Effects of Electronic Stability Control on Fatal Crash Risk

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Abstract

Objectives: A number of studies have reported the effectiveness of electronic stability control (ESC) in reducing the risk of fatal motor vehicle crashes. The purpose of the present study was to examine ESC effectiveness using the latest data and to determine whether differences exist by vehicle type, style, or manufacturer of passenger vehicles.

Methods: Fatal crash involvement rates per registered vehicle were compared for otherwise identically designed vehicle models with and without ESC. Comparisons were across model years, so models with ESC were newer than those without. Effectiveness estimates were adjusted to account for these vehicle age differences.

Results: Based on all fatal crashes in the United States during 10 years, ESC was found to have reduced fatal crash involvement risk by 33 percent — 20 percent for multiple-vehicle crashes and 49 percent for single-vehicle crashes. Effectiveness estimates were higher for SUVs than for cars — 35 percent for SUVs and 30 percent for cars, but this difference was not statistically significant. Fatal crash involvement risk was reduced by an estimated 2 percent for full-size vans equipped with ESC, but this estimate was based on relatively little data and was not statistically significant.

Conclusions: There are significant reductions in fatal crash rates when passenger vehicles are equipped with ESC. ESC leads to reductions especially for fatal single-vehicle crashes, but there also are reductions for fatal multiple-vehicle crashes. As ESC has expanded from sports and luxury vehicles into the general fleet, the overall estimate of its effectiveness has declined by approximately 10 percentage points compared with an earlier estimate using identical statistical procedures. However, it still is one of the most effective technologies yet developed for preventing serious crashes.

Keywords: Crash avoidance; Rollover; Loss of control

1. Introduction

Electronic stability control (ESC) is a crash avoidance technology that continuously monitors how well a vehicle responds to a driver's steering input and selectively applies the brakes and modulates engine power to keep the vehicle traveling along the intended path. First introduced in 1995, ESC since has become a common component in passenger vehicles.

A number of studies throughout the world have demonstrated the effectiveness of ESC in reducing the risk of motor vehicle crashes (Dang, 2007; Farmer, 2006; Green and Woodrooffe, 2006; Lie et al., 2006; Page and Cuny, 2006; Scully and Newstead, 2008; Thomas, 2006). Ferguson (2007) summarized the literature, reporting that single-vehicle crash risk was reduced by 33-35 percent for cars and 56-67 percent for SUVs. Risk of crashes involving multiple vehicles was not significantly reduced, except for the more serious crashes such as head-on crashes and those involving fatalities. Erke (2008) conducted a meta-analysis of eight studies, estimating a 49 percent reduction in single-vehicle overall crash risk, a 49 percent reduction in single-vehicle fatal crash risk, and a 32 percent reduction in multiple-vehicle fatal crash risk. However, the author thought these estimates likely were inflated by publication bias.

SUVs tend to have higher centers of gravity compared with cars, so they are more likely to be involved in the loss-of-control and rollover crashes addressed by ESC. Thus most studies have reported slightly greater overall effectiveness of ESC for SUVs compared with cars. For example, Dang (2007) estimated that ESC reduced police-reported crash involvements by 8 percent for cars and 10 percent for SUVs. The Highway Loss Data Institute (HLDI, 2006, 2009) reported that ESC reduced collision insurance losses by 16 percent for cars and 18 percent for SUVs. The latest HLDI study also noted a larger ESC effect for four-wheel drive versus two-wheel drive SUVs. Effectiveness estimates for individual SUV models ranged from a 44 percent reduction in losses to a 5 percent increase.

In response to the research findings, automakers increasingly have included ESC on their vehicles. Approximately 22 percent of the 2007 model cars and 53 percent of the 2007 model pickups, SUVs, and vans sold in the United States were equipped with ESC (Ward's Automotive Group, 2008). By the 2009 model year, every SUV model sold in the United States came with ESC as standard equipment (HLDI, 2009).

After intensive study using test tracks, simulators, and real-world crash data, the National Highway Traffic Safety Administration (NHTSA) issued regulations requiring all passenger vehicles manufactured after September 1, 2011 for sale in the United States to be equipped with ESC. In fact, Federal Motor Vehicle Safety Standard No. 126 calls for new vehicles to have ESC phased in much sooner: at least 55 percent of vehicles manufactured between September 1, 2008 and August 31, 2009 must have ESC, at least 75 percent of vehicles manufactured between September 1, 2009 and August 31, 2010 must have ESC, and at least 95 percent of vehicles manufactured between September 1, 2010 and August 31, 2011 must have ESC (NHTSA, 2007a).

So, whereas ESC at first appeared primarily in luxury cars, it now has filtered down to the general fleet. Also, some vehicles with ESC have been on the road for more than 10 years, so it may be possible to examine long-term effects. The purpose of the present study was to examine ESC effectiveness for the general fleet of passenger vehicles and to determine whether differences exist by vehicle type, style, or manufacturer. Fatal crash involvement rates per registered vehicle were compared for otherwise identical vehicle models with and without ESC.

2. Method

Vehicle models included in the study were those that changed from no ESC available in one model year to ESC as standard equipment in the next model year without any other significant design changes. Model years were restricted to, at most, the last 4 years without ESC and the first 4 years with ESC. Table 1 lists the 73 vehicle model/body styles included in the study.

(Table 1 inserted here)

Records of fatal crash involvements of relevant vehicles were extracted from the 1999-2008 files of the Fatality Analysis Reporting System, a federal database of fatal crashes occurring in all 50 states.

Vehicle registration counts by vehicle model, model year, and calendar year were obtained from the National Vehicle Population Profile of R.L. Polk and Company.

Vehicle registration counts are collected in July of each year, so they do not include new vehicles registered in the second half of the year. To ensure consistency of crash rates per registration, both crash and registration counts were restricted to calendar years subsequent to each model year. For example, crash and registration counts of 2007 models during calendar year 2007 were excluded. For each vehicle model, data were restricted to calendar years with exposure for both pre-ESC and ESC vehicles. In other words, if ESC first appeared in model year 2005, then the crash and registration data for that model were restricted to calendar years 2006-08.

If ESC has no effect on fatal crash risk, then fatal crash rates per registration should be approximately the same for the pre-ESC and ESC versions of each model. Thus the expected crash count for the ESC version should be the product of the crash rate for the pre-ESC version and the registration count for the ESC version. In this way, expected crash counts were computed for ESC versions of each of the relevant vehicle models. The risk ratio was defined as the sum of the observed crash counts for ESC vehicles divided by the sum of the expected counts. A risk ratio significantly less than 1 could be taken as evidence that ESC reduces fatal crash risk. Ninety-five percent confidence limits on the risk ratio were computed as follows (Silcocks, 1994):

$$\text{lower limit} = \beta_{0.025}(O, E + 1)/[1 - \beta_{0.025}(O, E + 1)] \text{ and}$$

$$\text{upper limit} = \beta_{0.975}(O + 1, E)/[1 - \beta_{0.975}(O + 1, E)],$$

where O is the sum of observed crashes, E is the sum of expected crashes, and $\beta_p(x, y)$ is the p^{th} percentile from the beta distribution with parameters x and y.

The comparisons were across model years but within the same calendar years, so vehicles without ESC were consistently older than vehicles with ESC. Farmer and Lund (2006) presented evidence that even minor differences in vehicle age could affect fatal crash rates. To account for these age effects, expected fatal crash counts were divided by various adjustment factors depending on the average ages of vehicles with and without ESC. For example, the risk of fatal crash involvement for a 2-year-old model is approximately 2 percent higher than that for a 1-year-old model. Thus for any vehicle model for which the pre-ESC versions averaged 2 years old and the ESC versions averaged 1 year old, the expected crash count was divided by 1.02. Adjustment factors ranged from 1.01 to 1.10.

Separate effectiveness estimates were computed for various types of fatal crash involvements: those involving another vehicle (multiple vehicle), those involving only the subject vehicle (single vehicle), rollovers, and those occurring on wet or slippery roadways.

3. Results

An illustrative example of the calculations may be helpful. The four-wheel drive Jeep Liberty without ESC (model years 2002-05) had 175 fatal crash involvements and 945,482 vehicle-years of exposure during calendar years 2007-08, so the fatal crash involvement rate was 185.1 per million vehicle-years. If the four-wheel drive Liberty with ESC (model years 2006-07) had approximately the same rate, then, based on 266,899 vehicle-years of exposure, one would expect about 49.4 fatal crash involvements. However, due to the differences in vehicle age, the pre-ESC vehicles should have a rate approximately 10 percent higher than that of the ESC vehicles. The expected crash count for the ESC vehicles therefore was lowered to 44.9. There actually were 28 fatal crash involvements for the four-wheel drive Liberty with ESC, many fewer than expected.

Similar calculations produced observed and expected crash counts for each of the vehicle models in Table 1. The sums of these counts are listed in Table 2 by vehicle type. Both cars and SUVs had many fewer crash involvements than expected. Cars with ESC had 226 fatal crash involvements compared with 323 expected. SUVs with ESC had 649 fatal crash involvements compared with 996 expected. However, there were six models of full-size vans in the analysis that, as a group, had approximately the same number of fatal crash involvements as expected (49 versus 50). The exposure for full-size vans was relatively small (about 200,000 registration-years with and without ESC), so the result is imprecise. Total exposure for all vehicle types was 13.1 million registration-years without ESC and 8.5 million registration-years with ESC. Overall, ESC was associated with a statistically significant 33 percent reduction in fatal crash involvement risk.

(Table 2 inserted here)

Effectiveness estimates were statistically significant for both multiple-vehicle and single-vehicle fatal crashes (Table 3). ESC was associated with a 20 percent reduction in multiple-vehicle fatal crash involvement risk and a 49 percent reduction in single-vehicle fatal crash involvement risk. Effectiveness estimates were higher for SUVs than for cars, but the differences were not statistically significant. ESC reduced multiple-vehicle fatal crash involvement risk by 21 percent for SUVs and 16 percent for cars. ESC reduced single-vehicle fatal crash involvement risk by 53 percent for SUVs and 46 percent for cars.

(Table 3 inserted here)

ESC was associated with a 57 percent reduction in multiple-vehicle rollover fatal crash involvement risk, a 73 percent reduction in single-vehicle rollover fatal crash involvement risk, a 50 percent reduction in multiple-vehicle fatal crash involvement risk on wet or slippery roads, and a 59 percent reduction in single-vehicle fatal crash involvement risk on wet or slippery roads (Table 4).

(Table 4 inserted here)

One of the goals of this update was to compare the ESC systems of different automakers. Seven of the automakers in Table 1 had sufficient exposure for producing individual effectiveness estimates (100,000 registration-years with and without ESC). Effectiveness estimates ranged from a 16 percent reduction in fatal crash risk for Honda/Acura models to a 41 percent reduction for Toyota/Lexus models (Table 5). These differences were not statistically significant.

(Table 5 inserted here)

Another goal was to compare ESC effectiveness for two-wheel and four-wheel drive SUVs. There are 15 SUV models in Table 1with both two-wheel and four-wheel drive versions. Effectiveness estimates of ESC for these 15 pairs are summarized in Figure 1. Estimated effectiveness was greater for the four-wheel drive version for 9 of the 15 pairs. However, many of the estimates were based on very little exposure, so none of the differences were statistically significant.

(Figure 1 inserted here)

Table 6 lists observed and expected fatal crash involvements by vehicle style. Almost all of the cars in the study were classified as either sports or luxury models. Comparison of SUVs by style was restricted to the 15 vehicle models with both two-wheel and four-wheel drive versions. ESC reduced fatal crash involvement risk by 29 percent for luxury cars, 21 percent for sports cars, 28 percent for two-wheel drive SUVs, and 44 percent for four-wheel drive SUVs. These differences were not statistically significant.

(Table 6 inserted here)

It is possible that the effectiveness of newer ESC systems differs from that of systems available in earlier years. As a check on this hypothesis, the study vehicles in Table 1 were divided into two groups: those with ESC before or during the 2001 model year, and those first getting ESC after the 2001 model year. Effectiveness estimates were computed separately for the two groups. Estimated effectiveness was lower for the newer ESC systems (22 versus 37 percent reduction), even though the newer group was dominated by SUVs (Table 7). However, the difference was not statistically significant.

(Table 7 inserted here)

ESC effectiveness also might differ by calendar year. Many vehicles likely were resold in later years, so their use patterns may have changed. Effectiveness estimates were computed using calendar years 2006-08 and compared with those from earlier years (Table 8). Although there were some differences between the estimates based on early and later calendar years, the differences were not statistically significant.

(Table 8 inserted here)

Finally, it was of interest to estimate the overall effect of ESC on fatal crashes involving the US vehicle fleet. An estimate of the fatal crash involvements already prevented by ESC is $F E / (1 - E)$, where F represents the fatal crash involvements of vehicles with ESC and E represents the proportional reduction in fatal crash risk due to ESC (Starnes, 2005). During calendar years 1994-2008, there were 7,487 fatal crash involvements in the United States of vehicle models with ESC as standard equipment. Thus, using E = 0.33, there have been at least 3,688 fatal crash involvements prevented by ESC systems. Fatal crash involvements of vehicle models with optional ESC could not be reliably classified, so they were excluded from these counts.

An estimate of the proportion of fatal crash involvements that could have been prevented if ESC installation rates had been higher is $E (P_2 – P_1) / (1 – E P_1)$, where P_1 and P_2 represent the actual and hypothetical installation rates, respectively (Evans, 1991). Using NHTSA estimates of installation rates (NHTSA, 2007b), the proportion of fatal crash involvements that could have been prevented if all new passenger vehicles in the United States had been equipped with ESC was computed for each of model years 2003-09. These proportions then were multiplied by the actual counts of fatal crash involvements for each model year and calendar year. If all 2003-09 model passenger vehicles had been equipped with ESC, approximately 3,700 fatal crash involvements could have been prevented in calendar year 2008. In total during calendar years 2002-08, approximately 15,600 fatal crash involvements could have been prevented if all new passenger vehicles had been equipped with ESC.

4. Discussion

As in most prior studies, ESC was estimated here to have greatly reduced the risk of a fatal crash. However, the estimated reduction of 33 percent is lower than that of some other studies. An earlier study using the same methodology reported a 43 percent reduction in fatal crash risk (Farmer, 2006). There was some evidence that this lessened effectiveness was due to those vehicle models that more recently added ESC. There were no clear differences in effectiveness across automakers, so it does not seem to be an issue of design philosophy.

Differences in effectiveness across vehicle models may have been due to characteristics of the drivers or differences in vehicle use patterns. Some vehicles may be more likely to be driven in situations that lead to loss of control, and those vehicles would benefit most from ESC. Sports cars, which tend to be driven faster and more aggressively than family cars, were the earliest adopters of ESC. It has been hypothesized that four-wheel drive SUVs are more affected by ESC than two-wheel drive SUVs because they are driven more on slippery roads (HLDI, 2009). Four-wheel drive versions of SUVs often received ESC before the two-wheel drive versions. It should be expected, then, that the effects of ESC will continue to decrease as these systems expand into the general fleet.

The lack of a significant ESC effect for full-size vans is puzzling. Large vans are particularly unstable, especially when fully loaded (Subramanian, 2004). Track tests have demonstrated that ESC keeps even fully loaded vans from tipping during extreme maneuvers, but it does not prevent them from spinning out (Forkenbrock and Garrott, 2004). Thus ESC systems developed for cars and SUVs may be insufficient for large vans. Further research is necessary to determine the most effective ESC systems for large vans.

Although ESC has been tremendously effective, it has not completely eliminated fatal crashes. More than 7,000 vehicles with ESC still have been involved in fatal crashes during the past 15 years. Some loss-of-control situations may be too severe to be corrected through ESC's selective braking. In other cases, the crash may be due to inappropriate or insufficient steering or braking by the driver. Highway safety researchers and policy makers have begun to discuss a vision of zero serious crashes at some point in the future (Fahlquist, 2006; Tingvall and Haworth, 1999). As part of this vision, automakers and their suppliers have been developing crash avoidance technology to complement ESC. Sensors tied to radar or video cameras are able to predict and respond to critical situations before the vehicle experiences loss of control. The effectiveness of such systems in the real world should be a high priority for future research.

In conclusion, there are significant reductions in fatal crash rates when passenger vehicles are equipped with ESC. ESC leads to reductions especially in fatal single-vehicle crashes, but there also are reductions in fatal multiple-vehicle crashes. As ESC has expanded from sports and luxury vehicles into the general fleet, estimates of its effectiveness have declined. However, it still is one of the most effective technologies developed for preventing serious crashes.

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Table 1
Vehicle models used for study of electronic stability control (ESC)

	Model years	
Make, model, body style	Without ESC	With ESC standard
Acura 3.5 RL 4D 2WD	1996-1999	2000-2003
Acura MDX 4D 4WD	2001-2002	2003
Aston Martin DB9 coupe	2005	2006
Aston Martin DB9 Volante convertible	2005	2006
Audi S4 Quattro 4D 4WD	2000	2001-2002
Audi TT coupe 2WD	2000	2001-2004
Audi TT Quattro coupe 4WD	2000	2001-2004
BMW 323 I 4D	1999	2000
BMW 328 I 4D	1999	2000
BMW 740 I 4D	1997	1998-2001
BMW 740 IL 4D	1996-1997	1998-2001
BMW M coupe 2D	1999-2000	2001-2002
BMW M Roadster convertible	1998-2000	2001-2002
BMW Z3 coupe 2.8 2D	1999	2000
BMW Z3 Roadster 2.3 convertible	1999	2000
BMW Z3 Roadster 2.8 convertible	1997-1999	2000
Buick Rainier 4D 2WD	2004-2005	2006-2007
Buick Rainier 4D 4WD	2004-2005	2006-2007
Cadillac Escalade 4D 2WD	2002	2003-2006
Chevrolet Avalanche 1500 4D 4WD	2002-2005	2006
Chevrolet Equinox 4D 2WD	2005-2006	2007
Chevrolet Equinox 4D 4WD	2005-2006	2007
Chevrolet TrailBlazer 4D 2WD	2002-2005	2006-2007
Chevrolet TrailBlazer 4D 4WD	2002-2005	2006-2007
Chevrolet TrailBlazer ext 4D 2WD	2002-2005	2006
Chevrolet TrailBlazer ext 4D 4WD	2002-2005	2006
Chevrolet Express Van 3500 2WD	2002-2004	2005-2007
Chevrolet Express Van 3500 ext 2WD	2000-2003	2004-2007
Dodge Sprinter CG Van 2500	2002-2003	2004-2006
Dodge Sprinter Van 2500	2002-2003	2004-2006
Ferrari 75 MM/MM F1/Maranello	2002-2003	2004-2005
Ferrari F430 Spider convertible	2005	2006-2007
GMC Envoy 4D 2WD	2002-2005	2006-2007
GMC Envoy 4D 4WD	2002-2005	2006-2007
GMC Envoy XL 4D 2WD	2002-2005	2006
GMC Envoy XL 4D 4WD	2002-2005	2006
GMC Savana Van 3500 2WD	2001-2004	2005-2007
GMC Savana Van 3500 ext 2WD	2000-2003	2004-2007
GMC Yukon XL 3/4T 2WD	2002-2005	2006
GMC Yukon XL 3/4T 4WD	2002-2005	2006
Honda Accord Hybrid 4D	2005	2006-2007
Honda Civic SI 2D	2006	2007
Honda S2000 convertible	2002-2005	2006-2007
Isuzu Ascender 4D 2WD	2004-2005	2006-2007
Isuzu Ascender 4D 4WD	2004-2005	2006-2007
Isuzu Ascender ext 4D 2WD	2003-2005	2006

continued

Table 1 (continued)
Vehicle models used for study of electronic stability control (ESC)

	Model years	
Make, model, body style	Without ESC	With ESC standard
Isuzu Ascender ext 4D 4WD	2003-2005	2006
Jaguar VDP 4D	1996-1997	1998-2001
Jaguar XJR SWB 4D	1996-1997	1998-2001
Jeep Grand Cherokee 4D 2WD	2005	2006
Jeep Liberty 4D 2WD	2002-2005	2006-2007
Jeep Liberty 4D 4WD	2002-2005	2006-2007
Kia Sorento 4D 2WD	2003-2006	2007
Kia Sorento 4D 4WD	2003-2006	2007
Lexus LS 400 4D	1996-1997	1998-2000
Lexus LX 470 4D 4WD	1998-1999	2000-2003
Lexus RX 300 4D 2WD	1999-2000	2001-2003
Lexus RX 300 4D 4WD	1999-2000	2001-2003
Maserati coupe 2D	2002-2003	2004-2007
Maserati Spyder convertible	2002-2003	2004-2006
Maybach 57 4D	2004-2005	2006-2007
Maybach 62 4D	2004-2005	2006-2007
Mercedes Benz M class 4D 4WD	1998	1999-2001
Mercedes Benz SLK class convertible	1998-2000	2001-2004
Mitsubishi Montero 4D 4WD	2001-2002	2003-2006
Pontiac Torrent 4D 2WD	2006	2007
Pontiac Torrent 4D 4WD	2006	2007
Toyota 4Runner 4D 2WD	1997-2000	2001-2002
Toyota 4Runner 4D 4WD	1997-2000	2001-2002
Toyota Land Cruiser 4D 4WD	1998-1999	2000-2003
Toyota RAV4 4D 2WD	2001-2003	2004-2005
Toyota RAV4 4D 4WD	2001-2003	2004-2005
Volkswagen Eurovan	1999-2000	2001-2003

2D = two door, 4D = four door, 2WD = two-wheel drive, 4WD = four-wheel drive, ext = extended

Table 2
Fatal crash involvements of ESC study vehicles by vehicle type, 1999-2008

	Without ESC		With ESC standard		
Vehicle type	Registration-years	Crashes	Registration-years	Observed crashes	Expected crashes*
Car	2,113,807	291	2,621,964	226	323.26
Full-size van	182,433	39	200,676	49	50.08
SUV	10,830,636	2,298	5,646,013	649	995.83
Total	13,126,876	2,628	8,468,653	924	1,369.17

*Adjusted for vehicle age; Risk ratio = 0.67; 95% confidence limits (0.62, 0.73)

Table 3
Observed and expected fatal crash involvements of study vehicles with ESC by vehicle type and number of vehicles in crash, 1999-2008

Crash type	Vehicle type	Observed crashes	Expected crashes*	Ratio	95% confidence limits	
					Lower	Upper
All	Car	226	323.26	0.70	0.59	0.83
	Full-size van	49	50.08	0.98	0.65	1.48
	SUV	649	995.83	0.65	0.59	0.72
	Total	924	1369.17	0.67	0.62	0.73
Multiple-vehicle	Car	143	169.75	0.84	0.67	1.06
	Full-size van	28	36.33	0.77	0.45	1.30
	SUV	452	572.21	0.79	0.70	0.90
	Total	623	778.29	0.80	0.72	0.89
Single-vehicle	Car	83	153.51	0.54	0.41	0.71
	Full-size van	21	13.75	1.53	0.74	3.26
	SUV	197	423.56	0.47	0.39	0.55
	Total	301	590.82	0.51	0.44	0.59

*Adjusted for vehicle age

Table 4
Observed and expected fatal crash involvements of study vehicles with ESC by vehicle type and crash type, 1999-2008

Crash type	Vehicle type	Observed crashes	Expected crashes*	Ratio	95% confidence limits	
					Lower	Upper
Multiple-vehicle rollover	Car	10	11.27	0.89	0.34	2.28
	Full-size van	2	17.69	0.11	0.01	0.47
	SUV	48	111.72	0.43	0.30	0.61
	Total	60	140.68	0.43	0.31	0.58
Single-vehicle rollover	Car	23	82.61	0.28	0.17	0.45
	Full-size van	6	5.58	1.07	0.28	4.18
	SUV	63	253.96	0.25	0.19	0.33
	Total	92	342.16	0.27	0.21	0.34
Multiple-vehicle wet road	Car	15	54.69	0.27	0.14	0.49
	Full-size van	6	12.85	0.47	0.15	1.32
	SUV	64	102.73	0.62	0.45	0.86
	Total	85	170.26	0.50	0.38	0.65
Single-vehicle wet road	Car	12	26.47	0.45	0.21	0.93
	Full-size van	3	0.98	3.05	0.24	168.23
	SUV	30	82.19	0.37	0.23	0.56
	Total	45	109.65	0.41	0.28	0.59

*Adjusted for vehicle age

Table 5
Observed and expected fatal crash involvements of study vehicles with ESC by vehicle make, 1999-2008

Vehicle make	Observed crashes	Expected crashes*	Ratio	95% confidence limits Lower	Upper
BMW	107	149.61	0.72	0.55	0.92
Chrysler/Dodge/Jeep	77	106.98	0.72	0.53	0.97
General Motors	160	213.74	0.75	0.61	0.92
Honda/Acura	52	62.15	0.84	0.57	1.23
Mercedes Benz	138	206.75	0.67	0.53	0.83
Toyota/Lexus	330	564.09	0.59	0.51	0.67
Volkswagen/Audi	15	24.71	0.61	0.30	1.20

*Adjusted for vehicle age

Table 6
Observed and expected fatal crash involvements of study vehicles with ESC by vehicle style, 1999-2008

Vehicle style	Observed crashes	Expected crashes*	Ratio	95% confidence limits Lower	Upper
Luxury cars	177	250.65	0.71	0.58	0.86
Sports cars	42	53.11	0.79	0.51	1.21
Other cars	7	19.50	0.36	0.13	0.89
Full-size vans	49	50.08	0.98	0.65	1.48
Paired 2WD SUVs	202	280.74	0.72	0.60	0.87
Paired 4WD SUVs	208	368.88	0.56	0.47	0.67
Unpaired SUVs	239	346.22	0.69	0.58	0.82

*Adjusted for vehicle age; 2WD = two-wheel drive, 4WD = four-wheel drive

Table 7
Observed and expected fatal crash involvements of study vehicles with ESC by design year and vehicle type, 1999-2008

First model year with ESC	Vehicle type	Observed crashes	Expected crashes*	Ratio	95% confidence limits	
					Lower	Upper
1998-2001	Car	222	311.15	0.71	0.60	0.85
	SUV	369	632.67	0.58	0.51	0.66
	Total	591	943.82	0.63	0.56	0.69
2002-2007	Car	4	12.11	0.33	0.08	1.09
	Full-size van	49	50.08	0.98	0.65	1.48
	SUV	280	363.17	0.77	0.66	0.90
	Total	333	425.35	0.78	0.68	0.91

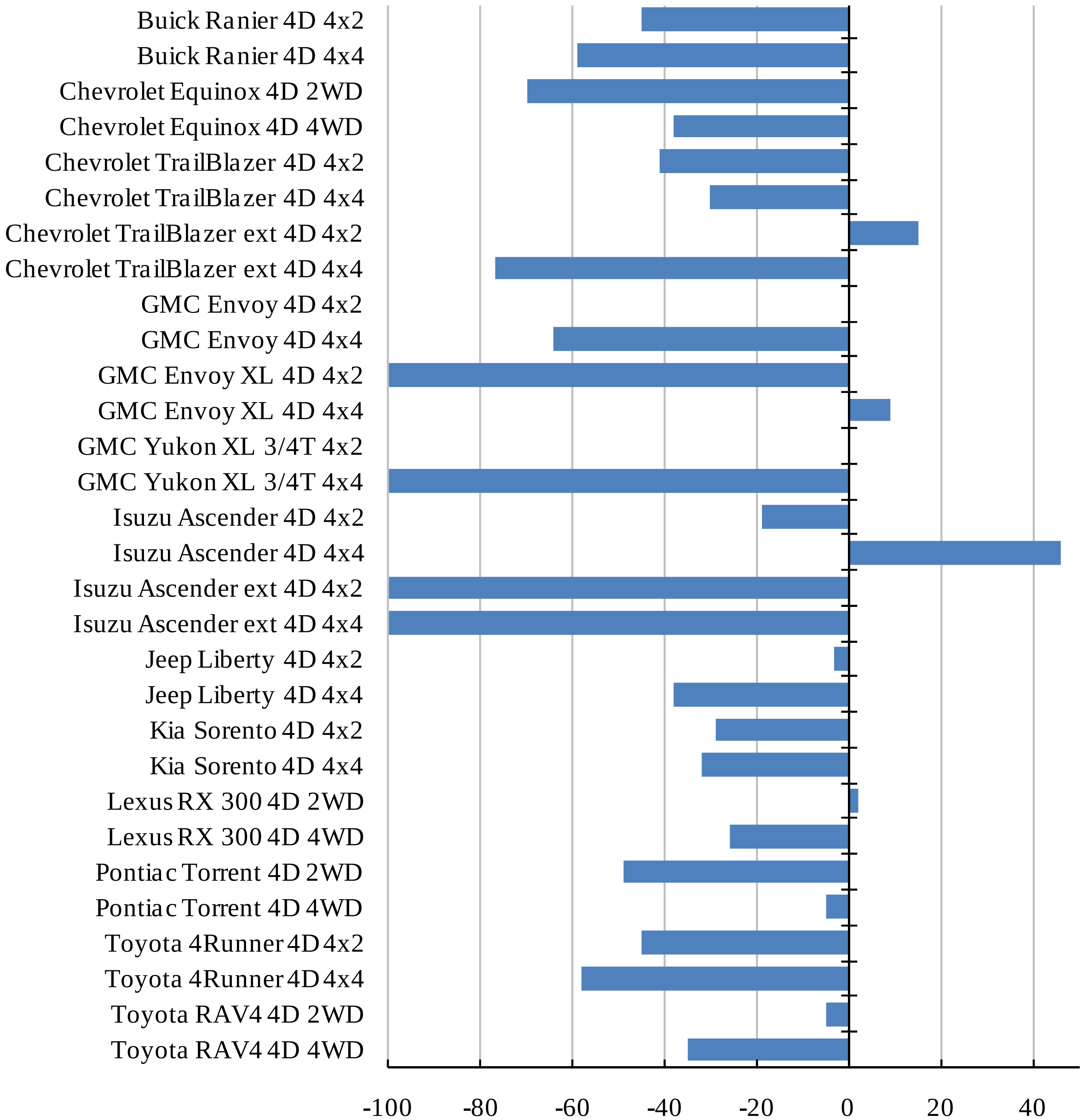
*Adjusted for vehicle age

Table 8
Observed and expected fatal crash involvements of study vehicles with ESC by design year and calendar year

First model year with ESC	Calendar year	Observed crashes	Expected crashes*	Ratio	95% confidence limits	
					Lower	Upper
1998-2001	1999-2005	330	556.12	0.59	0.52	0.68
	2006-2008	261	388.78	0.67	0.57	0.79
2002-2007	2003-2005	26	30.79	0.84	0.48	1.47
	2006-2008	307	387.78	0.79	0.68	0.92

*Adjusted for vehicle age

Figure 1
Percent change in fatal crash involvement risk due to ESC Two-wheel drive vs. four-wheel drive SUVs



4D = four door, 2WD = two-wheel drive, 4WD = four-wheel drive, ext = extended