



# 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, 2013**

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## 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 85 extra TBI cases, and an additional \$103 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 2013, there were 84 fatalities and 487 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 2013 in Wisconsin. Motorcyclists are 5 times as likely to visit an ER subsequent to a motor vehicle crash (MVC), 26 times as likely to be hospitalized and are 23 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 12 times higher (\$100,000 vs. \$8,500).

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, 2013**

	<b>Motorcycle Crash Victims</b>	<b>Passenger Vehicle Crash Victims</b>	<b>Ratio of Motorcycle To Passenger Vehicles</b>
<b>Total Crash Riders/Occupants</b>	2,603	217,412	
<b>Visited an ER -- Number</b>	856	15,139	
<b>Visited an ER -- Percent</b>	32.9%	7.0%	4.7
<b>Hospitalized -- Number</b>	487	1,465	
<b>Hospitalized -- Percent</b>	18.7%	.7%	26.7
<b>Died -- Number</b>	87	307	
<b>Died -- Percent</b>	3.2%	0.1%	22.9
<b>Total Medical Costs (millions)</b>	\$ 71.6	\$ 367	
<b>Average Medical Costs</b>	\$ 27,497	\$ 1,688	16.3
<b>Total Other Costs (millions)</b>	\$ 262	\$ 1,855	
<b>Average Other Costs</b>	\$ 100,484	\$ 8,533	11.7

In our analysis we perform a retrospective cohort study for 2013 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 2013 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 2013 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.

**Data Merging** – The CODES analysis database was created by using a technique called “probabilistic linkage” (10) from 1992-2012. 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. Starting in 2013, the quality of the data had improved to the point where “exact” linkage was used to merge crash and health related data. The data linkage for 2013 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](http://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** – 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 and to merge the crash and health outcomes data.

**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.

<b>Helmet Use:</b>	As reported by police officer on scene. Helmeted, not helmeted and unknown/missing.
<b>Alcohol Use:</b>	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.
<b>Age</b>	< 19, 19-24, 25-34, 35-44 (comparison group), 45-54, 55-64, 65 years or older.
<b>Sex</b>	Male vs. Female - female is the comparison group.
<b>Posted Speed Limit</b>	Less than 25 mph (comparison), 26-35 mph, 36-45 mph, 46+ mph
<b>Multi-Vehicle Crash</b>	Multiple vehicles vs. single vehicle only crash (comparison).
<b>Head On Crash</b>	Head On collision with another vehicle vs. Other crashes (comparison).
<b>Intersection Crash</b>	Crash at intersection vs. Other crashes (comparison).
<b>Driver Speeding</b>	Police reported driver speeding was a cause of the crash vs. Other (comparison).
<b>Traumatic Brain Injury:</b>	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
<b>Death</b>	Defined using “K” in the KABC0 scale, and using hospital and ED discharge codes indicating death.
<b>Maximum Abbrev. Injury Score</b>	Maximum AIS score for any body region. 1=minor 2=moderate 3=severe 4=critical 5=maximal 6=died
<b>Medical Costs</b>	Calculated from abbreviated injury scores and body part or region. See Presentation on estimating Medical and Other costs on the Wisconsin CODES website: <a href="http://www.chsra.wisc.edu/codes">www.chsra.wisc.edu/codes</a> . 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).
<b>Other Costs</b>	Calculated from abbreviated injury scores and body part or region.
<b>Quality of Life Costs</b>	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**

<b>VARIABLE</b>	<b>NUMBER</b>	<b>PERCENT</b>	<b>VARIABLE</b>	<b>NUMBER</b>	<b>PERCENT</b>
<b>Total Number</b>	2,603	100.0%	<b>Traumatic Brain Injury - No</b>	2,439	93.7%
			<b>Traumatic Brain Injury - Yes</b>	164	6.3%
<b>Speed 1-25</b>	554	21.3%			
<b>Speed 26-35</b>	594	22.9%	<b>Single Vehicle Crash</b>	1,510	58.0%
<b>Speed 36-45</b>	363	14.0%	<b>Multiple Vehicle Crash</b>	1,093	42.0%
<b>Speed 46-55</b>	1,003	38.5%			
<b>Speed Missing</b>	86	3.3%	<b>Crash at Intersection</b>	970	37.2%
			<b>Crash not at Intersection</b>	1,633	62.7%
<b>Male</b>	2,039	78.3%	<b>Urban</b>	1,175	45.1%
<b>Female</b>	453	17.4%	<b>Rural</b>	1,428	54.9%
<b>Sex Missing</b>	111	4.3%			
			<b>HEALTH OUTCOMES</b>		
<b>Not Helmeted</b>	1,475	56.7%	<b>Emergency Dept. Visit</b>	856	32.9%
<b>Helmeted</b>	957	36.8%			
<b>Helmet Missing</b>	111	6.6%	<b>Inpatient Hospital Stay</b>	487	18.7%
<b>Age &lt; 19</b>	83	3.2%	<b>Died</b>	84	3.2%
<b>Age 19-24</b>	336	12.9%			
<b>Age 25-34</b>	432	16.6%	<b>FOR CASES WITH</b>		
<b>Age 35-44</b>	441	16.9%	<b>TRAUMATIC BRAIN INJURY</b>		
				<b>Mean</b>	<b>St. Dev.</b>
<b>Age 45-54</b>	635	24.4%	<b>Medical Costs</b>	\$ 192,229	\$ 23,179
<b>Age 55-64</b>	414	15.9%			
<b>Age 65+</b>	146	5.6%	<b>Other Costs</b>	\$ 452,970	\$ 118,883
<b>Age Missing</b>	116	4.5%			
<b>Alcohol not a factor</b>	2,384	91.6%	<b>Quality of Life Costs</b>	\$ 765.360	\$ 163,274
<b>Alcohol a factor</b>	219	8.4%			
			<b>Total Comprehensive Costs</b>	\$ 1,410,559	\$ 303,474
<b>Driver was Speeding</b>	111	4.3%			
<b>Driver not Speeding</b>	2,492	95.7%	<b>Maximum Abbreviated</b>		
			<b>Injury Severity Score</b>	4.18	2.92
<b>Head On Collision</b>	49	1.9%			
<b>Not Head On Collision</b>	2,554	98.1%			

## RESULTS

In Wisconsin, in 2013, there were a total of 2,603 riders of cycles involved in crashes (Table 2). Males made up the overwhelming percentage of victims: 78%. Crashes occurred more often in rural locations (55%) than in urban locations (45%). Alcohol was indicated as being involved for 8% of crash victims. Helmet use was reported only 37% of the time, with missing helmet information in 7% of all cases. Of those involved in a motorcycle crash, 52% were hospitalized or had an ED visit. For those with TBI, the average medical cost was \$192,000, the average other costs were \$508,000, average quality of life costs were \$765,000 and average maximum abbreviated injury score (MAIS) was 4.2.

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 (3.2% vs 8.7%).

**Table 3.**  
**Number of Persons with Traumatic Brain Injury (TBI)**  
**By Helmet Use, Wisconsin, 2013**

<b>HELMET USE</b>	<b>Number</b>	<b>With TBI/ % of Total</b>
<b>Helmet Worn</b>	926	31
	100.0%	3.2%
<b>Helmet Not Worn</b>	1,347	128
	100.0%	8.7%

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 2.8 times as likely to have a TBI as those wearing helmets when only that variable is included in the model. In the full model, those not wearing a helmet are also 2.8 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. Thus, helmet use strongly predicts whether a crash victim will have a traumatic brain injury, as does alcohol use.

**Table 4.**  
**Likelihood of a Motorcycle Crash Victim**  
**Having a Traumatic Brain Injury,**  
**Wisconsin, 2013**

Explanatory Variable	Likelihood Ratio	Likelihood Ratio
<b>No Helmet</b>	<b>2.84</b>	<b>2.76</b>
<b>Helmet Missing</b>	.90	1.40
<b>Alcohol a Factor</b>		<b>2.31</b>
<b>Speeding</b>		2.23
<b>Speed Limit 26-35</b>		.79
<b>Speed Limit 36-45</b>		1.01
<b>Speed Limit 46+</b>		1.29
<b>Speed Limit Missing</b>		.48
<b>Rural Road</b>		1.08
<b>Intersection</b>		.73
<b>Multiple Vehicles</b>		.99
<b>Head On Collision</b>		.91
<b>Age &lt; 19</b>		3.88
<b>Age 19-24</b>		.89
<b>Age 25-34</b>		1.42
<b>Age 45-54</b>		1.86
<b>Age 55-64</b>		2.15
<b>Age 65+</b>		3.20
<b>Male</b>		1.07
<b>For Model:</b>		
<b>Degrees of Freedom</b>	2	19
<b>Chi-Square (sig. at .001)</b>	<b>30.1</b>	<b>77.8</b>

Likelihood ratios in bold are significant at the .001 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. For all outcomes, 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.

**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, 2013**

<b>HELMET USE</b>	<b>Medical Costs</b>	<b>Other Costs</b>	<b>Quality of Life Costs</b>	<b>Max. Abbrev. Injury Score</b>	<b>Death</b>
<b>Helmet Worn Number = 28</b>	\$ 186,103	\$ 364,494	\$ 626,910	3.23	3 9.7%
<b>Helmet Not Worn Number = 137</b>	\$ 195,019	\$ 473,671	\$ 795,212	3.77	20 15.6
<b>DIFFERENCE</b>	<b>\$ 8,916</b>	<b>\$ 109,177</b>	<b>\$ 168,302</b>	<b>0.54</b>	<b>5.9</b>

**Bold indicates that 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 2013, there would have been 85 fewer persons with TBI. Total “comprehensive” costs would have been \$103 million less – the effective cost to Wisconsin in 2013 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, 2013**

	<b>Helmet Not Worn (Actual)</b>	<b>IF Helmet Worn</b>	<b>Difference</b>
<b>Number Persons with Traumatic Brain Injury</b>	128	43	<b>85 (A)</b>
<b>Total Comprehensive Costs (medical + quality of life + other) for non-helmeted TBI Cases vs. average cost for helmeted non- TBI Cases</b>	\$ 1,463,902	\$ 256,934	<b>\$ 1,206,968 (B)</b>
<b>Cost Difference Due to Additional TBI Cases: (A) times (B)</b>			<b>\$ 103 million</b>

(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 85 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.

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