Highway Loss Data Institute Bulletin

Injury Odds and Vehicle Weight
Comparison of Hybrids and Conventional Counterparts

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INTRODUCTION

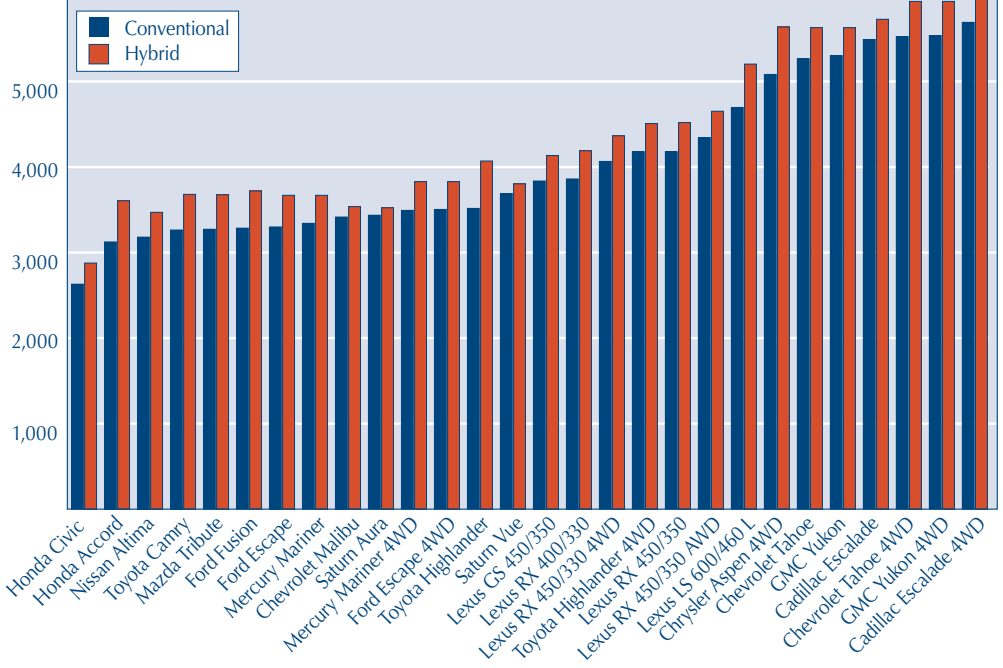
There is a strong relationship between vehicle weight and occupant safety. Larger and heavier vehicles offer more protection to their occupants than smaller, lighter vehicles. In a single vehicle crash with a deformable object, vehicle weight increases the likelihood that the object will deform, increasing the stopping distance for occupants. In collisions with bigger vehicles, the forces acting on the smaller one are higher. These forces along with other factors increase injury likelihood. Research from the Insurance Institute for Highway Safety (IIHS) dating back to the 1970s has shown that occupant death rates generally decrease as car size increases (O'Neill et al, 1977). More recently IIHS (2011) computed driver death rates for models with at least 100,000 registered vehicle years during 2006-09 and found driver death rates decreased as vehicle weight increased.

This Highway Loss Data Institute (HLDI) bulletin provides a comparative look at the injury odds for hybrid vehicles and their conventional counterparts. Hybrid vehicles are heavier than their conventional counterparts due to the added mass of the batteries and other components related to the dual power mode system. With the exception of curb weight, these matched pairs of vehicles have very similar vehicle characteristics which allows for further study of the effect of vehicle weight on injury rates.

METHODS

Insurance coverages – Automobile insurance covers damage to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on collision, personal injury protection (PIP) and medical payment (MedPay) coverages. Collision coverage insures against physical damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle. Personal injury protection coverage insures against medical, hospital, and other expenses for injuries sustained in crashes to insured drivers and other people in their vehicles, regardless of who is at fault in the collision. This coverage is sold in states with no-fault insurance systems, under which drivers are required to purchase insurance for their own protection. Medical payment coverage sold in tort states insures against injuries sustained by insured people in crashes for which they are responsible. In 2003, Colorado changed from a PIP state to a tort state[1].

FIGURE 1 CURB WEIGHT BY SERIES, HYBRID VS. CONVENTIONAL COUNTERPART



[1]Colorado was treated as a PIP state for calendar years 2002-03 and a tort state for 2004-10.

Concurrent coverage and injury odds – Concurrent coverage means a vehicle is insured under two relevant coverage types at the time of the loss. To have concurrent coverage a vehicle must have the same policy period for both coverage types (Collision and MedPay, or Collision and PIP). In addition, claims data for both coverage types are joined to see whether there are any associated claims. Injury rates are defined as the proportion of collision claims with an associated MedPay claim or PIP claim. Injury rates (π) measure how likely it is that for a given crash, a collision claim will produce a MedPay or PIP claim. Injury odds are defined as $\pi/(1-\pi)$ and they provide another way to measure injury risk. Injury odds are very close to injury rates when injury rates are small ($\pi<0.1$).

Vehicles studied – To be included in this study, a hybrid series had to have an exact conventional counterpart (e.g., Honda Civic hybrid/Honda Civic) or had a carefully selected conventional series comparable enough to be used in the pairing, (e.g., Lexus GS 450 hybrid/Lexus GS 350). The vehicles also had to have at least one injury claim to be included in the analysis. The Toyota Prius and the Honda Insight were excluded because they do not have conventionally powered counterparts. Studied vehicles were 2003-2011 models during 2002-2010 calendar years with only the four most current model years studied per calendar year. Twenty-seven series pairs were studied in the Collision and MedPay analysis with 4.3 million years of exposure, while 26 series pairs were studied in the Collision and PIP analysis with 5.6 million years of exposure. The curb weights for the most recent model year of all series pairs can be found in Figure 1. Curb weight for hybrids ranged from 2,877 pounds for the Honda Civic hybrid to 6,016 pounds for the Cadillac Escalade hybrid 4WD. Curb weight differences ranged from 3 percent heavier for the hybrid Saturn Aura four-door to 16 percent heavier for the Toyota Highlander four-door hybrid.

Analysis methods – Logistic regression analysis was used to quantify the difference between the injury odds of hybrids and their conventional counterparts while controlling for other factors. The primary predictor was the hybrid status of the vehicle. The other independent variables in this analysis included calendar year, rated driver age, rated driver gender, marital status, vehicle density (number of registered vehicles per square mile), garaging state, vehicle series and vehicle age. Reference categories for the categorical independent variables were assigned to the values with the highest exposure: calendar year = 2009, rated driver age = 40-64, gender = unknown for Collision and MedPay, female for Collision and PIP, marital status = unknown for Collision and MedPay, married for Collision and PIP, vehicle density = 500+, state = California for Collision and MedPay, Florida for collision and PIP, vehicle series= Honda Civic four-door. Vehicles with an age of -1 (e.g. 2011 models in 2010 calendar year) were grouped into vehicles with age 0.

This logistic regression produces estimates for each variable relative to the reference values for that variable. The exponent of a given estimate corresponds to the odds ratio for a particular value of a variable relative to the reference value for that variable. For example, the reference value for hybrid status was conventional vehicles. The estimate associated with the hybrid group was -0.2920, the exponent of which was 0.7468. This means that the odds of an injury for this group (hybrid) were approximately 25 percent lower than the odds for the reference group (conventional vehicles). The exponent of the intercept represents the odds of a Collision claim having an associated injury-related claim given that the value of each variable is set to the reference values and each numerical variable is set to 0.

RESULTS

Collision and MedPay – Table 1 lists exposure, claims, injury rate and injury odds by series. The results are sorted by series. Some extreme values arose when there was little exposure. These actual injury rates and injury odds show that before controlling for other covariates, injury in total is less likely in the hybrid vehicles.

Table 1 Exposure, Claims, Injury rate and Injury Odds by Series under Collision and MedPay Concurrent Coverage

	Conventional Vehicles					Hybrid Vehicles				
Make and series	Exposure	Collision Claims	MedPay Claims	Injury Rate	Injury Odds	Exposure	Collision Claims	MedPay Claims	Injury Rate	Injury Odds
Honda Accord	627,038	50,132	5,371	0.107	0.120	18,636	1,505	137	0.091	0.100
Nissan Altima	303,199	25,320	3,173	0.125	0.143	9,741	834	84	0.101	0.112
Saturn Aura	78,678	4,971	563	0.113	0.128	827	58	7	0.121	0.137
Toyota Camry	733,240	59,202	6,847	0.116	0.131	101,633	8,257	640	0.078	0.084
Honda Civic	752,964	67,578	7,663	0.113	0.128	185,131	14,678	1,391	0.095	0.105
Cadillac Escalade	730	52	5	0.096	0.106	205	13	1	0.077	0.083
Cadillac Escalade 4WD	2,552	156	9	0.058	0.061	516	60	5	0.083	0.091
Ford Escape	272,253	13,287	1,903	0.143	0.167	27,660	1,563	193	0.123	0.141
Ford Escape 4WD	208,745	9,205	1,211	0.132	0.151	21,774	1,212	113	0.093	0.103
Ford Fusion	25,530	1,659	168	0.101	0.113	5,051	336	26	0.077	0.084
Lexus GS 450/350	15,743	1,247	154	0.123	0.141	5,887	526	34	0.065	0.069
Toyota Highlander	63,208	3,667	377	0.103	0.115	17,968	1,215	93	0.077	0.083
Toyota Highlander 4WD	113,107	7,562	548	0.072	0.078	54,816	4,070	251	0.062	0.066
Lexus LS 600/460 L	202	19	1	0.053	0.056	103	6	2	0.333	0.500
Chevrolet Malibu	144,827	10,080	1,119	0.111	0.125	2,325	177	23	0.130	0.149
Mercury Mariner	22,590	1,290	165	0.128	0.147	2,348	129	14	0.109	0.122
Mercury Mariner 4WD	27,792	1,486	142	0.096	0.106	5,477	334	35	0.105	0.117
Lexus RX 400/330	10,992	660	60	0.091	0.100	9,320	681	58	0.085	0.093
Lexus RX 400/330 4WD	17,437	1,244	79	0.064	0.068	43,746	3,389	202	0.060	0.063
Lexus RX 450/350	54,451	3,428	350	0.102	0.114	798	68	5	0.074	0.079
Lexus RX 450/350 4WD	89,385	6,207	452	0.073	0.079	2,381	221	12	0.054	0.057
Chevrolet Tahoe	32,418	1,983	197	0.099	0.110	1,278	90	12	0.133	0.154
Chevrolet Tahoe 4WD	36,857	2,074	140	0.068	0.072	1,833	123	7	0.057	0.060
Mazda Tribute	12,862	680	102	0.150	0.176	337	21	5	0.238	0.313
Saturn Vue	98,770	5,030	715	0.142	0.166	7,640	458	56	0.122	0.139
GMC Yukon	11,194	698	74	0.106	0.119	675	30	4	0.133	0.154
GMC Yukon 4WD	19,822	1,208	52	0.043	0.045	950	66	6	0.091	0.100
Total	**3,776,585**	**280,125**	**31,640**	**0.113**	**0.127**	**529,059**	**40,120**	**3,416**	**0.085**	**0.093**

Table 2 summarizes the results of the logistic regression analysis of injury odds for Collision and MedPay. Results for all independent variables including hybrid status had p-values less than 0.05, indicating their effects on injury rates were statistically significant.

Table 2 Summary Results of Logistic Regression Analysis of Injury Rates under Collision and MedPay Concurrent Coverage

	Degree of Freedoms	Chi-Square	P-Value
Calendar Year	8	62.92	<0.0001
Rated Driver Age	4	633.64	<0.0001
Rated Driver Gender	2	87.33	<0.0001
Rated Driver Marital status	2	6.17	0.0457
State	32	1,351.84	<0.0001
Vehicle Age	1	78.52	<0.0001
Vehicle Density	2	21.55	<0.0001
Vehicle Series	26	778.12	<0.0001
Hybrid Status	1	221.71	<0.0001

Figure 2 compares the injury odds of hybrids with their conventional counterparts. The injury odds was estimated to be 0.14 ($p<0.0001$) for the heavier hybrids and 0.18 for their conventional counterparts. Hybrids, which are heavier, had injury odds 25.3 percent lower than their conventional counterparts. (Note: the injury odds of hybrids and conventional vehicles assume the values for each of the variables are set to the reference values. These odds will change based on changes in those assumptions; however the odds for hybrids will always be 25.3 percent lower than non-hybrids).

Figure 2 Estimated Injury Odds under Collision and MedPay Concurrent Coverage, Hybrid vs. Conventional Counterpart

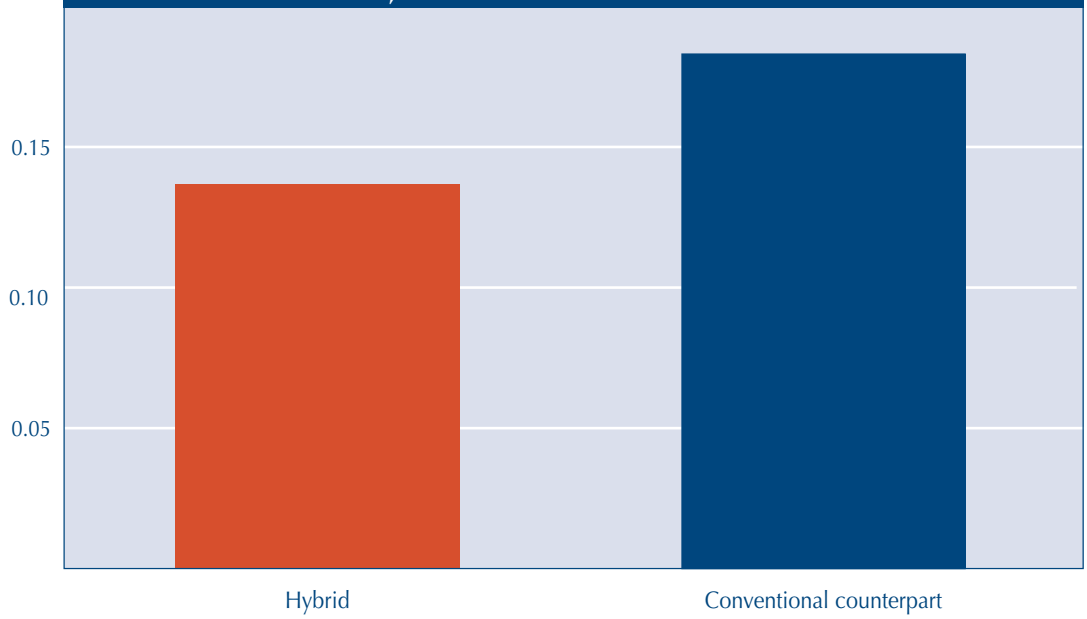


Table 3 lists details of the estimates for the independent variables. Only states with the highest and lowest odds ratios are listed, along with the comparison state of California. Detailed results for all states are listed in Appendix A.

Table 3 Detailed Results of Logistic Regression Analysis of Injury Rates under Collision and MedPay Concurrent Coverage

Parameter	Degrees of Freedom	Estimate	Odds Ratio	Standard Error	Likelihood Ratio 95% Confidence Limits		Wald Chi-square	p-value
Intercept	1	-1.6978		0.0265	-1.7499	-1.6459	4095.35	<0.0001
Calendar Year								
2002	1	-0.3987	0.6712	0.3934	-1.2667	0.2990	1.03	0.3108
2003	1	-0.1604	0.8518	0.0778	-0.3157	-0.0104	4.25	0.0393
2004	1	-0.0248	0.9755	0.0441	-0.1119	0.0611	0.32	0.5746
2005	1	-0.0887	0.9151	0.0297	-0.1470	-0.0308	8.95	0.0028
2006	1	-0.1226	0.8846	0.0243	-0.1703	-0.0750	25.40	<0.0001
2007	1	0.0259	1.0262	0.0187	-0.0109	0.0626	1.91	0.1671
2008	1	-0.0278	0.9726	0.0167	-0.0606	0.0050	2.77	0.0962
2010	1	-0.0689	0.9334	0.0188	-0.1058	-0.0321	13.46	0.0002
2009	0	0	1	0	0	0	.	.
Rated Driver Age								
<25	1	0.0727	1.0754	0.0224	0.0287	0.1165	10.52	0.0012
25-39	1	0.1011	1.1064	0.0140	0.0737	0.1284	52.51	<0.0001
65+	1	-0.3630	0.6956	0.0184	-0.3991	-0.3270	389.47	<0.0001
Unknown	1	-0.1380	0.8711	0.0288	-0.1947	-0.0818	22.96	<0.0001
40-64	0	0	1	0	0	0	.	.

Table 3 Detailed Results of Logistic Regression Analysis of Injury Rates under Collision and MedPay Concurrent Coverage (cont'd)

Parameter	Degrees of Freedom	Estimate	Odds Ratio	Standard Error	Likelihood Ratio 95% Confidence Limits		Wald Chi-square	p-value
Rated driver gender								
Female	1	-0.0181	0.9821	0.0307	-0.0785	0.0418	0.35	0.5555
Male	1	-0.1606	0.8516	0.0325	-0.2246	-0.0972	24.4	<0.0001
Unknown	0	0	1	0	0	0	.	.
Marital status								
Married	1	-0.0776	0.9253	0.0312	-0.1385	-0.0161	6.17	0.0130
Single	1	-0.0712	0.9313	0.0314	-0.1325	-0.0095	5.16	0.0232
Unknown	0	0	1	0	0	0	.	.
State								
Montana	1	-0.7935	0.4523	0.1492	-1.0985	-0.5124	28.29	<0.0001
Iowa	1	-0.6428	0.5258	0.0569	-0.7558	-0.5328	127.81	<0.0001
Vermont	1	-0.6018	0.5478	0.0928	-0.7881	-0.4242	42.08	<0.0001
West Virginia	1	-0.0046	0.9954	0.0543	-0.1121	0.1007	0.01	0.9330
Arizona	1	0.0420	1.0429	0.0370	-0.0309	0.1141	1.29	0.2558
Nevada	1	0.2412	1.2728	0.0499	0.1425	0.3381	23.38	<0.0001
California	0	0	1	0	0	0	.	.
Vehicle density								
0-99	1	-0.0384	0.9623	0.0173	-0.0723	-0.0047	4.96	0.0259
100-499	1	-0.0648	0.9373	0.0140	-0.0923	-0.0374	21.45	<0.0001
500+	0	0	1.0000	0	0	0	.	.
Vehicle age	1	0.0710	1.0736	0.0080	0.0553	0.0868	78.44	<0.0001
Vehicle make and series								
Honda Accord	1	-0.0868	0.9169	0.0191	-0.1243	-0.0494	20.63	<0.0001
Nissan Altima	1	0.0801	1.0834	0.0237	0.0336	0.1264	11.45	0.0007
Saturn Aura	1	0.0513	1.0526	0.0468	-0.0413	0.1423	1.20	0.2730
Toyota Camry	1	0.0228	1.0231	0.0186	-0.0138	0.0593	1.49	0.2218
Cadillac Escalade	1	-0.3101	0.7334	0.4301	-1.2649	0.4513	0.52	0.4709
Cadillac Escalade 4WD	1	-0.4320	0.6492	0.2779	-1.0231	0.0744	2.42	0.1200
Ford Escape	1	0.2903	1.3368	0.0268	0.2377	0.3427	117.54	<0.0001
Ford Escape 4WD	1	0.2372	1.2677	0.0324	0.1733	0.3003	53.60	<0.0001
Ford Fusion	1	0.0788	1.0820	0.0790	-0.0788	0.2310	1.00	0.3184
Lexus GS 450/350	1	-0.1834	0.8324	0.0788	-0.3408	-0.0316	5.41	0.0200
Toyota Highlander	1	-0.2075	0.8126	0.0505	-0.3076	-0.1095	16.86	<0.0001
Toyota Highlander 4WD	1	-0.4139	0.6611	0.0394	-0.4917	-0.3374	110.61	<0.0001
Lexus LS 600/460 L	1	0.4439	1.5588	0.6184	-1.0009	1.5112	0.52	0.4729
Chevrolet Malibu	1	0.0841	1.0877	0.0356	0.0140	0.1534	5.59	0.0181
Mercury Mariner	1	0.2054	1.2280	0.0818	0.0421	0.3630	6.30	0.0120
Mercury Mariner 4WD	1	-0.0304	0.9701	0.0806	-0.1915	0.1246	0.14	0.7062
Lexus RX 400/330	1	-0.3278	0.7205	0.0979	-0.5245	-0.1406	11.22	0.0008
Lexus RX 400/330 4WD	1	-0.4972	0.6082	0.0640	-0.6246	-0.3737	60.40	<0.0001
Lexus RX 450/350	1	-0.2424	0.7847	0.0584	-0.3583	-0.1294	17.24	<0.0001
Lexus RX 450/350 4WD	1	-0.4031	0.6682	0.0507	-0.5036	-0.3049	63.32	<0.0001
Chevrolet Tahoe	1	-0.2842	0.7526	0.0752	-0.4342	-0.1394	14.30	0.0002
Chevrolet Tahoe 4WD	1	-0.5034	0.6045	0.0871	-0.6781	-0.3364	33.39	<0.0001
Mazda Tribute	1	0.2917	1.3387	0.1067	0.0777	0.4962	7.48	0.0062
Saturn Vue	1	0.2737	1.3148	0.0415	0.1918	0.3544	43.58	<0.0001
GMC Yukon	1	-0.2350	0.7906	0.1214	-0.4804	-0.0037	3.74	0.0530
GMC Yukon 4WD	1	-0.9431	0.3894	0.1356	-1.2197	-0.6873	48.38	<0.0001
Honda Civic	0	0	1	0	0	0	.	.
Hybrid Status								
Hybrid	1	-0.2920	0.7468	0.0201	-0.3316	-0.2527	210.67	<0.0001
Conventional	0	0	1	0	0	0	.	.

Collision and PIP – Table 4 is similar to Table 1, it lists exposure, claims, injury rate and injury odds by series. The results are sorted by series. Some extreme values arose when there was little exposure. These actual injury rates and injury odds show that before controlling for other covariates, injury in total is less likely in the hybrid vehicles.

Table 4 Exposure, Claims, Injury rate and Injury Odds by Series under Collision and PIP Concurrent Coverage

	Conventional Vehicles					Hybrid Vehicles				
Make and series	Exposure	Collision Claims	PIP Claims	Injury Rate	Injury Odds	Exposure	Collision Claims	PIP Claims	Injury Rate	Injury Odds
Honda Accord	818,485	69,320	8,898	0.128	0.147	18,056	1,517	150	0.099	0.110
Nissan Altima	461,555	41,807	6,350	0.152	0.179	9,848	792	91	0.115	0.130
Chrysler Aspen 4WD	1,210	85	10	0.118	0.133	169	8	1	0.125	0.143
Saturn Aura	113,993	7,801	830	0.106	0.119	821	62	5	0.081	0.088
Toyota Camry	978,676	84,456	11,322	0.134	0.155	103,553	8,286	707	0.085	0.093
Honda Civic	1,019,413	95,510	13,094	0.137	0.159	173,817	13,576	1,464	0.108	0.121
Cadillac Escalade	2,015	116	5	0.043	0.045	469	30	1	0.033	0.034
Cadillac Escalade 4WD	3,299	235	17	0.072	0.078	671	48	4	0.083	0.091
Ford Escape	293,962	15,506	2,231	0.144	0.168	18,952	1,053	125	0.119	0.135
Ford Escape 4WD	312,520	15,231	2,188	0.144	0.168	23,611	1,372	161	0.117	0.133
Ford Fusion	34,940	2,573	240	0.093	0.103	5,825	416	39	0.094	0.103
Lexus GS 450/350	17,041	1,228	133	0.108	0.121	5,915	482	32	0.066	0.071
Toyota Highlander	61,026	3,552	445	0.125	0.143	14,583	852	83	0.097	0.108
Toyota Highlander 4WD	166,574	11,771	1,171	0.099	0.110	57,647	4,000	288	0.072	0.078
Chevrolet Malibu	171,497	12,899	1,453	0.113	0.127	2,242	173	15	0.087	0.095
Mercury Mariner	26,717	1,546	177	0.114	0.129	2,129	103	9	0.087	0.096
Mercury Mariner 4WD	54,136	3,317	380	0.115	0.129	6,344	359	36	0.100	0.111
Lexus RX 400/330	15,060	863	90	0.104	0.116	9,064	564	49	0.087	0.095
Lexus RX 400/330 4WD	24,361	1,638	130	0.079	0.086	48,720	3,499	269	0.077	0.083
Lexus RX 450/350	75,691	4,406	428	0.097	0.108	816	47	3	0.064	0.068
Lexus RX 450/350 4WD	131,887	9,273	787	0.085	0.093	2,552	201	14	0.070	0.075
Chevrolet Tahoe	42,514	2,414	220	0.091	0.100	1,346	73	4	0.055	0.058
Chevrolet Tahoe 4WD	41,655	2,476	211	0.085	0.093	1,794	109	9	0.083	0.090
Saturn Vue	126,807	6,897	977	0.142	0.165	8,090	529	66	0.125	0.143
GMC Yukon	11,776	616	42	0.068	0.073	659	30	2	0.067	0.071
GMC Yukon 4WD	22,045	1,465	111	0.076	0.082	953	55	5	0.091	0.100
Total	**5,028,854**	**397,001**	**51,940**	**0.131**	**0.151**	**528,109**	**40,054**	**3,632**	**0.091**	**0.100**

Table 5 summarizes the results of the logistic regression analysis of injury odds for Collision and PIP. Results for all independent variables including hybrid status had p-values less than 0.05, indicating their effects on injury rates were statistically significant.

Table 5 Summary Results of Logistic Regression Analysis of Injury Rates under Collision and PIP Concurrent Coverage

	Degree of Freedoms	Chi-Square	P-Value
Calendar Year	8	26.26	0.0009
Rated Driver Age	4	800.10	<0.0001
Rated Driver Gender	2	203.10	<0.0001
Rated Driver Marital Status	2	53.16	<0.0001
State	17	2,858.41	<0.0001
Vehicle Age	1	84.14	<0.0001
Vehicle Density	2	83.58	<0.0001
Vehicle Series	25	928.63	<0.0001
Hybrid Status	1	277.38	<0.0001

Figure 3 compares the injury odds of hybrids with their conventional counterparts. The injury odds were estimated to be 0.14 ($p<0.0001$) for the heavier hybrids and 0.20 for their conventional counterparts. Hybrids, which are heavier, had injury odds 26.5 percent lower than their conventional counterparts. (Note: as for the MedPay analysis, the injury odds of hybrids and conventional vehicles assume the values for each of the variables are set to the reference values. These odds will change based on changes in those assumptions however the odds for hybrids will always be 26.5 percent lower than non-hybrids).

Figure 3 Estimated Injury Odds under Collision and PIP Concurrent Coverage, Hybrid vs. Conventional Counterpart

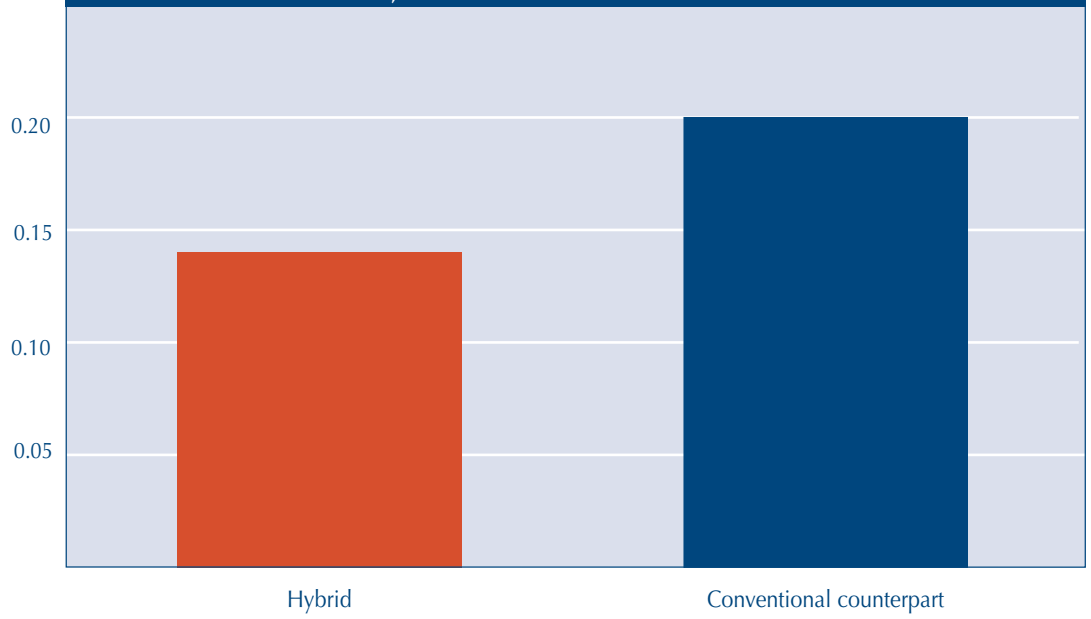


Table 6 lists details of the estimates for the independent variables. Only states with the highest and lowest odds ratios are listed, along with the comparison state of Florida. Detailed results for all states are listed in Appendix B.

Table 6 Detailed Results of Logistic Regression Analysis of Injury Rates under Collision and PIP Concurrent Coverage

Parameter	Degrees of Freedom	Estimate	Odds Ratio	Standard Error	Likelihood Ratio 95% Confidence Limits		Wald Chi-square	p-value
Intercept	1	-1.6284		0.0225	-1.6725	-1.5844	5,244.49	<0.0001
Calendar Year								
2002	1	0.0403	1.0411	0.2691	-0.5248	0.5370	0.02	0.8811
2003	1	0.0268	1.0272	0.0574	-0.0869	0.1381	0.22	0.6400
2004	1	0.0824	1.0859	0.0345	0.0145	0.1497	5.71	0.0169
2005	1	0.0521	1.0535	0.0236	0.0056	0.0983	4.86	0.0276
2006	1	-0.0210	0.9792	0.0196	-0.0595	0.0173	1.16	0.2825
2007	1	0.0410	1.0419	0.0152	0.0111	0.0709	7.24	0.0071
2008	1	0.0042	1.0042	0.0135	-0.0223	0.0307	0.1	0.7550
2010	1	-0.0197	0.9805	0.0149	-0.0488	0.0094	1.76	0.1850
2009	0	0	1	0	0	0	.	.
Rated driver age								
<25	1	0.1083	1.1144	0.0177	0.0736	0.1428	37.62	<0.0001
25-39	1	0.0945	1.0991	0.0117	0.0715	0.1174	65.15	<0.0001
65+	1	-0.3417	0.7106	0.0156	-0.3723	-0.3111	478.18	<0.0001
Unknown	1	-0.0215	0.9787	0.0203	-0.0613	0.0181	1.12	0.2889
40-64	0	0	1	0	0	0	.	.

Table 6 Detailed Results of Logistic Regression Analysis of Injury Rates under Collision and PIP Concurrent Coverage (cont'd)

Parameter	Degrees of Freedom	Estimate	Odds Ratio	Standard Error	Likelihood Ratio 95% Confidence Limits		Wald Chi-square	p-value
Rated driver gender								
Male	1	-0.1630	0.8496	0.0117	-0.1860	-0.1401	193.78	<0.0001
Unknown	1	0.0202	1.0204	0.0256	-0.0299	0.0706	0.62	0.4313
Female	0	0	1	0	0	0	.	.
Marital status								
Single	1	0.0394	1.0402	0.0125	0.0149	0.0639	9.90	0.0017
Unknown	1	0.1898	1.2090	0.0262	0.1383	0.2410	52.51	<0.0001
Married	0	0	1	0	0	0	.	.
State								
Michigan	1	-1.0654	0.3446	0.0264	-1.1173	-1.0139	1,629.11	<0.0001
North Dakota	1	-1.0550	0.3482	0.1398	-1.3399	-0.7909	56.96	<0.0001
Massachusetts	1	-0.7955	0.4514	0.0289	-0.8523	-0.7388	755.16	<0.0001
New York	1	-0.1850	0.8311	0.0147	-0.2137	-0.1562	159.36	<0.0001
Oregon	1	-0.1296	0.8784	0.0333	-0.1953	-0.0647	15.15	<0.0001
Washington	1	-0.1153	0.8911	0.0258	-0.1661	-0.0648	19.93	<0.0001
Florida	0	0	1	0	0	0	.	.
Vehicle density								
0-99	1	-0.1152	0.8912	0.0185	-0.1516	-0.0790	38.74	<0.0001
100-499	1	-0.0878	0.9159	0.0111	-0.1097	-0.0660	62.02	<0.0001
500+	0	0	1	0	0	0	.	.
Vehicle age	1	0.0591	1.0609	0.0064	0.0465	0.0718	84.10	<0.0001
Vehicle make and series								
Honda Accord	1	-0.0794	0.9237	0.0152	-0.1091	-0.0496	27.32	<0.0001
Nissan Altima	1	0.1115	1.1180	0.0177	0.0768	0.1461	39.75	<0.0001
Chrysler Aspen 4WD	1	0.0466	1.0477	0.3236	-0.6439	0.6370	0.02	0.8854
Saturn Aura	1	-0.0660	0.9361	0.0388	-0.1425	0.0094	2.90	0.0888
Toyota Camry	1	0.0177	1.0179	0.0149	-0.0114	0.0469	1.42	0.2333
Cadillac Escalade	1	-1.2650	0.2822	0.4180	-2.2020	-0.5342	9.16	0.0025
Cadillac Escalade 4WD	1	-0.4805	0.6185	0.2283	-0.9579	-0.0586	4.43	0.0353
Ford Escape	1	0.2122	1.2364	0.0250	0.1629	0.2611	71.81	<0.0001
Ford Escape 4WD	1	0.1806	1.1979	0.0246	0.1321	0.2287	53.71	<0.0001
Ford Fusion	1	-0.0045	0.9955	0.0658	-0.1354	0.1227	0.00	0.9455
Lexus GS 450/350	1	-0.4071	0.6656	0.0833	-0.5738	-0.2471	23.90	<0.0001
Toyota Highlander	1	-0.1411	0.8684	0.0480	-0.2362	-0.0479	8.63	0.0033
Toyota Highlander 4WD	1	-0.3126	0.7315	0.0297	-0.3712	-0.2547	110.57	<0.0001
Chevrolet Malibu	1	-0.0183	0.9819	0.0308	-0.0790	0.0419	0.35	0.5535
Mercury Mariner	1	0.0678	1.0702	0.0797	-0.0914	0.2213	0.72	0.3950
Mercury Mariner 4WD	1	-0.0301	0.9703	0.0536	-0.1363	0.0737	0.31	0.5747
Lexus RX 400/330	1	-0.4094	0.6640	0.0908	-0.5914	-0.2353	20.33	<0.0001
Lexus RX 400/330 4WD	1	-0.3984	0.6714	0.0543	-0.5061	-0.2933	53.86	<0.0001
Lexus RX 450/350	1	-0.4285	0.6515	0.0528	-0.5332	-0.3263	65.96	<0.0001
Lexus RX 450/350 4WD	1	-0.4607	0.6308	0.0389	-0.5377	-0.3851	140.07	<0.0001
Chevrolet Tahoe	1	-0.4351	0.6472	0.0719	-0.5786	-0.2966	36.61	<0.0001
Chevrolet Tahoe 4WD	1	-0.4081	0.6649	0.0719	-0.5516	-0.2698	32.26	<0.0001
Saturn Vue	1	0.1747	1.1909	0.0356	0.1044	0.2440	24.07	<0.0001
GMC Yukon	1	-0.7425	0.4759	0.1574	-1.0650	-0.4466	22.26	<0.0001
GMC Yukon 4WD	1	-0.4899	0.6127	0.0978	-0.6868	-0.3029	25.08	<0.0001
Honda Civic	0	0	1	0	0	0	.	.
Hybrid status								
Hybrid	1	-0.3077	0.7351	0.0190	-0.3452	-0.2706	261.29	<0.0001
Conventional	0	0	1	0	0	0	.	.

DISCUSSION

Hybrids on average are approximately 10 percent heavier than their conventional counterparts and have lower injury rates in a crash. Under both MedPay and PIP coverages, the odds of sustaining an injury in a hybrid were about 25 percent lower than in a lighter non-hybrid vehicle. Previous analytical attempts have been made to disentangle the separate effects of vehicle weight and size on safety. The difficulty comes when attempting to hold one of these values constant while varying the other because mass and weight are highly correlated in the passenger vehicle fleet. The comparison of regular and hybrid versions in this study may be as good a natural experiment as can be done to look at the effects of mass independent of size, because the sizes and structures of the compared vehicles are the same.

In a multi-vehicle collision, the heavier vehicle will be favored as the momentum from the heavier vehicle will be transferred to the lighter one. Less obviously, heavier vehicles also have an advantage in single-vehicle crashes, as their greater mass means they will move and deform more of the objects they hit. In this study the heavier hybrids were found to have lower injury rates than their non hybrid counterparts. This is consistent with findings from previous studies which have shown vehicle weight to be protective (IIHS, 2011 and Kahane, 2003) while others have found that vehicle weight reduction reduces fatalities (Van Auken and Zellner, 2005). The results of this study are encouraging from an energy and environmental standpoint. The use of hybrid vehicles reduces fuel consumption and thus reduces exhaust emissions while simultaneously improving safety.

Appendix A Detailed Results of Logistic Regression Analysis of Injury Rates under Collision and MedPay Concurrent Coverage by State

Parameter	Degrees of Freedom	Estimate	Odds Ratio	Standard Error	Likelihood Ratio 95% Confidence Limits		Wald Chi-square	p-value
State								
Alabama	1	-0.1891	0.8277	0.0337	-0.2555	-0.1234	31.50	<0.0001
Alaska	1	-0.0873	0.9164	0.1070	-0.3024	0.1176	0.67	0.4145
Arizona	1	0.0420	1.0429	0.0370	-0.0309	0.1141	1.29	0.2558
Arkansas	1	-0.2197	0.8028	0.0571	-0.3331	-0.1090	14.78	0.0001
Colorado	1	-0.3020	0.7393	0.0472	-0.3954	-0.2104	40.97	<0.0001
Connecticut	1	-0.2795	0.7562	0.0480	-0.3746	-0.1864	33.91	<0.0001
Georgia	1	-0.0654	0.9367	0.0272	-0.1189	-0.0123	5.78	0.0162
Idaho	1	-0.4194	0.6574	0.0932	-0.6064	-0.2409	20.26	<0.0001
Illinois	1	-0.4262	0.6530	0.0212	-0.4679	-0.3846	402.99	<0.0001
Indiana	1	-0.3300	0.7189	0.0337	-0.3964	-0.2643	95.84	<0.0001
Iowa	1	-0.6428	0.5258	0.0569	-0.7558	-0.5328	127.81	<0.0001
Louisiana	1	-0.0347	0.9659	0.0304	-0.0946	0.0246	1.30	0.2535
Maine	1	-0.5476	0.5783	0.0814	-0.7104	-0.3913	45.28	<0.0001
Mississippi	1	-0.1598	0.8523	0.0448	-0.2484	-0.0726	12.71	0.0004
Missouri	1	-0.4520	0.6364	0.0390	-0.5291	-0.3762	134.43	<0.0001
Montana	1	-0.7935	0.4523	0.1492	-1.0985	-0.5124	28.29	<0.0001
Nebraska	1	-0.5284	0.5895	0.0663	-0.6605	-0.4005	63.51	<0.0001
Nevada	1	0.2412	1.2728	0.0499	0.1425	0.3381	23.38	<0.0001
New Hampshire	1	-0.4491	0.6382	0.0483	-0.5447	-0.3555	86.65	<0.0001
New Mexico	1	-0.0190	0.9812	0.0598	-0.1378	0.0968	0.10	0.7508
North Carolina	1	-0.2731	0.7610	0.0276	-0.3275	-0.2192	97.80	<0.0001
Ohio	1	-0.5026	0.6050	0.0246	-0.5510	-0.4545	416.57	<0.0001
Oklahoma	1	-0.1354	0.8734	0.0503	-0.2349	-0.0378	7.25	0.0071
Rhode Island	1	-0.5604	0.5710	0.0574	-0.6745	-0.4494	95.31	<0.0001
South Carolina	1	-0.1916	0.8256	0.0712	-0.3335	-0.0544	7.25	0.0071
South Dakota	1	-0.5319	0.5875	0.1255	-0.7862	-0.2936	17.97	<0.0001
Tennessee	1	-0.4117	0.6625	0.0310	-0.4727	-0.3513	176.83	<0.0001
Vermont	1	-0.6018	0.5478	0.0928	-0.7881	-0.4242	42.08	<0.0001
Virginia	1	-0.5234	0.5925	0.0270	-0.5766	-0.4706	374.49	<0.0001
West Virginia	1	-0.0046	0.9954	0.0543	-0.1121	0.1007	0.01	0.9330
Wisconsin	1	-0.4248	0.6539	0.0351	-0.4940	-0.3565	146.65	<0.0001
Wyoming	1	-0.4671	0.6268	0.1316	-0.7342	-0.2173	12.59	0.0004
California	0	0	1	0	0	0	.	.

Appendix B Detailed Results of Logistic Regression Analysis of Injury Rates under Collision and PIP Concurrent Coverage by State

Parameter	Degrees of Freedom	Estimate	Odds Ratio	Standard Error	Likelihood Ratio 95% Confidence Limits		Wald Chi-square	p-value
State								
Colorado	1	-0.3412	0.7109	0.4797	-1.4133	0.5074	0.51	0.4768
Delaware	1	-0.1909	0.8262	0.0450	-0.2799	-0.1035	17.99	<0.0001
Hawaii	1	-0.7754	0.4605	0.0583	-0.8914	-0.6626	176.60	<0.0001
Kansas	1	-0.7665	0.4646	0.0445	-0.8547	-0.6801	296.13	<0.0001
Kentucky	1	-0.2007	0.8182	0.0338	-0.2673	-0.1348	35.24	<0.0001
Maryland	1	-0.3454	0.7079	0.0196	-0.3839	-0.3070	310.19	<0.0001
Massachusetts	1	-0.7955	0.4514	0.0289	-0.8523	-0.7388	755.16	<0.0001
Michigan	1	-1.0654	0.3446	0.0264	-1.1173	-1.0139	1629.11	<0.0001
Minnesota	1	-0.6446	0.5249	0.0317	-0.7070	-0.5829	414.46	<0.0001
New Jersey	1	-0.3295	0.7193	0.0195	-0.3678	-0.2914	286.29	<0.0001
New York	1	-0.1850	0.8311	0.0147	-0.2137	-0.1562	159.36	<0.0001
North Dakota	1	-1.0550	0.3482	0.1398	-1.3399	-0.7909	56.96	<0.0001
Oregon	1	-0.1296	0.8784	0.0333	-0.1953	-0.0647	15.15	<0.0001
Pennsylvania	1	-0.3549	0.7012	0.0211	-0.3963	-0.3137	283.67	<0.0001
Texas	1	-0.3990	0.6710	0.0180	-0.4344	-0.3637	490.29	<0.0001
Utah	1	-0.2624	0.7692	0.0448	-0.3511	-0.1753	34.25	<0.0001
Washington	1	-0.1153	0.8911	0.0258	-0.1661	-0.0648	19.93	<0.0001
Florida	0	0	1	0	0	0	.	.

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