Real-world effects of General Motors Forward Collision Alert and Front Automatic Braking Systems

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ABSTRACT

Objective: Forward collision warning and automatic emergency braking have been established as effective in reducing rear-end crashes. The objective of the current study was to examine the effectiveness of Forward Collision Alert and Front Automatic Braking, which are forward collision warning and automatic emergency braking systems from General Motors that have not been evaluated in prior IIHS research.

Method: Poisson regression was used to compare involvement rates in rear-end striking crashes of all severities, with any injuries, and with injuries in other vehicles (third-party injuries) between vehicles with Front Automatic Braking and Forward Collision Alert or with Forward Collision Alert alone and the same vehicle models where the optional systems were not purchased, controlling for other factors that have been previously shown by IIHS to affect crash risk.

Results: Vehicles equipped with Front Automatic Braking and Forward Collision Alert were involved in 43% fewer rear-end striking crashes of all severities, 64% fewer rear-end striking crashes with any injuries, and 68% fewer rear-end striking crashes with third-party injuries compared with the same vehicles without a front crash prevention system. Involvement rates in these crash types were 17%, 30%, and 32% lower, respectively, among vehicles with Forward Collision Alert alone than among the same vehicles without any system.

Conclusions: The effects of Front Automatic Braking and Forward Collision Alert features from General Motors are similar to what has been found with front crash prevention systems from other manufacturers. These findings add further evidence to suggest that many crashes will be prevented or reduced in severity when front crash prevention systems become more widespread in the vehicle fleet.

Introduction

Rear-end crashes are a common occurrence. In 2016, there were almost 2.4 million rear-end crashes reported to the police in the United States, which made up about one third of all U.S. police-reported crashes that year (Insurance Institute for Highway Safety, 2018). Forward collision warning systems that warn drivers when a rear-end crash is imminent, and automatic emergency braking systems that apply the brakes when drivers do not intervene, are effective countermeasures to prevent these crashes. Internationally, in Sweden rear-end crash rates were found to be 27% lower among Volvo vehicles with a low-speed automatic emergency braking system than Volvo vehicles without it (Isaksson-Hellman & Lindman, 2016). In a study conducted in Europe and Australia, Volvo and Mazda vehicles with low-speed automatic emergency braking had rear-end injury crash rates that were 38% lower than comparison vehicles without the system (Fildes et al., 2015).

Similar benefits for front crash prevention systems have been found in the United States. Cicchino (2017) compared rear-end striking crash involvement rates between vehicles with optional front crash prevention systems and the same vehicle models where the optional systems were not purchased using U.S. state crash data. Vehicles from Fiat Chrysler, Honda, Mercedes-Benz, and Volvo were examined in analyses of forward collision warning alone, and Acura, Mercedes-Benz, Subaru, and Volvo vehicles were included in analyses of forward collision warning with automatic emergency braking. On average, forward collision warning alone reduced rear-end striking crash involvement rates by 27% and rear-end striking crash involvement rates in injury crashes by 20%, and forward collision warning with automatic emergency braking reduced involvement rates in these crash types by 50% and 56%, respectively.

The goal of the current study was to evaluate the effectiveness of Forward Collision Alert, a forward collision warning system, and Front Automatic Braking, an automatic emergency braking system, on rear-end striking crash involvements among General Motors vehicles, which have not been previously examined by IIHS. Note that General Motors now refers to the Front Automatic Braking system as the “Forward Automatic Braking” system.

Methods

Vehicles

General Motors provided Vehicle Identification Numbers (VINs) of model year 2013–2015 vehicles from Buick, Cadillac, Chevrolet, and GMC brands with and without Forward Collision Alert, Front Automatic Braking with Forward Collision Alert, and other collision avoidance systems. Study vehicles, which are listed in Table 1, all offered Forward Collision Alert alone and Front Automatic Braking with Forward Collision Alert as optional features.

Table 1. Study vehicle series and model years

Make	Series	Model years
Buick	LaCrosse 2WD	2014–2015
Buick	LaCrosse 4WD	2014–2015
Buick	Regal 2WD	2014–2015
Buick	Regal 4WD	2014–2015
Cadillac	ATS 2D 2WD	2015
Cadillac	ATS 2D 4WD	2015
Cadillac	ATS 4D 2WD	2013–2015
Cadillac	ATS 4D 4WD	2013–2015
Cadillac	CTS 2WD	2014–2015
Cadillac	CTS 4WD	2014–2015
Cadillac	Escalade 2WD	2015
Cadillac	Escalade 4WD	2015
Cadillac	Escalade ESV 2WD	2015
Cadillac	Escalade ESV 4WD	2015
Cadillac	SRX 2WD	2013–2015
Cadillac	SRX 4WD	2013–2015
Cadillac	XTS 2WD	2013–2015
Cadillac	XTS 4WD	2013–2015
Chevrolet	Impala	2014–2015
Chevrolet	Suburban 2WD	2015
Chevrolet	Suburban 4WD	2015
Chevrolet	Tahoe 2WD	2015
Chevrolet	Tahoe 4WD	2015
GMC	Yukon 2WD	2015
GMC	Yukon 4WD	2015
GMC	Yukon XL 2WD	2015
GMC	Yukon XL 4WD	2015

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

Among the General Motors vehicles included in this analysis, *Forward Collision Alert* can either use a camera, radar, or both types of sensors to detect leading vehicles. Forward Collision Alert (independent of sensing technology used) displays a green indicator when a lead vehicle is detected that turns amber if following the lead vehicle too closely. If the system detects that a rear-end collision is imminent, the driver is alerted with a red indicator display that flashes on the windshield in most vehicles, and either eight beeps will sound or both sides of the Safety Alert Seat (if equipped), which provides haptic seat vibration pulses, will pulse five times.

Vehicles that use radar or both camera and radar sensing for the Forward Collision Alert system are also equipped with both Front Automatic Braking and Adaptive Cruise Control systems. Hence, the vehicles with Forward Collision Alert alone analyzed in this study were equipped with the camera-based version of the Forward Collision Alert system, which for the set of vehicles evaluated can detect lead vehicles within distances of 60 m (197 ft) and operates at speeds above 40 km/h (25 mph).

Front Automatic Braking in the current data set uses information from radar, or both camera and radar sensors, to automatically apply the brakes when the vehicle detects a rear-end collision is imminent and the driver has not responded. The system is operational even at very low speeds. Vehicles with Front Automatic Braking in this data set could detect lead vehicles to distances of approximately 110 m (360 ft).

Study vehicles may have been equipped with other optional collision avoidance features, including Lane Departure Warning (with or without Lane Keep Assist), a lane departure prevention feature; Side Blind Zone Alert (with or without Lane Change Alert), a lane change assist system; Rear Parking Assist, Front Parking Assist, Rear Vision Camera, Surround Vision Camera, Rear Cross-Traffic Alert, Rear (Reverse) Automatic Braking, and Automatic Parking Assist, which are low-speed or parking assist features; fixed or steerable high-intensity discharge (HID) headlights; cornering lights; and Intellibeam headlights, which turn the vehicle’s high beam headlights on and off based on surrounding traffic conditions. Because advanced headlight features could potentially affect the risk of rear-ending another vehicle in the dark, the presence of these optional features were controlled for in analyses. Other collision avoidance features listed above were not expected to affect the target rear-end crash type. LED headlights were standard on some study vehicle series and were not controlled for in analyses because they were not an optional feature.

Crash and exposure data

Police-reported crash data that included VINs were available and obtained from 23 states, and included 2012–2016 data from Delaware, Florida, Georgia, Idaho, Kansas, Louisiana, Michigan, Minnesota, Missouri, Nebraska, New Jersey, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Utah, and Wyoming; 2012–2013 data from Indiana, Nevada, and Rhode Island; 2012–2015 data from Iowa; and 2014–2016 data from Maryland.

Rear-end striking crash involvements were categorized as those where the crash type was a rear end and the initial point of impact to the striking vehicle was in the front (11 o'clock, 12 o'clock, or 1 o'clock). In two-vehicle rear-end crashes, the initial point of impact to the struck vehicle was the rear (5 o'clock, 6 o'clock, or 7 o'clock). In rear-end crashes involving three or more vehicles, any vehicle with an initial impact to the front was considered to be involved in a rear-end strike regardless of the initial impact points to other vehicles in the crash. Injury crashes were categorized as those in which any person involved in the crash had a coded injury of any severity. Crashes with third-party injuries were those where occupants of crash-involved vehicles other than the striking vehicle were injured.

Data on vehicle exposure, density of registered vehicles in the ZIP code where the vehicle is garaged, and rated driver on the vehicle's insurance policy (age, gender, marital status, insurance risk level) were obtained from the Highway Loss Data Institute (HLDI). HLDI's database includes information on approximately 85% of insured U.S. passenger vehicles. Vehicle exposure was expressed in insured vehicle days, and is presented as insured vehicle years in tables. Vehicle feature data, crash data, and insurance exposure data were merged by matching VINs within states. Crashes that occurred in a different state than where a vehicle was insured were not included in analyses.

Regression models

Poisson regression was used to model rear-end striking crash involvement rates per insured vehicle year for vehicles with front crash prevention, controlling for other factors that may affect crash risk. Separate models were constructed to examine rear-end strikes of all severities, rear-end strikes with any injuries, and rear-end strikes with third-party injuries, with crash involvements as the dependent variable and insured vehicle days as the exposure variable. Independent variables in the models included indicators for the presence or absence of Front Automatic Braking with Forward Collision Alert (with either a radar or both camera and radar sensing), Forward Collision Alert alone (with only the camera-based sensor), fixed HID headlights, steerable HID headlights, Intellibeam headlights, and cornering lights; rated driver age (15–24, 25–29, 30–39, 40–49, 50–59, 60–64, 65–69, 70+, unknown), gender (male, female, unknown), marital status (married, single, unknown), and insurance risk level (standard risk, nonstandard risk, unknown); state; calendar year; and registered vehicle density per square mile (0–99, 100–499, 500+) in the ZIP code where the vehicle is garaged. An additional independent variable capturing the vehicle series and model year was included to prevent confounding of vehicle feature effects with other vehicle design changes that may occur between vehicle series and model years. Regression models used a logarithmic link function.

Overdispersion in the Poisson models was controlled for by estimating a scale parameter in SAS (i.e., PSCALE) and adjusting statistics accordingly. Negative binomial models were considered, but were ultimately not used because they did not converge when examining all injury and third-party injury crashes.

Results

Study vehicles were involved in a total of 40,800 crashes, and were the striking vehicle in 4,098 rear-end crashes, 1,153 rear-end injury crashes, and 943 rear-end third-party injury crashes. Only 4% of rear-end injury crashes involved fatalities or serious (A-level on the KABCO scale) injuries. Involvement rates in the three crash severities examined were lowest among vehicles with Front Automatic Braking with Forward Collision Alert, followed by vehicles with Forward Collision Alert alone, and were highest among vehicles without front crash prevention (Table 2).

Table 2. Rear-end striking crash involvement rates of study vehicles with Forward Collision Alert (FCA) alone, with Front Automatic Braking (FAB) and FCA, and with no system (not controlling for factors that can affect crash risk)

System	Insured vehicle years	Rear-end		Rear-end injury		Rear-end third-party injury	
		Crashes	Rate (x1,000)	Crashes	Rate (x1,000)	Crashes	Rate (x1,000)
FAB + FCA	82,004	236	2.88	56	0.68	46	0.56
FCA	464,212	1,965	4.23	556	1.20	460	0.99
No system	319,768	1,897	5.93	541	1.69	437	1.37
Total	865,984	4,098	4.73	1,153	1.33	943	1.09

Results of Poisson regression models examining the effects of General Motors front crash prevention systems on rear-end striking crash involvement rates controlling for characteristics of the rated driver, garage location of the vehicle, and the presence of advanced headlight systems are summarized in Table 3. Full model results appear in Tables A1-A3 in the Appendix. Involvement rates were 43% lower in rear-end striking crashes of all severities, 64% lower in rear-end striking crashes with injuries, and 68% lower in rear-end striking crashes with third-party injuries for vehicles with Front Automatic Braking with Forward Collision Alert than for vehicles without a front crash prevention system. For vehicles with Forward Collision Alert alone, involvement rates were 17%, 30%, and 32% lower, respectively, in these three corresponding rear-end crash types compared with vehicles without front crash prevention. All these comparisons were statistically significant.

Table 3. Adjusted rate ratios from Poisson regression models examining the effects of Forward Collision Alert (FCA) alone and Front Automatic Braking (FAB) with FCA on rear-end striking crash involvement rates

	Rate ratio (95% confidence interval)		
Analysis	Rear-end striking	Rear-end striking with injury	Rear-end striking with third-party injury
FAB + FCA vs. no system	0.57 (0.43, 0.78)	0.36 (0.21, 0.62)	0.32 (0.17, 0.60)
FCA vs. no system	0.83 (0.72, 0.96)	0.70 (0.54, 0.91)	0.68 (0.51, 0.91)

Discussion

The Forward Collision Alert and Front Automatic Braking systems from General Motors are effective in reducing rear-end crash rates to a similar degree as has been established for other forward collision warning and automatic emergency braking systems (Cicchino, 2017). Effect sizes for Front Automatic Braking with Forward Collision Alert (using radar or camera and radar sensing) were larger than for the camera-based Forward Collision Alert system alone, which is also consistent with the pattern of results seen with front crash prevention systems from other automakers. Evidence from a variety of crash avoidance systems suggest that technology is most effective when it does not rely entirely on an appropriate response from the driver to prevent a crash. For example, a study of rear crash prevention systems from General Motors found that the combination of Rear Parking Assist (a rear parking sensor system that warns the driver) and a Rear Vision Camera reduced police-reported backing crashes by 42%, and when Rear Automatic Braking was added to those systems the crash reduction increased to 78% (Cicchino, 2018). Front Automatic Braking with Forward Collision Alert was additionally more effective in preventing rear-end injury crashes than Forward Collision Alert alone, which was expected given that automatic emergency braking can lower the speed of the striking vehicle and thus lessen the severity of a rear-end crash that still occurs.

An important limitation of this study is that Forward Collision Alert and Front Automatic Braking were optional systems. Analyses controlled for some driver characteristics that were related to crash risk, but drivers who chose to purchase vehicles with these systems may differ from those who did not in uncontrolled ways that could potentially decrease or increase the size of effects.

Twenty automakers representing more than 99% of the U.S. auto market have agreed to make automatic emergency braking a standard feature on virtually all new cars by 2022. This study provides additional evidence demonstrating that when front crash prevention systems proliferate through the vehicle fleet, a large proportion of a common crash type will be prevented.

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APPENDIX

Note: For brevity, effects by state and by vehicle series/model year combinations are omitted from Tables A1-A3.

Table A1. Parameter estimates of Poisson regression model examining the effects of Forward Collision Alert alone and Front Automatic Braking with Forward Collision Alert on rear-end striking crashes of all severities

Parameter	Estimate	Effect % (95% confidence interval)		*p*-value
Front Automatic Braking with Forward Collision Alert (ref=without)	−0.5695	−43	(−57, −25)	<.0001
Forward Collision Alert (ref=without)	−0.1807	−17	(−28, −4)	0.0131
Fixed HID headlights (ref=without)	−0.1115	−11	(−24, 5)	0.1639
Steerable HID headlights (ref=without)	−0.0500	−5	(−21, 15)	0.5986
Intellibeam headlights (ref=without)	−0.0923	−9	(−29, 17)	0.4624
Cornering lights (ref=without)	−0.0110	−1	(−44, 75)	0.9699
Calendar year 2012 (ref=2016)	−2.2382	−89	(−97, −64)	0.0003
Calendar year 2013 (ref=2016)	−0.2147	−19	(−38, 5)	0.1138
Calendar year 2014 (ref=2016)	−0.0549	−5	(−18, 9)	0.4547
Calendar year 2015 (ref=2016)	−0.0014	0	(−10, 11)	0.9786
Age 25–29 (ref=15–24)	−0.0490	−5	(−26, 23)	0.7051
Age 30–39 (ref=15–24)	−0.2186	−20	(−36, 1)	0.0577
Age 40–49 (ref=15–24)	−0.4562	−37	(−50, −20)	0.0001
Age 50–59 (ref=15–24)	−0.6540	−48	(−59, −34)	<.0001
Age 60–64 (ref=15–24)	−0.9404	−61	(−70, −48)	<.0001
Age 65–69 (ref=15–24)	−0.9673	−62	(−71, −50)	<.0001
Age 70+ (ref=15–24)	−1.1124	−67	(−74, −58)	<.0001
Unknown age (ref=15–24)	−0.5763	−44	(−58, −25)	<.0001
Female (ref=male)	0.0097	1	(−9, 12)	0.8495
Unknown gender (ref=male)	−0.4668	−37	(−60, −3)	0.0375
Married (ref=single)	−0.2276	−20	(−29, −11)	<.0001
Unknown marital status (ref=single)	0.0441	5	(−31, 59)	0.8376
Nonstandard insurance risk (ref=standard)	0.4194	52	(26, 84)	<.0001
Registered vehicle density 0-99 per square mile (ref= 500+)	−0.5719	−44	(−53, −33)	<.0001
Registered vehicle density 100–499 per square mile (ref= 500+)	−0.1974	−18	(−26, −8)	0.0005
Scale	1.4939			

Table A2. Parameter estimates of Poisson regression model examining the effects of Forward Collision Alert alone and Front Automatic Braking with Forward Collision Alert on rear-end striking crashes with injuries

Parameter	Estimate	Effect % (95% confidence interval)		*p*-value
Front Automatic Braking with Forward Collision Alert (ref=without)	−1.0226	−64	(−79, −38)	0.0003
Forward Collision Alert (ref=without)	−0.3502	−30	(−46, −9)	0.0079
Fixed HID headlights (ref=without)	−0.0192	−2	(−26, 30)	0.8933
Steerable HID headlights (ref=without)	0.0117	1	(−28, 42)	0.9463
Intellibeam headlights (ref=without)	0.0516	5	(−33, 64)	0.8202
Cornering lights (ref=without)	0.2437	28	(−54, 253)	0.6387
Calendar year 2012 (ref=2016)	−10.5936	−100	*	0.8860
Calendar year 2013 (ref=2016)	−0.2811	−25	(−55, 26)	0.2805
Calendar year 2014 (ref=2016)	0.0027	0	(−22, 30)	0.9837
Calendar year 2015 (ref=2016)	−0.0122	−1	(−18, 19)	0.8986
Age 25–29 (ref=15–24)	0.0082	1	(−37, 60)	0.9723
Age 30–39 (ref=15–24)	−0.1111	−11	(−41, 35)	0.5961
Age 40–49 (ref=15–24)	−0.3886	−32	(−56, 4)	0.0738
Age 50–59 (ref=15–24)	−0.4704	−38	(−59, −4)	0.0316
Age 60–64 (ref=15–24)	−0.7655	−53	(−72, −23)	0.0028
Age 65–69 (ref=15–24)	−0.8630	−58	(−75, −30)	0.0008
Age 70+ (ref=15–24)	−0.8786	−58	(−73, −35)	0.0001
Unknown age (ref=15–24)	−0.4619	−37	(−63, 7)	0.0874
Female (ref=male)	−0.0716	−7	(−22, 11)	0.4348
Unknown gender (ref=male)	−0.7774	−54	(−78, −5)	0.0355
Married (ref=single)	−0.3106	−27	(−40, −10)	0.0025
Unknown marital status (ref=single)	0.2368	27	(−36, 151)	0.4972
Nonstandard insurance risk (ref=standard)	0.5380	71	(24, 137)	0.0012
Registered vehicle density 0-99 per square mile (ref= 500+)	−0.4579	−37	(−53, −14)	0.0030
Registered vehicle density 100–499 per square mile (ref= 500+)	−0.1518	−14	(−29, −5)	0.1315
Scale	1.4283			

*****standard error too large to calculate confidence interval

Table A3. Parameter estimates of Poisson regression model examining the effects of Forward Collision Alert alone and Front Automatic Braking with Forward Collision Alert on rear-end striking crashes with third-party injuries

Parameter	Estimate	Effect % (95% confidence interval)		*p*-value
Front Automatic Braking with Forward Collision Alert (ref=without)	−1.1359	−68	(−83, −40)	0.0004
Forward Collision Alert (ref=without)	−0.3823	−32	(−49, −9)	0.0097
Fixed HID headlights (ref=without)	0.0276	3	(−25, 40)	0.8623
Steerable HID headlights (ref=without)	0.0395	4	(−29, 52)	0.8387
Intellibeam headlights (ref=without)	0.0168	2	(−38, 67)	0.9473
Cornering lights (ref=without)	0.3267	39	(−53, 309)	0.5538
Calendar year 2012 (ref=2016)	−10.2928	−100	*	0.8903
Calendar year 2013 (ref=2016)	−0.2441	−22	(−56, 40)	0.4127
Calendar year 2014 (ref=2016)	0.0469	5	(−21, 40)	0.7501
Calendar year 2015 (ref=2016)	0.0709	7	(−13, 32)	0.5045
Age 25–29 (ref=15–24)	−0.0115	−1	(−40, 40)	0.9645
Age 30–39 (ref=15–24)	−0.1289	−12	(−36, 64)	0.5715
Age 40–49 (ref=15–24)	−0.4455	−36	(−60, 2)	0.0604
Age 50–59 (ref=15–24)	−0.5672	−43	(−65, −9)	0.0184
Age 60–64 (ref=15–24)	−0.8960	−59	(−77, −28)	0.0018
Age 65–69 (ref=15–24)	−0.9660	−62	(−78, −33)	0.0008
Age 70+ (ref=15–24)	−0.9209	−60	(−76, −35)	0.0002
Unknown age (ref=15–24)	−0.5050	−40	(−66, 8)	0.0903
Female (ref=male)	−0.1187	−11	(−27, 9)	0.2464
Unknown gender (ref=male)	−0.6540	−48	(−78, 22)	0.1322
Married (ref=single)	−0.3426	−29	(−43, −11)	0.0028
Unknown marital status (ref=single)	0.0711	7	(−52, 141)	0.8632
Nonstandard insurance risk (ref=standard)	0.4572	58	(9, 129)	0.0157
Registered vehicle density 0-99 per square mile (ref= 500+)	−0.4769	−38	(−56, −13)	0.0058
Registered vehicle density 100–499 per square mile (ref= 500+)	−0.1503	−14	(−31, 7)	0.1811
Scale	1.4427			

*****standard error too large to calculate confidence interval