Traffic Safety Facts
Research Note

DOT HS 812 937 March 2020

The Relationship Between Passenger Vehicle Occupant Injury Outcomes and Vehicle Age or Model Year in Police-Reported Crashes

Summary

This study examines the relationship between passenger vehicle occupant injury severity outcomes and the vehicle age or model year (MY) in police-reported crashes. It shows that occupants of older model year vehicles and higher vehicle age had a higher percentage of occupants who were severely injured. The study uses both univariate descriptive analysis and statistical modeling that adjusts for other confounding factors.

When examining the role of vehicle age, the univariate descriptive analysis shows that among all passenger vehicle (passenger cars, SUVs, pickup trucks, or vans) occupants involved in police-reported crashes, the percentages of occupants who were severely injured was: 1.20 percent/1.60 percent/1.89 percent/2.20 percent for vehicle age groups 1-6 years/7-11 years/12-15 years/>15 years, respectively. Also, the percentages of occupants who were severely injured, when examining by vehicle model year, were: 3.09 percent/2.50 percent/1.65 percent/1.08 percent for vehicle model year groups MY 1987 and earlier/MY 1988-1994/MY 1995-2011/MY 2012-2018, respectively.

After adjusting for many occupant, vehicular, and crash factors, the multivariate regression model analysis shows the similar results that when compared to the baseline of a vehicle 1 to 6 years old, that the odds of severe injury is 1.11 times for occupants of vehicles 7 to 11 years old, 1.19 times for occupants of vehicles 12 to 15 years old, and 1.23 times for vehicles older than 15 years. Also, when compared to the baseline of a vehicle in MY 2012-2018, the results have shown that the odds of severe injury is 1.15 times for occupants of vehicles in MY 1995-2011, 1.28 times for occupants of vehicles in MY 1988-1994, and 1.50 times for vehicles in MY 1987 and older.

This study uses NHTSA's National Automotive Sampling System General Estimates System (NASS-GES) 2012-2015 data as well as the 2016-2017 data from the replacement system in 2016 – the Crash Report Sampling System (CRSS).

Introduction

During the last two decades, many vehicular safety innovations and improvements have occurred. Some of these innovations and improvements include the advanced frontal and side air bags, front end crumple zones, crash severity sensing system, roof crush strength, occupant compartment strength, seat belt load limiters and pretensioners (including child safety seats, booster seats), electronic stability control, antilock braking systems, lane departure warning systems, and forward collision warning systems. Safety effects and estimation of lives already saved by the introduction of Federal Motor Vehicle Safety Standards (FMVSSs) and other vehicle safety technologies has been extensively studied and reported.[1-4]

Among these studies several investigations examining the relationship between vehicle occupant injury outcomes and vehicle age or model year, either through the univariate descriptive analysis or by statistical modeling analysis that controls for other vehicle, occupant, and environment factors, have also been conducted.[5-12] Similar conclusions have been reached, based on The Fatality Analysis Reporting System (FARS), National Accident Sampling System Crashworthiness Data System (NASS-CDS), Crash Injury Research and Engineering Network (CIREN), as well as National Collision Data Base (NCDB) of Canada, Crash Database for the State of New South Wales of Australia, and tele phone survey data in the Auckland region of New Zealand. That is, an occupant's injury severity experienced during a motor vehicle traffic crash increased as vehicle age increased and in older model year vehicles.

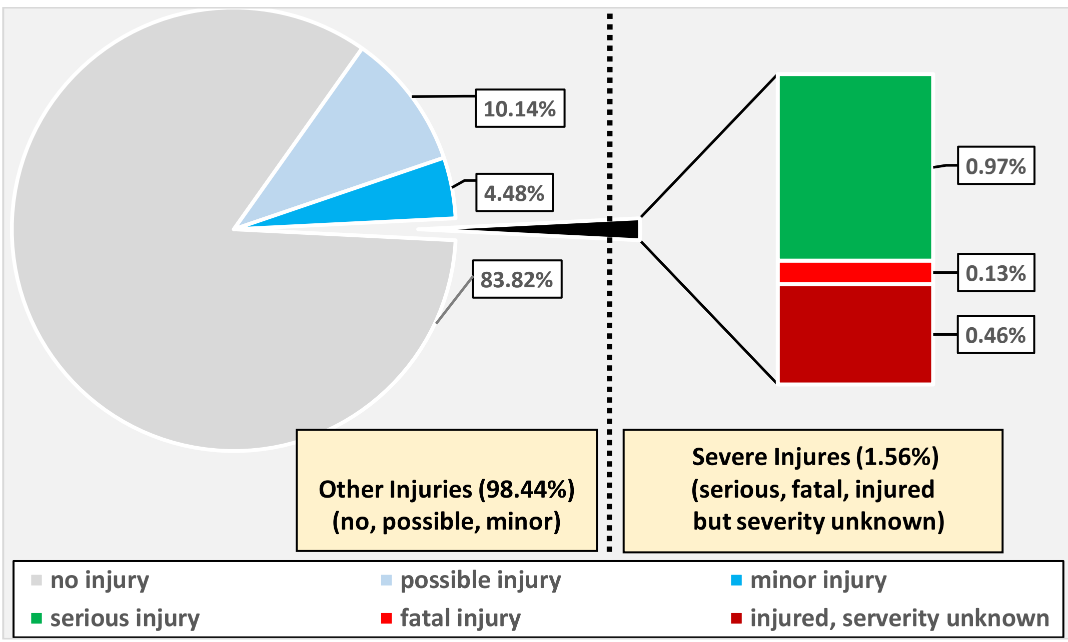
The objective of this work is to use NHTSA's NASS-GES 2012-2015 and CRSS 2016-2017 data, through both univariate descriptive statistics and multivariate statistical modeling analysis, to examine the relationship between passenger vehicle occupant injury outcomes and the vehicle age or model year. This study further confirmed previous findings, based on a large and more complete crash dataset.

Data and Methodology

Police-reported crash data from NASS-GES and CRSS for calendar years 2012 to 2017 were used for this analysis. NASS-GES (2015 and before) and CRSS (2016 and after) are obtained from a nationally representative probability sample selected from all police-reported crashes. To be eligible for the NASS-GES and CRSS sample, a police crash report must be completed for the crash, and the crash must involve at least one motor vehicle traveling on a trafficway, and must result in property damage, injury, or death. About 50,000 police crash reports per year (this number varies from year to year) were selected in a multistage probability sample.

The response variable examined in this study is the injury severity outcome of the passenger vehicle occupant. Occupant injury severity outcome in police-reported crashes was reported by the *KABCO* scale: *K*-fatal injury, *A*-serious injury, *B*-minor injury, *C*-possible injury, *O*-no injury, *U*-injured, severity unknown. Killed or Seriously Injured is a standard metric for measuring safety risks, particularly in transportation and road traffic safety policy areas. In this analysis, occupant injury severity outcomes were separated into two groups: *Severe Injures* (*K*, *A*, *U*) versus *Other Injuries* (*B*, *C*, *O*). Those occupants, who were known to be injured but injury severity unknown (*U*), are assumed to have been sent to the nearby medical facility or trauma center immediately after the vehicle crash, and therefore are grouped into severe injuries in this study. Figure 1 presents the distribution of occupant injury severity outcome in the dataset used in this analysis (occupants with unknown injury severity were excluded from the analysis). It shows that less than two percent of all occupants involved in police-reported crashes were severely injured (including fatally injured).

Figure 1: Percentage Distribution (%) of Weighted Passenger Vehicle Occupants (N = 83,664,081) by Injury Severity Outcome. Source: NASS-GES 2012-2015 and CRSS 2016-2017.



The age of a vehicle is measured by subtracting the vehicle MY from the calendar year at the time of the crash (vehicle whose age was calculated to be negative one was recoded to be age one). Due to the fact that some model year vehicles do not exist in some vehicle age groups in the crash dataset and the sample size requirements for reliable regression modeling analysis, we have grouped the vehicle age as 1 to 6 years, 7 to 11 years, 12 to 15 years, and >15 years. The MY is categorized as 2012 to 2018, 1995 to 2011, 1988 to 1994 and 1987 and earlier.

Besides the two major variables, vehicle age and MY, the other confounding factors were selected based on the literature review and findings related to this topic. The confounding variables chosen in the present work are: vehicle speeding status (non-speeding, speeding), day of week (weekday - 6 a.m. Monday to 5:59 p.m. Friday, weekend - 6 p.m. Friday to 5:59 a.m. Monday), vehicle initial point of impact (rear, right side, front, left side, other/unknown), occupant role (driver, passengers), occupant restraint use (used, unknown, not used), occupant sex (male, female), occupant age (0-15, 16-24, 25-44, 45-64, 65+), time of day (daytime: 6 a.m. to 5:59 pm, nighttime: 6 p.m. to 5:59 am), relation to roadway (on roadway, median/shoulder/other, off roadway), vehicle rollover (no, yes), driver alcohol use (no, yes), and passenger vehicle body type (passenger car, pickup truck, SUV, van, and other light truck).

The descriptive (univariate) statistics of the relationship between vehicle occupant injury severity outcomes and vehicle age or MY, and other selected confounding factors (variables) was conducted to estimate the occupant severely injured risk. The complex survey design adjusted Rao-Scott chi-square test is used to test the association (dependence) between occupant injury severity outcome and the levels of the factor (variable) examined. It is statistically significant at $\alpha = 0.05$ significance level when p-value < 0.05.

Also, the relationship between vehicle occupant injury outcomes and vehicle age or MY, after controlling for other confounding factors, is assessed by multivariate logistic regression in which the "Other Injuries" essentially form one element of the binary outcome ("Severe Injuries" versus "Other Injuries"). This procedure helps to assess their relative influence as well as estimate the amount of risk each factor carried (odds ratio) in potentially influencing the risk of severe injuries.

Frequency (percentage) table and the regression estimates in the following sections are all based on the weighted data. Due to the complex nature of the NASS-GES/CRSS sample design, the SURVEYFREQ and the SURVEYLOGISTIC procedures of SAS Version 9.4 are used in this work. [13]

Results

Study results are presented in the following two sections: descriptive statistical analysis and multivariate logistic regression model analysis.

Descriptive Statistical Analysis

Weighted descriptive statistical analysis of the passenger vehicle occupant injury severity outcomes by vehicle age, model year, and other confounding factors were conducted. The results are shown in Table 1.

When examining the role of vehicle age, the data in Table 1 shows that the percentages of occupants who were severely injured was: 1.20 percent/1.60 percent/1.89 percent/2.20 percent for vehicle age groups 1-6 years/7-11 years/12-15 years/>15 years, respectively. The complex survey design adjusted Rao-Scott chi-square test of the association (dependence) between occupant injury severity outcomes and vehicle age shows that the percentages of severe injuries between vehicle age groups are significantly different (i.e., there is a significant association) at the 99 percent confidence level (p-value <0.0001).

Table 1 also shows that the percentages of occupants who were severely injured, when examining by vehicle model year, were: 3.09 percent/2.50 percent/1.65 percent/1.08 percent for vehicle model year groups MY 1987 and earlier/MY 1988-1994/MY 1995-2011/MY 2012-2018, respectively. The percentages of severe injuries between the model year groups are significantly different (i.e., there is a significant association) at the 99 percent confidence level (p-value <0.0001).

Female occupants, as compared to male occupants, are estimated to have a higher percent of severe injuries (1.60% for female versus 1.52% for male) in police-reported motor vehicle traffic crashes. Although this difference is not statistically significant at the 95 percent confidence level (p-value=0.0818) in descriptive analysis, multivariate logistic regression modeling analysis do indicate that this difference is statistically significant at the 95 percent confidence level after adjusting for other confounders (i.e., an increased odds of severe injuries for female occupants, as seen in Table 2).

Passengers, as compared to drivers, have displayed a higher percent of severe injuries (1.70% for passengers versus 1.51% for driver) in police-reported motor vehicle traffic crashes. Although this difference is not statistically significant at the 95 percent confidence level (p-value=0.1084) in descriptive analysis, multivariate logistic regression modeling analysis do indicate that this difference is statistically significant at the 95 percent confidence level after adjusting for other confounders (i.e., an increased odds of severe injuries for passengers, as seen in Table 2).

Multivariate Logistic Regression Analysis

The relationship between occupant injury outcome and vehicle age or model year depicted in descriptive statistics, i.e., the percent of occupants that were severe injured increased as the vehicle age increased and in earlier model year vehicles, has also persisted based on the multivariate logistic regression analysis which controls for other potential confounding factors. Table 2 lists the categories of vehicle age, model year and other confounding factors that were used in the multivariate logistic regression model and shows the odds ratio (OR) estimate and the 95 percent confidence intervals (CI) for each factor (variable) from the model used in this work.

After adjustment for several crash, vehicular, and occupant confounding factors, the regression model shows OR estimates for vehicles in three older vehicle age groups compared to the reference vehicle age group of 1 to 6 years (rows 3 through 6 of Table 2). The OR estimates and 95 percent CI range from 1.11 (1.02 - 1.21) for vehicles 7 to 11 years old, 1.19 (1.04 - 1.37) for vehicle 12 to 15 years old, and 1.23 (1.05 - 1.45) for vehicle ages >15 years, respectively. That is, the odds of an occupant in a passenger vehicle 7 to 11 years old was 1.11 times as likely to be severely injured, compared to an occupant in a passenger vehicle 1 to 6 years old. Similarly, the odds of an occupant in a passenger vehicle 12 to 15 years old or >15 years, was 1.19 or 1.23 times as likely to be severely injured, compared to an occupant in a passenger vehicle 1 to 6 years old, respectively. The regression modeling analysis shows that the occupant risk of severe injury increased as the vehicle age increased.

Similarly, the vehicle model year OR estimates are shown in rows 7 to 10 of Table 2. These OR estimates and 95 percent CI are respectively 1.15 (1.00 - 1.33) for vehicle MY 1995-2011, 1.28 (1.05 - 1.57) for vehicle MY 1988-1994, and 1.50 (1.16 - 1.94) for vehicle MY 1987 and older, compared to the reference category of MY 2012-2018. Therefore, the odds of an occupant in a passenger vehicle of MY 1995-2011/MY 1988-1994/MY 1987 and older, was 1.15/1.28/1.50 times as likely to be severely injured, compared to an occupant in a MY 2012-2018 passenger vehicle respectively. The regression modeling analysis demonstrated that the occupant risk of severe injury was higher in older model year vehicles.

The other interesting and meaningful results, arrived from the multivariate logistic regression model after adjusting for other factors, are listed as follows (see page 7).

Table 1: Descriptive Statistics of the Weighted Passenger Vehicle Occupant Injury Severity Outcomes by Vehicle Age, Model Year, and Other Confounding Factors.

Factors		Occupant Injury Severity				Statistical Significance ǂ
		Severe Injures		Other Injuries		
		Number	%	Number	%	
Vehicle Age	†1-6 years	408,483	1.20	33,739,324	98.80	χ^2 (*d.f.*=3) = 177.18 (*p*-value <0.0001)
	7-11 years	396,921	1.60	24,392,552	98.40	
	12-15 years	276,968	1.89	14,392,095	98.11	
	>15 years	221,657	2.20	9,836,082	97.80	
Model Year	†2012-2018	199,480	1.08	18,247,599	98.92	χ^2 (*d.f.*=3) = 130.90 (*p*-value <0.0001)
	1995-2011	1,030,624	1.65	61,331,061	98.35	
	1988-1994	60,858	2.50	2,371,933	97.50	
	1987 & earlier	13,066	3.09	409,459	96.91	
Speeding Status	†non-speeding	1,106,841	1.42	76,770,702	98.58	χ^2 (*d.f.*=1) = 41.66 (*p*-value <0.0001)
	speeding	197,188	3.41	5,589,350	96.59	
Day of Week	†weekday	845,087	1.42	58,683,517	98.58	χ^2 (*d.f.*=1) = 60.76 (*p*-value <0.0001)
	weekend	458,941	1.90	23,676,535	98.10	
Initial Point of Impact	†rear	216,148	0.93	23,041,342	99.07	χ^2 (*d.f.*=4) = 200.86 (*p*-value <0.0001)
	right side	130,679	1.55	8,323,291	98.45	
	front	744,538	1.76	41,647,308	98.24	
	left side	146,801	1.75	8,249,477	98.25	
	other/unknown	65,862	5.66	1,098,634	94.34	
Occupant Role	†driver	935,595	1.51	61,037,410	98.49	χ^2 (*d.f.*=1) = 2.58 (*p*-value =0.1084*)
	passengers	368,433	1.70	21,322,642	98.30	
Restraint Use	†used	879,383	1.19	73,266,726	98.81	χ^2 (*d.f.*=2) = 129.22 (*p*-value <0.0001)
	not used	172,091	13.38	1,114,197	86.62	
	unknown	223,400	2.78	7,800,343	97.22	
Sex	†male	652,061	1.52	42,350,462	98.48	χ^2 (*d.f.*=1) = 3.03 (*p*-value =0.0818**)
	female	651,968	1.60	40,009,591	98.40	
Age	†0-15	79,102	1.00	7,838,025	99.00	χ^2 (*d.f.*=4) = 102.85 (*p*-value <0.0001)
	16-24	315,758	1.56	19,989,776	98.44	
	25-44	439,342	1.54	28,069,888	98.46	
	45-64	315,506	1.62	19,175,858	98.38	
	65+	154,320	2.07	7,286,505	97.93	
Time of Day	†daytime	816,440	1.36	59,362,614	98.64	χ^2 (*d.f.*=1) = 166.50 (*p*-value <0.0001)
	nighttime	487,589	2.08	22,997,438	97.92	
Relation to Roadway	†on roadway	882,291	1.20	72,887,623	98.80	χ^2 (*d.f.*=2) = 230.36 (*p*-value <0.0001)
	median/shoulder/other	92,675	2.83	3,181,719	97.17	
	off roadway	329,063	4.97	6,290,710	95.03	
Rollover	†no	1,112,295	1.36	80,840,203	98.64	χ^2 (*d.f.*=1) = 117.38 (*p*-value <0.0001)
	yes	191,733	11.20	1,519,849	88.80	
Driver Alcohol Use	†no	1,166,826	1.43	80,568,414	98.57	χ^2 (*d.f.*=1) = 165.51 (*p*-value <0.0001)
	yes	137,202	7.11	1,791,638	92.89	
Body Type	†van	77,458	1.32	5,780,992	98.68	χ^2 (*d.f.*=4) = 18.90 (*p*-value =0.0008)
	passenger car	812,100	1.65	48,510,532	98.35	
	pickup truck	150,750	1.54	9,637,089	98.46	
	sport utility	260,967	1.41	18,242,961	98.59	
	other (light truck)	2,753	1.44	188,478	98.56	

† Category of the factor with the lowest percentage of severe injuries (used as the reference category in Table 2).

ǂ Complex survey design adjusted Rao-Scott χ^2 test of association (dependence) between occupant injury severity outcome and the levels of the factor (variable) examined.

* Not statistically significant at the α = 0.05 level.

** Statistically significant at the α = 0.1 level.

Source: NASS-GES 2012-2015 and CRSS 2016-2017.

Table 2. Multivariate Logistic Regression Predicting the Passenger Vehicle Occupant Risk of Severe Injures

Estimates of Odds Ratio (OR)				
Effect		Point Estimates	95% Confidence Intervals (CI)	Pr > |t|
Vehicle Age	†1-6 years	1.00		
	7-11 years	1.11	1.02 - 1.21	0.0209
	12-15 years	1.19	1.04 - 1.37	0.0138
	>15 years	1.23	1.05 - 1.45	0.0123
Model Year	†2012-2018	1.00		
	1995-2011	1.15	1.00 - 1.33	0.0600**
	1988-1994	1.28	1.05 - 1.57	0.0168
	older than 1987	1.50	1.16 - 1.94	0.0021
Speeding Status	†non-speeding	1.00		
	speeding	1.28	1.08 - 1.52	0.0046
Day of Week	†weekday	1.00		
	weekend	1.07	1.01 - 1.14	0.0261
Initial Point of Impact	†rear	1.00		
	right side	1.22	1.00 - 1.48	0.0537**
	front	1.35	1.09 - 1.67	0.0070
	left side	1.53	1.21 - 1.92	0.0005
	other/unknown	0.96	0.72 - 1.29	0.7917*
Occupant Role	†driver	1.00		
	passengers	1.29	1.11 - 1.51	0.0013
Restraint Use	†used	1.00		
	not used	7.73	6.82 - 8.76	<0.0001
	unknown	2.04	1.48 - 2.89	<0.0001
Sex	†male	1.00		
	female	1.25	1.19 - 1.30	<0.0001
Age	†0-15	1.00		
	16-24	1.40	1.22 - 1.60	<0.0001
	25-44	1.66	1.42 - 1.95	<0.0001
	45-64	2.06	1.74 - 2.45	<0.0001
	65+	2.77	2.35 - 3.27	<0.0001
Time of Day	†daytime	1.00		
	nighttime	1.09	1.03 - 1.16	0.0045
Relation to Roadway	†on roadway	1.00		
	median/shoulder/other	1.40	1.17 - 1.67	0.0003
	off roadway	1.88	1.69 - 2.08	<0.0001
Rollover	†no	1.00		
	yes	4.50	3.90 - 5.18	<0.0001
Driver Alcohol Use	†no	1.00		
	yes	1.93	1.73 - 2.16	<0.0001
Body Type	†van	1.00		
	passenger car	1.22	1.08 - 1.38	0.0012
	pickup truck	0.96	0.81 - 1.15	0.6536*
	sport utility	0.98	0.87 - 1.09	0.6699*
	other (light truck)	0.76	0.45 - 1.29	0.3102*

† The reference category.

* Not statistically significant at the α = 0.05 level.

** Statistically significant at the α = 0.1 level.

Source: NASS-GES 2012-2015 and CRSS 2016-2017.

• The odds of an occupant in a speeding vehicle was 1.28 times as likely to be severely injured, compared to an occupant of a non-speeding vehicle.
• The odds of an occupant in a crash that occurred during the weekend was 1.1 times as likely to be severely injured, compared to an occupant involved in a crash that occurred during a weekday.
• The odds of an occupant in a vehicle that was struck in the front, left side, and right side was 1.35, 1.53, and 1.22 times as likely to be severely injured, respectively, compared to an occupant in a vehicle that was struck in the rear.
• The odds of a passenger was 1.29 times as likely to be severely injured, compared to the driver of a vehicle.
• The odds of an unrestrained occupant was 7.73 times as likely to be severely injured, compared to a restrained occupant.
• The odds of a female occupant was 1.25 times as likely to be severely injured, compared to a male occupant.
• The odds of an occupant in the age group 65+, 45-64, 25-44, or 16-24 were 2.77, 2.06, 1.66, and 1.40 times, respectively, as likely to be severely injured, compared to an occupant 15 or younger.
• The odds of an occupant in a nighttime crash was 1.1 times as likely to be severely injured, compared to an occupant in a daytime crash.
• The odds of an occupant in a vehicle that ran off the roadway was 1.88 times as likely to be severely injured, compared to an occupant in a vehicle that did not run off the roadway.
• The odds of an occupant in a vehicle that rolled over was 4.50 times as likely to be severely injured, compared to an occupant in a vehicle that did not roll over.
• The odds of an occupant in a vehicle where the driver had any police-reported alcohol involvement was 1.93 times as likely to be severely injured, compared to an occupant in a vehicle whose driver was reported to have no alcohol involvement by the police.
• The odds of an occupant in a passenger car was 1.22 times as likely to be severely injured, compared to an occupant in a light truck (van, SUV, pickup, or other light truck).

Discussion and Conclusion

This present study, through both univariate descriptive analysis and statistical modeling analysis adjusting for many other confounding factors, has examined the relationship between passenger vehicle occupant injury severity outcomes and the vehicle age or model year using the NASS-GES/CRSS databases. The specific benefits of many vehicular safety innovations and improvements (the child safety seats, electronic stability control, antilock braking systems, roof crush strength, lane departure warnings, etc.) were not measured in this study. For example, while the present analysis shows that the newer vehicle model year groups were inversely associated with occupant injury severity outcome, this study does not identify which aspects of the model year group with particular vehicular designs are responsible for the reduction in the risk of severe injury to vehicle occupants.

While the relationship between vehicle occupant injury severity outcomes and the vehicle age or model year are measured in this report, the possible reasons for this relationship are not derived in this report (some valuable discussions can be seen in Lécuyer & Chouinard (2006)). Also, this study does not analyze the population of passenger vehicle occupants in the United States in order to measure the overall risk of an occupant in this population being severely injured. The present report merely analyzes the experience that passenger vehicle occupants in police-reported crashes have had.

In summary, the findings of this study support previous research in observing that the percentages of occupants severely injured in motor vehicle traffic crashes increased as the age of the vehicles being driven increased and in vehicles of earlier model years.

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