CODES

Crash Outcome Data Evaluation System

HEALTH OUTCOMES AND COSTS RESULTING FROM TRAUMATIC BRAIN INJURY CAUSED BY NOT WEARING A HELMET, FOR MOTORCYCLE CRASHES IN WISCONSIN, 2003-2005

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SUMMARY

We evaluated the impact of a variety of motorcycle/moped crash related factors, including crash type, speed limit, rural/urban crash location, demographics, alcohol involvement and helmet use, on the likelihood of being having a traumatic brain injury (TBI) and subsequent injury severity and costs, for Wisconsin from 2003-2005. Multiply imputed probabilistic links between crash data and Emergency Department visits/hospital discharges were used in the analysis. Multiple imputation was used to estimate missing values for age, sex, speed limit and helmet use. Strong predictors of cyclists ending up with a traumatic brain injury were:

- Those not wearing a helmet were almost two and a half times as likely to suffer TBI as those wearing a helmet.
- Cycle operators for whom police report alcohol involvement were 2.2 times more likely to suffer TBI as other cyclists.
- Cyclists involved in crashes where police report speeding, or occurring on roads with speed limits over 55 miles per hour, were almost half again as likely to suffer TBI as others.

For persons with TBI, not wearing a helmet was associated with significantly higher costs, injury severity and likelihood of death. Altogether, not wearing a helmet was associated with 501 extra TBI cases, 27 additional deaths and $393 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 the Wisconsin. In 2005 alone, there were 93 fatalities and 689 hospitalizations involving motorcyclists in crashes. Both the incidence of serious health outcomes and the costs associated with motorcycle crashes far exceed those for other crash victims who were occupants of passenger vehicles. Table 1 (next page) shows several pieces of health and cost outcome information for motorcycle crash victims and passenger vehicle victims for 2005 in Wisconsin. Motorcyclists are 4 times as likely to visit an ER subsequent to a motor vehicle crash (MVC), 17.8 times as likely to be hospitalized and are 11.7 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 ($21,050 vs $1,592) and other costs which are 8.8 times higher ($82,334 vs. $9,359).

These numbers clearly indicate that motorcyclists involved in crashes are far more likely to suffer serious injury or death than other types of MVC victims. While not every 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 (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, 2005

	Motorcycle Crash Victims	Passenger Vehicle Crash Victims	Ratio of Motorcycle to Passenger Vehicles
Total Crash Riders/Occupants	3,487	175,190	0.020
Visited an ER -- Number	1,523	19,657	
Visited an ER -- Percent	43.7%	11.2%	3.9
Hospitalized -- Number	689	1,945	
Hospitalized -- Percent	19.8%	1.1%	17.8
Died -- Number	93	400	
Died -- Percent	2.7%	0.2%	11.7
Total Medical Costs (millions)	$ 73.4	$ 273.6	
Average Medical Costs	$ 21,050	$ 1,562	13.5
Total Other Costs (millions)	$ 287.1	$ 1,639.6	
Average Other Costs	$ 82,334	$ 9,359	8.8

In our analysis we perform a retrospective cohort study for 2003 to 2005 which links together crash, operator and demographic factors with information on helmet use to evaluate several crash outcomes:

Likelihood of Hospitalization or an Emergency Department visit with associated traumatic brain injury (and subsequently)

- ⇒ Increased Medical Costs for TBI victims by helmet use
- ⇒ Other Costs for TBI victims by helmet use
- ⇒ Maximum Abbreviated Injury Score (MAIS) for TBI victims by helmet use
- ⇒ Likelihood of Death for TBI victims by helmet use

We expect that the lack of helmet use will have a strong positive impact on the likelihood of TBI, and may positively impact the other outcomes as well (comparing TBI cases wearing and not wearing helmets).

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 2003-2005 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, 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 2003-2005 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 two data sets, probabilistic linkage iteratively estimates a set of log odds weights used to determine the probability that specific records in both data sets apply to the same person/event. 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 2003-2005 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. In utilizing the CODES2000 software, developed through contracts to NHTSA, we utilized *multiply imputed* linked data, rather than only “high” probability links. To generate the multiply imputed linked data the CODES2000 software utilized monte carlo simulation methods to representatively sample linked pairs of records with low probabilities, as well as select linked pairs with high probabilities. This is done because only utilizing a sample of linked data with high probabilities could conceivably lead to a skewed sample. The resulting set of linkages we utilize in this analysis are both representative of the underlying population of interest and are relatively unbiased with respect to the relationships between the variables of interest in the study.

Case Selection -- Motorcycle crashes refer to both drivers and passengers of motorcycles and mopeds. 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 1 (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, including multiple imputation, logistic and OLS regression and to pool the sample variances for estimating effect parameters.

Analysis –Multiple imputation (11,12) was used to estimate missing values for sex, age, speed limit and helmet use (the only study variables with missing values). Logistic regression (through 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) OLS regression was used to estimate the impact of helmet use for persons with TBI. PROC MIANALYZE was used to estimate pooled variance estimates.

Figure 1. Elements in the Model

Age	< 19, 19-24, 25-34, 35-44, 45-54, 55-64, 65 years or older. Less than 19 years is the comparison group.
Alcohol Use:	Combines BAC results with police officer report of whether or not alcohol was a factor in the crash. No alcohol reported involved is the comparison group.
Crash Type	Head on collision with another vehicle vs other type of crash.
Death	Defined using "K" in the KABC0 scale, and using hospital and ER discharge codes indicating death.
Emer.Dept Visit	For cases with an ER linkage, but were not admitted as an inpatient.
Helmet Use:	As reported by police officer on scene. Helmeted, not helmeted and unknown/missing. Multiple imputation is used to assign estimated values for cases with missing information for helmet use, age, sex and speed limit.
Hospitalization	For Cases with an inpatient hospital linkage.
Maximum Abbrev. Injury Score	Maximum AIS score for any body region. Used as a cardinal variable. 1=minor 2=moderate 3=severe 4=critical 5=maximal 6=died
Motorcycle/Moped	Full size cycle vs mopeds. Defined using cycle size, VIN "style" and whether someone was classified as riding a moped by the police.
Posted Speed Limit	Less than 25 mph, 26-35 mph, 36-45 mph, 46-55 mph, 56+ mph. Less than 25 is the comparison group.
Rural/Urban	Rural: Unincorporated areas of less than 5,000 population. Urban: Other locations. .Urban is the comparison group.
Sex	Male vs Female - female is the comparison group.
Traumatic Brain Injury:	Generated from 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 Only available for cases with an ED visit or inpatient hospital admission.
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). If only Medical and Other costs are combined, the estimates comprise "Human Capital" model costs as used by both the NSC and NHTSA. All cost estimates are adjusted for inflation.
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	9,848	100.0%	**Traumatic Brain Injury - No**	8,692	88.3%
			Traumatic Brain Injury - Yes	1,156	11.7%
Speed 1-25	2,228	21.3%	**Motorcycle**	7,655	56.4%
Speed 26-35	2,291	21.8%	**Moped**	2,193	43.6%
Speed 36-45	1,373	13.5 %			
Speed 46-55	3,545	34.1%	**Single Vehicle Crash**	650	22.9%
Speed 56+	411	3.1%	**Multiple Vehicle Crash**	2,149	53.2%
Male	8,015	81.4%	**Rural**	4,419	44.9%
Female	1,833	18.6%	**Urban**	5,429	55.1%
Not Helmeted	6,310	64.1%	**Emergency Dept. Visit**	3,964	40.3%
Helmeted	3,538	35.9%			
			Inpatient Hospital Stay	1,924	19.5%
Age < 19	487	5.0%	**Died**	280	2.9%
Age 19-24	1,555	15.8%			
Age 25-34	2,090	21.2%			
Age 35-44	2,315	24.2%	**CASES WITH TBI**	**Mean**	**St. Dev.**
Age 45-54	2,115	21.5%	**Medical Costs**	$ 100,080	$ 37,846
Age 55-64	921	9.4%	**Other Costs**	$ 260,998	$ 128,097
Age 65+	295	3.0%	**Quality of Life Costs**	$ 449,954	$ 154,444
			Maximum Abbreviated Injury Severity Score	2.86	.48
Crash at Intersection	3,470	35.2%			
			CASES WITHOUT TBI		
Alcohol not a factor	8,812	88.9%			
Alcohol a factor	1,036	11.1%	**Medical Costs**	$ 9,105	$ 49,407
			Other Costs	$ 58,033	$ 83,379
Driver was Speeding	1,357	13.8%	**Quality of Life Costs**	$ 46,370	$ 87,646
			Maximum Abbreviated Injury Severity Score	1.60	.36

RESULTS

In Wisconsin, in 2003-2005, there were a total of 9,848 riders of cycles involved in crashes (Table 2). Males made up the overwhelming percentage of victims: 81%. Crashes occurred more often in rural locations (55%) than in urban locations (45%). Alcohol was indicated as being involved for 11.1% of crash victims. Helmet use was reported only 35.9% of the time, with missing helmet information in 8.2% of all cases. Of those involved in a motorcycle crash, 59.8% were hospitalized or had an ED visit. For those with TBI, the average medical cost was $100,000, the average other costs were $261,500, average quality of life costs were $245,000 and average maximum abbreviated injury score (MAIS) was 2.95.

Table 3 shows the percentage of persons who suffered a traumatic brain injury, and for those suffering TBI, the numbers and percentages who had only an ER visit vs those who had an inpatient admission. Cyclists not wearing a helmet were over twice as likely to suffer TBI as those wearing a helmet (6.5% vs 14.2%). Additionally, those not wearing a helmet were 13% more likely to be admitted to a hospital compared to those wearing a helmet (50.4% vs 63.3%).

Table 3.
Number of Persons with Traumatic Brain Injury,
Percent Visiting an Emergency Room
and Number Admitted as an Inpatient,
By Helmet Use, Wisconsin, 2003-2005

HELMET USE	Number	With TBI/ % of Total	ER Visit / % of TBI	Hospitalized / % of TBI
Helmet Worn	3,530	230	114	116
	100.0%	6.5%	49.6%	50.4%
Helmet Not Worn	6,538	926	340	586
	100.0%	14.2%	36.7%	63.3%

Table 4, below, shows the results from two logistic regression models which estimate the impact of not wearing a helmet on the likelihood of having a traumatic brain injury as a result of a cycle crash. One model includes only the variable for not wearing a helmet, while the other includes a variety of variables which have been included in other research. The results for helmet use are quite robust. Motorcycle crash victims not wearing a helmet are 2.48 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 2.38 times as likely to have TBI as those wearing a helmet. Notably, alcohol use increases the likelihood of a TBI by 2.2 (120%), speeding increases the risk by 1.45 (45%) and crashes occurring at speeds of 55+ miles per hour increases the likelihood of TBI by 1.35 (35%). Thus, helmet use more strongly predicts whether a crash victim will have a TBI than any other variable, with alcohol use and vehicle speed also having significant impacts.

Table 4.
Factors Affectiing the Likelihood of a Motorcycle Crash Victim Having a Traumatic Brain Injury, Wisconsin, 2003-2005

Explanatory Variable	Likelihood Ratio	Likelihood Ratio
No Helmet	**2.48**	**2.38**
Alcohol		**2.19**
Speeding		**1.45**
Intersection		0.94
Speed 26-35		1.08
Speed 36-45		1.33
Speed 46-55		1.55
Speed 56-65		**1.35**
Rural Crash		0.87
Full Size Cycle		0.93
Head On Collision		0.66
Age 19-24		0.79
Age 25-34		0.85
Age 35-44		0.76
Age 45-54		0.80
Age 55-64		1.11
Age 65 Or Older		1.12
Male Rider		0.81

Likelihood ratios in bold and red are significant at the .01 level

Table 5 shows information for 5 outcome measures, for persons diagnosed with a traumatic brain injury (only), 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 significant at the .01 level except for medical costs. For persons not wearing a helmet, other costs are almost $41,000 higher, quality of life costs are $28,000 higher. MAIS is .19 higher (about 7%) and they are 45% more likely to die.

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, 2003-3005

HELMET USE	Medical Costs	Other Costs	Quality of Life Costs	Max. Abbrev. Inj. Score	Likelihood of Dying
Helmet Worn	$ 98,823	$ 228,390	$ 427,237	2.71	15
Number = 230					6.53
Helmet Not Worn	$ 100,392	$ 269,080	$ 455,586	2.90	88
Number = 936					9.46%
DIFFERENCE	$ 1,569	**$ 40,690**	**$ 28,349**	**0.19**	**2.93%**

Outcome measure differences in bold and red are significant at the .01 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 2003-2005, there would have been 501 fewer persons with TBI. Total “comprehensive” costs would have been $363 million less. For the remaining 425 “expected” cases, average costs would have about $71,000 less, totaling $30 million more in total higher costs. Altogether, the “freedom” to not wear helmets cost almost $400 million in Wisconsin from 2003-2005.

Table 6.
Estimated Number Persons with Traumatic Brain Injury,
Estimated Costs and Estimated Additional Costs,
if Persons Not Wearing a Helmet Had Worn a Helmet,
Wisconsin, 2003-2005

	Helmet Not Worn (Actual)	If Helmet Had Been Worn	Difference
Number Persons with Traumatic Brain Injury	926	425	501
Total Comprehensive Costs (Medical + Other + Quality of Life) per case	$ 825,059(a)	$ 99,979(b)	$ 725,080
Total Comprehensive Costs only for TBI Patients per case	$ 825,059(c)	$ 754,450(d)	$ 70,609
Cost Difference Due to Additional TBI Cases [(a-b) times 501 added cases]			$ 363,265,000
Cost Difference Due to Increased Cost for Person with TBI [c-d) times expected 425 cases]			$ 30,009,000
Total Difference in Costs			**$ 393,274,000**

DISCUSSION

Our results are in agreement those of other studies which show helmet use to be protective against serious head injuries in the event of a motorcycle crash. As with many other studies, our results indicate that even for those persons who do suffer a traumatic brain injury and visit an ER or are admitted to an inpatient setting, costs and injury severity are lower for persons wearing a helmet, and the likelihood of death is reduced. The main cost differential comes from the reduction in TBI related cases, with significant savings even for those with TBI who wear helmets. Additionally, not wearing a helmet leads to 501 additional cases of TBI and to 27 additional deaths – resulting in extraordinary burden and suffering for both cyclists and their families.

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