstruction identified or reported in almost all motorcycle crashes from 1992-2004.

GES also identifies the general light condition at the time of the crash, considering the presence of external roadway lighting fixtures.

The majority of motorcycle crashes, 69%, occurred in the daylight from 1992-2004 (Figure 36). The number of motorcycle crashes occurring in the daylight increased in recent years, following the general trend.

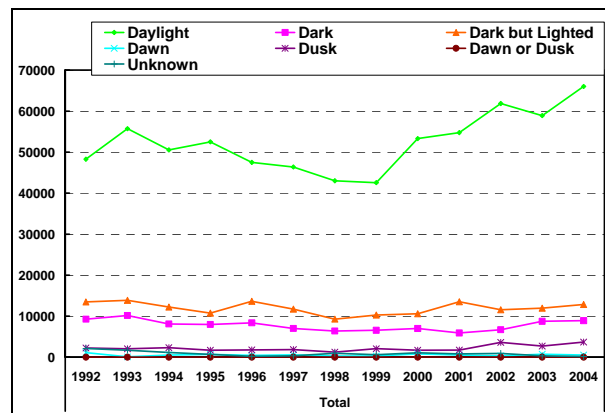


Figure 36. Light Condition for GES Motorcycle Crashes

Although 26% of the crashes occurred in a dark related light condition (dark and dark but lighted), those crashes resulted on over 43% of the fatalities (Figure 42). The fatality rate per crash involved rider is higher

in crashes occurring in the dark as compared to those in a “dark but lighted” condition (5.2% vs. 3.8%). Also, crashes in the dark had a lower “no injury” rate than those in dark but lighted condition (9% vs. 15%).

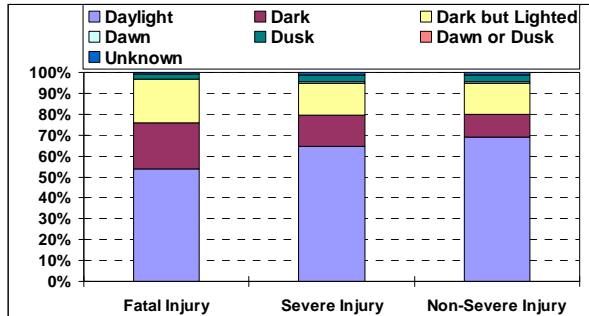


Figure 37. Injury Severity by Light Condition for GES Motorcycle Crashes (1992-2004)

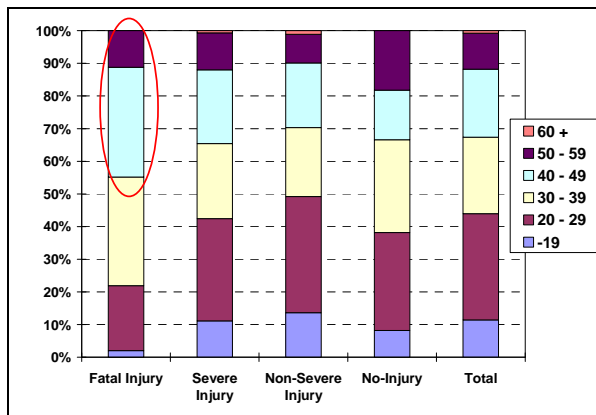


Figure 38. DARK by Injury Severity and Age (1999 - 2004)

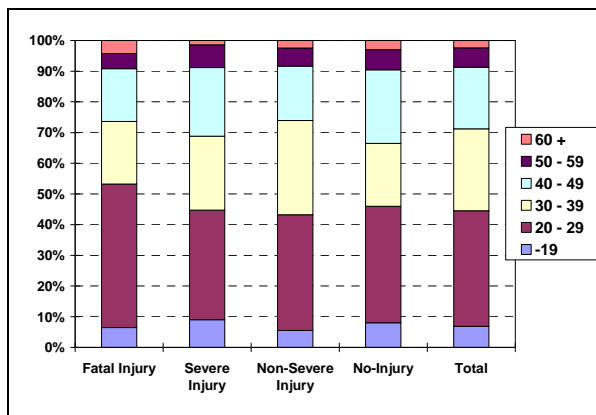


Figure 39. DARK but LIGHTED by Injury Severity and Age (1999 - 2004)

Riders age 40 and older were over represented in fatal motorcycle crashes occurring in the dark road condition. They were 33% of all crash involved riders

but made up 45% of the riders killed in the dark (Figure 38). In contrast they were 29% of crash involved riders in the “Dark but Lighted” condition but made up 26% of those killed and (Figure 39). This corresponds to riders over 40 being 1.5 times more likely to die in a motorcycle crash occurring in a dark versus a crash occurring in a “dark but lighted” road condition.

SUMMARY AND DISCUSSION

Results from this nationally representative descriptive overview of motorcycle crashes on U. S. are summarized below. Key observations are compared with findings from a recent statistical study of motorcycle crashes in the state of Indiana from January 2003 to October 2005 [5] and the landmark study by Hurt et al of on-scene, in-depth investigation of motorcycle accidents in Los Angeles during 1976 and 1977 [6]. The Indiana study, by Savolainen and Mannering, used nested logit and standard multinomial logit probabilistic models to show which variables play significant roles in motorcycle crash injury outcomes in Indiana.

Motorcycle crashes have been on the rise in the U. S. due increased exposure driven by a rapid increase in sales since the late 1990s. However, motorcycle crashes, when they occur, are becoming more deadly. Normalizing to 1992 levels, the risks for involvement and no-severe injury in motorcycle crashes has decreased over twelve years to 0.87 and 0.81 respectively in 2004, implying that there are fewer crashes per registered motorcycle. In contrast, the fatality risk increased to 1.18 in 2004. Motorcycle riders also represent a very vulnerable segment of road users in the U.S. Inherently, a motorcycle is more challenging and less stable to operate than a four-wheeled vehicle, offering little or no protection to the rider in a crash. Riders were over 4 times likely to be killed in traffic crashes in 2005 in comparison to occupants of other motor vehicles.

Crash Configuration: Frontal impacts and roadside departures were the two most prevalent motorcycle crash configurations, at 36% and 19% of all crashes in 1992-2004. They were also dominant in all injury severities and accounted for 75% of motorcycle riders killed from 1992-2004; 39% killed in frontal impacts and 37% in roadside departures. As compared to all crashes, a rider was about two times more likely to be killed in a roadside departure. In the Indiana study, crashes resulting in roadside departures and collisions with roadside objects were found to be much more

likely to produce severe injuries, and collisions with trees and poles most likely to produce a fatality.

Both frontal and roadside departure crashes have become more severe in recent years, when comparing injury rates per crash involvement in the two ranges of years (1992-1997) and (1999-2004). Roadside departure's fatality rates increased from 4.3% to 6.5% and frontal crashes rates increased from 2.5% to 4.3% in recent years.

Crashes where another vehicle turned into or across the path of a motorcycle moving straight forward were the most common frontal crash configuration at 17% of all motorcycle crashes and resulted in 18% of all riders killed. Crashes of motorcycles into rear of other vehicles were 8% and results in 6.7% of rider killed. "Head On" frontal crashes, resulted in 8% of all riders killed, while only being 1.1% of all the motorcycle crashes in this study. "Head On" motorcycle crashes have an exceptionally high fatality rate of 19.2% rider killed per crash involvement, over 5 times the rate of all frontal crashes. In the Indiana study, head on crashes greatly increased the probability of fatalities, resulting in a 566% higher likelihood to be killed.

Rider age: There is substantial increase in the proportion of riders age 40 and older in recent motorcycle crashes. Riders over 40 increased to 38% of the population and nearly doubled to 40% of the fatalities in 1999-2004, as compared with 1992-1997. Riders under 30 were 36% of the crash population and 38% of fatalities in recent years. In contrast, Hurt at al reported a median age of 26 for riders killed in their crash population with riders 17-26 year old accounting for 50% of the fatalities. The recent increase in age for the crash involved rider follows the trend in motorcycle owner age in the U. S. According to the MIC Surveys of Motorcycle Ownership and Usage, the median age of motorcycle owners was 41 years old in 2003 as compared to 27 years in 1985. Motorcycle owners over 40 years old were 53% in 2003 steadily increasing from 21%, 26%, and 44% in 1985, 1990, and 1998 respectively.

Similar to the trend in all motorcycle crashes, the segment of riders 40-59 years old has increased in both frontal impacts and roadside departures in recent years. However, while the numbers of riders 20-29 in motorcycle crashes have decreased in recent years, they were a bigger proportion of the fatalities. Considering the ratio of fatalities to crash involvement, the under 30 rider was 1.9 and 2 times more likely to be killed in a frontal crash and in a roadside departure in 1999-2004 as compared to 1992-1997. The over 50 rider was 1.7 times more likely to be killed in recent

frontal crashes and 1.5 times more likely to be killed in recent roadside departures. Overall, riders under age 30 were most vulnerable followed by riders over 50 in all motorcycle crashes. In the Indiana study, the results showed that older riders are more likely to be involved in severe crashes in both single- and two-vehicle crashes even when controlling for all other factors.

Driver pre-crash action: For most crashes, at all severity levels, the motorcycle driver was not able to or did not attempt any avoidance maneuvers. For fatal crashes, drivers did not maneuver in 71% of the cases; drivers ages 50-59 did not attempt to maneuver in 77% of fatal crashes. This is an indication that riders have short reaction times before the crash and demonstrate a lack of awareness or no expectation of impending danger for both the driver of the motorcycle and the driver of the other vehicle in two-vehicle crashes.

One of the principle findings from the Hurt study was that the lack of "motorcycle conspicuity" and lack of caution and awareness and of both rider and driver were main causes of two-vehicle motorcycle crashes. The driver of the other vehicle who violated the motorcycle right-of-way explained that he/she never saw the motorcycle before the crash.

Alcohol involvement: The percent of riders who died in a motorcycle crash and had been drinking increased from 18% in 1992-1997 to 22% in 1999-2004. This is a conservative estimate due to large proportion of unknown alcohol involvement status for GES fatal crashes. Per NHTSA, 34% of the riders had been drinking in all 2005 fatal crashes involving motorcycles, 27% had a blood alcohol level (BAC) 0.08 g/dl or higher [6]. In this study, the GES data showed a marked increase in 30-49 year old riders who were drinking in motorcycle crashes of all severity levels relative to other riders. Per NHTSA, the age groups 35-39, 40-44, and 45-49 of fatally injured riders in 2005 had the highest percentage of BAC 0.08 or above [6].

In comparison to other parts of the world, the ratio of alcohol involvement in 2004 U. S. motorcycle crashes was 6.2 times higher than Japan and 1.8 times that of the European Union (EU) (Figure 40).

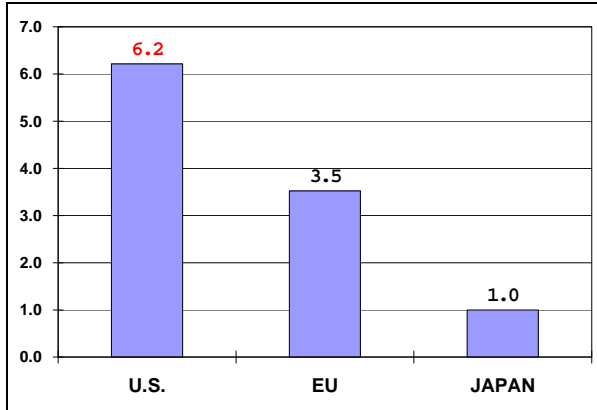


Figure 40. Comparison of Alcohol Involvement in 2004 Motorcycle Crashes between U.S. (GES), EU (MAIDS [7]), and JAPAN (ITARDA [8]).

Helmet use: 43% of the motorcycle crash population in the U. S. who did not wear a helmet in 1999-2004. As compared to 1992-1997, the percent of 40-49 age riders killed in recent years who were not wearing a helmet was 1.34 that of earlier years (61% vs. 45%); for the 19 years and younger rider, the rate 1.28 times that of earlier years (54% vs. 42%).

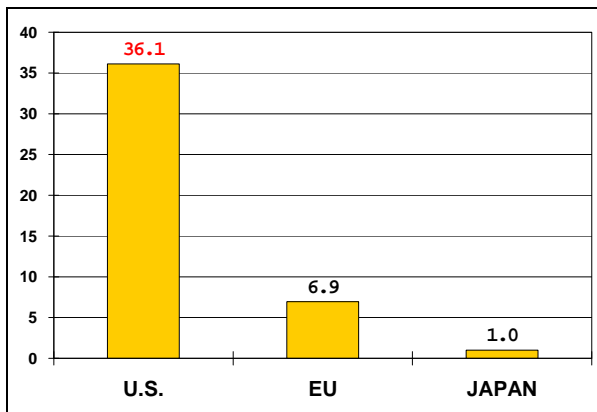


Figure 41. Comparison of Non Helmet Use in 2004 Motorcycle Crashes between US, EU, and JAPAN.

In comparison to other part of the world, the percent of crash involved riders in the U. S. who did not wear a helmet in 2004 were over 36 times and 5 times the percent in Japan and EU respectively (Figure 42).

In addition, it is worth noting that the number of the states with universal helmet laws has decreased in recent years (Figure 48).

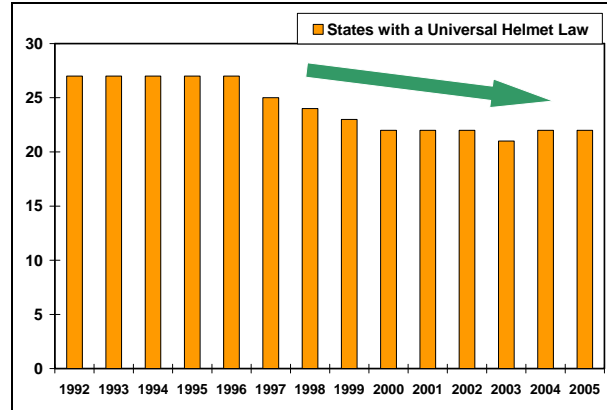


Figure 42. State in the US with a Universal Helmet Law

Speed Relation: A large percentage of fatal motorcycle crashes are coded by police as speed being a contributing cause of the crash speed related as compared with crashes with less severe outcomes: 40% of fatal crashes vs. 14% of no injury crashes. This is especially true for younger riders: 54% of fatal crashes for riders younger than 30 are coded as speed related in contrast with 26% of fatal crashes for riders over 40 years old.

Motorcycle Related: The motorcycle itself did not have any failures and was not a contributing factor in almost all the GES crashes. Motorcycles with engine displacement “over 750cc” were dominant in both frontal impacts and roadside departures at all severity levels in recent motorcycle crashes. They were involved in 77% of frontal crashes and 68% of roadside departures in 1998-2004. Hurt at al reported the “over 750cc” motorcycles were 33% of their 1970s crash population in Los Angeles.

The larger motorcycle population has been increasing in the U. S. MIC estimates that “over 749cc” size engine displacement increased from 66% of the total motorcycle population in 1998 to 76% in 2003 [2]. The “450-749cc” motorcycles decreased from 21% in 1998 to 16.5% in 2003 from. Polk’s National Vehicle Population Profile (NVPP) data shows a continued increase in overall motorcycle registration in the U. S., in particular for the “over 750cc” size motorcycle (Figure 41) [12].

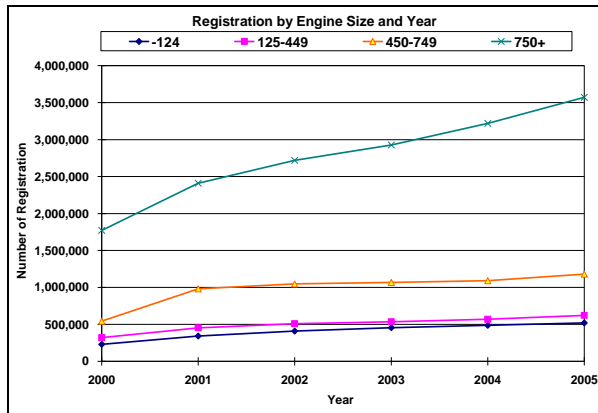


Figure 43. Polk NVPP Motorcycle Registration Data by Engine Displacement

The “over 750cc” motorcycles have a higher fatality rate per crash involvement than the 450-749cc in frontal crashes (5.2 vs. 3.5%). The “over 750cc” riders were 1.5 times more likely to be killed in frontal crashes than the 450-749cc motorcycle riders. However, both motorcycle sizes had a similar but high fatality rate in roadside departures (6.4% for 450-749cc riders and 6.8% for riders of “over 750cc” riders). It is worth noting that the Hurt data indicates a fatality rate of 9.1% for the “over 750cc” size motorcycles.

Posted Speed Limit: Motorcycle crashes occur on roads with all speed limits. As expected, there is an increase in crash severity levels on roads with higher speed limits. 52% of the fatal crashes occurred on roads with speed limits less than 45 mph. However, 30% of the fatal crashes occurred on roads with 46-55 mph speed limit. Motorcycles with engine displacement “over 750cc” are dominant at all severity levels with percentages increasing at higher speeds limits. However, the 450-749cc size is prominent on roads with 45-55 speed limits and is involved in 35% of the fatal crashes.

Relation to Junction: Crashes or location of point of departure of the motorcycle from the road in a crash occurred 38% within an intersection and 48% away from a junction in 1992-2004. However, crashes away from a junction were 1.7 times more fatal than crashes within an intersection and accounted for 64% of riders killed. In the Hurt study, the fatal crashes were also less associated with an intersection: 65% of the cases investigated were associated with an intersection; however those resulted in only 33% of the fatalities. Hurt et al reported that fatal crashes were more involved with the rider losing control by running off the road, typically on a curve. In the Indiana study,

Relative to environment, motorcycle crashes in 1992-2004 occurred primarily on a dry road surface, with the

majority, almost 70%, during daylight. However, crashes occurring in the dark or dark but lighted road condition resulted in over 43% of the fatalities. It is interesting to note that fatality rate per crash involved rider is higher in crashes occurring in the dark as compared to those in a “dark but lighted” condition (5.2% vs. 3.8%). Riders over 40 years old were over represented in fatal motorcycle crashes in the dark only condition, making up 45% of the rider killed in the dark. In contrast they were 26% of riders killed in the “dark but lighted” condition. Riders over 40 were 1.5 times more likely to die in a motorcycle crash occurring in a dark versus a crash occurring in a “dark but lighted” road condition.

FURTHER STUDIES

Some limitations of this study are highlighted as follows. A study of injury severities in crashes where the rider attempted breaking or steering corrective actions would be useful. Also, a study of injury severity and other attribute in crashes where the driver was negotiating a curve is needed.

While this crash study focused on the motorcycle and rider, characteristics of the other vehicle and driver would provide more insights into motorcycle crash involvement and severity in two-vehicle crashes. In particular, investigating vision obstruction, pre-crash actions, vehicle maneuver, alcohol involvement, speed relation, and vehicle class would be useful.

Overall, GES provides a historical perspective of a large number of useful crash, rider, motorcycle, and environment attributes. However, fatal and high severity crashes are under represented. Also, GES provides insufficient detail to obtain a good understanding of crash causation, injury mechanisms, and crash dynamics.

Focused studies based on the more comprehensive U. S. State crash data files, may provide better insights to certain crash attributes, for example, influence of roadway features, environmental factors, rider pre-crash actions, and other vehicle characteristic.

In-depth studies, such as special crash investigations and crash reconstructions would be very valuable to understand injury mechanisms and crash dynamics. Such studies would also better support the development of engineering countermeasures to the rapidly growing motorcycle crash problem.

CONCLUSIONS AND OPPORTUNITIES FOR SAFETY IMPROVEMENTS

A key finding of the 1992-2004 NASS/GES motorcycle crash study is that in addition to the increase in problem size due to exposure, motorcycle crashes are becoming more deadly. Also, as compared to all crashes, riders were around two times more likely to be killed in a roadside departure. Overall, riders under age 30 were most vulnerable in motorcycle crashes followed by riders over age 50.

Examination of motorcycle crash data trends pre- and post-1998 show that increased severity and higher fatalities rates are mainly attributed to the following:

- Increase in roadside departures, vehicles turning into the path of the motorcycle, and head-on crashes
- Lack of rider awareness for impending crash
- Speeding for riders under 30
- Increased alcohol use for riders ages 30-49
- Decreased helmet use for riders under 19 and 40-49 years old
- “over 750cc” engine size motorcycles in frontal crashes
- Riding on roads with higher speed limits
- Crashes away from a junction
- Riders over 40 in dark road conditions.

Findings support opportunities in safety strategies such as rider education, focused by age groups, relative to speeding, helmet use, and alcohol consumption. Speed risk awareness campaigns can be focused to younger drivers. Alcohol involvement risk awareness education can be focused to rider ages 30-50. Helmet use education campaigns would benefit riders of all ages. As compared to other part of the world, there are considerable opportunities for improvements to lessen alcohol use and increase helmet use for the U. S. motorcycle rider.

Findings also support countermeasures such as improved lighting, whether for the motorcycle and/or roadway. This would improve overall visibility and the benefits would target the growing over 40 age rider population who showed increased vulnerability in dark road conditions versus dark but lighted road conditions.

Although motorcycles of all engine sizes are vulnerable in roadside departure crashes, the “over 750cc” riders were 1.5 times more likely to be killed in frontal crashes than the 450-749cc motorcycle riders. This highlights the need for countermeasures to improve safety performance of larger motorcycles in frontal crashes.

Findings also highlight the need for a more in depth study of the growing roadside departure motorcycle crash problem.

ACKNOWLEDGEMENTS

This study was performed at the National Crash Analysis Center (NCAC) of George Washington University under a visiting scholar program with Honda R&D Motorcycle Center, Japan. The authors would like to acknowledge the contribution of Dr. Gerry Stewart for his expert data analysis, Jim Ouellet of Head Protection Research Laboratory and Umesh Shankar of NHTSA for their valuable insights and discussions on the subject.

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