Crash rates of convertible cars

June 2020

Eric R. Teoh

Insurance Institute for Highway Safety
4121 Wilson Boulevard, 6th floor
Arlington, VA 22203
research@iihs.org
+1 703 247 1500

iihs.org

CONTENTS

ABSTRACT

Objective: Convertible cars have existed since among the first automobiles, and the lack of substantial roof structure creates some safety concerns. While crash tests have demonstrated that convertibles can resist excessive intrusion in front and side crashes and that strong A-pillars and roll bars can help maintain survival space in rollovers, little work has been done examining the real-world crash experience of these vehicles. The objective of this study was to compare the crash experience of recent convertibles with nonconvertible versions of the same cars using the most recent crash data.

Methods: Rates of driver deaths and police-reported crash involvements were compared for 1- to 5-year-old convertible cars and their nonconvertible versions during 2014–2018. Exposure measures included registered vehicle years and vehicle miles traveled (VMT). These rates were compared using the standardized mortality ratio to account for possible differences in exposure distribution. Crash circumstances (e.g., point of impact, rollover, ejection) and behavioral outcomes (e.g., speeding, alcohol impairment, seat belt use) were compared for drivers killed in crashes.

Results: Convertibles had lower driver death rates and police-reported crash involvement rates on the basis of both registered vehicle years and VMT. However, the differences in driver death rates were not statistically significant. Driver deaths per 10 billion VMT were 11% lower for convertibles, and driver involvements in police-reported crashes per 10 million VMT were 6% lower. On average, convertibles were driven 1,595 fewer miles per year than the nonconvertible versions of these cars. Among fatally injured drivers, convertibles had higher rates of ejection, and behavioral differences were minimal.

Conclusions: Safety concerns associated with convertibles' lack of substantial roof structure were not supported by the results of this study. Minimal differences in behavioral outcomes suggest that the study design minimized differences in the study groups.

Practical Applications: Convertibles do not pose a safety risk to consumers. Consumers interested in convertibles should consider crash test ratings, safety features, and vehicle size and weight, just as they would if shopping for a nonconvertible car.

Keywords: convertible cars; driver death rates; crash rates; passenger vehicle safety

INTRODUCTION

Convertibles, which are passenger vehicles with retractable or removable roofs, have existed since among the first automobiles. For example, the 1897 Daimler Grafton Phaeton and the 1908 Ford Model T both had retractable roof structures. While some pickup trucks and SUVs, most notably the Jeep Wrangler, had versions with retractable roofs throughout the years, most convertibles are two-door cars. Retractable roof structures of convertibles consist of either frame-supported stretched fabric or multiple hard panels, the latter of which are known as retractable-hardtop convertibles. Many convertibles also have a nonconvertible version available during the same model year.

The lack of substantial roof structure leads to a couple of safety concerns for convertibles—namely that they may provide less protection in rollovers and that the occupant compartment structure unsupported by the truss-like roof and pillars may allow for more intrusion in planar crashes (i.e., crashes involving frontal, side, or rear impacts that don't involve a rollover). Having strong occupant compartments that resist intrusion and prevent occupant ejection is a widely recognized fundamental principle of vehicle crashworthiness (O'Neill 2009). Increased roof strength has been shown to be protective for (nonconvertible) passenger vehicle occupants in rollover crashes (Brumbelow and Teoh 2009; Brumbelow et al. 2009). Occupant compartment deformation has been correlated with injury severity (Eigen and Glassbrenner 2003), and vehicles with strong B-pillars, as measured in the Insurance Institute for Highway Safety (IIHS) side crash test, have been shown to be associated with lower driver death risk in real-world side impact crashes (Teoh and Arbelaez 2019; Teoh and Lund 2011).

The primary way of measuring occupant compartment strength and other aspects of crashworthiness is through crash testing. In 2007, IIHS conducted a crash test series of midsize convertible cars (IIHS 2007) using the Institute's standard crashworthiness evaluation tests that

are normally applied to nonconvertibles. These tests showed that the convertibles tested were designed with strong occupant compartments and side airbags that protected their occupants (particularly front-seat occupants), despite the lack of roof structure. Wech and Ostmann (1996) conducted full-scale rollover crash tests of convertibles and showed that strong A-pillars and rear roll bars are important features in maintaining occupant survival space during rollovers. As vehicle designs improve and are subjected to regulatory and consumer information crash testing, these crashworthiness aspects of convertibles are expected to have improved, or at least have been maintained, over time.

In terms of examining the differences between convertibles and nonconvertibles in real-world outcomes, little work has been done. A study of 1985–1993 model year vehicles (Kahane 1997) found that convertibles have slightly higher death rates than two-door cars, and the authors speculated that such differences largely reflected the behavior of people choosing to drive different types of vehicles. However, the study did not isolate the convertible/nonconvertible difference to a large extent, since many two-door cars were not available as convertibles and studying convertibles was not the primary purpose of that study. With the release of its convertible crash test results, IIHS also released some analyses comparing convertibles with nonconvertible versions of the same vehicles (IIHS 2007). The analyses found that convertibles had lower driver death rates overall, but higher death rates in rollovers—a difference that declined during the study period. More recently, the Highway Loss Data Institute (HLDI) studied the insurance loss experience of convertibles and nonconvertible versions of the same vehicles (HLDI, 2020). The study found that convertibles had lower injury rates and collision claim rates than the nonconvertible versions; the effect was larger for retractable-hardtop convertibles than for soft-tops. IIHS analyses of driver death rates by make and series (IIHS 2020) include some

examples of convertibles and their nonconvertible versions, but the analyses excludes many due to low registration counts and was not specifically designed to examine convertibles. The purpose of the current study was to carefully compare the crash experience of recent convertible cars with their nonconvertible versions using the most recent crash data.

METHODS

The current study analyzed the crash experience of 1- to 5-year-old convertible cars and their nonconvertible versions in the United States during 2014–2018. These vehicles were identified from the series names in the vehicle information databases maintained by the Highway Loss Data Institute (HLDI). The nonconvertible versions had to be a two-door car, which excluded some potential convertible/nonconvertible pairs like the Audi A3, for which only a four-door was available as a nonconvertible during the study period. The study included all cars with both a convertible and nonconvertible version on the road (meaning the number of registered vehicles was greater than zero for both the convertible and nonconvertible version). Variants (e.g., BMW M3 is a high-performance variant of the 3 series) were included, provided that both convertible and nonconvertible versions existed. Vehicle make, series, and model year were identified in all data sources by decoding Vehicle Identification Numbers (VINs).

Data on drivers killed in crashes were obtained from the Fatality Analysis Reporting System, a census of crashes resulting in fatality within 30 days that is maintained by the National Highway Traffic Safety Administration (NHTSA). Counts of driver involvements in crashes reported to police were obtained from two national samples—the National Automotive Sampling System General Estimates System (NASS-GES) and the Crash Report Sampling System (CRSS), which became the successor to NASS-GES beginning in 2016. Both databases were designed and are maintained by NHTSA. The update to the sampling design between these two databases

could result in a “jump” in counts, but there is no reason to believe this would differ between convertibles and their nonconvertible versions, so no adjustment was made. FARS includes information on crash circumstances such as weather condition, number of vehicles, rollover, ejection, and point of impact and also on driver seat belt use, speeding, and alcohol impairment. Multiple imputation values provided in FARS (Subramanian 2002) were analyzed to account for missing values of driver blood alcohol content (BAC). No information was available regarding whether the convertibles’ roofs were open or closed during the time of the crash.

Exposure measures were registered vehicle years (the sum of annual registration counts over multiple years), based on data obtained from IHS Markit, and vehicle miles traveled (VMT). Odometer readings/dates at the VIN level were obtained from CARFAX, a unit of IHS Markit, and transformed to average daily VMT at the level of make/series/model year by HLDI. Estimates of total VMT were obtained by multiplying daily VMT estimates by number of days in the years and number of registered vehicle years. Therefore, VMT accounts for both convertible/nonconvertible differences in the numbers of vehicles on the road and how much they are driven. Restricting to vehicles at least one year old allowed for a full year of exposure to be reflected in counts of registered vehicles and for vehicles to have sufficient time on the road to compute estimates of VMT.

Crash rates of convertibles and nonconvertibles were compared using the standardized mortality ratio (SMR). The SMR accounts for differences in exposure distribution among the two study groups. In the current study, if certain vehicles are much more likely to be convertibles than nonconvertibles, then they would be overrepresented in the convertible sample and underrepresented in the nonconvertible sample. To compute the SMR, for each vehicle, the expected number of deaths in convertibles is computed as the product of the crash rate for the

nonconvertible version and the exposure of the convertible version. Then the observed and expected values are summed across vehicles, and the SMR is the sum of observed values divided by the sum of expected values. Confidence intervals for the SMR are computed using the beta distribution (Silcocks 1994).

RESULTS

Table 1 provides the main results of the current study. Study vehicles, with full breakdowns of the counts in Table 1, are listed in the Appendix. Convertibles were driven 1,595 fewer miles per year on average than their nonconvertible versions, and were outnumbered by nearly a factor of three in terms of registered vehicle years. Convertibles had much lower rates of both driver deaths and driver involvements in police-reported crashes. Rates of police-reported crash involvements were 20% lower for convertibles on the basis of registered vehicle years, and 6% lower when considering vehicle miles traveled; these two differences were the only ones statistically significant at the 0.05 type-1 error level. Driver death rates were 23% lower for convertibles on the basis of registered vehicle years, and 11% lower when considering vehicle miles traveled. Police-reported crash involvements were 21% less likely to be fatal for convertible drivers, compared with drivers of nonconvertible versions of these cars.

Table 1. Crash experience and exposure of the study convertibles and their nonconvertible versions, 2014–2018

Crash and exposure counts	Convertible	Nonconvertible version
Driver deaths	86	360
Driver crash* involvements	75,037	285,859
Registered vehicle years (RVY)	2,178,120	6,229,294
Vehicle miles traveled (VMT)	18,265,365,805	62,175,420,582
Average annual VMT per vehicle	8,386	9,981
Rates		
Driver deaths per million RVY	39.5	57.8
Driver deaths per 10 billion VMT	47.1	57.9
Driver deaths per 10,000 crashes*	11.5	12.6
Crashes* per 1,000 RVY	34.5	45.9
Crashes* per 10 million VMT	41.1	46.0
Standardized mortality ratios, observed/expected=SMR (95% CI)		
Driver deaths per million RVY	86/112.0 = 0.77 (0.57, 1.03)	
Driver deaths per 10 billion VMT	86/96.6 = 0.89 (0.66, 1.20)	
Driver deaths per 10,000 crashes*	86/108.2 = 0.79 (0.59, 1.06)	
Crashes* per 1,000 RVY	75,037/93,426.3 = 0.80 (0.79, 0.81)	
Crashes* per 10 million VMT	75,037/80,190.4 = 0.94 (0.93, 0.95)	

Note. CI = confidence interval.
*Driver involvements in crashes of any severity that were reported to police.

Table 2 documents the circumstances of drivers killed in crashes of the study vehicles. Rollovers were similar between convertibles and their nonconvertible versions (24% vs 23%), and ejection was more likely in convertibles (21% vs 17%). Among rollover crashes, the likelihood of ejection was higher for convertibles (43% vs 35%, not shown in table). Distribution of the initial impact direction were similar. Convertible drivers killed in crashes were less likely to have been unbelted and to have been speeding, and were slightly more likely impaired by alcohol and to have crashed at night. However, all these differences were small and are not indicative of substantial variation in behavior or crash circumstances.

Table 2. Factors among drivers killed in crashes of the study vehicles, 2014–2018

	Convertible		Nonconvertible version	
Factor	N	%	N	%
Single-vehicle crash	43	50.0	181	50.3
Front initial impact	53	61.6	212	58.9
Side initial impact	17	19.8	80	22.2
Rear initial impact	4	4.7	23	6.4
Rollover	21	24.4	82	22.8
Ejection	18	20.9	61	16.9
Unbelted	31	36.0	141	39.2
Speeding	33	38.4	157	43.6
BAC 0.08+ g/dL	33	38.4	130	36.1
Nighttime (9 p.m.–6 a.m.)	49	57.0	198	55.0
May 1–September 30	35	40.7	147	40.8
Precipitation	10	11.6	39	10.8
All driver deaths	86	100	360	100

Note. BAC = blood alcohol content.

DISCUSSION

The current study found that, even when accounting for differences in VMT, convertible cars had lower driver death rates and rates of police-reported crash involvements, although the differences in driver death rates were not statistically significant. While these findings do not directly imply that the convertible versions of these cars are more protective to their occupants or that they are superior in terms of crash avoidance, the findings do not support concerns that convertibles' lack of roof structures make them less protective to their occupants except for the case of ejection, which was more likely among fatally injured convertible drivers.

A major strength of this study is that it compared convertibles with the nonconvertible versions of the same cars, as driver death rates are known to vary widely even within the same class of vehicles (IIHS 2020). This minimized differences in vehicle design, availability of safety features, and biases associated with owner demographics and how they use their cars. Examining

behavioral outcomes among drivers killed in crashes did not point to large differences between convertibles and nonconvertibles.

However, the study design does not entirely eliminate the potential biases referenced above. While differences in VMT were captured, there could be differences in the actual miles accrued that may have influenced study outcomes. For instance, if convertibles tend to be driven in nicer weather or on less busy roads, that could have affected observed driver death and crash rates. However, convertibles did not differ from their nonconvertible versions in terms of warmer months and precipitation in fatal crashes (Table 2). It is possible that, even when comparing cars with the same make/series, the convertible version is more frequently purchased as a secondary vehicle and the nonconvertible more frequently as a primary vehicle, which would affect usage. Another limitation was that the sample size of convertible driver deaths was small, which limited statistical power and the ability to compare hardtop and soft-top convertibles as in HLDI's study (2020). Despite the limitations of the current study, the findings indicate that convertibles are not a major safety concern.

ACKNOWLEDGEMENTS

This work was supported by the Insurance Institute for Highway Safety.

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APPENDIX

Table A. Driver deaths and police-reported crash involvements, registered vehicle years, and vehicle miles traveled of study vehicles, 2014–2018

			Convertible				Nonconvertible version			
Make	Series	Model year	Driver deaths	Driver crash* involvements	Registered vehicle years	Vehicle miles traveled	Driver deaths	Driver crash* involvements	Registered vehicle years	Vehicle miles traveled
Audi	A5	2010–2017	1	1,977	100,619	881,724,437	2	3,249	151,351	1,614,108,170
	RS5	2013–2015	0	0	2,867	19,483,996	0	220	14,187	114,193,064
	S5	2010–2017	1	845	31,859	255,216,075	3	1,073	63,591	609,392,186
	TT	2009–2017	0	422	11,115	78,170,143	0	955	28,830	241,651,928
BMW	1 series	2009–2013	4	2,311	64,445	506,163,679	4	2,542	74,176	699,171,468
	2 series	2015–2017	1	1,502	27,181	226,695,055	2	549	47,061	446,583,708
	3 series	2009–2013	2	3,989	185,291	1,544,013,848	3	4,747	190,591	1,864,732,521
	4 series	2014–2017	2	2,835	101,324	888,389,698	6	8,485	176,016	1,766,322,552
	6 series	2009–2017	2	2,077	58,337	442,555,829	3	1,037	32,737	281,659,974
Chevrolet	Camaro	2011–2017	26	12,958	295,258	2,656,577,510	106	93,953	1,467,841	16,593,050,850
	Corvette	2009–2017	5	1,147	122,440	478,529,204	20	7,163	368,209	1,707,764,818
Fiat	500	2012–2017	3	2,517	94,654	861,636,086	20	16,655	508,456	5,357,127,195
Ford	Mustang	2009–2017	22	23,939	459,435	4,398,580,174	112	85,273	1,580,117	16,195,376,585
Infiniti	G	2009–2013	2	3,115	56,888	519,227,862	11	8,040	123,546	1,327,940,004
	Q60	2014–2015	0	217	12,542	108,552,200	3	1,226	32,699	329,817,775
Jaguar	F-Type	2015–2017	0	445	8,988	49,360,482	2	68	17,845	110,704,486
	XK	2009–2015	0	373	16,914	90,513,315	0	528	13,957	85,253,018
Mercedes-Benz	C-Class	2017–2017	0	0	8,012	63,752,849	0	428	14,684	137,806,378
	CLK-Class	2009–2009	0	243	5,667	42,361,958	0	247	3,548	34,810,138
	E-Class	2011–2017	3	3,593	144,258	1,055,815,943	3	4,176	116,216	1,079,968,367
	S-Class	2017–2017	0	152	3,469	21,309,237	0	0	1,135	9,121,682
Mini	Cooper	2009–2017	3	2,113	110,734	909,128,726	16	19,054	604,101	5,957,540,290
Mitsubishi	Eclipse	2009–2012	2	263	18,511	181,531,565	1	3,324	32,326	368,476,794
Nissan	370Z	2010–2017	1	828	25,284	170,554,430	18	3,921	127,761	1,126,421,236
Smart	Fortwo	2009–2017	3	35	16,979	128,937,293	11	3,701	140,697	1,087,347,478
Volkswagen	New Beetle	2009–2017	3	7,142	195,049	1,686,584,210	14	15,243	297,616	3,029,077,920
Total			86	75,037	2,178,120	18,265,365,805	360	285,859	6,229,294	62,175,420,582

* Driver involvements in crashes of any severity that were reported to police.