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, 2011

Wayne Bigelow
Center for Health Systems Research and Analysis
University of Wisconsin – Madison
March, 2013

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

THE UNIVERSITY *of* WISCONSIN MADISON

WISCONSIN DEPARTMENT OF TRANSPORTATION

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) costs. 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 at higher speeds. 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 much higher for TBI crash victims than non-TBI victims. Altogether, not wearing a helmet was associated with 96 extra TBI cases, and an additional $97 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 2011, there were 81 fatalities and 560 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 2011 in Wisconsin. Motorcyclists are 4 times as likely to visit an ER subsequent to a motor vehicle crash (MVC), 25 times as likely to be hospitalized and are 14 times as likely to die, compared to crash victims who were occupants of passenger vehicles. Motorcyclists cost have average medical costs 16 times as high as those for passenger vehicle occupants ($27,000 vs. $1,700) and other costs which are 11 times higher ($98,000 vs. $9,000).

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, 2011

	Motorcycle Crash Victims	Passenger Vehicle Crash Victims	Ratio of Motorcycle To Passenger Vehicles
Total Crash Riders/Occupants	2,832	207,395	
Visited an ER -- Number	1,086	19,573	
Visited an ER -- Percent	38.4%	9.4%	4.1
Hospitalized -- Number	560	1,733	
Hospitalized -- Percent	19.8%	.8%	24.8
Died -- Number	81	329	
Died -- Percent	2.9%	0.2%	14.5
Total Medical Costs (millions)	$ 78	$ 350	
Average Medical Costs	$ 27,360	$ 1,686	16.2
Total Other Costs (millions)	$ 278	$ 1,876	
Average Other Costs	$ 98,132	$ 9,045	10.8

In our analysis we perform a retrospective cohort study for 2011 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 2011 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 2011 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 2011 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, 19-24, 25-34, 35-44 (comparison group), 45-54, 55-64, 65 years or older.

Sex Male vs. Female - female 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	2,832	100.0%	Traumatic Brain Injury - No	2,662	94.0%
			Traumatic Brain Injury - Yes	170	6.0%
Speed 1-25	590	20.8%			
Speed 26-35	627	22.1%	Single Vehicle Crash	1,708	60.3%
Speed 36-45	354	12.5%	Multiple Vehicle Crash	1,124	39.7%
Speed 46-55	1,135	40.1%			
Speed Missing	126	4.5%	Crash at Intersection	1,033	36.5%
			Crash not at Intersection	1,799	63.5%
Male	2,251	79.5%	Urban	1,201	42.4%
Female	477	17.5%	Rural	1,631	57.6%
Sex Missing	84	3.0%			
			HEALTH OUTCOMES		
Not Helmeted	1,565	55.2%			
Helmeted	1,090	38.5%	Emergency Dept. Visit	1,086	39.3%
Helmet Missing	177	6.3%			
			Inpatient Hospital Stay	560	19.2%
Age < 19	84	3.0%			
Age 19-24	386	13,6%	Died	98	2.9%
Age 25-34	467	16.5%			
Age 35-44	484	17.3%	**FOR CASES WITH TRAUMATIC BRAIN INJURY**	Mean	St. Dev.
Age 45-54	693	24.5%	Medical Costs	$ 207,336	$ 38,254
Age 55-64	483	17.1%			
Age 65+	145	5.1%			
Age Missing	90	3.2%	Other Costs	$ 438,812	$ 111,049
Alcohol not a factor	2,585	91.3%	Quality of Life Costs	$ 765,098	$ 165,122
Alcohol a factor	247	8.7%			
			Total Comprehensive Costs	$ 1,411,243	$ 301,356
Driver was Speeding	122	4.3%			
Driver not Speeding	2,710	95.7%	Maximum Abbreviated Injury Severity Score	3.71	.29
Head On Collision	57	2.0%			
Not Head On Collision	2,775	98.0%			

RESULTS

In Wisconsin, in 2011, there were a total of 2,832 riders of cycles involved in crashes (Table 2). Males made up the overwhelming percentage of victims: 79%. Crashes occurred more often in rural locations (58%) than in urban locations (42%). Alcohol was indicated as being involved for 8.7% of crash victims. Helmet use was reported only 39% of the time, with missing helmet information in 6.3% of all cases. Of those involved in a motorcycle crash, 56% were hospitalized or had an ED visit. For those with TBI, the average medical cost was $207,000, the average other costs were $438,000, average quality of life costs were $765,000 and average maximum abbreviated injury score (MAIS) was 3.7.

Table 3 shows the percentage of persons who suffered a traumatic brain injury by helmet use. Cyclists not wearing a helmet were over three times as likely to suffer TBI as those wearing a helmet (2.7% vs 8.8%).

Table 3.
Number of Persons with Traumatic Brain Injury (TBI)
By Helmet Use, WIsconsins 2011

HELMET USE	Number	With TBI/ % of Total
Helmet Worn	1,061	29
	100.0%	2.7%
Helmet Not Worn	1,427	138
	100.0%	8.8%

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 iin the model. In the full model, those not wearing a helmet are 3.6 times as likely to have TBI as those wearing a helmet. Notably, alcohol use increases the likelihood of a TBI by a factor of 2.3 and crashing on roads with a speed limit of 46 mph or higher increases the likelihood of having a TBI by 140%. Thus, helmet use strongly predicts whether a crash victim will have a traumatic brain injury, with alcohol use and speed of travel (defined as speed limit) also having significant impacts at the .001 level.

Table 4.
Likelihood of a Motorcycle Crash Victim
Having a Traumatic Brain Injury,
Wisconsin, 2011

Explanatory Variable	Likelihood Ratio	Likelihood Ratio
No Helmet	**3.54**	**3.60**
Helmet Missing	.63	1.01
Alcohol a Factor		**2.27**
Speeding		1.79
Speed Limit 26-35		1.60
Speed Limit 36-45		1.65
Speed Limit 46+		**2.40**
Speed Limit Missing		.27
Rural Road		.65
Intersection		.83
Multiple Vehicles		.70
Head On Collision		1.50
Age < 19		1.57
Age 19-24		1.39
Age 25-34		1.06
Age 45-54		1.49
Age 55-64		1.54
Age 65+		1.58
Male		.98
For Model:		
Degrees of Freedom	2	19
Chi-Square (sig. at .001)	**43.2**	**89.1**

Likelihood ratios in bold are significant at the .001 level.

Table 5 shows information for 5 outcome measures, for persons diagnosed <u>with</u> a traumatic brain injury and by whether or not the crash victims were wearing a helmet. Except for the likelihood of dying, differences between persons wearing a helmet vs. those not wearing a helmet are insignificant at the .001 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. The only exception is for death, where those wearing helmets had no deaths, whereas 14.3% of those not wearing a helmet and with TBI, died. This finding has not been found in other years of analysis for Wisconsin.

Table 5.
Average Costs, Injury Scores and Percent Dying,
for Persons Wearing and Not Wearing Helmets,
for Crash Victims <u>with</u> a Traumatic Brain Injury,
Wisconsin, 2011

HELMET USE	Medical Costs	Other Costs	Quality of Life Costs	Max. Abbrev. Injury Score	Death
Helmet Worn Number = 28	$ 215,573	$ 330,276	$ 684,478	3.53	0 .0
Helmet Not Worn Number = 137	$ 207,384	$ 456,678	$ 786,107	3.75	**20** **14.5**
DIFFERENCE	$ 8,190	$ 126,402	$ 101,629	0.22	14.5

No Differences were significant at the .001 level

Table 6 (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 2011, there would have been 96 fewer persons with TBI. Total "comprehensive" costs would have been $97 million less – the effective cost to Wisconsin in 2011 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, 2011

	Helmet Not Worn (Actual)	IF Helmet Worn	Difference
Number Persons with Traumatic Brain Injury	138	42	**96 (A)**
Total Comprehensive Costs (medical + quality of life + other) for non-helmeted TBI Cases vs. average cost for helmeted non-TBI Cases	$ 1,230,328	$ 218,179	**$ 1,012,149 (B)**
Cost Difference Due to Additional TBI Cases: (A) times (B)			**$ 97 million**

(A) Number of additional TBI cases due to no helmet use.
(B) Total cost per non-helmet wearing TBI victim vs Total cost for helmeted non-TBI victim.

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 96 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