INJURY PATTERNS AND SEVERITY AMONG HOSPITALIZED MOTORCYCLISTS: A COMPARISON OF YOUNGER AND OLDER RIDERS

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ABSTRACT

In recent years there has been a significant increase in mortality among motorcyclists, especially older riders (40+ years). However, few studies have compared the nature and severity of injuries sustained by older vs. younger cyclists. The purpose of this analysis was to determine differences, if any, in injury patterns to older vs. younger motorcyclists and to explore rider, vehicle, and environmental factors associated with these differences. Older riders were found to have a significantly higher incidence of thoracic injury, especially multiple thoracic injuries, and specifically multiple rib fractures. Older motorcyclists were also more likely to ride larger motorcycles, and were more involved in collisions involving overturning or striking highway structures. Large engine sizes were associated with increased risk of head and thoracic injuries, but not abdominal injuries. The magnitude of increased risks related to 1000+ cc engine size was higher among older motorcyclists than younger motorcyclists.

Since 1997, there has been an increase in injuries and fatalities to motorcyclists. Data from the National Center for Statistics and Analysis of the National Highway Safety Administration (NHTSA) reveal that, as of 2004, fatalities had increased for the eighth year in a row. While there has also been an increase in motorcycle registrations during this period, the rate of increase in fatalities has been greater than that of registrations (NHTSA, 2005).

Concomitant with these changes, there has been a significant change in the pattern of motorcyclist deaths, with a growing proportion of older riders. In 1991 this older group accounted for 15% of deaths, but had grown to 46% by 2004. Although fatalities increased in all age groups, the largest increase has been in the group of riders over the age of 49; thus, the mean age of fatally injured motorcyclists has increased from 29.3 in 1990 to 37.9 in 2002. At the same time there has been an increase in the average engine size of motorcycles, from a mean of 769 cc in 1990 to 999 cc in 2002. On a national level, this trend has been associated with an increasing number of states repealing or modifying motorcycle helmet use laws, as well as a decreasing helmet use rate among observed motorcyclists (Stutts, et al., 2004). Recommendations from NHTSA include the need for better data on the causes of crashes among older riders and the differences in the types of injuries sustained by older and younger riders (NHTSA, 2002).

Previous research has reported both decreased crash rates and increased injury rates among older motorcyclists (Haworth, 2004; Mulvihill and Haworth, 2005). Stutts et al. (2004) examined trends in motorcyclist deaths, vehicle registrations, and crash rates from 1990-2002. They showed that, during this period the numbers of motorcyclists aged 16-24 declined, while those 35 and older increased. Significant differences were observed in the crash patterns of older and younger motorcyclists in North Carolina, with older motorcyclists crashing more often on high speed roadways and in rural areas, having fewer run-off-road events, being involved in fewer single-vehicle crashes, having more crashes at intersections, and having more alcohol/drug involvement. These differences may affect the patterns of injury experienced by motorcyclists in various age groups.

Despite the burden of injury associated with motorcycle crashes, few comprehensive studies have been conducted to examine the types of injuries sustained by hospitalized motorcyclists; instead, the majority of studies have focused primarily on fatalities, comparing riders with and without helmets, and trends in head injury following repeal or passage of motorcycle helmet laws.

In a study of fatally injured riders, Sarkar et al. (1995) noted that 36% of deaths among helmeted riders were due to the trunk, as compared to 19% among the non-helmeted. Similar findings were noted in a California study of fatalities before and after a mandatory helmet law (Kraus et al., 1994). Thus, among helmeted motorcyclists, a substantial proportion of fatalities that occur will involve serious chest and abdominal trauma.

Several studies have also addressed the high rates of lower extremity, chest, and abdominal injuries following motorcycle crashes. Kraus et al. (2002), in a study of the incidence of thoracic and abdominal injuries among injured motorcyclists in California, reported that multiple intra-thoracic and intra-abdominal injuries were common, and that the number and bilaterality of rib fractures were strongly associated with serious injuries to the thoracic and abdominal organs. In a British study of injured motorcyclists, Ankarath et al. (2002) showed that thoracic and abdominal trauma, as well as pelvic ring fractures associated with long bone injuries, were the major contributors to reduced survival, following head injury. However, these studies did not address the role of the age of the motorcyclist.

The purpose of this analysis is to compare the types of injuries sustained by older vs. younger motorcyclists hospitalized in the state of Maryland, and to examine the characteristics of their crashes, motorcycles, and helmet usage.

METHODS

Data were obtained on all injured operators hospitalized in the state of Maryland during the period 1998 to 2002. The data are based on a linkage of two data sources, hospital discharge records from the Health Services Cost Review Commission (HSCRC), and police reports from the Maryland Automated Accident Reporting System (MAARS). Injury diagnoses were coded using the Abbreviated Injury Scale (AIS), 1990. The AIS divides injuries by body region, structure injured, and the nature and severity of the injury. The nine body regions include head, chest, abdomen, spine, neck, face, upper extremity, lower extremity, and external skin. The injury severity score (ISS) is a measure that reflects both the number of injuries and their threat to life. The ISS was used as an estimate of severity due to multiple trauma.

Using probabilistic techniques (Jaro, 1995) these data were linked in order to obtain information on all operators of motorcycles admitted to acute care hospitals. The uniform hospital discharge abstract data were obtained from all 52 non-federal acute care hospitals in the state. This estimate excludes outpatient cases and deaths which occurred either at the scene, in transport, or in an emergency department. The overall data linkage effort is part of the Crash Outcome Data Evaluation System (CODES) project, which is funded by NHTSA (Finison, 2000).

For the purpose of this analysis, older motorcyclists were defined as those aged 40 years or greater. Data on crash characteristics were obtained from police crash reports; helmet use (yes/no) was also available but no details on helmet type were provided. Engine size was determined using a program that utilized the vehicle identification number (VIN) of the motorcycle (Polk, 2004). Engine sizes were grouped into two categories (<1000 cc vs.1000+ cc) in accordance with NHTSA data showing that the mean engine size among motorcyclist fatalities was 999 cc during 2002. Data on injuries were obtained from the hospital discharge records, which provide ICD-9 codes for specific injuries. In order to obtain injury severity scores (ISS), these diagnoses were first translated into Abbreviated Injury Scores.

Statistical analyses used SAS/STAT software, Version 9.1 (SAS Institute, Inc., 2000-2004). Comparisons were done using chi-square tests of proportions. Also, the formulae for the Mantel-Haenszel risk ratio were adapted to calculate rate ratios and 95 percent confidence intervals for injury and fatality risk by age among the hospitalized motorcyclists. When examining mortality by body region, the reference group was all hospitalized injured motorcyclists among all age groups combined. In analyses of the effects of age, the group of motorcyclists younger than age 40 served as the reference group. In some instances, relationships between injury risk and a variable of interest were stratified by age. If a rate ratio is close to 1.0, that suggests no difference by age or another variable of interest, whereas if a rate ratio and its lower 95 percent confidence interval both exceed 1.0, such a finding suggests a high likelihood that a characteristic resulted in higher risk.

RESULTS

Of motorcyclists known to have been hospitalized, 60% were successfully linked to their police reports. After the data linkage was completed, there were a total of 1,253 motorcyclists, of whom approximately two-thirds (66%) were 39 years of age or less. The vast majority (95%) of injured riders were men.

Table 1 shows the characteristics of the riders age 40 or older and those younger than 40. The proportion of motorcyclists over the age of 40 was higher for women than for men (48% vs. 34%, $p=.023$, not shown in table). With respect to the engine size of the vehicle, older riders were significantly more likely to have motorcycles with engines of at least 1000 cc, with 66% and 20% of older and younger riders having large engines, respectively.

Overall, 83% were helmeted, but the older riders were significantly more likely to wear helmets (89% vs. 80%, $p<.001$). The median injury severity score for older riders was 9, as compared to 8 for younger motorcyclists, a statistically significant difference (p=.03). Among this population of hospitalized motorcyclists, there was a difference, albeit not statistically significant, in the mortality rate among the younger vs. older riders (2.7% vs. 4.4%).

Table 1 – Characteristics of Motorcyclists by Age

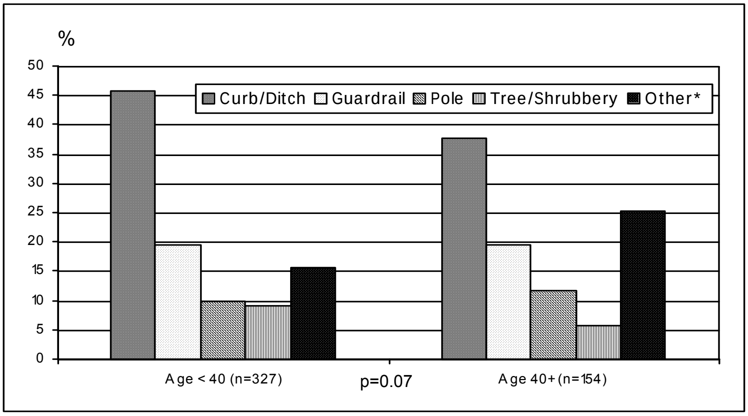
	Total (N=1,253) %	Age<40 (n=823) %	Age 40+ (n=430) %	p
Male	95	96	93	0.02
Died	3.3	2.7	4.4	0.10
Median ISS	8	8	9	0.03
Helmeted *	83	80	89	<0.001
Engine <1,000 cc	64	80	34	<0.001
Crash Type				
Other vehicle(s)	48	51	42	
Fixed Object/Parked Vehicle	28	29	25	
Overturn	9	6	14	
Other **	15	13	18	<0.001

* There were 14% (n=119) cases with unknown helmet use among ages 39 or younger, and 13% (n=54) among ages 40 and over.
** Other crash type includes collisions with animals and other objects.

There was also a significant difference in the nature of the collisions that resulted in injury. For both groups, the major causes were collisions with another vehicle or fixed object/ parked car. However, older motorcyclists had a significantly greater proportion of crashes that involved overturning, more than twice as many as among motorcyclists younger than 40. In addition, older motorcyclists had an increased percentage of crashes involving “other” causes, including collisions with an animal or an object not classified as fixed or a car. When stratified by engine size, the increased percentage of overturns among older motorcyclists was present for both engines of less than 1000 cc and 1000+ cc (data not shown).

Figure 1 shows a comparison of the types of fixed objects struck according to the age group of the motorcyclist. It is apparent that for both groups the main type of fixed object struck was a curb or ditch; however, older riders were significantly more likely to strike an embankment, fence, bridge overpass, or other structure.

Figure 1 – Fixed Object Struck by Age Group

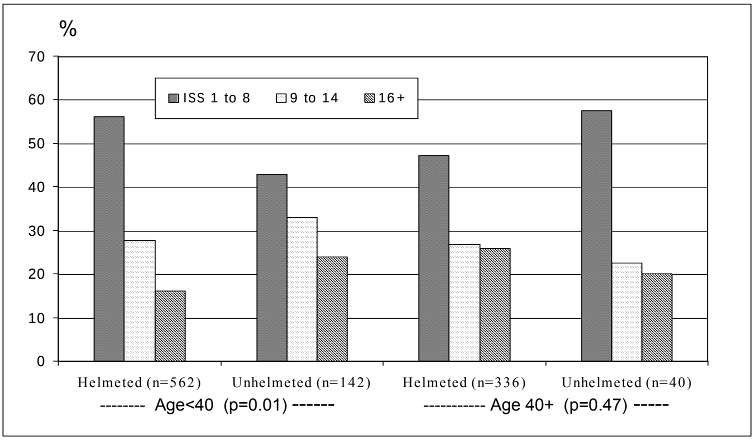


* Other fixed object includes embankment, fence, bridge-overpass, building, and etc.

Injury risk does appear to be related to crash types. Thoracic injuries were increased among motorcyclists involved in both fixed object/parked vehicle and overturn crashes relative to crashes involving other vehicles. Head injuries also were increased in both fixed object and overturn crashes, with a larger risk associated with overturn crashes (RR=1.48; 95% CI=1.11-1.97). Some of the increased risk of thoracic injury among older motorcyclists may have been attributable to their overinvolvement in overturn crashes.

Figure 2 shows the distribution of injury severity for older and younger riders with and without helmets. Overall, the majority of injuries were mild in nature (52%, with 28% classified as moderate and 20% severe). Among the younger riders, those with helmets had significantly lower injury severity scores than those without helmets (p=.01). On the other hand, among the older riders, helmet use seemed to have no association with injury severity score.

Figure 2 – Distribution of Injury Severity Score (ISS)
By Age and Helmet Use

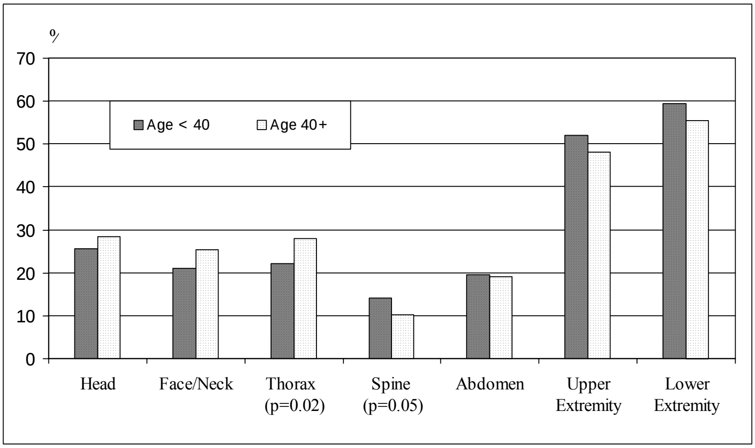


Large engine sizes (1,000+ cc) were associated with an increased risk of head injury (data not shown). Motorcyclists age 39 or younger operating such motorcycles had a rate ratio (RR) of 1.27 (95% CI= 0.89-1.81) and those age 40 or older had a rate ratio of 1.61 (95% CI= 1.02-2.56) for head injury compared with operators of smaller engines. Abdominal injury risk did not appear to be affected by engine size, with RRs of 0.86 for ages younger than 40 and 0.82 for ages 40+.

Age differentials in thoracic injury risk were present among hospitalized motorcyclists with bikes having engine sizes of 1,000+ cc, but not among riders with smaller motorcycle engines. Thoracic injury risk among motorcyclists operating engine sizes of 1,000+ cc were increased for those age 40 or older relative to younger motorcyclists (RR=1.25; 95% CI=0.83-1.89).

Figure 3 shows the distribution of specific injury types among younger vs. older motorcyclists admitted to hospitals. For both groups, the most common body region of injury was lower extremity, followed by upper extremity. Older riders had a significantly higher percentage of thoracic injuries. This was especially apparent for rib fractures; among younger motorcyclists, 21% had three or more rib fractures, whereas the percentage for the older group was 44% (p<.001, not shown). Injuries to the spine were significantly more common among younger riders.

Figure 3 - Distribution of Injured Anatomic Region by Age Group



The distribution of injuries by anatomic region, age and helmet use is presented in Table 2. The global p value indicates whether there was a difference in the association of helmet use and a given injury, depending on age. For the majority of injuries there was no such difference in the nature of the association; however, for head and facial injuries, younger riders with helmets had fewer head and facial injuries, whereas older riders with helmets had more such injuries**.** It is unknown whether there were differences in types of helmets worn by the two age groups.

Table 2 –Injured Anatomic Region
By Age and Helmet Use

Anatomic Region	<40 Year			40+			Global p
	Helmet Use			Helmet Use			
	Yes (n=562) %	No (n=142) %	P	Yes (n=336) %	No (n=40) %	p	
Head	24	38	0.004	31	22	0.27	0.010
Face/Neck	17	36	0.001	28	18	0.17	0.001
Thorax	23	24	0.87	30	32	0.69	0.799
Spine	15	15	0.95	12	12	0.86	0.905
Abdomen	21	13	0.05	19	15	0.53	0.663
Upper Ext	55	40	0.002	49	45	0.62	0.260
Lower Ext	59	56	0.50	56	48	0.33	0.603

Table 3 shows the most seriously injured anatomic region, as defined by maximum AIS, comparing older and younger riders with and without helmets. Among the unhelmeted riders younger than 40, the most serious injury usually was a head injury (34%), followed by lower extremity injuries (31%), and thoracic injury (14%). For younger riders with helmets, lower extremity injury achieved the highest rank (34%), followed by head (20%), and then upper extremity injuries (18%). Among the older riders, for both the helmeted and unhelmeted riders, lower extremity injuries were the most serious injury, followed by head and thoracic injuries. In the unhelmeted group, approximately one quarter of riders (24%) had their most serious injury to the chest.

Table 3 – Most Seriously Injured Body Region
By Age and Helmet Use*

	<40 Age			40+ Age		
	Helmet Use			Helmet Use		
Anatomic Region	Yes (n=543) %	No (n=139) %	P	Yes (n=325) %	No (n=37) %	p
Head	20	34		26	24	
Face/Neck	3	6		5	5	
Thorax	14	14		18	24	
Spine	4	2		2	5	
Abdomen	6	2		6	8	
Upper Extremity	18	11	0.001	13	0	0.30
Lower Extremity	34	31		30	32	

* There were 36 known helmet use cases with only unspecified injury body region, 22 younger than 40 and 14 ages 40+.

Table 4 shows the rate ratios and 95% confidence intervals for mortality by body region injured. As mentioned previously, the data do not include deaths at the scene. However, among those hospitalized, significant increases in mortality were observed among motorcyclists who had head injuries, thoracic injuries, and abdominal injuries, with the highest risk occurring among the group with thoracic injuries (rate ratio (RR)=2.43; 95% confidence interval (CI)=1.49-3.96). These categories were not mutually exclusive because some motorcyclists had injuries in multiple body regions.

A further comparison (data not shown) of death rates among older vs. younger riders showed that older motorcyclists had almost twice the risk of dying from head injuries and abdominal injuries than those younger than 40. In contrast, thoracic injuries were equally lethal for both groups of hospitalized cyclists. However, due to the small number of deaths involved, and the fact that these deaths were only among those hospitalized, it is difficult to draw further conclusions from these mortality patterns.

Table 4 – Rate ratios and 95% confidence intervals (CI) for death by body region among hospitalized motorcyclists

Body region	Deaths	Total injured	Deaths per 1,000	Rate ratio*	95% CI
Head	20	332	60	1.84	1.09-3.10
Thorax	24	302	79	2.43	1.49-3.96
Abdomen	15	242	62	1.89	1.07-3.37
Total	41	1,253	33	1.0*	

*Reference group consists of all hospitalized motorcyclists

CONCLUSIONS

In this population of motorcyclists admitted to Maryland hospitals, older riders had a significantly higher incidence of thoracic injury, most notably multiple thoracic injuries, including multiple (three or more) rib fractures. Many interesting vehicular and occupant differences have been noted between older and younger motorcyclists admitted to hospitals following injury. Older riders are more likely to ride larger motorcycles (bigger engine sizes), and also more likely to wear helmets. Older motorcyclists also differed with respect to their crash patterns: they were more likely to be involved in collisions involving overturning, or striking other highway structures such as embankments, fences, bridge overpasses or others. This does not appear to be a result of older riders' preference for motorcycles with larger engines, as their increased risk of overturns was observed for both smaller and larger engine sizes. The increased risk of thoracic injury is present primarily among older motorcyclists riding larger motorcycles.

One strength of this study was its focus on the population of motorcyclists whose injuries resulted in hospitalization. The linkage rates were high such that the data likely were representative of this group. However, this study does not include either the majority of deaths in motorcycle crashes (N=220) or all police-reported motorcycle crashes (N=5,923) that occurred during the period of study (1998-2002). The absence of data on deaths that occurred at the scene of the crash, en route to the hospital, and in the emergency department strongly limits the conclusions that can be drawn about age and injury type in relationship to risk of death. Another limitation of this analysis was that statistical power was sometimes less than optimal because of small numbers in some subgroups.

This study examined crash characteristics in relation to age rather than crash risk. In Maryland, younger motorcyclists are more likely to crash and be hospitalized; however, in the absence of data on travel, the extent of age differentials in crash risk is unknown.

These findings contradict some of those reported by Stutts et al. (2004), who did not observe an increased risk of overturn crashes or running-off-road crashes among older motorcyclists. Potentially, this may be because they studied all police-reported crashes, whereas this study analyzes only motorcyclists admitted to a hospital.

Although the finding of lower percentages of head injuries among unhelmeted older motorcyclists seems somewhat paradoxical, it may be a reflection of the fact that scene deaths are not included in these analyses. Perhaps older riders without helmets were more likely to die before hospital arrival, thus skewing the association between injury severity and helmet use in that age group. In order to address these possible biases, future research should include the entire spectrum of motorcyclists involved in crashes: those who were uninjured, those who were treated in the emergency department, and those who died at the scene or en route to the hospital.

Although studies have documented the role of trunk injuries resulting from vehicular crashes (Morris et al., 2002, 2003) few have addressed these injuries among motorcyclists. Coben et al. (2001), in an analysis of motorcycle-related hospitalizations in the U.S, did not find thoracic injuries among the principal diagnoses mentioned as part of the 2001 Nationwide Inpatient Sample of the Healthcare Cost and Utilization Project.

Kraus et al. (2002), on the other hand, also found that thoracic and abdominal injuries among injured motorcyclists were common, and also noted that the most common injury to the thorax was rib fracture. Moreover, those with rib fractures were 14 times more likely to have an intra-thoracic injury of any severity, and 41 times more likely to have multiple thoracic injuries compared with riders with no rib fractures. Rib fractures were also associated with the presence of multiple and/or severe abdominal injuries. In addition, the odds of internal organ injuries increased with the number and bilaterality of rib fractures. However, the authors did not report on the relationship of age to thoracic injury in their population.

Anatomic changes in the thorax associated with aging include changes in rib angles as well as bone density (Kent et al., 2005). Perhaps these changes contribute to the greater risk of rib fractures in the older group. There are also physiologic changes in pulmonary compliance which also may place older motorcyclists at higher risk of complications following serious thoracic injury (Kent et al., 2005).

When they are injured, older motorcyclists are significantly more likely to incur serious thoracic injuries, which carry a high risk of mortality. Thus, as the aging of the motorcycling population increases, with the growing popularity of the sport among baby boomers, an increase in mortality may be anticipated among those injured. It is unclear whether there are any effective countermeasures that could decrease the incidence of overturns and other types of crashes found to be more common in this group. A review of the training literature reported no reductions in crash risk arising from motorcycle training (Haworth, 2004). Research efforts should address protection of the chest and abdomen for motorcyclists of all ages; perhaps some type of protective vest could be developed to lessen the incidence and severity of these injuries.

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