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Original Research

Car Ratings Take a Back Seat to Vehicle Type: Outcomes of SUV Versus Passenger Car Crashes

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Abstract

Background
Car safety ratings are routinely utilized in making automobile purchase decisions. These 1- to 5-star ratings are based on crash test data comparing vehicles of similar type, size and weight.

Objectives
We hypothesized that car safety ratings are less important than vehicle factors such as vehicle type and weight in predicting outcomes of head-on crashes.

Methods
A retrospective study was conducted on severe head-on motor vehicle crashes entered into the FARS (Fatality Analysis Reporting System) database between 1995 and 2010. This database includes all US motor vehicle crashes that resulted in a death within 30 days of the accident. Outcomes of SUV versus passenger car and passenger car versus passenger car head-on crashes were compared by safety rating. Exclusion criteria was added to eliminate collisions with insufficient information or unbelted passengers. The paired crash results were entered into a logistic regression model with driver death as the outcome of interest.

Results
The database contained 83,251 vehicles of any type that were involved in head-on crashes. In head-on crashes where the passenger car front driver crash rating was superior to the SUV's, the odds of death were 4.52 times higher for the driver of the passenger car (95% CI: 3.06–6.66). Ignoring crash ratings, the odds of death were 7.64 times higher for the passenger car driver (95% CI: 5.59–10.44). In passenger car versus passenger car head-on crashes, a lower car safety rating was associated with a 1.28 times higher odds of death (95% CI: 1.05–1.57). In passenger car vs. passenger car head-on crashes, each one point lower car safety rating resulted in a 1.22 times higher odds of death (95% CI: 1.03–1.44).

Conclusion
Vehicle type (passenger car versus SUV) is a much more important predictor of death than crash safety ratings in SUV versus passenger car head-on crashes.

Keywords
5-star safety rating; head-on collision; car crash; FARS; vehicle safety; accidents, traffic/statistics & numerical data; accidents, traffic/mortality; automobiles; equipment design; risk factors

Introduction

Motor vehicle crashes constitute the leading cause of death among Americans from 1 to 34 years of age. According to the National Highway Traffic Safety Administration (NHTSA), the total cost to society for injuries and damages, without valuing reduced quality of life, related to motor vehicle crashes exceeded $242 billion in 2010.[1] Sport utility vehicles (SUVs) have been shown to cause more extensive damage to other vehicles involved in a crash.[2] From the years 1985 through 1993, the number of pickup trucks, vans and sport utility vehicles in the United States (US) increased by 50%. In 2003, SUVs accounted for 20% of newly registered passenger vehicles, up from 7% a decade earlier. Meanwhile, cars were accounting for a declining proportion of newly registered passenger vehicles—54% in 2003, down from 68% in 1993.[3-5] More recently, this trend in the US has continued in a dramatic way. In 2015, SUV sales surpassed sedan sales for the first time, and in 2019, SUVs made up 47.4% of new car sales, while sedans only made up 22.1%.[6,7]

Along with fuel efficiency and affordability, safety ratings are routinely utilized in making automobile purchase decisions. These 1 to 5 star ratings are assessed by data from frontal, side barrier and side pole crashes comparing vehicles of similar type, size and weight. Furthermore, SUVs have been shown to cause more extensive damage to other passenger vehicles involved in a crash.[5]

Prior studies evaluating the performance of frontal crash test ratings have found that 1 to 4 star rated passenger cars have a 7–36% increase in driver death rates compared to other passenger cars with 5-star ratings.[8] In our study, we hypothesized that car safety ratings are less important than other vehicle factors, specifically vehicle type, in predicting outcomes of head–on crashes between SUVs and standard passenger vehicles.

Methods

Study Design

This retrospective study consisted of drivers in severe frontal motor vehicle crashes involving two vehicles (passenger cars and SUVs) from the Fatality Analysis Reporting System (FARS) database occurring between 1995 and 2010, with both cars' specifications and safety ratings known. Crashes involving more than two vehicles were excluded. To be included in FARS, a crash must involve a motor vehicle traveling on a roadway customarily open to the public and must result in a death. All fatal crashes in the US are required to be entered into the FARS database. The authors' Health Sciences Institutional Review Board approved this study.

Study Setting and Population

"The FARS, which became operational in 1975, contains data on a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. The NHTSA has a cooperative agreement with an agency in each state's government to provide information on all qualifying fatal crashes to FARS. The FARS data are obtained solely from the state's existing documents: Police Accident Reports, State Vehicle Registration Files, State Driver Licensing Files, State Highway Department Data, Vital Statistics, Death Certificates, Coroner/Medical Examiner Reports, Hospital Medical Reports, Emergency Medical Service Reports, and other state records. The specific data elements may be modified slightly each year to conform to changing user needs, vehicle characteristics and highway safety emphasis areas.[9-11] The FARS data do not include any personal information and therefore fully conform to the privacy rules of the Heath Insurance Portability and Accountability Act (HIPAA) of 1996."[11]

Selection of Participants

Two-car head-on crashes between a highly (safety) rated passenger car and a more poorly rated SUV were included in the initial analysis as the primary study objective. In the secondary investigation (secondary study objective), outcomes of all passenger car versus SUV head-on collisions (head-on for both vehicles) were then compared without regard to safety rating. We also analyzed the outcomes of head-on collisions involving a lower rated passenger car vs. a higher rated SUV. Finally, passenger car vs. passenger car head-on crashes were then analyzed controlling for weight and safety rating (tertiary study objective). The information obtained from the FARS database was confined to crashes involving a maximum of two cars to prevent multiple vehicle crash confounders. Passenger cars were defined as vehicles in the FARS database designated as 2-door/4-door sedans, 3-door/5-door hatchbacks, station wagons or convertibles. SUVs were defined as vehicles in the FARS database designated as small/mid-size/full-size/large utility vehicles. Any vehicles with missing or unknown information regarding seat position, restraint use, death, vehicle type, vehicle weight or safety rating were excluded from the study. Driver fatalities are defined in FARS as deaths that occur within 30 days of the crash.

The exclusion of records by database attributes for this analysis was as follows: head-on (frontal-to-frontal) crashes with complete driver information—83,251 records; all drivers wearing seatbelts—53,310; including only cars and SUVs—48,842; all model years known and keeping only 1995 or newer—25,489; eliminating those crashes with more than two cars, unknown exact car specifications, unknown crash ratings—3,962 records; crashes between a car and SUV—1,232 records.

Vehicular Safety Ratings

With data made available from FARS, each individual vehicle's specifications (such as model, class, manufacturer and year) were entered into a safercar.gov database. The database provided information on front driver, front passenger, side driver, side passenger, 4x2 (two wheel drive) rollover and 4x4 (four wheel drive) rollover ratings; front driver safety ratings only were of interest to this study. Contingent upon the results of the query, the 1–5 star front driver safety rating stratified the vehicle into either a "Lower-Rated" or "Higher-Rated" vehicle when compared to its counterpart (either being a passenger car or SUV) in the head-on crash.[12]

Statistical Analysis

A logistic regression model stratified by crash identifier (ID) was used to investigate the paired crashes with regard to vehicle type and vehicle safety rating with driver death as the outcome of interest. In order to investigate the efficacy of the 5-star rating system within a vehicle type, a logistic regression model stratified by crash ID was used to analyze 1,247 passenger car vs. passenger car head-on crashes in the database with complete information. The estimated regression coefficients were used to determine any association between safety ratings and driver fatality. Odds ratios with 95% confidence intervals were estimated to determine the magnitude of this association. Statistical analysis was completed with SAS version 9.3 (Cary, NC).

Results

In the higher-rated car vs. lower-rated SUV collision analysis, after applying our exclusionary criteria to the initial 83,251 cars in frontal crashes dataset, 502 vehicles remained eligible. In 155 crashes the passenger car driver was killed, and in 46 crashes the SUV driver was killed, resulting in a total of 201 fatalities. In the univariate logistic regression (stratified by crash ID) on paired crashes, vehicle type (car or SUV) is a significant predictor of driver death ($p<0.0001$; OR, 4.52; 95% CI, 3.06–6.66). Odds of death for the passenger car driver are estimated to be 4.5 times higher than the odds of death for the SUV driver. (**Table 1, row 1**)

Lower-Rated Car versus Higher-Rated SUV

In the lower-rated car vs. higher-rated SUV analysis, 336 crashes remained after applying the exclusionary criteria. In 119 crashes the car driver was killed, and in 22 crashes the SUV driver was killed, resulting in a total of 141 fatalities. In the univariate logistic regression (stratified by crash ID), in paired crashes where the SUV's safety rating is better than the car's safety rating, driver death is significantly associated with vehicle type ($p<0.0001$; OR, 9.82; CI, 5.28–18.26). The odds of death for the car driver are estimated to be 9.8 times the odds of death for the SUV driver. (**Table 1, row 2**)

Table 1. Comparative Analyses for Head-on Crashes Involving Passenger Car vs. SUV

Vehicle Type	No. of Involved Vehicles	Driver Fatalities	Percent Driver Death by Car Type	Odds Ratio of Driver Death Car/SUV	95% CI of OR
Car vs. Lower-Rated SUV	502	Car 155 SUV 46	61.75% 18.33%	OR=4.52 RR= 3.37	3.06–6.66
Car vs. Higher-Rated SUV	336	Car 119 SUV 22	70.83% 13.10%	OR=9.82 RR=5.41	5.28–18.26
Overall Car vs. SUV	1,232	Car 407 SUV 89	66.07% 14.45%	OR=7.64 RR=4.57	5.59–10.44

OR = odds ratio; RR = relative risk

Car versus SUV Regardless of Safety Rating

Of all paired car vs. SUV crashes not accounting for crash rating, (**Table 1, row 3**) 1,232 remained in the dataset. When not accounting for crash ratings, vehicle type is highly predictive of driver death in head-on crashes between cars and SUVs. Odds of death for the car driver are 7.6 times higher than the odds of death for the SUV driver (p<0.0001; OR, 7.64; 95% CI, 5.59–10.44). In an additional logistic regression incorporating crash rating as a co-variable, the odds of driver death are estimated to decrease by 22% for a 1-star increase in safety rating over both cars and SUVs. Broken down by vehicle type, the estimated decrease in odds of driver death corresponding to a one-star increase in crash ratings was 18% for SUVs and 27% for cars.

In order to assess the role of missing data as a confounder, the 1,034 paired crashes of car vs. SUV that were eliminated due to lack of seatbelt use, model earlier than 1995 or missing safety rating were analyzed. The odds of death was 6.1 times higher (p<0.0001) for the passenger car driver in these eliminated crashes which was in line with the findings in the study population.

Passenger Car versus Passenger Car

There were 1,247 passenger car vs. passenger car head-on crashes in the database with complete information. (**Table 2**) The driver of the car with the lower safety rating died in 217 crashes while the driver of the higher-rated car survived (expected result). In 169 crashes the driver of the higher-rated car died, while the driver of the lower-rated car survived (unexpected result). In passenger car vs. passenger car head-on crashes, a lower car safety rating was associated with a 1.28 times higher odds of death (95% CI: 1.05–1.57). In a univariate logistic regression (stratified by crash ID) with vehicle rating as a co-variable, a one point lower (worse) safety designation is a significant predictor of driver death (p<0.03; OR 1.22; 95% CI: 1.03–1.44). In head-on crashes involving two passenger cars, the odds of driver death are estimated to increase by 22% for a one-star decrease in crash rating.

In passenger car vs. passenger car crashes adjusted for vehicle weight, crash rating was no longer a significant predictor of driver death (p=0.93; OR 1.01; 95% CI, 0.84–1.21). The relationship between vehicle weight and outcomes adjusted for crash ratings was statistically significant (p<0.0001; OR 0.88; 95% CI, 0.85–0.91). An increase in vehicle weight of 100 lbs. was associated with a 12% decrease in the odds of driver death. This model, that was adjusted for weight and safety rating, was only for passenger car vs. passenger car crashes which are more numerous than SUV vs. passenger car crashes or SUV vs. SUV crashes.

Discussion

This study quantifies the relationship between driver deaths in passenger cars vs. SUVs involved in head-on crashes adjusted for front driver safety ratings. Our analysis of the FARS database makes it apparent that the 1- to 5-star crash ratings are much less important than vehicle type in determining outcomes in these crashes. In the passenger car vs. SUV crashes, there were significantly more driver deaths in the passenger car; more than four-fold greater odds of death if the passenger car had the higher safety rating and almost ten times greater if the SUV was better rated. The five-star safety rating system is a relative safety predictor for cars of similar weight and type, but a less significant safety predictor for crashes of different vehicle types.

In 1978, NHTSA initiated the 1 to 5-star safety rating system. This has provided manufactur-

Table 2. Analysis of Passenger Car vs. Passenger Car Head-on Collisions

Vehicle Type	No. of Crashes	Driver Fatalities By Car Rating	Odds Ratio Driver Death Lower Car Rating	95% CI
Car vs. Car	1,247 crashes 2,494 vehicles	"Lower" Car 217 "Higher" Car 169 Same Outcome 530 Tied Ratings 331	Overall 1.28 One Pt. Lower 1.22	Overall 1.05–1.57 One Pt. Lower 1.03–1.44

ers with frontal, side, and rollover crash test analyses in order to improve vehicle occupant protection and provided consumers with information to help guide their purchase of safer vehicles. The NHTSA frontal crash tests examine force of impact to multiple areas of the body in average adult-sized males and small-sized females, with collisions occurring at 35 mph to fixed barriers; only vehicles of similar weight class (plus or minus 250 pounds) are compared to one another.[13] This study demonstrates that a better passenger car crash safety rating is to some extent protective in passenger car vs. passenger car crashes of similar weights; however, this protective effect is significantly negated when one vehicle is heavier than the other with better passenger outcomes seen in the heavier car. This claim is further reinforced in a study we previously published in the Journal of the South Carolina Medical Association. Berlioz et al. found there to be a 19.41% decrease in personal injury scores per 1000-pound increase in weight and the safest passenger vehicles overall were the larger SUVs and pickup trucks.[14]

There is a fiscal incentive for drivers to buy more fuel-efficient vehicles, which by design, tend to be smaller, lighter passenger vehicles.[15] These passenger vehicles with reported excellent safety ratings may provide a false degree of confidence to the buyer regarding the relative safety of these vehicles as demonstrated by the findings in this study. Our analysis suggests that the consumer should be more aware of an honest interpretation of safety ratings, and how these ratings translate to real world performance.

In the 1980s and 1990s, SUVs developed a reputation for being unsafe due to their propensity to cause injuries in rollover crashes. Manufacturers subsequently worked on widening the wheel-base and lowering the center of gravity in the SUVs produced in the last decade. In 1995, Electronic Stability Control (ESC) was introduced as a safety feature to prevent rollover fatalities.[16] ESC was found to reduce the rates of single car crash fatalities in SUVs by 67.0% and reduce single car crash fatalities of passenger cars by 35.0%.[17] In 2012 the NHTSA required electronic stability control to be standard on all "passenger cars, multipurpose passenger vehicles, trucks, and buses with a gross vehicle weight rating of 4,536 kg (10,000 pounds or less)."[18] As a result, rollover crashes are much less common in SUVs and currently, the larger SUVs are some of the safest cars on the roadways with fewer rollovers and outstanding outcomes in frontal crashes with passenger cars.

Previous studies have analyzed the relationships between size, weight and vehicle type to mortality in frontal vehicular collisions. These studies have demonstrated higher fatalities in smaller, lighter vehicles.[5,8,15] Injuries depend on the forces that act on the occupants, and these forces are affected by several key physical factors. First of all, heavier vehicles transmit larger forces to occupants in lighter vehicles. Secondly, larger vehicle size creates a crush zone space between harmful forces and the occupant. Finally, in frontal crashes, SUVs tend to ride over shorter passenger vehicles, due to bumper mismatch, crushing the occupant of the passenger car.[5,8,15] A prior study done at our institution compared passenger deaths in head-on collisions between passenger cars and SUVs without investigating safety rating. Even when the weight of the passenger car was greater than the weight of the SUV, the occupants of the passenger car still had a higher mortality rate than the occupants of the SUV (40.1% mortality rate in the passenger car vs. 24.4% mortality rate in the SUV).[19] When two vehicles are involved in a crash, the overwhelming majority of fatalities occur in the smaller and lighter of the two vehicles.[4,20-23] But even when weight matched, outcomes are better in SUVs because of the bumper mismatch and passenger space crush issues.[24,25]

Limitations

Limitations of the study include not knowing driver demographics (specifically pre-existing medical conditions) as well as the data excluded from the major analysis. Patient factors such as age, gender and risk pool (i.e., varying levels of a driver's risk-taking behavior) could have confounded the analysis; however, the average age of SUV buyers is five years older than those who purchase traditional passenger cars. This potential bias would put the SUV drivers at higher risk of death and injury than the passenger car drivers, which is not what we found. A number of crashes had to be excluded from this study because of missing data for specific variables such as seat belt use, vehicle year, vehicle specifications and safety ratings, and this is a possible source of bias. However, a brief analysis of the excluded data revealed fatality ratios consistent with our current findings as well as with those found in the literature. With the significant shift to SUVs in recent years, the average SUV on the road may be slightly younger and thus safer than the average passenger car, which could have influenced the results. As the type of cars on the road continues to change, especially with the increasing use of electric cars, future investigation of how electric cars fare against other passenger cars and SUVs in head-on collisions is warranted. In addition, our data applied to severe car crashes with a death in one of the vehicles and these results may not necessarily generalize to minor crashes. Finally, all deaths within 30 days of the accident are included in the FARS database and the fatality may be due to factors unrelated to the accident.

Conclusion

The findings of this study show that 1- to 5-star car safety ratings do not comprehensively explain vehicle safety to buyers. In the passenger car versus SUV head-on collisions we analyzed, there were significantly more driver deaths in the passenger car regardless of safety rating—more than four-fold greater odds of death if the passenger car had the higher safety rating. Vehicle type (passenger vehicle versus SUV) is a much more important predictor of death than crash safety ratings in SUV versus passenger car head-on crashes. The size, weight and design provide increased safety of SUVs in head-on crashes with passenger cars, and should be taken into consideration when purchasing a car, while consumers should also be made more aware of the limitations of vehicle safety ratings.

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Conflicts of Interest

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