THE RISK OF FATALITY IN MOTORCYCLE CRASHES WITH ROADSIDE BARRIERS

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ABSTRACT

The objective of this study is to examine the issue of fatal motorcycle collisions with guardrail based on U.S. accident statistics. Motorcycle crashes were found to be the leading source of fatalities in guardrail crashes. In 2005 for the first time, motorcycle riders suffered more fatalities (224) than the passengers of cars (171) or any other single vehicle type involved in a guardrail collision. In terms of fatalities per registered vehicle, motorcycle riders are dramatically overrepresented in number of fatalities resulting from guardrail impacts. Motorcycles compose only 2% of the vehicle fleet, but account for 42% of all fatalities resulting from guardrail collisions. Motorcycle-guardrail crash fatalities are a growing problem. From 2000-2005, the number of car occupants who were fatally injured in guardrail collisions declined by 31% from 251 to 171 deaths. In contrast, the number of motorcyclists fatally-injured in guardrail crashes increased by 73% from 129 to 224 fatalities during the same time period. Over two-thirds of motorcycle riders who were fatally injured in a guardrail crash were wearing a helmet. Approximately, one in eight motorcyclists who struck a guardrail were fatally injured – a fatality risk over 80 times higher than for car occupants involved in a collision with a guardrail.

INTRODUCTION

Motorcyclists are vulnerable highway users. Unlike passenger vehicle occupants, motorcycle riders have neither the protective structural cage nor the advanced restraints which are commonplace in cars and light trucks. Previous research has shown that motorcycle crashes into roadside barrier are particularly dangerous. In one of the earliest studies on this issue, Ouelett (1982) investigated the outcome of motorcycle-guardrail crashes drawn from a larger database of approximately 900 motorcycle crashes in the Los Angeles area (Hurt et al, 1981). He reported that motorcycle impacts with guardrail impacts have a much higher fatality risk than motorcycle crashes in general. Other researchers have also noted the increased risk of motorcycle collisions with guardrails (Domham, 1987; Quincy et al, 1988, Gibson and Benetatos, 2000, and Berg et al, 2005).
Because of an upsurge in motorcycle fatalities, the issue of motorcycle safety is receiving renewed attention. As shown in Figure 1, motorcycle registrations in the U.S. are growing at the rate of 7-8% per year. Unfortunately, fatal motorcycle crashes are growing at a comparable rate.

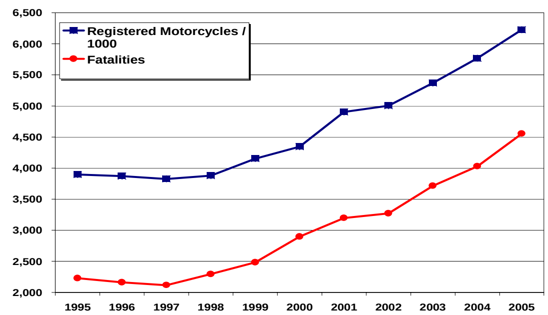

Figure 1. U.S. Motorcycle Registrations vs. Crash Fatalities (NHTSA, 2006)

OBJECTIVE

Motivated by the growing U.S. motorcycle fleet and number of motorcyclist fatalities, the objective of this study is to examine one facet of this problem – the magnitude and characteristics of fatal motorcycle collisions with guardrail.

APPROACH

This study was based on the analysis of the Fatality Analysis Reporting System (FARS) database and the National Automotive Sampling System (NASS) General Sampling System (GES). FARS, a comprehensive census of all traffic related fatalities in the U.S., was analyzed to determine guardrail crash fatality trends. GES was analyzed to determine the number of occupants who were exposed to guardrail crashes. The GES sample included both fatal and non-fatal crashes into guardrail. GES is a comprehensive database containing information on approximately 60,000 randomly sampled police reported accidents each year. Cases from GES are assigned weights that can be used to estimate the number of similar accidents that may have taken place that year that were not sampled. Because GES is a sample of police reported accidents, NHTSA (2000) notes that GES estimates are subject to both sampling and non-sampling errors. In both FARS and GES, a guardrail collision was defined to be a crash in which the most harmful event was a collision with a guardrail.

Prior to 2004, FARS aggregated guardrail length of need and guardrail end treatments into a single guardrail category. It was therefore not possible in FARS to identify which portion of the guardrail system was struck. For example, it was not possible to determine differential fatality risk in guardrail length of need versus guardrail end treatments. Beginning in 2004, FARS began to code guardrail 'face' separately from guardrail 'end'. However, because only two years from our 16 year dataset contains this distinction, both guardrail categories from FARS 2004-2005 data were aggregated into a single guardrail group.

RESULTS

The analysis which follows investigates fatality risk for motorcycle collisions with two different types of roadside barrier: metal guardrail and concrete barriers.

Fatality Risk in Guardrail Collisions

Figure 2 presents the distribution of fatalities by vehicle body type in collisions in which a guardrail impact was the most harmful event. The distribution of fatalities and vehicle registrations are for the 2005 calendar year (NHTSA, 2006).

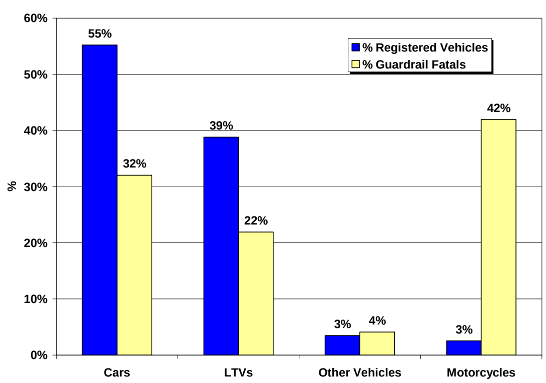

Figure 2. Guardrail Crash Fatalities vs. Registrations by Vehicle Body Type (FARS 2005; NHTSA, 2006)

In absolute numbers, motorcycle riders now account for more fatalities than the passengers of any other vehicle type involved in a guardrail collision. As shown in Figure 2, motorcycle riders accounted for 42% of all fatalities resulting for a guardrail collision in 2005. Following motorcycle riders were car occupants with 32% of all fatalities in this crash mode. This was a particularly surprising finding as cars compose over half of the vehicle fleet (55%) while motorcycles comprise only 3% of the registered vehicles. The occupants of light trucks and vans (LTVs), a category which includes pickup trucks, sport utility vehicles, minivans, and full sized vans, trailed car occupants with 22% of the guardrail crash fatalities and 39% of the registered vehicles in 2005. In terms of fatalities per registered vehicle, motorcycle riders are dramatically overrepresented in number of fatalities resulting from guardrail impacts.

As shown in Figure 3, the problem of motorcycle fatalities in guardrail collisions is a growing problem. From 2000-2005, the number of car occupants who were fatally injured in guardrail collisions declined by 31% from 251 deaths in 2001 to 171 deaths in 2005. In contrast, the number of fatally-injured motorcyclists increased by 73% from 129 to 224 fatalities during the same time period. In 2000, fatalities from motorcycle-guardrail collisions exceeded the number of deaths from LTV-guardrail collisions. In 2005, motorcyclist rider fatalities (224) resulting from guardrail collisions surpassed car fatalities (171) for the first time.

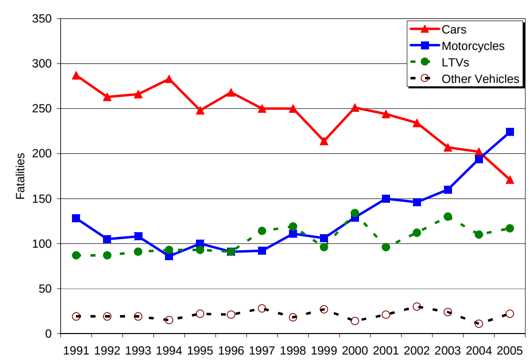

Figure 3. Motorcycle Rider Fatalities Exceeded Car Occupant Fatalities in Guardrail Crashes for the first time in 2005 (FARS 1991-2005)

Probability of Fatality in Guardrail Collisions

To analyze the risk of fatal motorcycle crashes with guardrail, the probability of fatality in this collision mode was computed as a function of vehicle body type. For this study, fatality risk was defined as shown below:

$$FatalityRisk = \frac{NumberOfFatalities}{NumberOfExposedOccupants}$$

The number of persons who were fatally injured in guardrail collisions was obtained from FARS 2000-2005. The number of occupants who were exposed to guardrail collisions was obtained from GES 2000-2005. In both databases, a guardrail collision was defined to be a crash in which the most harmful event was a collision with a guardrail. Table 1 presents the average annual number of fatalities and exposed occupants during this five year time period.

Table 1. Fatality Risk in Guardrail Collisions by Body Type from 2000-2005 (GES, FARS)

Vehicle Type	Number of Occupants exposed to Guardrail Collisions	Number of Fatalities from Guardrail Collisions	Fatality Risk	Relative Fatality Risk compared with Car Occupants
Cars	855,900	1,309	0.15%	1.0
LTV	260,200	699	0.27%	1.8
Motorcycles	8,100	1,003	12.4%	81.1

Approximately one of every eight motorcyclists who struck a guardrail was fatally injured. This fatality risk is substantially higher than incurred by either car or LTV occupants. Only one to two of every 1000 car occupants were fatally injured in a crash with a guardrail. Another way to consider this risk is by comparison to the relative risk to which car occupants are exposed in guardrail crashes. In Table 1, a relative fatality risk was computed for each vehicle body type category as shown below:

$$\text{Relative Fatality Risk} = \frac{FatalityRiskforSubjectVehicleType}{FatalityRiskforCarOccupants}$$

In a guardrail collision, motorcycle riders have a risk of fatality over 80 times greater than car occupants. LTV occupants have 1.8 times the risk of fatality of a car occupant. In a guardrail collision, there is little to protect a motorcyclist from injury. The vehicle structure and occupant restraints which could protect a car or LTV occupant are simply not present in current motorcycle designs.

Fatality Risk in Collisions with Concrete Barriers

Figure 4 presents the number of fatalities in collisions with concrete barriers as a function of vehicle type. Unlike guardrail crashes, most fatalities in concrete barrier collisions are suffered by car occupants, followed by the occupants of LTVs. Motorcyclists suffer the third highest number of fatalities in concrete barrier collisions. The fact that motorcyclist collisions are the leading cause of fatalities in guardrail collisions, but only the third leading cause of fatalities in concrete barrier collisions, may provide an important insight into the mechanism of injury in these crashes. Either concrete barriers pose a markedly lower fatality risk for motorcyclists than do guardrails or motorcyclists are proportionally less likely to collide with concrete barriers than guardrails.

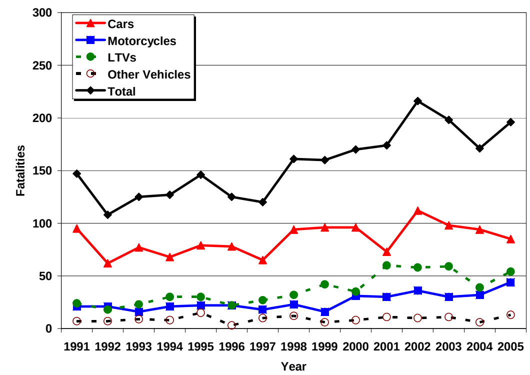

Figure 4. Fatalities in Concrete Barrier Crashes 1991-2005 (FARS 1991-2005)

Figure 5 presents the distribution of fatalities by vehicle body type in collisions in which an impact with a concrete barrier was the most harmful event. The distribution of fatalities and vehicle registrations are for the 2005 calendar year (NHTSA, 2006).

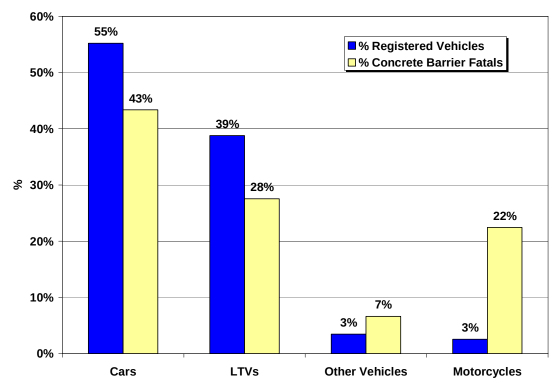

Figure 5. Concrete Barrier Crash Fatalities vs. Registrations by Vehicle Body Type (FARS 2005; NHTSA, 2006)

As witnessed earlier, motorcyclists are overrepresented in fatality risk. Motorcycles accounted for only 3% of registered vehicles in the U.S. in 2005, but incurred 22% of all fatalities in concrete barrier collisions. Comparing motorcycle-guardrail and motorcycle-concrete barrier fatalities per registered vehicle, guardrail collisions pose a greater risk for motorcyclists than concrete barriers.

Table 2. Fatality Risk in Concrete Barrier Collisions by Body Type from 2000-2005

Vehicle Type	Number of Occupants exposed to Guardrail Collisions	Number of Fatalities from Guardrail Collisions	Fatality Risk	Relative Fatality Risk compared with Car Occupants
Cars	526,260	558	0.11%	1.0
LTV	148,321	305	0.19%	1.9
Motorcycles	2,574	203	7.9%	74.4

Approximately one of every twelve motorcyclists who struck a guardrail was fatally injured. This fatality risk is lower than the risk for motorcyclists which strike guardrail, and substantially higher than incurred by either car or LTV occupants. As for guardrail collisions, a relative fatality risk was computed for each vehicle body type category. In a guardrail collision, motorcycle riders have a risk of fatality over 70 times greater than car occupants.

Comparison of Motorcyclist Fatality Risk by Object Stuck

As shown in Figure 6, guardrail collisions pose a substantially greater risk for motorcyclists than do collisions with either concrete barrier or cars. The fatality risk in motorcycle-guardrail collisions is 12%. The fatality risk in motorcycle-concrete barrier collisions is 8%. The fatality risk for motorcycle-car collision is 4.8% - approximately only one-third risk of a motorcycle-guardrail collision.

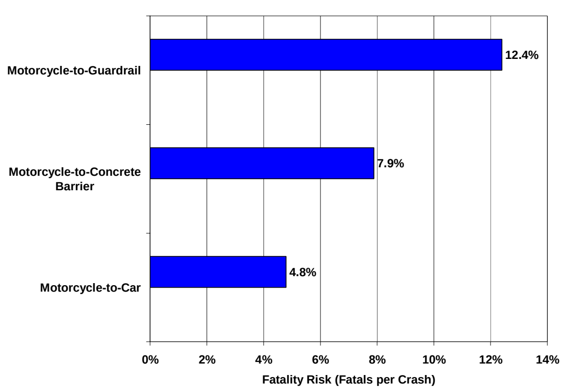

Figure 6. Fatality Risk by Object Struck (FARS-2005) in 2005

Effect of Helmet Use

One method of protecting motorcyclist in crashes is the use of a helmet. Figure 7 shows that in 2005 over two-thirds of all motorcycle riders who were fatally injured in guardrail crashes were wearing their helmets. This helmet use rate is slightly higher than the helmet use rate for motorcyclists in all fatal crashes (55%). Unfortunately, motorcycle helmets do not appear to completely protect motorcycle riders against fatality in guardrail crashes. Presumably, helmets reduce the incidence of head injury in guardrail crashes. However, even if the national motorcycle helmet usage rate was 100%, Figure 7 shows that motorcycle collisions with guardrail would still result in fatalities.

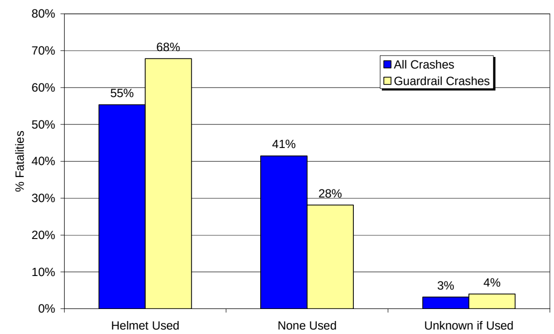

Figure 7. Distribution of Motorcycle Fatalities by Helmet Use in 2005

Implications

Motorcyclists are vulnerable highway users, particularly in guardrail crashes. Because of a lack of protective equipment, motorcycle riders are exposed to a much greater risk of death in a crash than are passenger vehicle occupants. This study has shown that in terms of fatalities per registered vehicle motorcycle riders are over-represented in fatalities in guardrail crashes. Motorcycle rider fatalities exceeded car occupant fatalities in guardrail crashes for the first time in 2005.

Crash testing of roadside barriers under NCHRP 350 (Ross et al, 1993) has led to a remarkably low number of fatalities for passenger vehicle occupants involved in guardrail collisions. Motorcycle riders however have not enjoyed the same benefit. Even if a future guardrail system were implemented which eliminated all passenger vehicle-guardrail fatalities, over 40% of all guardrail fatalities in 2005 would remain unless the motorcycle-to-guardrail collision problem is remediated. A possible solution are motorcycle-friendly guardrail systems, developed and tested by groups in both Europe and Australia, which have the potential to mitigate the consequences of a motorcycle-guardrail collision. Berg et al (2005) provides examples of these systems.

Motorcycle-guardrail crash fatalities are an unmet and growing safety problem in the U.S. Motorcycle-based countermeasures being developed by motorcycle manufacturers may provide part of the solution to this problem, but are likely to be of limited success as demonstrated by the failure of helmets to protect completely against fatality. In conjunction with these motorcycle-based countermeasures, there is a critical need to adopt improved barrier designs to protect these vulnerable road users.

CONCLUSIONS

This paper has examined the risk of fatality in motorcycle collisions with guardrails. The conclusions of this study are as follows:

1. Motorcycle crashes are the leading source of fatalities in guardrail crashes in the U.S. In 2005 for the first time, motorcycle riders suffered more fatalities (224) than the passengers of cars (171) or any other single vehicle type involved in a guardrail collision.
2. In terms of fatalities per registered vehicle, motorcycle riders are dramatically over-represented in number of fatalities resulting from guardrail impacts. In 2005, motorcycles composed only 3% of the vehicle fleet, but accounted for 42% of all fatalities resulting from guardrail collisions, and 22% of the fatalities from concrete barrier collisions.
3. Over two-thirds of motorcycle riders who were fatally injured in a guardrail crash were wearing a helmet.
4. Motorcycle-guardrail crash fatalities are a growing problem. From 2000-2005, the number of car occupants who were fatally injured in guardrail collisions declined by 31% from 251 to 171 deaths. In contrast, the number of fatally-injured motorcyclists increased by 73% from 129 to 224 fatalities during the same time period.
5. Approximately, one in eight motorcyclists who struck a guardrail were fatally injured – a fatality risk over 80 times higher than for car occupants involved in a collision with a guardrail.
6. Guardrail collisions pose a substantially greater risk for motorcyclists than do concrete barrier collisions. The fatality risk in motorcycle-guardrail collisions is 12%. The fatality risk in motorcycle-concrete barrier collisions is 8%.
7. Motorcycle-roadside barrier crash fatalities are an unmet and growing safety problem in the U.S. There is a critical need for the development and / or implementation of new safety programs, advanced barrier designs, and enhanced vehicle-based countermeasures to protect motorcyclists in collisions with guardrails.

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