INSURANCE SPECIAL REPORT

Motorcycle Antilock Braking System (ABS)

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Introduction

According to the National Highway Traffic Safety Administration (NHTSA, 2008) motorcycle registrations increased by 75 percent during 1997-2006. Analysis by the Insurance Institute for Highway Safety of data from the Fatality Analysis Reporting System shows that, during the same time period, fatalities in motorcycle crashes increased by 128 percent. Unlike automobiles, motorcycles offer little if any occupant protection. Only 20 percent of automobile crashes result in injury or death, whereas 80 percent of motorcycle crashes have this outcome (NHTSA, 2005). Therefore any countermeasure aimed at reducing the likelihood of motorcycle crashes should significantly reduce the risk of injury or death.

One technology designed to reduce the likelihood of motorcycle crashes is antilock braking systems (ABS). While in motion, motorcycles are kept stable by the gyroscopic effect of the wheels and lateral grip of the tires. If a wheel is braked too hard, so that it locks, both lateral grip and gyroscopic effect are lost. When this occurs, the motorcycle is immediately destabilized, and any remaining tire grip is engaged in uncontrolled skidding, leaving no grip for maneuvering. ABS has independent braking sensors for each wheel. If the system detects a difference in the rotation speeds of the wheels, it partially releases brake pressure to allow the locked wheel to spin and the tire to retain grip before reapplying the brake. ABS then modulates braking pressure to achieve optimum braking.

The Highway Loss Data Institute (HLDI) initially reported on motorcycle ABS in April 2008, in which the model years of the motorcycles studied ranged from 2003 to 2007. Significant reductions in collision claim frequencies and overall losses were found for motorcycles equipped with ABS. No significant reductions were found for claim severities. This report updates and expands the initial analysis by adding the 2008 model year, increasing the number of make/series from 12 to 18, and doubling the collision exposure. This study also includes an analysis of medical payment coverage, which typically pays for operator injuries, and bodily injury liability coverage, which typically pays for passenger injuries.

Methods

Coverages

Motorcycle insurance covers damage to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for physical damage versus injuries. Also, different coverages may apply depending on who is at fault. In the present study, three different insurance coverage types were examined: collision, bodily injury liability, and medical payment. Collision insures against physical damage to a motorcycle sustained in a crash when the driver is at fault. Medical payment covers injuries sustained by motorcycle operators, whereas bodily injury liability typically insures against injuries to motorcycle passengers.

Rated Drivers (Riders)

For insurance purposes, a rated driver is assigned to each motorcycle on a policy. The rated driver is the one who typically is considered to represent the greatest loss potential for the insured vehicle. In a multiple-vehicle/driver household, the driver assigned to a vehicle can vary by insurance company and state. Information on the actual driver at the time of a loss is not available in the HLDI database. HLDI collects a limited number of factors about rated drivers. For the present study, data were stratified by rated driver age group (<25, 25-39, 40-64, 65+, or unknown) and gender (male, female, or unknown).

Subject Motorcycles

For motorcycles to be included in the present study, their vehicle identification numbers (VINs) had to have an ABS indicator. This allowed for very tight control over the study population. Twenty motorcycles met this criterion, but two of them did not have claims and therefore were excluded. There were motorcycles available with ABS that were not included because their VINs did not have an ABS indicator.

All of the Honda motorcycles (both ABS and non-ABS) were equipped with combined braking systems (CBS). CBS applies braking force to both wheels when either the rear or front brake control is engaged. Even with CBS, wheel lock still is possible. With or without ABS, CBS may affect collision losses. Due to the small sample of non-CBS motorcycles in the study, the effect of CBS could not be evaluated. This is not expected to bias the results because the motorcycles in the study differed only by whether or not they were equipped with ABS. Each ABS/non-ABS pair either did or did not have CBS. ABS showed a benefit in both the CBS and non-CBS groups, suggesting the presence of CBS on some of the motorcycles did not confound the observed effect of ABS.

Analysis Methods

Data were collected by vehicle make and series, rated driver age and gender, and vehicle age and density. Vehicle density was defined as the number of registered vehicles (<100, 100-499, and 500+) per square mile. Vehicle age was defined as the difference between the calendar year and model year, measured in years.

As previously mentioned, rated driver age group and gender were included in the analysis. The dataset also was stratified by make/series and vehicle density (<100, 100-499, and 500+ vehicles per square mile). For example, a 1-year-old Honda Gold Wing, equipped with ABS, with a 40-64 year-old male as the rated driver, and garaged in an area with a vehicle density of 100-499 vehicles per square mile constituted one unit of observation. The distributions of motorcycle exposure by coverage type for the six independent variables are listed in the Appendices. Rated driver factors and vehicle density were included to control for their potential impact on losses and not to produce estimates for these variables. The estimated parameters for these variables may not generalize from this subset to the much larger motorcycle population.

Regression analysis was used to quantify the effect of ABS on motorcycle losses while controlling for other covariates. Claim frequency was modeled using a Poisson distribution, whereas claim severity was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Reference categories for the categorical independent variables were assigned to the values with the highest exposure. The reference categories were as follows: make/series = Honda Gold Wing, ABS = without ABS, rated driver age range = 40-64, vehicle density = 100-499 vehicles per square mile, and rated driver gender = male. Losses for each unit of observation were weighted by the exposure in the linear regression. The key independent variable in the model, ABS, was treated as categorical. Models were constructed that examined the interaction of the rated driver factors and vehicle density with the presence or absence of ABS. None of these interactions were found to be significant.

RESULTS

COLLISION COVERAGE

Summary results of the regression analysis of motorcycle collision claim frequencies using the Poisson distribution are listed in Table 1. Results for all independent variables in the model, including ABS, had p-values less than 0.05, indicating their effects on claim frequencies were statistically significant. Detailed results of the regression analysis using claim frequency as the dependent variable are listed in Table 2. The table shows estimates and significance levels for the individual values of the categorical variables. To make results more illustrative, a column was added that contains the exponents of the estimates. The exponent of the intercept equals 0.0000687 claims per day, or 2.5 claims per 100 insured vehicle years. The intercept outlines losses for the reference (baseline) categories: the estimate corresponds to the claim frequency for a Honda Gold Wing without ABS, with vehicle age 0, garaged in a medium vehicle density area, and driven by a male age 40-64. The remaining estimates are in the form of multiples, or ratios relative to the reference categories. For example, the estimate corresponding to female gender equals 0.87, so female rated drivers had estimated claim frequencies 13 percent lower than those for male rated drivers.

The estimate corresponding to motorcycle ABS (-0.25) was highly significant ($p<0.0001$). The estimate corresponded to a 22 percent reduction in claim frequencies for motorcycles equipped with ABS. Individual make/series motorcycles were included in the model, and estimates of their effect on collision claim frequencies were reported in Table 2. As previously mentioned, the reference category for the make/series variable was the Honda Gold Wing. Significant predictions for make/series ranged from 1.37 for the Triumph Tiger to 5.4 for the Honda CBR1000RR. All make/series estimates were significant at the $p=0.05$ level except for the Aprilia Caponord and Suzuki V-Strom 650. Vehicle age significantly affected collision claim frequency. Claim frequencies were estimated to decrease 19 percent ($p<0.0001$) for each 1-year increase in vehicle age.

Driver age was highly significant in predicting motorcycle collision claim frequency. Compared with losses for rated drivers ages 40-64 (reference category), estimated claim frequencies were 145 percent higher ($p<0.0001$) for rated drivers 24 and younger, 23 percent higher ($p<0.0001$) for rated drivers ages 25-39 and 18 percent higher ($p=0.003$) for rated drivers 65 and older. Rated driver gender also significantly predicted collision claim frequencies. Compared with losses for male rated riders (reference category), estimated claim frequencies were 8 percent lower ($p=0.02$) for drivers with unknown gender and 13 percent lower, nearly significant ($p=0.06$), for female rated drivers.

Motorcycle collision claim frequencies increased with vehicle density. Compared with losses in medium vehicle density areas (reference category), estimated claim frequencies were 9 percent higher ($p=0.04$) in high vehicle density areas and 13 percent lower ($p=0.002$) in low vehicle density areas.

Table 1 Summary Results of Linear Regression Analysis of Collision Claim Frequencies			
	Degrees of Freedom	Chi-Square	p-value
ABS	1	31.920	<0.0001
Vehicle Make/Series	17	432.810	<0.0001
Vehicle Age	1	289.610	<0.0001
Rated Driver Age	4	87.180	<0.0001
Rated Driver Gender	2	7.350	0.025
Vehicle Density	2	23.230	<0.0001

Table 2 Detailed Results of Linear Regression Analysis of Collision Claim Frequencies					
Parameter	Estimate	Exponent Estimate	Standard Error	Chi-Square	p-value
Intercept	-9.586	6.87E-05	0.046	44,115.80	<0.0001
ABS					
ABS Model	-0.246	0.782	0.044	30.8	<0.0001
Non-ABS Model	0	1.000	0		
Vehicle Make/Series					
Aprilia Caponord	0.100	1.105	1.001	0.01	0.920
Aprilia Scarabeo 500	0.871	2.390	0.270	10.44	0.001
Harley Davidson V-Rod	0.662	1.938	0.097	46.78	<0.0001
Honda CBR1000RR	1.686	5.400	0.502	11.27	0.001
Honda Gold Wing	0	1.000	0		
Honda Interceptor 800	0.882	2.417	0.078	128.03	<0.0001
Honda Reflex	0.570	1.767	0.081	49.27	<0.0001
Honda Silver Wing	0.716	2.047	0.076	89.71	<0.0001
Honda ST1300	0.241	1.273	0.080	9.16	0.003
Kawasaki Concours 14	0.941	2.561	0.098	91.47	<0.0001
Suzuki Bandit 1250	0.941	2.563	0.136	48.13	<0.0001
Suzuki B-King	1.432	4.187	0.222	41.55	<0.0001
Suzuki Burgman 650	0.660	1.935	0.067	98.1	<0.0001
Suzuki SV650	1.093	2.983	0.084	169.3	<0.0001
Suzuki V-Strom 650	0.104	1.110	0.127	0.68	0.411
Triumph Sprint ST	1.065	2.901	0.104	104.47	<0.0001
Triumph Tiger	0.314	1.368	0.152	4.23	0.040
Yamaha FJR1300	0.449	1.567	0.062	53	<0.0001
Vehicle Age	-0.214	0.807	0.013	276.61	<0.0001
Rated Driver Age					
Unknown	0.362	1.436	0.068	28.04	<0.0001
14-24	0.897	2.452	0.108	69.66	<0.0001
25-39	0.209	1.232	0.050	17.24	<0.0001
40-64	0	1.000	0		
65+	0.167	1.181	0.057	8.66	0.003
Rated Driver Gender					
Female	-0.137	0.872	0.074	3.46	0.063
Male	0	1.000	0		
Unknown	-0.087	0.917	0.038	5.16	0.023
Vehicle Density					
0-99	-0.136	0.873	0.043	9.95	0.002
100-499	0	1.000	0		
500+	0.081	1.085	0.040	4.18	0.041

Summary results of the regression analysis of motorcycle collision claim severities using the Gamma distribution are listed in Table 3. Of the six variables included in the analysis, only vehicle make/series and vehicle age had p-values less than 0.05. Neither the rated driver nor the driving environment significantly affected the claim size.

Detailed results of the regression analysis using motorcycle collision claim severity as the dependent variable are listed in Table 4. The structure of the table, as well as the variables and reference categories, are the same as those used for claim frequency in Table 2. The variables and reference categories that were used for claim frequency were used for claim severity. The exponent of the intercept equals $8,829. The intercept outlines losses for the reference (baseline) categories: the estimate corresponds to the claim severity for a Honda Gold Wing without ABS, with vehicle age of 0, garaged in a medium vehicle density area, and driven by a male age 40-64.

The estimate corresponding to the ABS effect was a 4 percent increase in claim severity. However, the estimate was not significant (p=0.3), indicating ABS does not affect claim severity. As previously mentioned, vehicle make/series and vehicle age were significant predictors of claim severity. Significant estimates of claim severities for the 18 make/series motorcycles, compared with those for the Honda Gold Wing (reference category), ranged from 23 percent lower for the Honda ST1300 to 74 percent lower for the Honda Reflex. As motorcycles age, their claim severities decrease. The model estimated a 4 percent decrease (p<0.0001) in claim severity per 1-year increase in vehicle age.

Table 3 Summary Results of Linear Regression Analysis of Collision Claim Severities			
	Degrees of Freedom	Chi-Square	p-value
ABS	1	1.020	0.312
Vehicle Make/Series	17	643.930	<0.0001
Vehicle Age	1	16.070	<0.0001
Rated Driver Age	4	4.600	0.331
Rated Driver Gender	2	2.910	0.233
Vehicle Density	2	5.340	0.069

Table 4 Detailed Results of Linear Regression Analysis of Collision Claim Severities					
Parameter	Estimate	Exponent Estimate	Standard Error	Chi-Square	p-value
Intercept	9.086	8,829.03	0.040	52,266.80	<0.0001
ABS					
ABS Model	0.037	1.038	0.0371	1.02	0.313
Non-ABS Model	0	1.000	0		
Vehicle Make/Series					
Aprilia Caponord	-0.497	0.608	0.825	0.36	0.547
Aprilia Scarabeo 500	-1.139	0.320	0.223	26.16	<0.0001
Harley Davidson V-Rod	-0.503	0.605	0.083	36.59	<0.0001
Honda CBR1000RR	-0.199	0.819	0.479	0.17	0.677
Honda Gold Wing	0	1.000	0		
Honda Interceptor 800	-0.587	0.556	0.0654	80.56	<0.0001
Honda Reflex	-1.355	0.258	0.0673	404.93	<0.0001
Honda Silver Wing	-1.054	0.349	0.0635	275.2	<0.0001
Honda ST1300	-0.260	0.771	0.067	15.04	0.0001
Kawasaki Concours 14	-0.406	0.667	0.0833	23.7	<0.0001
Suzuki Bandit 1250	-0.826	0.438	0.113	53.43	<0.0001
Suzuki B-King	-0.609	0.544	0.1883	10.46	0.001
Suzuki Burgman 650	-0.845	0.429	0.0562	226.35	<0.0001
Suzuki SV650	-0.793	0.453	0.0714	123.27	<0.0001
Suzuki V-Strom 650	-0.850	0.427	0.1066	63.67	<0.0001
Triumph Sprint ST	-0.454	0.635	0.0876	26.83	<0.0001
Triumph Tiger	-0.491	0.612	0.1261	15.18	<0.0001
Yamaha FJR1300	-0.477	0.621	0.0513	86.47	<0.0001
Vehicle Age	-0.042	0.959	0.010	16.25	<0.0001
Rated Driver Age					
Unknown	0.089	1.094	0.060	2.2	0.139
14-24	0.122	1.130	0.088	1.95	0.163
25-39	0.011	1.011	0.043	0.07	0.794
40-64	0	1.000	0		
65+	0.047	1.048	0.047	1	0.317
Rated Driver Gender					
Female	0.091	1.095	0.062	2.17	0.140
Male	0	1.000	0		
Unknown	-0.014	0.986	0.032	0.2	0.656
Vehicle Density					
0-99	0.038	1.039	0.036	1.1	0.295
100-499	0	1.000	0		
500+	0.080	1.083	0.034	5.57	0.018

Table 5 summarizes the effects of the independent variables on motorcycle collision overall losses, derived from the claim frequency and claim severity models. Overall losses can be calculated by simple multiplication because the estimates for the effect of ABS on claim frequency and claim severity were in the form of ratios relative to the reference (baseline) categories. The standard error for overall losses can be calculated by taking the square root of the sum of the squared standard errors for claim frequency and severity. Based on the value of the estimate and the associated standard error, the corresponding two-sided p-value was derived from a standard normal distribution approximation.

The estimated effect of ABS was a significant (p=0.0003) 19 percent decrease in collision overall losses. This is a strong indication that ABS is effective in reducing collision overall losses for motorcycles. Estimated overall losses for the 18 make/series motorcycles, compared with those for the Honda Gold Wing (reference category), ranged from 54 percent lower for the Honda Reflex to 342 percent higher for the Honda CBR1000RR. Ten of the make/series estimates were significantly different from the reference category, and the other seven estimates were not significant. Vehicle age also had significant effects in reducing collision overall losses. Collision overall losses were estimated to decrease 23 percent (p<0.0001) for each 1-year increase in vehicle age. Driver age was a significant predictor of motorcycle collision overall losses. Compared with losses for rated drivers ages 40-64 (reference category), estimated overall losses were 177 percent higher (p<0.0001) for rated drivers 24 and younger, 25 percent higher (p=0.0011) for rated drivers ages 25-39, and 24 percent higher (p=0.004) for rated drivers 65 or older. Estimated overall losses for drivers with unknown gender were 10 percent lower (p=0.04) than those for male rated drivers (reference category). Estimated overall losses for rated female drivers were not significant.

Motorcycle collision overall losses were predicted to increase with vehicle density. Compared with losses in medium vehicle density in areas (reference category), estimated overall losses were 17 percent higher (p=0.002) in high vehicle density areas and 9 percent lower, nearly significant (p=0.08), in low vehicle density areas.

Table 5 Results for Collision Overall Losses Derived from Claim Frequency and Severity Models

Parameter	Frequency Estimate	Frequency Standard Error	Severity Estimate	Severity Standard Error	Overall Losses Estimate	Overall Losses Standard Error	Overall Losses Exponent Estimate	Overall Losses p-value
Intercept	-9.586	0.046	9.086	0.040	-0.500	0.060	0.606	<0.0001
ABS								
ABS Model	-0.246	0.044	0.037	0.037	-0.209	0.058	0.812	0.0003
Non-ABS Model	0	0	0	0	0	0	1	
Vehicle Make/Series								
Aprilia Caponord	0.100	1.001	-0.497	0.825	-0.397	1.297	0.673	0.760
Aprilia Scarabeo 500	0.871	0.270	-1.139	0.223	-0.267	0.350	0.765	0.444
Harley Davidson V-Rod	0.662	0.097	-0.503	0.083	0.159	0.128	1.173	0.212
Honda CBR1000RR	1.686	0.502	-0.199	0.479	1.487	0.694	4.424	0.032
Honda Gold Wing	0	0	0	0	0	0	1	
Honda Interceptor 800	0.882	0.078	-0.587	0.065	0.295	0.102	1.343	0.004
Honda Reflex	0.570	0.081	-1.355	0.067	-0.785	0.105	0.456	<0.0001
Honda Silver Wing	0.716	0.076	-1.054	0.064	-0.337	0.099	0.714	0.0006
Honda ST1300	0.241	0.080	-0.260	0.067	-0.019	0.104	0.981	0.856
Kawasaki Concours 14	0.941	0.098	-0.406	0.083	0.535	0.129	1.707	<0.0001
Suzuki Bandit 1250	0.941	0.136	-0.826	0.113	0.115	0.177	1.122	0.513
Suzuki B-King	1.432	0.222	-0.609	0.188	0.823	0.291	2.277	0.005
Suzuki Burgman 650	0.660	0.067	-0.845	0.056	-0.185	0.087	0.831	0.033
Suzuki SV650	1.093	0.084	-0.793	0.071	0.300	0.110	1.350	0.006
Suzuki V-Strom 650	0.104	0.127	-0.850	0.107	-0.746	0.165	0.474	<0.0001
Triumph Sprint ST	1.065	0.104	-0.454	0.088	0.611	0.136	1.842	<0.0001
Triumph Tiger	0.314	0.152	-0.491	0.126	-0.178	0.198	0.837	0.370
Yamaha FJR1300	0.449	0.062	-0.477	0.051	-0.028	0.080	0.973	0.731
Vehicle Age	-0.214	0.013	-0.042	0.010	-0.256	0.017	0.774	<0.0001
Rated Driver Age								
Unknown	0.362	0.068	0.089	0.060	0.451	0.091	1.570	<0.0001
14-24	0.897	0.108	0.122	0.088	1.019	0.1387	2.771	<0.0001
25-39	0.209	0.050	0.011	0.043	0.220	0.0661	1.246	0.001
40-64	0	0	0	0	0	0	1	
65+	0.167	0.057	0.047	0.047	0.214	0.074	1.238	0.004
Rated Driver Gender								
Female	-0.137	0.074	0.091	0.062	-0.046	0.096	0.955	0.634
Male	0	0	0	0	0	0	1	
Unknown	-0.087	0.038	-0.014	0.032	-0.101	0.050	0.904	0.043
Vehicle Density								
0-99	-0.136	0.043	0.038	0.036	-0.098	0.056	0.907	0.082
100-499	0	0	0	0	0	0	1	
500+	0.081	0.040	0.080	0.034	0.161	0.052	1.174	0.002

Medical Payment Coverage

Summary results of the regression analysis of motorcycle medical payment claim frequencies using the Poisson distribution are listed in Table 6. Results for the following independent variables: ABS, vehicle make/series, vehicle age and rated driver gender had p-values less than 0.05, indicating their effects on claim frequencies were statistically significant. Rated driver age was marginally significant while vehicle density was not significant.

Detailed results of the regression analysis using claim frequency as the dependent variable are listed in Table 6. The exponent of the intercept equals 0.000046 claims per day, or 16.8 claims per 1,000 insured vehicle years. The estimate corresponding to motorcycle ABS (-0.36) was highly significant (p=0.003). The estimate corresponded to a 30 percent reduction in medical payment claim frequencies for motorcycles equipped with ABS.

The estimate corresponding to the ABS effect on medical payment claim severity was a nonsignificant (p=0.32) 13 percent increase in claim severity, indicating ABS does not affect claim severity. Rated driver age and make/series were the strongest predictors of claim severity. The predictive value of make/series is perhaps a proxy for policy limits. More expensive motorcycles are more likely to have higher policy limits than less expensive motorcycles. Higher policy limits allow higher claim severities to occur in the event of a crash. The Honda Gold Wing is the most expensive motorcycle in the study. The make/series estimates for the other motorcycles studied are less than that for the Gold Wing except for the Honda CBR1000RR, which typically is among the motorcycles with the highest collision losses primarily due to its very high claim frequency.

Overall losses for medical payment coverage were calculated in the same fashion as collision coverage. ABS was estimated to reduce overall medical payment losses by 21 percent, although the estimate was not statistically significant (p=0.16).

Table 6 Summary Results of Linear Regression Analysis of Medical Payment Claim Frequencies

	Degrees of Freedom	Chi-Square	p-value
ABS	1	9.640	0.002
Vehicle Make/Series	17	92.390	<0.0001
Vehicle Age	1	57.850	<0.0001
Rated Driver Age	4	9.140	0.058
Rated Driver Gender	2	7.840	0.020
Vehicle Density	2	1.820	0.403

Table 7 Detailed Results of Linear Regression Analysis of Medical Payment Claim Frequencies

Parameter	Estimate	Exponent Estimate	Standard Error	Chi-Square	p-value
Intercept	-9.985	4.61E-05	0.109	8,387.580	<0.0001
ABS					
ABS Model	-0.358	0.699	0.119	9.050	0.003
Non-ABS Model	0	1	0		
Vehicle Make/Series					
Aprilia Scarabeo 500	0.041	1.042	1.004	0.000	0.968
Harley Davidson V-Rod	0.206	1.229	0.261	0.620	0.431
Honda CBR1000RR	0.759	2.135	0.309	6.010	0.014
Honda CBR600RR	1.445	4.241	0.177	66.640	<0.0001
Honda Gold Wing	0	1	0		
Honda Interceptor 800	0.367	1.444	0.252	2.120	0.146
Honda Reflex	0.744	2.104	0.168	19.620	<0.0001
Honda Silver Wing	0.559	1.750	0.182	9.480	0.002
Honda ST1300	0.582	1.789	0.170	11.640	0.001
Kawasaki Concours 14	0.502	1.651	0.292	2.950	0.086
Suzuki Bandit 1250	0.343	1.410	0.416	0.680	0.409
Suzuki B-King	0.617	1.854	0.714	0.750	0.387
Suzuki Burgman 650	0.347	1.415	0.191	3.300	0.069
Suzuki SV650	1.137	3.119	0.187	37.010	<0.0001
Suzuki V-Strom 650	0.406	1.501	0.257	2.500	0.114
Triumph Sprint ST	1.029	2.797	0.257	16.020	<0.0001
Triumph Tiger	0.677	1.968	0.310	4.760	0.029
Yamaha FJR1300	0.028	1.028	0.190	0.020	0.884
Vehicle Age	-0.234	0.792	0.031	55.330	<0.0001
Rated Driver Age					
Unknown	0.064	1.066	0.141	0.210	0.649
14-24	0.529	1.698	0.191	7.680	0.006
25-39	0.077	1.080	0.125	0.380	0.537
40-64	0	1	0		
65+	-0.165	0.848	0.150	1.210	0.271
Rated Driver Gender					
Female	-0.072	0.931	0.188	0.150	0.703
Male	0	1	0		
Unknown	0.253	1.288	0.093	7.340	0.007
Vehicle Density					
0-99	-0.028	0.972	0.096	0.080	0.772
100-499	0	1	0		
500+	0.104	1.109	0.096	1.180	0.277

Table 8 Summary Results of Linear Regression Analysis of Medical payment Claim Severities

	Degrees of Freedom	Chi-Square	p-value
ABS	1	1.010	0.314
Vehicle Make/Series	17	53.340	<0.0001
Vehicle Age	1	0.000	0.981
Rated Driver Age	4	34.650	<0.0001
Rated Driver Gender	2	15.970	0.0003
Vehicle Density	2	0.060	0.970

Table 9 Detailed Results of Linear Regression Analysis of Medical Payment Claim Severities

Parameter	Estimate	Exponent Estimate	Standard Error	Chi-Square	p-value
Intercept	8.018	3,034.798	0.113	5,032.420	<0.0001
ABS					
ABS Model	0.120	1.127	0.120	1.000	0.318
Non-ABS Model	0	1	0		
Vehicle Make/Series					
Aprilia Scarabeo 500	-1.129	0.324	0.897	1.580	0.208
Harley Davidson V-Rod	-0.791	0.453	0.304	6.790	0.009
Honda CBR1000RR	0.076	1.079	0.323	0.060	0.814
Honda CBR600RR	-0.206	0.814	0.195	1.120	0.291
Honda Gold Wing	0	1	0		
Honda Interceptor 800	-0.440	0.644	0.262	2.820	0.093
Honda Reflex	-0.410	0.664	0.1716	5.720	0.017
Honda Silver Wing	-0.570	0.566	0.1949	8.540	0.004
Honda ST1300	-0.441	0.643	0.1672	6.970	0.008
Kawasaki Concours 14	-0.172	0.842	0.3156	0.300	0.586
Suzuki Bandit 1250	-0.471	0.624	0.4172	1.280	0.259
Suzuki B-King	-0.049	0.952	0.905	0	0.957
Suzuki Burgman 650	-0.957	0.384	0.1965	23.740	<0.0001
Suzuki SV650	-0.566	0.568	0.1977	8.190	0.004
Suzuki V-Strom 650	-0.746	0.474	0.2535	8.660	0.003
Triumph Sprint ST	-0.973	0.378	0.2758	12.460	0.0004
Triumph Tiger	-0.323	0.724	0.3219	1.010	0.316
Yamaha FJR1300	-0.549	0.578	0.1772	9.590	0.002
Vehicle Age	-0.001	0.999	0.033	0.000	0.981
Rated Driver Age					
Unknown	0.756	2.130	0.152	24.760	<0.0001
14-24	-0.422	0.656	0.206	4.200	0.040
25-39	0.073	1.076	0.147	0.250	0.617
40-64	0	1	0		
65+	0.093	1.097	0.154	0.360	0.547
Rated Driver Gender					
Female	0.399	1.490	0.191	4.380	0.036
Male	0	1	0		
Unknown	-0.319	0.727	0.105	9.270	0.002
Vehicle Density					
0-99	0.023	1.023	0.098	0.050	0.818
100-499	0	1	0		
500+	0.018	1.019	0.103	0.030	0.858

Table 10 Results for Medical Payment Overall Losses Derived from Claim Frequency and Severity Models

Parameter	Frequency Estimate	Frequency Standard Error	Severity Estimate	Severity Standard Error	Overall Losses Estimate	Overall Losses Standard Error	Overall Losses Exponent Estimate	Overall Losses p-value
Intercept	-9.985	0.109	8.018	0.113	-1.967	0.157	0.140	<0.0001
ABS								
ABS Model	-0.358	0.119	0.120	0.120	-0.239	0.169	0.788	0.157
Non-ABS Model	0	0	0	0	0	0	1	
Vehicle Make/Series								
Aprilia Scarabeo 500	0.041	1.004	-1.129	0.897	-1.088	1.346	0.337	0.419
Harley Davidson V-Rod	0.206	0.261	-0.791	0.304	-0.585	0.401	0.557	0.144
Honda CBR1000RR	0.759	0.309	0.076	0.323	0.834	0.447	2.303	0.062
Honda CBR600RR	1.445	0.177	-0.206	0.195	1.239	0.263	3.452	<0.0001
Honda Gold Wing	0	0	0	0	0	0	1	
Honda Interceptor 800	0.367	0.252	-0.440	0.262	-0.073	0.364	0.930	0.841
Honda Reflex	0.744	0.168	-0.410	0.172	0.334	0.240	1.396	0.165
Honda Silver Wing	0.559	0.182	-0.570	0.195	-0.010	0.266	0.990	0.969
Honda ST1300	0.582	0.170	-0.441	0.167	0.140	0.239	1.151	0.557
Kawasaki Concours 14	0.502	0.292	-0.172	0.316	0.330	0.430	1.390	0.443
Suzuki Bandit 1250	0.343	0.416	-0.471	0.417	-0.128	0.589	0.880	0.828
Suzuki B-King	0.617	0.714	-0.049	0.905	0.568	1.153	1.765	0.622
Suzuki Burgman 650	0.347	0.191	-0.957	0.197	-0.610	0.274	0.543	0.026
Suzuki SV650	1.137	0.187	-0.566	0.198	0.5716	0.272	1.771	0.036
Suzuki V-Strom 650	0.406	0.257	-0.746	0.254	-0.3400	0.361	0.712	0.346
Triumph Sprint ST	1.029	0.257	-0.973	0.276	0.055	0.377	1.057	0.884
Triumph Tiger	0.677	0.310	-0.323	0.322	0.354	0.447	1.425	0.428
Yamaha FJR1300	0.028	0.190	-0.549	0.177	-0.521	0.260	0.594	0.045
Vehicle Age	-0.234	0.031	-0.001	0.033	-0.235	0.046	0.791	<0.0001
Rated Driver Age								
Unknown	0.064	0.141	0.756	0.152	0.820	0.208	2.271	<0.0001
14-24	0.529	0.191	-0.422	0.206	0.108	0.281	1.113	0.702
25-39	0.077	0.125	0.073	0.147	0.150	0.192	1.162	0.435
40-64	0	0	0	0	0	0	1	
65+	-0.165	0.150	0.093	0.154	-0.072	0.215	0.930	0.737
Rated Driver Gender								
Female	-0.072	0.188	0.399	0.191	0.327	0.268	1.387	0.222
Male	0	0	0	0	0	0	1	
Unknown	0.253	0.093	-0.319	0.105	-0.066	0.140	0.936	0.639
Vehicle Density								
0-99	-0.028	0.096	0.023	0.098	-0.005	0.137	0.995	0.969
100-499	0	0	0	0	0	0	1	
500+	0.104	0.096	0.018	0.103	0.122	0.140	1.130	0.384

Bodily Injury Liability Liability Coverage

Due to limited exposure, only 12 of the 18 motorcycles used in collision coverage analysis were used in analysis of bodily injury liability coverage. Summary results of the regression analysis of motorcycle bodily injury liability claim frequencies using the Poisson distribution are listed in Table 11. Results for all of the independent variables except rated driver gender had p-values less than 0.05, indicating their effects on claim frequencies were statistically significant.

Detailed results of the regression analysis using claim frequency as the dependent variable are listed in Table 12. The exponent of the intercept equals 0.0000085 claims per day, or 3.1 claims per 1,000 insured vehicle years. The estimate corresponding to motorcycle ABS (-0.394) was significant ($p = 0.03$). The estimate corresponded to a 33 percent reduction in bodily injury liability claim frequencies for motorcycles equipped with ABS. The estimated claim frequency for rated drivers 24 and younger was more than 4 times that for rated drivers ages 40-64 (reference category).

Of the 12 estimates for make/series, only two were statistically different from the reference make/series. Claim frequencies were estimated to be 0.474 for the Yamaha FJR1300 and 2.614 for the Honda CBR1000RR. Claim frequencies were estimated to decrease 16 percent ($p = 0.0002$) for each 1-year increase in vehicle age.

None of the variables in the analysis were shown to have a statistically significant impact on bodily injury liability claim severity. Although ABS was estimated to reduce overall bodily injury liability losses by more than 43 percent, the estimate was not statistically significant ($p = 0.185$).

REFERENCES

National Highway Traffic Safety Administration. 2008. Traffic Safety Facts, 2007. Report no. DOT HS-810-990. Washington, DC: US Department of Transportation.

National Highway Traffic Safety Administration. 2005. Without Motorcycle Helmets We All Pay the Price. Washington, DC: US Department of Transportation.

Table 11 Summary Results of Linear Regression Analysis of Bodily Injury Liability Claim Frequencies	Degrees of Freedom	Chi-Square	p-value
ABS	1	5.050	0.025
Vehicle Make/Series	11	22.610	0.020
Vehicle Age	1	14.540	0.0001
Rated Driver Age	4	17.980	0.001
Rated Driver Gender	2	4.010	0.135
Vehicle Density	2	6.420	0.040

Table 12 Detailed Results of Linear Regression Analysis of Bodily Injury Liability Claim Frequencies

Parameter	Estimate	Exponent Estimate	Standard Error	Chi-Square	p-value
Intercept	-11.679	8.47E-06	0.159	5,429.750	<0.0001
ABS					
ABS Model	-0.394	0.674	0.182	4.690	0.030
Non-ABS Model	0	1	0		
Vehicle Make/Series					
Harley Davidson V-Rod	-0.033	0.968	0.409	0.010	0.936
Honda CBR1000RR	0.961	2.614	0.342	7.900	0.005
Honda Gold Wing	0.000	1.000	0.000		
Honda Interceptor 800	-0.243	0.784	0.360	0.460	0.500
Honda Reflex	-0.689	0.502	0.3926	3.080	0.079
Honda Silver Wing	0.035	1.036	0.284	0.020	0.901
Honda ST1300	0.015	1.015	0.260	0.000	0.955
Kawasaki Concours 14	-0.225	0.799	0.517	0.190	0.664
Suzuki Bandit 1250	-1.088	0.337	1.006	1.170	0.280
Suzuki Burgman 650	-0.390	0.677	0.330	1.390	0.238
Suzuki SV650	-0.066	0.936	0.363	0.030	0.855
Yamaha FJR1300	-0.747	0.474	0.316	5.600	0.018
Vehicle Age	-0.176	0.839	0.047	14.110	0.0002
Rated Driver Age					
Unknown	0.159	1.172	0.288	0.300	0.582
14-24	1.415	4.116	0.353	16.110	<0.0001
25-39	-0.007	0.993	0.233	-	0.976
40-64	0	1	0		
65+	0.354	1.424	0.185	3.660	0.056
Rated Driver Gender					
Female	-0.153	0.858	0.331	0.210	0.643
Male	0	1	0		
Unknown	-0.289	0.749	0.147	3.860	0.049
Vehicle Density					
0-99	-0.163	0.850	0.163	1.000	0.316
100-499	0	1	0		
500+	0.257	1.293	0.150	2.930	0.087

Table 13 Summary Results of Linear Regression Analysis of Bodily Injury Liability Claim Severities

	Degrees of Freedom	Chi-Square	p-value
ABS	1	0.200	0.652
Vehicle Make/Series	11	6.490	0.839
Vehicle Age	1	0.230	0.628
Rated Driver Age	4	4.520	0.341
Rated Driver Gender	2	0.150	0.928
Vehicle Density	2	0.200	0.906

Table 14 Detailed Results of Linear Regression Analysis of Bodily Injury Liability Claim Severities

Parameter	Estimate	Exponent Estimate	Standard Error	Chi-Square	p-value
Intercept	10.150	25,578.310	0.293	1,201.140	<0.0001
ABS					
ABS Model	-0.179	0.836	0.393	0.210	0.648
Non-ABS Model	0	1	0		
Vehicle Make/Series					
Harley Davidson V-Rod	-0.289	0.749	0.994	0.080	0.771
Honda CBR1000RR	0.108	1.114	0.768	0.020	0.888
Honda Gold Wing	0	1	0		
Honda Interceptor 800	0.622	1.863	0.748	0.690	0.405
Honda Reflex	-1.273	0	0.906	1.980	0.160
Honda Silver Wing	-0.856	0.425	0.872	0.960	0.326
Honda ST1300	-0.512	0.599	0.531	0.930	0.334
Kawasaki Concours 14	-0.572	0.564	0.832	0.470	0.491
Suzuki Bandit 1250	-0.014	0.986	1.535	0.000	0.993
Suzuki Burgman 650	-0.862	0.422	0.696	1.530	0.216
Suzuki SV650	-0.144	0.866	0.913	0.020	0.875
Yamaha FJR1300	-0.003	0.997	0.609	0	0.996
Vehicle Age	-0.043	0.958	0.088	0.240	0.626
Rated Driver Age					
Unknown	-1.347	0.260	0.699	3.710	0.054
14-24	-0.665	0.514	0.806	0.680	0.409
25-39	-0.097	0.908	0.681	0.020	0.887
40-64	0	1	0		
65+	0.238	1.269	0.390	0.370	0.541
Rated Driver Gender					
Female	0.226	1.254	0.671	0.110	0.736
Male	0	1	0		
Unknown	0.079	1.082	0.320	0.060	0.806
Vehicle Density					
0-99	0.052	1.054	0.336	0.020	0.876
100-499	0	1	0		
500+	0.162	1.176	0.367	0.190	0.659

Table 15 Results for Bodily Injury Liability Overall Losses Derived from Claim Frequency and Severity Models

Parameter	Frequency		Severity		Overall Losses			
	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error	Exponent Estimate	p-value
Intercept	-11.679	0.159	10.150	0.293	-1.529	0.333	0.217	<0.0001
ABS								
ABS Model	-0.394	0.182	-0.179	0.393	-0.574	0.433	0.563	0.185
Non-ABS Model	0	0	0	0	0	0	1	
Vehicle Make/Series								
Harley Davidson V-Rod	-0.033	0.409	-0.289	0.994	-0.322	1.075	0.725	0.765
Honda CBR1000RR	0.961	0.342	0.108	0.768	1.069	0.841	2.912	0.204
Honda Gold Wing	0	0	0	0	0	0	1	
Honda Interceptor 800	-0.243	0.360	0.622	0.748	0.379	0.830	1.461	0.648
Honda Reflex	-0.689	0.393	-1.273	0.906	-1.962	0.987	0.141	0.047
Honda Silver Wing	0.035	0.284	-0.856	0.872	-0.821	0.917	0.440	0.371
Honda ST1300	0.015	0.260	-0.512	0.531	-0.498	0.591	0.608	0.400
Kawasaki Concours 14	-0.225	0.517	-0.572	0.832	-0.797	0.979	0.451	0.416
Suzuki Bandit 1250	-1.088	1.006	-0.014	1.535	-1.102	1.836	0.332	0.548
Suzuki Burgman 650	-0.390	0.330	-0.862	0.696	-1.251	0.770	0.286	0.104
Suzuki SV650	-0.066	0.363	-0.144	0.913	-0.210	0.982	0.811	0.831
Yamaha FJR1300	-0.747	0.316	-0.003	0.609	-0.751	0.686	0.472	0.274
Vehicle Age	-0.176	0.047	-0.043	0.088	-0.219	0.100	0.803	0.028
Rated Driver Age								
Unknown	0.159	0.288	-1.347	0.699	-1.188	0.756	0.305	0.116
14-24	1.415	0.353	-0.665	0.806	0.750	0.879	2.116	0.394
25-39	-0.007	0.233	-0.097	0.681	-0.104	0.720	0.901	0.885
40-64	0	0	0	0	0	0	1	
65+	0.354	0.185	0.238	0.390	0.592	0.431	1.808	0.170
Rated Driver Gender								
Female	-0.153	0.331	0.226	0.671	0.073	0.748	1.076	0.922
Male	0	0	0	0	0	0	1	
Unknown	-0.289	0.147	0.079	0.320	-0.210	0.352	0.810	0.550
Vehicle Density								
0-99	-0.163	0.163	0.052	0.336	-0.111	0.373	0.895	0.767
100-499	0	0	0	0	0	0	1	
500+	0.257	0.150	0.162	0.367	0.419	0.397	1.520	0.291

Appendix A Distribution of Exposure for Independent Variables, Collision Coverage

Vehicle Make/Series	Exposure without ABS	Percent of Series	Exposure with ABS	Percent of Series
Aprilia Caponord	1	2%	64	98%
Aprilia Scarabeo 500	120	34%	234	66%
Harley Davidson V-Rod	2,052	79%	551	21%
Honda CBR1000RR	22	89%	3	11%
Honda Gold Wing	61,949	80%	15,712	20%
Honda Interceptor 800	4,335	76%	1,404	24%
Honda Reflex	6,001	87%	909	13%
Honda Silver Wing	5,961	84%	1,122	16%
Honda ST1300	6,781	68%	3,142	32%
Kawasaki Concours 14	1,120	53%	978	47%
Suzuki Bandit 1250	885	82%	198	18%
Suzuki B-King	202	99%	3	1%
Suzuki Burgman 650	7,447	86%	1,198	14%
Suzuki SV650	2,702	95%	131	5%
Suzuki V-Strom 650	2,339	85%	426	15%
Triumph Sprint ST	1,314	66%	680	34%
Triumph Tiger	1,470	84%	281	16%
Yamaha FJR1300	6,397	37%	10,765	63%
Total	**111,099**	**75%**	**37,801**	**25%**

	Exposure	Percent of Total
Vehicle Age		
-1	1,227	1%
0	22,160	15%
1	34,976	23%
2	31,451	21%
3	25,513	17%
4	18,997	13%
5	11,569	8%
6	3,008	2%
Rated Driver Age		
Unknown	9,034	6%
14-24	1,063	1%
25-39	16,550	11%
40-64	104,169	70%
65+	18,084	12%
Rated Driver Gender		
Female	9,684	7%
Male	83,269	56%
Unknown	55,947	38%
Vehicle Density		
0-99	45,234	30%
100-499	60,499	41%
500+	43,168	29%

Appendix B Distribution of Exposure for Independent Variable, Medical Payment Coverage

Vehicle Make/Series	Exposure without ABS	Percent of Series	Exposure with ABS	Percent of Series
Aprilia Scarabeo 500	31	35%	57	65%
Harley Davidson V-Rod	647	83%	129	17%
Honda CBR1000RR	273	99%	3	1%
Honda CBR600RR	784	100%	2	0%
Honda Gold Wing	17,351	81%	3,974	19%
Honda Interceptor 800	942	77%	283	23%
Honda Reflex	1,984	89%	252	11%
Honda Silver Wing	1,837	83%	368	17%
Honda ST1300	1,704	72%	673	28%
Kawasaki Concours 14	267	54%	230	46%
Suzuki Bandit 1250	226	78%	65	22%
Suzuki B-King	57	99%	1	1%
Suzuki Burgman 650	1,455	80%	362	20%
Suzuki SV650	755	96%	34	4%
Suzuki V-Strom 650	611	84%	117	16%
Triumph Sprint ST	323	64%	182	36%
Triumph Tiger	378	87%	55	13%
Yamaha FJR1300	1,045	28%	2,634	72%
Total	**30,671**	**77%**	**9,420**	**23%**

	Exposure	Percent of Total
Vehicle Age		
-1	306	1%
0	5,973	15%
1	9,330	23%
2	8,211	20%
3	6,799	17%
4	5,090	13%
5	3,323	8%
6	1,060	3%
Rated Driver Age	**Exposure (Yrs)**	**%**
Unknown	4,144	10%
14-24	582	1%
25-39	4,257	11%
40-64	25,977	65%
65+	5,130	13%
Rated Driver Gender	**Exposure (Yrs)**	**%**
Female	2,155	5%
Male	25,866	65%
Unknown	12,070	30%
Density	**Exposure (Yrs)**	**%**
0-99	13,389	33%
100-499	16,099	40%
500+	10,603	26%

Appendix C Distribution of Exposure for Independent Variable, Bodily Injury Liability Coverage

Vehicle Make/Series	Exposure without ABS	Percent of Series	Exposure with ABS	Percent of Series
Harley Davidson V-Rod	1,825	79%	471	21%
Honda CBR1000RR	1,424	100%	2	0%
Honda Gold Wing	55,249	80%	13,922	20%
Honda Interceptor 800	4,707	76%	1,472	24%
Honda Reflex	6,302	87%	920	13%
Honda Silver Wing	6,112	85%	1,110	15%
Honda ST1300	6,357	69%	2,893	31%
Kawasaki Concours 14	1,067	55%	870	45%
Suzuki Bandit 1250	962	82%	209	18%
Suzuki Burgman 650	5,109	82%	1,148	18%
Suzuki SV650	3,071	96%	137	4%
Yamaha FJR1300	4,420	30%	10,317	70%
Total	**96,605**	**74%**	**33,470**	**26%**

	Exposure	Percent of Total
Vehicle Age		
-1	1,206	1%
0	20,356	16%
1	29,044	22%
2	27,415	21%
3	23,034	18%
4	17,077	13%
5	10,458	8%
6	1,487	1%
Rated Driver Age	**Exposure (Yrs)**	**%**
Unknown	8,977	7%
14-24	1,304	1%
25-39	14,454	11%
40-64	88,583	68%
65+	16,758	13%
Rated Driver Gender	**Exposure (Yrs)**	**%**
Female	5,835	4%
Male	72,444	56%
Unknown	51,797	40%
Vehicle Density	**Exposure (Yrs)**	**%**
0-99	39,326	30%
100-499	52,750	41%
500+	38,000	29%

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