CODES

Crash Outcome Data Evaluation System

HEALTH AND COST OUTCOMES RESULTING FROM TRAUMATIC BRAIN INJURY CAUSED BY NOT WEARING A HELMET, FOR MOTORCYCLE CRASHES IN WISCONSIN, 2008

Wayne Bigelow
Center for Health Systems Research and Analysis
University of Wisconsin – Madison
March, 2010

To contact the author: (608) 263-4846
wayne@chsra.wisc.edu

SUMMARY

We evaluated the impact of a variety of motorcycle crash related factors, including crash type, speed limit, highway type, demographics, alcohol involvement and helmet use, on the likelihood of being having a traumatic brain injury (TBI) and subsequent injury severity and healthcare (and other) resource utilization. Helmet use was found to have a strong protective effect on the likelihood of TBI across all other factors. Alcohol involvement in the crash was found to increase the probability of TBI, as were crashes involving head-on collisions. For persons **with** TBI, wearing a helmet was not associated with lower costs, lower injury severity or likelihood of death. The main protective effect provided by wearing a helmet was in reducing the number of crash victims who had traumatic brain injury. Estimated costs were over 14 times higher for TBI crash victims than non-TBI victims. Altogether, not wearing a helmet was associated with 95 extra TBI cases, and an additional $134 million in “comprehensive” costs (as defined by the National Safety Council).

BACKGROUND

Injuries associated with motorcycle crashes remain a major cause of morbidity and mortality in Wisconsin. In 2008, there were 90 fatalities and 676 hospitalizations involving motorcyclists in crashes. Both the incidence of serious health outcomes and the costs associated with motorcycle crashes far exceed those for crash victims who were occupants of other types of motor vehicles. Table 1 (next page) shows several pieces of health and cost outcome information for motorcycle crash victims and passenger vehicle crash victims for 2008 in Wisconsin. Motorcyclists are 4.1 times as likely to visit an ER subsequent to a motor vehicle crash (MVC),19.6 times as likely to be hospitalized and are 13 times as likely to die, compared to crash victims who were occupants of passenger vehicles. Motorcyclists cost have average medical costs 13.5 times as high as those for passenger vehicle occupants ($22,196 vs. $1,649) and other costs which are 10 times higher ($87,635 vs. $8,621).

These numbers clearly show that motorcyclists involved in crashes are far more likely to suffer serious injury or death compared to other types of MVC victims. While not all injury associated with motorcycle crashes can be mitigated, research has shown that much of the injury and cost associated with motorcycle crashes could be reduced by the use of a helmet. In particular, traumatic brain injury related injury outcomes and costs might be reduced significantly if a motorcycle rider involved in a crash wore a helmet. Head injuries have been shown to be a major source of the injuries associated with motorcycle crashes (1,2,3,4,5). Several studies of motorcycle crash outcomes have shown that helmet use is strongly associated with traumatic brain injuries (TBI) (1,2,3,4,6,7,8,9). To extend their analysis, we evaluate the impact of helmet use in the context of crash characteristics, demographic factors and alcohol use.

Table 1.
Number Crash Victims, Number and Percent Visiting an Emergency Room, Hospitalized and Died, and Total and Average Medical and Other Costs, For Motorcycle and Passenger Vehicle Crash Victims, Wisconsin, 2008

	Motorcycle Crash Victims	Passenger Vehicle Crash Victims	Ratio of Motorcycle to Passenger Vehicles
Total Crash Riders/Occupants	3,455	238,129	
Visited an ER -- Number	1,375	22,761	
Visited an ER -- Percent	39.8%	9.6%	4.1
Hospitalized -- Number	676	2,266	
Hospitalized -- Percent	19.6%	1.0%	19.6
Died -- Number	90	359	
Died -- Percent	2.6%	0.2%	13.0
Total Medical Costs (millions)	$ 77	$ 398	
Average Medical Costs	$ 22,196	$ 1,649	13.5
Total Other Costs (millions)	$ 303	$ 2,053	
Average Other Costs	$ 87,635	$ 8,621	10.2

In our analysis we perform a retrospective cohort study for 2008 which links together crash, operator and demographic factors with information on helmet use to evaluate several crash outcomes:

- Hospitalization or an Emergency Department visit with associated traumatic brain injury (and subsequently)
  - ⇒ Medical Costs
  - ⇒ Other Costs
  - ⇒ Quality of Life
  - ⇒ Maximum Abbreviated Injury Score (MAIS)
  - ⇒ Likelihood of Death

We expect that the lack of helmet use will have a strong impact on the likelihood of TBI, and may impact the other outcomes negatively as well. We also anticipate that alcohol involvement and crash characteristics which increase the force of impact in a crash (e.g. higher speed limits as a proxy for speed and head on collisions with another vehicle) will increase the likelihood of TBI.

METHODS

Data Sources – The data used in this analysis is from the Wisconsin Crash Outcomes and Data Evaluation System (CODES) database. The Wisconsin CODES project is funded through grants from NHTSA and the Bureau of Traffic Safety within the Wisconsin Department of Transportation. The CODES data is comprised of two sets of records. The first is the Wisconsin motor vehicle crash records data. The 2008 crash data was obtained through the Wisconsin Department of Transportation. This crash data contains information on all reportable crashes (with at least one injury or fatality, or at least $1000 in property damage). The data are collected by police officers at the crash scene (augmented at WisDOT), and include detailed information on the time, location and characteristics of the crash, as well as on the vehicle(s) and occupant(s) involved. The 2008 hospital discharge and Emergency Department (ED) data is obtained from the Wisconsin Hospital Association. State law mandates that all Wisconsin licensed hospitals report all emergency room visits and inpatient discharges. This data combines detailed information on patient demographics, up to nine ICD-9 and five procedure codes, an external cause of injury code (E-Code), charges and length of stay.

Probabilistic Data Merging – The CODES analysis database was created by using a technique called "probabilistic linkage" (10). By utilizing common information in both data sets, probabilistic linkage iteratively estimates a set of log odds weights used to determine the probability that specific records apply to the same person. The information used to link Wisconsin's CODES data included sex, age, date of birth, zip code of residence, county of crash, E-code derived type of injury and dates of hospitalization and of the crash. The data linkage for 2008 was performed by staff within the Department of Health and Family Services. More information regarding probabilistic linkage can be found on the Wisconsin CODES website at: www.chsra.wisc.edu/codes.

Case Selection -- Motorcycle crashes refer to both operators and passengers of motorcycles. Mopeds are not included in the analysis because crashes involving them almost exclusively occur in urban areas and on streets with low posted speed limits. Traumatic brain injury cases include hospitalizations or ED visits with corresponding ICD-9 codes indicating concussion, skull fracture or internal brain injury. Study variables used in the analysis are described in Figure 1 (next page). Table 2 (second next page) contains information on the number of cases and percentages for the study variables.

Software – Probabilistic linkage was performed using CODES2000 software (Strategic Matching, New Hampshire). ISS scores were generated using ICDMAP-90 software (John Hopkins, Baltimore, MD). SAS software (SAS Institute, Inc., Cary, NC) was used for all statistical analysis.

Analysis –Logistic regression was used to estimate the effect of study variables on the likelihood of traumatic brain injury and of death for persons with TBI. For the other four outcomes (Medical costs, Other costs, Quality of Life Costs and MAIS) T-Tests were used to estimate the impact of helmet use for persons with TBI.

Figure 1.

Helmet Use:	As reported by police officer on scene. Helmeted, not helmeted and unknown/missing.
Alcohol Use:	Combines BAC results with police officer reports of whether or not alcohol was a factor in the crash. No alcohol reported is the comparison group.
Age	< 19 (comparison group), 19-24, 25-34, 35-44, 45-54, 55-64, 65 years or older.
Sex	Male vs. Female - female is the comparison group.
Rural/Urban	Rural: Unincorporated areas of less than 5,000 population. Urban: Other locations. Urban is the comparison group.
Posted Speed Limit	Less than 25 mph (comparison), 26-35 mph, 36-45 mph, 46+ mph
Multi-Vehicle Crash	Multiple vehicles vs. single vehicle only crash (comparison).
Head On Crash	Head On collision with another vehicle vs. Other crashes (comparison).
Intersection Crash	Crash at intersection vs. Other crashes (comparison).
Driver Speeding	Police reported driver speeding was a cause of the crash vs. Other (comparison).
Traumatic Brain Injury:	Generated from ED and Hospital ICD-9 codes as defined in the Barell Injury matrix: 800.00 – 800.99, 801.00 – 801.99, 802.00 – 803.99, 804.00 – 804.99, 850.20 -- 850.49, 850.60 – 850.89, 851.00 – 854.99
Death	Defined using "K" in the KABC0 scale, and using hospital and ED discharge codes indicating death.
Maximum Abbrev. Injury Score	Maximum AIS score for any body region. 1=minor 2=moderate 3=severe 4=critical 5=maximal 6=died
Medical Costs	Calculated from abbreviated injury scores and body part or region. See Presentation on estimating Medical and Other costs on the Wisconsin CODES website: www.chsra.wisc.edu/codes . These costs, when combined with "other costs" and "quality of life" costs comprise "Comprehensive" crash costs as defined by the National Safety Council (NSC). All cost estimates are adjusted for medical and CPI inflation and for a Wisconsin specific cost adjustment factor. Costs estimates are based on work reported in Zaloshnja et.al. (11).
Other Costs	Calculated from abbreviated injury scores and body part or region.
Quality of Life Costs	Calculated from abbreviated injury scores and body part or region.

Table 2.
Number and Percent of Cases for Study Variables, and Mean and Standard Deviation for Four Outcome Variables

VARIABLE	NUMBER	PERCENT	VARIABLE	NUMBER	PERCENT
Total Number	3,455	100.0%	**Traumatic Brain Injury - No**	3,283	95.0%
			Traumatic Brain Injury - Yes	172	5.0%
Speed 1-25	673	19.5%			
Speed 26-35	774	22.4%	**Single Vehicle Crash**	2,067	59.8%
Speed 36-45	456	13.2%	**Multiple Vehicle Crash**	1,388	40.2%
Speed 46-55	1,367	39.6%			
Speed Missing	185	5.4%	**Crash at Intersection**	1,185	34.3%
			Crash not at Intersection	2,270	65.7%
Male	2,708	78.4%	**Urban**	1,523	44.1%
Female	631	18.2%	**Rural**	1,932	55.9%
Sex Missing	116	3.4%			
			HEALTH OUTCOMES		
Not Helmeted	1,786	51.7%			
Helmeted	1,399	40.4%	**Emergency Dept. Visit**	1,375	39.8%
Helmet Missing	270	7.8%			
			Inpatient Hospital Stay	676	19.6%
Age < 19	121	3.5%			
Age 19-24	500	14.5%	**ED Visit or Hospital Stay**	1,965	56.9%
Age 25-34	557	16.1%			
Age 35-44	755	21.9%	**Died**	90	2.6%
Age 45-54	847	24.5%			
Age 55-64	443	12.8%	**FOR CASES WITH TRAUMATIC BRAIN INJURY**		
Age 65+	104	3.0%		**Mean**	**St. Dev.**
Age Missing	128	3.7%	**Medical Costs**	$ 197,641	$ 22,880
Alcohol not a factor	3,048	88.2%	**Other Costs**	$ 469,980	$ 103,808
Alcohol a factor	407	11.8%			
			Quality of Life Costs	$ 831,756	$ 103,180
Driver was Speeding	158	4.6%			
Driver not Speeding	3,297	95.4%	**Total Comprehensive Costs**	$1,499,376	$ 194,596
Head On Collision	65	1.9%	**Maximum Abbreviated**		
Not Head On Collision	3,390	98.1%	**Injury Severity Score**	3.89	.27

RESULTS

In Wisconsin, in 2008, there were a total of 3,455 riders of cycles involved in crashes (Table 2). Males made up the overwhelming percentage of victims: 78%. Crashes occurred more often in rural locations (56%) than in urban locations (44%). Alcohol was indicated as being involved for 11.8% of crash victims. Helmet use was reported only 40.4% of the time, with missing helmet information in 7.8% of all cases. Of those involved in a motorcycle crash, 57% were hospitalized or had an ED visit. For those with TBI, the average medical cost was $198,000, the average other costs were $470,000, average quality of life costs were $832,000 and average maximum abbreviated injury score (MAIS) was 3.9.

Table 3 shows the percentage of persons who suffered a traumatic brain injury by helmet use. Cyclists not wearing a helmet were almost four times as likely to suffer TBI as those wearing a helmet (2.3 vs 7.6%).

Table 3.
Number of Persons with Traumatic Brain Injury (TBI)
By Helmet Use, WIsconsin 2008

HELMET USE	Number	With TBI/ % of Total
Helmet Worn	1,367	32
	100.0%	2.3%
Helmet Not Worn	1,650	136
	100.0%	7.6%

Table 4 (next page) shows the results of two logistic regression models. These models estimate the impact of not wearing a helmet on the likelihood of having a traumatic brain injury in a cycle crash. One model includes only the variable for not wearing a helmet (and for missing helmet information), while the other includes a variety of conditions which have been used in other analyses reported in journals or performed at NHTSA. The results for helmet use are quite robust. Motorcycle crash victims not wearing a helmet are 3.5 times as likely to have a TBI as those wearing helmets when only that variable is included. In the full model, those not wearing a helmet are 3.43 times as likely to have TBI as those wearing a helmet. Notably, alcohol use increases the likelihood of a TBI by 180%, being involved in a head on collision by 450% and having a crash on a road with a posted speed limit over 45 by 290%. Thus, helmet use strongly predicts whether a crash victim will have a traumatic brain injury, with alcohol use, head-on collisions and crashes at higher speeds also having significant impacts at the .001 level.

Table 4.
Likelihood of a Motorcycle Crash Victim Having a Traumatic Brain Injury, Wisconsin, 2008

Explanatory Variable	Likelihood Ratio	Likelihood Ratio
No Helmet	**3.52**	**3.43**
Helmet Missing	.642	.78
Alcohol a Factor		**1.84 ***
Speeding		1.60
Speed Limit 26-35		1.24
Speed Limit 36-45		2.26
Speed Limit 46+		**2.89**
Speed Limit Missing		.51
Rural Crash		.83
Intersection		1.49
Multiple Vehicles		.58
Head On Collision		**4.54**
Age 19-24		.79
Age 25-34		.94
Age 35-44		1.26
Age 45-54		1.19
Age 55-64		1.43
Age 65+		2.76
Male		0.84
For Model: Degrees of Freedom	2	19
Chi-Square (sig. at .001)	**50.9**	**128.9**

Likelihood ratios in bold are significant at the .01 level, except for Alcohol being a factor in the crash, which is significant at the .002 level.

Table 5 shows information for 5 outcome measures, for persons diagnosed with a traumatic brain injury and by whether or not the crash victims were wearing a helmet. All outcome measure differences between persons wearing a helmet vs. those not wearing a helmet are insignificant at the .01 level. Thus, wearing a helmet impacts whether or not a rider suffers a traumatic brain injury (with consequent injury severity and cost increases), but not whether costs and outcomes are higher or more severe for TBI victims directly.

Table 5.
Average Costs, Injury Scores and Percent Dying, for Persons Wearing and Not Wearing Helmets, for Crash Victims with a Traumatic Brain Injury, Wisconsin, 2008

HELMET USE	Medical Costs	Other Costs	Quality of Life Costs	Max. Abbrev. Injury Score	Death
Helmet Worn Number = 32	$ 235,600	$ 399,456	$ 825,940	3.72	3 9.4%
Helmet Not Worn Number = 136	$ 188,342	$ 493,252	$ 839,164	3.93	22 16.2%
DIFFERENCE	$ 47,258	$ 93,796	$ 13,224	0.21	6.8%

No Differences were significant at the .001 level

The presence of traumatic brain injury is determined by using ED and hospital diagnosis codes. It may have been the case that not wearing a helmet would lead to increased death rates for persons who never entered an emergency room or hospital. We examined rates of death for persons with no ED visit or inpatient admission (for whom we could not determine whether there was traumatic brain injury). The percentage of persons wearing a helmet who died was 1.47% (9 persons). The percentage of persons not wearing a helmet who died was 5.44% (37 persons). This difference was significant (Mantel-Haenszel Chi Square= 14.73, probability <.0001), indicating that helmet use did significantly lower the risk of death for persons who didn't have an ED visit or an admission. The upshot of this is that there could well be significant additional numbers of cycle riders who died of TBI, but who we can't directly identify. As such, our estimates of cost are not as high as they would be if we could identify such persons – making our cost estimates conservative.

Table 5 (below) shows the actual number of persons with a TBI and associated costs for persons not wearing a helmet, the expected number and costs if they had worn a helmet, and the total cost differential. Had helmets been worn by all motorcycle riders involved in a crash in 2008, there would have been 95 fewer persons with TBI. Total "comprehensive" costs would have been $134 million less – the effective cost to Wisconsin in 2008 for the freedom to not wear motorcycle helmets.

Table 5.
Estimated Number Persons with Traumatic Brain Injury, Estimated Costs and Estimated Cost Savings, if Persons Not Wearing a Helmet Had Worn a Helmet, Wisconsin, 2008

	Helmet Not Worn (Actual)	IF Helmet Worn	Difference
Number Persons with Traumatic Brain Injury	136	41	95 (A)
Total Comprehensive Costs (medical + quality of life + other) for non-helmeted TBI Cases vs. average cost for helmeted non-TBI Cases	$ 1,520,758 (A)	$ 113,852	$ 1,406,906 (B)
Cost Difference Due to Additional TBI Cases: (A) times (B)			**$ 133,656,070**

DISCUSSION

Our results continue to agree with those of other studies which show helmet use to be protective against serious head injuries in the event of a motorcycle crash. Unlike some other studies, our results do not indicate that injury severity and the likelihood of death are reduced for those persons who do suffer a traumatic brain injury but were wearing a helmet. The main cost impact results from the reduction in TBI related cases rather than cost differentials for crash victims with TBI who were or were not wearing a helmet. Not wearing a helmet resulted in 95 additional cases of TBI – a condition which results in extraordinary burden and suffering for both cyclists and their families, as well as the likelihood of long term disability and potential costs to the government.

References

1. Bachulis, B. L.; Sangster, W.; Gorrell, G. W., and Long, W. B. Patterns of injury in helmeted and non-helmeted motorcyclists. American Journal of Surgery. 1988 May; 155(5):708-11.

2. Baker SP, O'Neill B Ginsberg MJ Li G. The Injury Fact Book. 2nd ed. ,New York, Oxford University Press. 1992.

3. Chiu, W. T.; Yeh, K. H.; Li, Y. C.; Gan, Y. H.; Chen, H. Y., and Hung, C. C. Traumatic brain injury registry in Taiwan. Neurological Research. 1997 Jun; 19(3):261-4.

4. Evans, L. and Frick, M. C. Helmet effectiveness in preventing motorcycle driver and passenger fatalities. Accident Analysis & Prevention. 1988 Dec; 20(6):447-58.

5. Karlson T, Quade C. Head Injuries Associated with Motorcycle Use - Wisconsin, 1991. 1994(43): 423-; 429-431.

6. Kelly, P.; Sanson, T.; Strange, G., and Orsay, E. A prospective study of the impact of helmet usage on motorcycle trauma. Annals of Emergency Medicine . 1991 Aug; 20(8):852-6.

7. Krantz KPG. Head and neck injuries to motorcycle and moped riders - With special regard to the effect of protective helmets. 1985; 16, 253.

8. Orsay, E.; Holden, J. A.; Williams, J., and Lumpkin, J. R. Motorcycle trauma in the state of Illinois: analysis of the Illinois Department of Public Health Trauma Registry [see comments]. Annals of Emergency Medicine. 1995 Oct; 26(4):455-60.

9. Rowland, J.; Rivara, F.; Salzberg, P.; Soderberg, R.; Maier, R., and Koepsell, T. Motorcycle helmet use and injury outcome and hospitalization costs from crashes in Washington State. American Journal of Public Health. 1996 Jan; 86(1):41-5.

10. Jaro MA. Advances in record-linkage methodology as applied to matching the 1985 census of Tampa, Florida. 1989; 84, 414-420.

11, Zaloshnja, E., Miller, T., Romano, E., Spicer, R., 2003. Crash costs by body part injured, fracture involvement, and threat-to-life severity, United States, 2000. Accid Anal Prev 36 (2004) 415-42