Analysis of Tow-Away Crash Injuries with the Introduction of Sled-Certified Airbags

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Abstract

Background: In September 1997, NHTSA permitted an optional sled test for unbelted male dummies in lieu of a rigid-barrier test to facilitate the introduction of airbags that deploy less forcefully and to reduce the likelihood of airbag induced injuries and fatalities to front seat occupants. Overall, fewer airbag-induced deaths have been occurring among children and small stature adults exposed to sled-certified airbag deployments, however, little is known about the effect of these systems on non-fatal occupant injuries.

Methods: This evaluation was conducted to identify performance differences for first generation versus sled-certified airbag systems among drivers and right-front passengers. The National Automotive Sampling System Crashworthiness Data System (NASS CDS) was used as a source of crash, occupant and injury characteristics for calendar years 1997-2005. Model year 1994 and newer vehicles were included where airbag presence and airbag type could be determined. In total, the study considered injury outcomes of 11,711 airbag protected drivers (5,416 first generation and 6,295 sled-certified airbags) involved in frontal crashes without rollovers. When Delta-V, a measure of crash severity was not reported by NASS/CDS, it was imputed using NASS researcher estimated delta-V when available. Logistic regression was used to calculate odds ratios (OR) and 95 percent confidence intervals (95% CI) for Maximum Abbreviated Injury Scale (MAIS) 1 injury relative to no injury, the odds of sustaining an MAIS 2 or higher injury relative to MAIS 0-1 and sustaining an MAIS 3 or higher injury relative to MAIS 0-2. The analysis was stratified by belt use and low versus medium/high delta-V (delta-V < or ≥15 mph).

Findings: Effects of airbag generation differed by belt status and delta-V. Compared with belted drivers with first-generation airbags, belted drivers with sled-certified airbags had a significantly reduced risk of minor (AIS 1) injuries in low delta-V crashes and no significant change in the risk of moderate to severe injuries at both low and medium/high delta-Vs. At medium/high delta-Vs, unbelted drivers with sled-certified airbags had a borderline significant increase in MAIS 2+ injuries and smaller non-significant increases in MAIS 1 and MAIS 3+ injuries compared with those who had first-generation airbags. Right-front passengers had similar findings, but they were not statistically significant. When separated by body region, belted drivers with sled-certified airbags had reduced risks for AIS 1 facial injury (OR = 0.67; 95% CI: 0.55, 0.82), AIS 1 upper extremity injury (OR = 0.74; 95% CI: 0.61, 0.90), and AIS 2+ lower extremity injury (OR = 0.68; 95% CI:0.52, 0.90). In contrast, unbelted drivers had significantly increased risks of AIS 1 facial injury (OR = 2.03; 95% CI: 1.30, 3.19) and AIS 2+ chest injuries in medium/high delta-V crashes (OR = 2.07; 95% CI: 1.09, 3.90).

Discussion. Among belted drivers, sled-certified airbags appear to decrease the risk of injury among belted drivers for some body regions and offer equivalent protection in the remaining body regions. Unbelted drivers with sled-certified airbags in medium/high delta-V crashes may be at increased risk for moderate to severe chest injuries. These findings need to be examined further using other databases.

Background

Frontal driver and passenger airbags are designed to provide supplemental restraint to occupants during frontal and near frontal collisions. The National Highway Traffic Safety Administration (NHTSA) estimates that frontal airbags have saved the lives of 16,905 drivers and right front passengers from 1987 to 2004 (NHTSA 2006). They are effective in protecting properly seated adult occupants seated in these positions. However, from the early to mid-nineties, NHTSA and others identified crash cases where injuries and fatalities attributed to airbag deployments occurred. A large percentage of these casualties were infants placed near deploying airbags, unbelted or improperly belted children seated in the right front passenger seat and small stature adults seated in the driver and right front passenger seats.

In an effort to reduce the likelihood of injuries associated with deploying airbags, the NHTSA initiated a number of corrective actions that have lead to a considerable decline in airbag related deaths (Arbogast, 2005, Ferguson, 2003, Kahane 2006). First, a public awareness campaign was initiated to instruct parents to place infants and children in the back seat and to encourage motorists to sit at least 10 inches away from airbag while driving. At the same time, NHTSA amended the Federal Motor Vehicle Safety Standard (FMVSS) No. 208 in March of 1997 to allow manufacturers to rapidly introduce less-aggressive airbags starting with model year 1998 vehicles. The changes allowed manufacturers to certify their vehicles using a 30 MPH sled test for unbelted dummies that subjects the occupant compartment to a less aggressive crash pulse when compared with the previously required 30 MPH rigid barrier test. In order to adequately protect unbelted adult occupants during barrier test conditions, it is necessary to deploy the airbag more rapidly and with higher force than is needed to meet requirements associated with the optional sled test.

In response to the 1997 amendment, the NHTSA reported that manufacturers made significant changes in average airbag inflation characteristics including an 11 percent decrease in airbag peak pressure and a 22 percent decrease in the slope of the pressure rise for model year 1998 vehicles compared with 1997 vehicles (Hinch, 1999). It was expected that the introduction of less aggressive or depowered systems would reduce the threat of airbag induced occupant injuries during low severity crash events. However, NHTSA and others have expressed concern that sled-certified bags may provide lower levels of protection to unbelted occupants in high-speed crashes (NHTSA 2000, NHTSA 2006, Ferguson 2003). Some suggest that these unrestrained adult drivers and passengers may not be adequately restrained during crashes and may even overpower less aggressive airbag systems.

A number of studies have explored the impact of the 1997 amendment to FMVSS 208 in terms of fatality risk to adult drivers and right front passengers of all ages. In August of 2006, NHTSA published a report indicating that fatality risk for children ages 0-12 seated in the front seat is 45 percent lower with sled-certified airbags compared with first generation systems. In addition, the study concludes that sled-certified airbags are equally effective in preventing driver deaths compared with first generation systems. Braver et. al. (2005) sought to determine if sled-certified frontal airbags influence the likelihood of fatal injury to drivers in frontal crashes (Braver et al., 2005). This study generated rate ratios by model year for passenger vehicle driver deaths per vehicle registration. The results showed that the change from barrier certification to sled certification generally led to equivalent or increased driver protection for all vehicle types excluding light trucks (11 percent decrease in fatality risk).

Some evaluations of non-fatal injuries have been conducted to identify the influence of sled-certified airbag systems. However, findings of these studies vary considerably based on the particular body region evaluated, source data and methods of analysis. A 2004 study by Segui-Gomez et. al. explored differences between sled-certified and non-sled-certified systems using the National Automotive Sampling System, Crashworthiness Data System (NASS/CDS) (Segui-Gomez 2004). It was concluded that drivers in sled-certified airbag-equipped vehicles sustained fewer and less severe injuries in frontal crashes than drivers with non-sled-certified airbags. The study also indicated that the percentage of crashes with airbag deployment was significantly lower for 1998 and newer vehicles indicating differences in exposure to airbag deployment for vehicle occupants. A study by Jernigan et. al. 2003, explored the effect of depowering airbags on upper extremity injury using NASS/CDS. The study identified an increase in the overall incidence of upper extremity injury with depowering. The study also indicated that long bone fractures may be less frequent due to depowering yet the rate of joint dislocations appears to increase. This study considered NASS CDS 1993-2000 crash years and, accordingly, it is possible there were too few model year 1998 and later vehicles in the sample to adequately understand the impact of depowering on upper extremity injuries.

A review of high-severity crash cases collected by NHTSA's CIREN program was conducted where improved performance of second generation airbags was discovered (Augenstein 2004). The study indicated that zero child fatalities were observed for vehicles equipped with sled-certified systems, whereas four child fatalities were observed for first generation systems. The study also identified zero cases of out-of-position adult fatalities at a deltaV less than 20 MPH. For first generation airbags, there were nine adult fatalities that may have been due to occupants being out-of-position in this deltaV range. The study also observed that unrestrained drivers appeared to receive better protection from deploying sled-certified airbags than unrestrained right front passengers.

In this study, we compare the odds of injury for drivers and right front passengers were compared for barrier-certified versus sled-certified airbag systems to determine if statistically significant differences in protection exist. Injury odds ratios were calculated for low speed versus, moderate and high speed crashes and for belted versus unbelted occupants. Subsequently, we examined injury odds ratios for selected body regions were examined to evaluate if any differences in protection exist for sled-certified airbags versus first generation systems.

Methods

Source Data

Data from the National Automotive Sampling System/Crashworthiness Data System (NASS CDS) were used for this analysis. NASS CDS contains detailed data collected by professional crash investigators. Each crash investigated involves at least one motor vehicle in transport on a public roadway where one or more vehicles who were towed from the scene. For each investigation, a detailed review of police accident reports, hospital records, out-of-hospital care records, photographs of the vehicles, and the vehicles themselves is conducted. Injury data are collected only for occupants of towed vehicles. When possible, vehicle damage data and other characteristics are used to estimate crash severity based on energy absorbed by vehicle structures. This estimate is known as deltaV and is calculated based on the Crash3 algorithm (Crash3, 1981).

A nationally representative sample of crashes is investigated with oversampling of recent model vehicle crashes (less than 5 years old) where higher severity injuries occur. This oversampling ensures adequate data to study this population of interest. Final data can be weighted to represent national numbers. Each case is then weighted based on its probability of sampling to represent the nationwide incidence of towaway crashes and resulting injuries.

Data from NASS CDS 1997-2005 crash years were included in this analysis. Front outboard seated occupants (driver and right front passenger) of 1994-2005 model year passenger vehicles were included (i.e. passenger cars, sport utility vehicles, pickup trucks, minivans and midsize passenger vans). Only occupants protected by a frontal airbag at their seating position were included in the analysis. Many early vehicles were equipped only with driver side frontal airbags and no passenger airbag. In this case, drivers were included and right front passengers were excluded from the analysis. Airbag availability was determined using data supplied by the Highway Data Loss Institute, Arlington, Virginia. In addition, vehicle airbag systems were classified as first generation versus sled-certified systems based on data published by NHTSA (Analytical Users Manual, 1997;

www.safercar.gov) and automobile manufacturers, as compiled by University of Maryland, Baltimore (Braver et al., 2007).

Crash Populations- The complete NASS CDS 1997-2005 dataset contains a total of 40,855 unweighted crash cases representing 22,724,294 crashes. These crashes involve 72,285 vehicles and 92,691 occupants which correspond to 40,607,745 vehicles and 43,766,813 occupants in the population. Of these occupants, 27 percent were involved in pure frontal collisions where the principle direction of force (PDOF) was 12 o'clock. An additional 16 percent were involved in near frontal crashes where the PDOF was 11 or 1 o'clock. For this analysis, 11, 12 and 1 o'clock PDOF crashes, based on the highest severity damage to the vehicle were retained.

Cases involving a rollover preceding or following the primary frontal impact event were excluded and cases where an occupant was partially or fully ejected were also removed. A number of key data elements are required for this analysis including the level of injury sustained by each occupant, the use of 3-point safety belts, type of frontal airbag present and a measure of crash severity known as deltaV. Cases where one or more of these factors was coded as unknown were removed from the analysis; however, delta-V was imputed to minimize the loss of cases. A methodology to retain some unknown deltaV cases is discussed below. The resulting dataset, where all key factors are known, includes 9,282 unweighted drivers and 2,547 right front passengers corresponding to 3,938,848 drivers and 990,588 right front passengers in the population.

Within the frontal crash sample, deltaV is coded as unknown for nearly 28 percent of the unweighted cases under consideration (4,382 unweighted drivers and 1,150 passengers). These include cases where crash direction is known based on Collision Deformation Classification (CDC) information and the airbag can be accurately classified as first generation or sled-certified.

DeltaV is calculated using the WinSmash algorithm which quantifies the change in velocity experienced by a vehicle in the longitudinal and lateral directions during a crash. In order to accurately calculate deltaV, certain basic assumptions must be met. First, damage information must be known for vehicles involved in the collision. For qualifying events, damage profiles or CDC information must be known. Another assumption which must be met is that the vehicle in question and its impact partner reach a common velocity during impact. In the case of non-fixed object and impacts where little structural overlap occurs (i.e., during sideswipe and sideslaps) or in the case of underrides or overrides, this assumption may not be valid.

For cases where a precise deltaV cannot be calculated, WinSmash reports estimated deltaV values in intervals. In addition, NASS investigators use certain criteria to categorize an impact as minor, moderate or severe in nature. In terms of deltaV ranges, estimated values correspond with crash deltaVs from 0-14 mph (0-24 kph), 15-24 mph (25-39 kph) and 25 mph and higher (40 kph and higher) respectively. For cases with a missing deltaV, estimated deltaV values classified as minor, moderate and severe deltaV crashes and coincide with deltaV categories used when the actual deltaV is known. In applying estimated deltaV values, a total of 3,157 additional frontal crash cases were made available for analysis.

Table 1 summarizes person, vehicle and crash characteristics for drivers and right front passengers who met all inclusion criteria. When estimated deltaVs were used to categorize vehicles by severity, the final population available for analysis increased to 2,835,971 drivers (5,416 unweighted) who had sled-certified airbag systems present and were involved in planar only frontal crashes. A total of 2,457,900 drivers (6,295 unweighted) had first generation airbags present. For right front passengers, 1,696,566 (4,215 unweighted) had first generation airbags present and 1,324,224 (4,429) has sled-certified systems present.

Case Weight Adjustment- As mentioned above, weighting factors reflect the unequal probability of sampling for each case and must be applied during analysis in order to accurately reflect the national incidence of tow-away crashes occurring in the US. However, high variability in the case weights can be problematic during some analyses. In particular, outlier case weights or cases with extremely high weights can significantly bias regression results and conclusions. Figure 1 shows the distribution of case weights for the sample described in Table 1. Due to the oversampling of higher severity injury cases which occur less frequently than low severity injuries, the majority of NASS CDS cases have a weighting factor below 1,000. For the frontal crash sample, the mean weight is 452 with a standard deviation of 1,412. This implies that, on average, each crash involved driver included within NASS CDS represents the crash experience of 452 other tow-away crash involved drivers. However, individual case weights range from 1 to over 36,000. Further analyzing the sample, we find that 98 percent of the cases have a weight that falls within 2 standard deviations of the mean case weight (i.e., case weights greater than 0 but less than 3,275). Only 234 of the 10,957 cases in the study population have a weighting factor above 3,275. In order to reduce the potential bias due to the inclusion of these cases in the final population for analysis, cases with a total weight higher than 3,272 were not included in the analysis.

Injury Outcome Variables

All coded injuries are assigned an Abbreviated Injury Severity (AIS) code which uniquely identifies the body region, details related to the anatomic structure involved, as well as the severity of the injury sustained (insert AIS reference). The AIS severity indicates the threat to life associated with a particular injury and ranges from 1 to 6 where an AIS 1 injury is minor, AIS 2 is moderate, AIS 3 is serious, AIS 4 is severe, AIS 5 is critical and AIS 6 is maximum or generally non-survivable. For the purpose of this analysis, the Maximum AIS score assigned to an occupant is referred to as an MAIS injury. If an occupant sustains one or more injuries at or above AIS level 3 (i.e. one or more AIS 3, 4 5 or 6 level injuries) or a fatality results, this occupant is referred to as MAIS 3+ injured. The analysis presented below considers the odds of MAIS 2+ and MAIS 3+ injury. Too few cases of occupant injury at or above AIS 4 exist within the dataset to allow meaningful results for MAIS4+ or MAIS5+ injured occupants. Similarly, the odds of minor injury compare MAIS 1 injury relative to no injury at all. If an occupant is fatally injured due to crash forces, they are assigned an MAIS level of 6 for the whole body analysis. All occupants who died due to non-crash related reasons (i.e., ruled disease) were removed from the analysis.

The AIS scale was used to classify the maximum severity of injury within each body region. The AIS 90 injury coding assigns injuries to one of eight body regions. These body regions include the head, face, neck, chest, spine, abdomen, upper extremity and lower extremity. For each of the eight body regions, three dummy variables were created to indicate if an AIS 1 injury was sustained or if an AIS 2 or higher or AIS 3 or higher injury was sustained. These codes are assigned based on injuries occurring within a particular body region and they are not affected by other injuries sustained within other body regions. For example if an occupant sustains one or more head injuries with an AIS severity of three or higher, this person is considered Head 3+ injured. Similarly, if a person sustains chest injuries with an AIS severity of three or higher, this person is considered Chest3+ injured. Using this convention, 24 additional variables were created for analysis (8 body regions x 3 AIS severity thresholds).

Tables 3 and 4 show the unweighted counts of drivers injured by their highest severity injury across the whole body (MAIS) and by the highest AIS level injury per body region. Table 3 includes all drivers in crashes under 15 MPH and Table 4 shows driver counts for crashes over 15 MPH based on total deltaV or estimated deltaV category.

Statistical Analysis

For this analysis, logistic regression was used to calculate person level and body region level injury odds ratios for occupants protected by sled-certified airbag systems compared with occupants protected by barrier-certified airbags. The population analyzed includes front seat occupants that were involved in frontal tow-away crashes. The dependent variable in the logistic model was dichotomous and indicates the presence of any injury at or above a given severity across the whole body. In addition, injury analyses were conducted by body region where the outcome variable was dichotomous and indicates the presence of an injury at or above a given severity within each body region of interest.

Injury odds ratios were calculated at two Maximum AIS thresholds (MAIS 1 and MAIS 2+) to identify if sled certified airbags have a differential effect on low severity versus moderate severity injuries. In some cases, MAIS 3+ injury odds were calculated if sufficient data was available to provide meaningful results. Reference groups were MAIS 0 when studying risk of MAIS 1 injuries, MAIS 0-1 when studying MAIS 2+ injuries, and MAIS 0-2 when studying MAIS 3+ injuries.

During the analysis, potentially confounding factors were controlled for that could affect the odds of injury beyond the presence or absence of a sled certified frontal airbag. Models were built by systematically including all parameters which could impact driver injury outcome. Those parameters which had significant coefficients where the $p<0.20$ remained in the model while those with non-significant coefficients were removed using a backwards elimination process. If a given parameter was known to impact injury mechanism or if it explained important crash dynamics, the parameter remained in the model even if its coefficient was not significant. These parameters were selected based on findings of previous research and experience of the research team. Variable definitions are as follows:

Crash severity - The following deltaV ranges were used classify events as low, moderate and high speed : 0-14 mph (0-24 kph), 15-24 mph (25-39 kph) and 25 mph and higher (40 kph and higher) respectively.

Manual restraint usage - Belted occupants who were restrained by 3-point belts only. This analysis was limited to adult occupants. Restrained children seated in the right front seat were excluded from the analysis.

Seating position - Only front seat outboard seating positions were considered during this analysis. Characteristics of occupant protection systems are expected to vary considerably for drivers when compared with right front passengers due to the presence of the steering assembly, varied geometry of frontal airbags and due to varied inflation characteristics of these systems.

Age - Occupant age was coded as a dichotomous variable for all adult front seat occupants 16 years and older. The categories included persons who were16-64 years or 65 and higher years old.

Gender - Occupant gender was assigned based on coded information.

Height and weight - Occupants were classified as small stature or large based on height and weight information. Small stature adults include those over 16 years old and shorter than 5 foot 3 inches. Large occupants are those heavier than 195 lbs regardless of height and gender. This minimum corresponds with the weight of the 70^{th} percentile male. Two dichotomous variables were created based on occupant height and weight; yes/no small stature and yes/no large occupant.

Vehicle body type - Passenger vehicle platforms (including passenger cars, Minivans, SUV's, Pickups and Passenger vans) were partitioned into two groups. Passenger cars and minivans were grouped together as cars while SUV's, pickups and passenger vans were considered LTV's. This was a dichotomous variable indicating if a vehicle was an LTV or a passenger car.

Occupant compartment intrusion – The extent of occupant compartment intrusion was characterized using a 4 category dummy variable. Intrusion of any component at the occupant's seating position was as follows: 0 inches of intrusion, 1-5 inches, 6-11 inches, 12 or more inches.

Multiple Impact Events - The occurrence of multiple significant crash events was coded to characterize the total loading scenario experienced by occupants. Since deltaV and estimated deltaV are available only for the single highest severity event, CDC extent of damage was used to characterize the occurrence of a second moderate to high severity impact. If the damage extent of the second highest impact was 2 or higher, this was flagged as a multiple impact crash. This was a dichotomous variable indicating yes/no to the occurrence of a multiple impact crash.

Analysis was performed separately for drivers and right front passengers by belt use for vehicles equipped with airbags (independent of deployment) who were involved in frontal crashes (11, 12, and 1 o'clock direction of force). Analysis was performed across all speeds and stratified by low speed (Delta-V < 15) versus medium and high speed (Delta-V >=15). The body region level analysis was also stratified by these parameters. Odds ratios were calculated only for populations where more than 30 unweighted cases were available in each of the four conditions analyzed here (i.e. injured with sled certified airbags present, uninjured with sled certified airbags present, injured with first generation airbags present, uninjured with first generation airbags present). The reliability of estimates based on fewer cases may lead to unreliable results due to the complex design of NASS CDS and the high variability seen in the case weights. Unweighted case counts for each of these conditions by crash deltaV category and belt use status for drivers are presented in Tables 3 and 4.

Stata 9.0 was used to run all the regression models. It accommodates the complex stratified sample design used by NASS/CDS. Variances and standard errors are estimated using Taylor linearization.

Findings

The results of the logistic regression analysis are presented in Tables 5-12 below. Each table lists the odds of AIS 1, AIS 2+ injury including 95 percent confidence limits for the odds ratios. In some cases, AIS 3+ injury odds were computed based on available data. Analyses are presented separately for drivers and right front passengers and for belted and unbelted occupants. Regression model results are first presented controlling for crash deltaV and subsequently for subpopulations by deltaV. This presentation allows for the evaluation of sled certified airbag performance overall controlling for crash deltaV and during low versus high deltaV crashes separately.

Odds ratio estimates were calculated for sled certified airbag presence versus first generation airbag presence. An odds ratio less than one indicates that there is an overall reduced chance of injury for occupants with sled certified airbags present compared with similar occupants involved in similar crashes with a first generation airbag present. If the upper 95 percent confidence limits of the odds ratio estimate is less than 1, this would indicate a statistically significant reduction. Conversely, a lower confidence limit above 1 indicates significant higher odds of injury when sled certified airbags are present compared with similar crashes where first generation systems were present.

Overall Driver Odds of Injury

Table 5 presents odds of MAIS 1, MAIS 2+ and MAIS 3+ injury for all drivers by belt use. The models controlled for deltaV, occupant age and gender, and intrusion.

For belted drivers, the odds ratio for MAIS 1 injury was 0.78 (95% CI: 0.67, 0.91) indicating a 22 percent reduction in the odds of minor injury for drivers with sled certified airbags compared with drivers in similar crashes with first generation airbags. This result was statistically significant at the 5 percent level. For MAIS 2+ injuries, an odds ratio of 0.86 (95% CL: 0.71, 1.05) was found. The point estimate for MAIS 2+ injury indicates a tendency for reduced odds but was not significant. There was no difference in the likelihood of sustaining serious or worse injuries (MAIS 3+) in vehicles with sled-certified versus first generation airbags (OR 0.97; CL 0.67-1.41),

For all unbelted drivers in frontal crashes with an airbag present, the odds ratio for MAIS 1 injury suggests a 19 percent reduction in the odds of minor injury for unbelted drivers however this finding was not statistically significant. The odds of MAIS 2+ and MAIS 3+ were 1.23 (95% CL: 0.85, 1.80) and 1.20 (95% CL: 0.65, 2.25), respectively. These results were not statistically significant however; they indicate tendency for increased odds of MAIS 2+ and MAIS 3+ injury for unbelted drivers.

In low severity crashes (deltaV <15 MPH), the odds of MAIS 1 injury for belted drivers was 22 percent lower for drivers in sled-certified versus first generation airbags (OR 0.78; 95% CL: 0.67, 0.91). The odds ratios for MAIS 2+ injuries was 0.87 (95% CL: 0.62, 1.23) and was not statistically significant at the 5 percent level. The odds ratio estimate for MAIS 3+ injury suggests no changes in the risk of serious injury for belted drivers for vehicles equipped with sled certified airbags relative to first generation systems. For unbelted drivers in low speed crashes, the odds of MAIS 1 injury was 0.70 suggesting a reduction in minor injuries however the result was not statistically significant. Little change in odds of MAIS 2+ injury was detected and there were too few unbelted frontal crashes with MAIS 3+ injured driver cases to determine differences in MAIS 3+ injury odds during low speed crashes.

For medium and high severity crashes (deltaV>15 MPH), the odds ratio for MAIS 1 injury for belted drivers was 0.79 (95% CL: 0.58, 1.07). This result was not statistically significant; however, the result indicates a tendency for reduced minor severity injury odds for belted drivers in medium and high severity crashes. The odds of MAIS 2+ and MAIS 3+ injury was 0.87 (95% CL: 0.63, 1.21) and 1.00 (95% CL:0.66, 1.50) respectively during these crashes however these results were not significant at the 5 percent level. For unbelted drivers, the odds of MAIS 1 injury suggest little change. The odds of MAIS 2+ injury was 1.66 (95% CL: 0.99, 2.80). Although this result for high severity frontal crashes was not statistically significant, it suggests some increase in moderate and higher severity injuries for unbelted drivers. The odds of MAIS 3+ injury for unbelted drivers during high speed crashes indicated no clear difference with a sled certified airbag present compared with drivers with a first generation airbag present.

Driver Injuries by Body Region

Head Injuries- Table 6 shows the odds of AIS 1 as well as AIS 2 and higher head injury controlling for crash severity, occupant age and gender, intrusion, multiple impacts, and driver height. Overall, few significant changes in head injury odds were detected. For belted occupants, the AIS 1 head injury odds ratio was 0.81 (95% CL: 0.56, 1.17) suggesting a slight but non-statistically significant reduction in minor head injuries with the introduction of sled certified airbags. For AIS 2+ head injury, little change was detected.

For unbelted drivers, the odds of AIS 1 and AIS 2+ head injury are close to one indicating little change in head injury odds.

When stratified by deltaV, the odds of head injury for belted drivers during lower severity crashes indicates a tendency for a reduction of AIS 1 and AIS 2+ head injury odds with the presence of a sled certified airbag yet these results were not statistically significant at the 5 percent level. The odds ratios were 0.77 (95% CL: 0.48, 1.22) and 0.75 (95% CL: 0.42, 1.34) respectively for the group. Among unbelted drivers, the odds of AIS 1 head injury during low severity impacts suggests a 28 percent reduction in injury however the result was not significant. Too few cases were available to estimate AIS 2+ head injury odds for this population.

For the medium/high deltaV category, the odds of AIS 2+ head injury among belted drivers was 1.39 (95% CL: 0.84, 2.30) indicating the tendency for an increase head injury odds however the result was not statistically significant. Among unbelted drivers involved in medium/high deltaV crashes, the odds of AIS1 head injuries and the odds of AIS 2+ head injuries suggest increased odds of minor and moderate severity head injuries however the results are not statistically significant.

Facial Injuries- Table 7 shows the odds of AIS 1 driver face injuries controlling for crash deltaV, intrusion, vehicle body type, and multiple impacts. Overall, the odds ratio for AIS 1 face injury for belted drivers was 0.67 (95% CL: 0.55, 0.82). Based on the unweighted sample size as shown in Tables 4 and 5, there were too few cases available in the AIS 2 and higher category to provide meaningful estimates. For unbelted drivers, the odds ratio for AIS 1 facial injuries was 1.66 (95% CL: 1.16, 2.39) suggesting an increased odds of facial injury during crashes with sled certified airbags compared with first generation systems.

When stratified by crash deltaV category, a similar odds ratio of 0.68 (95% CL: 0.52, 0.88) for AIS 1 face injuries was found for belted drivers involved in low severity crashes. For unbelted drivers, an odds ratio of 1.46 (95% CL: 0.70, 3.02) was found suggesting an increase in the odds of minor facial injury. However, this result was not statistically significant as indicated by the wide confidence interval for the estimate. In medium/high severity crashes, belted drivers were 34 percent less likely to sustain and AIS 1 facial injury (OR 0.66, 95% CL: 0.47, 0.94). For the unbelted, the AIS 1 face injury odds ratio was 2.03 (95% CL: 1.30, 3.19) indicating a doubling of the odds of a minor facial injury with the introduction of sled certified airbags.

Chest Injuries- Table 8 shows the odds of AIS 1 and AIS 2+ chest injuries for drivers while controlling for crash severity category, occupant age and gender, and intrusion. For AIS 2+ chest injuries, the overall odds ratio was 1.52 (95% CL: 0.93, 2.48) suggesting an increase in moderate severity chest injury odds for belted drivers with the introduction of sled certified airbags, but this estimate was not statistically significant. For AIS 2+ chest injuries for the unbelted, the odds ratio was 1.76 (95% CL: 0.94, 3.30) indicating a tendency for increases in moderate severity chest injury odds however the estimate is not statistically significant.

During low deltaV crashes, little change in AIS 1 injury odds was detected and there were too few observations available to accurately determine changes in AIS 2+ chest injury for both belted and unbelted drivers during low speed crashes.

For belted drivers involved in moderate to high deltaV crashes, the estimate for minor (AIS 1) chest injuries suggests little change in the risk of injury. However the AIS 2+ chest injury odds ratio suggests a possible increased risk of moderate and higher injury for belted drivers involved in moderate and high severity frontal crashes. The odds ratio for AIS 2+ chest injuries was 1.47 (95% CL: 0.80, 2.68). For unbelted drivers involved in moderate and high deltaV crashes, the odds of AIS 2+ chest injury doubled (OR 2.07, 95% CL: 1.09, 3.90) in vehicles with sled certified airbags.

Abdominal Injuries- Table 9 presents results for the analysis of abdominal injuries. Although a sufficient number of cases were available for analysis in some crash and belt use categories, the findings indicate no statistically significant differences in airbag performance controlling for crash severity, vehicle body type, multiple impact and gender. Few reliable trends were observed for this body region and model fit was poor suggesting that explanatory variables did not adequately capture the relationship between crash, vehicle and occupant characteristics and abdominal injury occurrence. For this reason, abdominal injury results will not be discussed further.

Upper Extremity Injuries- Table 10 shows the odds of AIS 1 and AIS 2+ upper extremity injuries for drivers while controlling for crash severity, intrusion, vehicle body type and driver gender. Overall, belted drivers in vehicles with sled-certified airbags were 26 percent less likely to sustain AIS 1 upper limb injuries (OR 0.74 (95% CL: 0.61, 0.90). The odds ratio for AIS 2+ upper limb injuries for belted drivers indicates some reduction in minor severity injury odds (20 percent reduction) however this result was not statistically significant. For the unbelted, the odds of AIS 1 and AIS 2+ upper limb injury both suggest the tendency for reduced upper extremity injury risk with sled certified airbags present however neither estimate is statistically significant at the 5 percent level.

In low deltaV crashes , the odds ratio for upper extremity injury for belted drivers was 0.75 (95% CL: 0.60, 0.93). Point estimates indicate a 22 percent higher risk of sustaining AIS 2+ upper extremity injuries in low speed crashes, however this estimate was not significant. For unbelted drivers during low severity crashes, there was an estimated 50 percent reduction in the odds of a minor upper extremity injury; however, this was not significant. There were too few cases available to draw reliable conclusion regarding AIS 2+ upper extremity injury odds for unbelted drivers during low severity crashes. Similarly, for the medium/high deltaV category, results were not statistically significant however the AIS1 and AIS 2+ estimates indicate the tendency for reductions with the presence of a sled certified airbag.

Lower Extremity Injuries- Table 11 shows the odds of AIS1 and higher as well as AIS 2 and higher lower extremity injuries for drivers controlling for crash severity, occupant age and gender, intrusion and vehicle body type. Overall, for belted drivers, the odds ratio estimate for AIS 2+ lower limb injuries was 0.68 (95% CL: 0.52, 0.90). This finding indicates a reduction in lower extremity injury odds for belted drivers for moderate severity and higher injuries. For unbelted drivers, the odds ratio for AIS 1 and AIS 2+ injury for unbelted drivers indicates little change overall.

When stratified by crash deltaV category, the odds of AIS 1 lower limb injury for belted and unbelted occupants suggests little difference in the risk of minor lower extremity injury. For the medium/high deltaV category, the odds ratio AIS 2+ lower extremity injury was 0.62 (95% CL: 0.45, 0.85). This odds ratio indicates a statistically significant reduction in the odds of moderate severity injury for belted drivers involved in medium to high severity frontal crashes. For the unbelted population involved in medium to high severity frontal crashes, the odds ratio for AIS1 and AIS 2+ lower extremity injury suggests little difference in injury odds with sled certified airbags present compared with first generation systems.

Overall Right Front Passenger Odds of Injury

Analyses of right front passenger injury odds were conducted (Table 12). The results suggest no clear differences in injury odds for right front passengers with the introduction of sled certified airbags. There is a general tendency for increased MAIS 1, MAIS 2+ and MAIS 3+ injury odds for unbelted right front passengers during medium/high deltaV crashes. However, it is important to note that these results were generated based on an analysis of a small sample and its interpretation could lead to unreliable results.

When the population of right front passenger injuries was separated by body region, the number of cases available for analysis was too sparse to draw any meaningful conclusions. We were not able to provide finer analyses by body region due to the small sample size.

Discussion

This paper examined changes in injury risk associated with the introduction of sled certified airbags relative to first generation systems by using data from the NASS CDS 1997-2005. The majority of cases present within NASS CDS are minor severity or no injury cases, which limited the number of analyses that could be conducted on moderate to severe injuries.

Overall, a significant reduction in low severity injuries for belted drivers was associated with the change. In general, the introduction of sled certified airbags has not affected the odds of severe injury (MAIS 3+) for belted drivers during frontal collisions.

Unbelted drivers with sled-certified airbags had a borderline significant increase in the risk of MAIS 2+ injuries, with smaller non-significant increases in MAIS 1 and MAIS 3+ injuries. This finding is consistent with anecdotal evidence using CIREN data where unrestrained drivers have appeared to receive reduced protection by sled certified airbags compared with first generation systems (Schneider 2005, Augenstein 2005). It is possible that unbelted occupants may not be as well restrained by depowered systems and may contact other interior components including the steering assembly, dash panels, or the a-pillar among others. Studies of mortality among drivers of vehicles with sled-certified airbags have not observed an increased risk of dying among unbelted drivers (Kahane, 2006; Braver et al., 2005; Braver et al., 2007); thus, the increased risk of AIS 2+ injuries among unbelted drivers with sled-certified airbags in this study was unexpected.

By body region, belted drivers appeared to have lower or equal odds of face, upper extremity and lower extremity injury with a sled certified airbag present compared with drivers who had first generation airbag systems. A reduction in airbag aggressivity, improved tethering of airbags, and changes to fold patterns due to sled certification may explain the significant reduction in the odds of these injuries. This finding differs significantly from findings of Jernigan et. al. who reported increased risk of sever upper extremity injury for occupants exposed to depowered airbags. Their NASS CDS study covered 1993-2001 crash years which included a smaller sample of vehicles equipped with depowered airbags. Some researchers speculate that the majority of the injuries prevented by airbag depowering results from changes in airbag deployment threshold rather than difference in occupant protection provided by these systems (Segui-Gomez 2003).

Among unbelted occupants in sled-certified airbags, significant increases in AIS 2+ chest injury odds were observed for medium/high delta-V crashes. This is worrisome as it suggests potential adverse consequences from depowering. For the belted population, a non-significant tendency towards reduced chest injury protection (increased AIS 2+ injury odds) was observed for the subpopulation of medium and high deltaV frontal collisions. It is possible that overstated belt use might contribute to this finding. Previous research has indicated that belt use is overstated in police reported data and even in data derived from fully investigated crashes (Malliaris 1998). Since safety belt use rates have steadily increased over the study period, we anticipate fewer inaccurate reports of belt use in recent crash years compared with early crash years. Over reporting of belt use for earlier crashes (which comprised a higher proportion of first generation vehicles) may have artificially raised the odds ratios for injury among belted drivers. NASS CDS's reported belt use rates have remained relatively constant over the 1997-2005 crash study period and have been higher than those observed in roadside surveys, which have shown increasing belt use rates. For this reason, a higher degree of overreporting during the earlier years of the study period is likely.

The study observed a non-significant increase in AIS 2+ head injuries for both belted and unbelted drivers involved in moderate to high severity crashes with sled-certified airbags present. It is possible that minor head contact with interior components might occur due to reduced levels of restraint provided by depowered airbags. The data was explored further to determine if higher severity head injury changes occurred (AIS 3+) ; however, there was insufficient data available to determine reliable effects.

Fewer U.S. drivers are operating vehicles while unrestrained. Recent belt use estimates by the National Occupant Protection Use Survey (NOPUS) indicated belts use was 81 percent in 2006 (NOPUS 2006). In the fall of 1996, safety belt use was 61 percent.

<u>Study Strengths and Limitations-</u> One important limitation of this study relates to the sample size available within NASS CDS, which includes about 5,000 police-reported crashes per year. When the population of interest is stratified by crash severity and occupant restraint use, this results in a smaller number of cases for evaluation. This is particularly true for high speed events involving unbelted occupants. All data presented here is accompanied by appropriate tests of significance that take into account the complex sample design used by NASS CDS. In addition, unweighted case counts are presented by body region to allow the reader to appropriately consider the number of cases used to draw conclusions. NASS CDS uses a complex system of oversampling crashes that involve later model year passenger vehicles and result in hospitalizations and deaths. Consequently, some findings may be influenced by sample design and case weights.

A strength of this analysis involves imputation of missing delta-V data within NASS CDS. Of particular importance is crash severity or deltaV. Missing deltaV data could introduce a bias into the analysis because crashes with missing delta-V's tend to have higher fatality rates (Farmer 2006). During this analysis, cases with missing deltaV values were included when an estimated deltaV value was provided. This surrogate for deltaV relies on a non-exact estimate based on NASS researcher opinion and estimates of damage for non-inspected vehicles. For these reasons, this estimate may be less accurate than case with typical deltaV values assigned (calculated using Winsmash) and may be a source of error in this analysis. Results using all cases (including those based on estimated delta-V) versus cases with calculated delta-V values were compared. Findings regarding risk of overall MAIS 1, MAIS 2+ and MAIS 3+ injuries for both the belted and unbelted populations were similar using both samples. It is important to note that an airbag that is sled-certified may not have been redesigned at the time that the optional sled certification test was introduced. Although most manufacturers met optional requirements by depowering airbags (through reductions in airbag inflator output), some may have met optional sled certification requirements without making any changes to their airbags at all. Unfortunately, no public data exists to determine if an airbag was depowered in order to meet the optional sled test requirements. Consequently, this is a study of the effects of changing airbag regulations to permit depowering rather than a study of the direct effects of depowering.

Conclusions

Overall, this study identified that the introduction of sled certified airbags has led to equivalent protection for drivers involved in frontal crashes. For belted drivers, sled certified airbags appeared to offer the same or better protection when compared with first generation airbags in preventing injuries. Reductions in minor injuries were found for the face and upper extremity. It is likely that reductions in airbag deployment pressure in combination with higher deployment thresholds were responsible for this difference. A reduction in moderate severity injuries was found for the lower extremity during medium and high severity crashes. The reason for this change is unexplained and requires further investigation.

For unbelted drivers, sled certified airbags were associated with reduced protection for the face and chest. These negative changes were found during medium and high severity crashes. Small numbers hampered the assessment of injury risks of unbelted front-seat occupants population involved in medium and high severity crashes. Further research using other databases would be desirable in order to confirm whether sled-certified airbags and advanced airbags have detrimental effects on the non-fatal injury risk of unbelted drivers.

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Table 1. General Characteristics of the NASS CDS 1997-2005 Tow-Away Crash Involved Population (unweighted distributions)

	Driver		RF Passenger	
	First Generation (n= 5,416),%	**Sled Certified (n= 6,295),%**	**First Generation (n= 1,897),%**	**Sled Certified (n= 1,482),%**
Occupant Age (YRS)				
0-15	0%	0%	16%	12%
16-34	52%	50%	50%	49%
35-64	37%	40%	21%	26%
65+	9%	9%	10%	9%
DeltaV Range (MPH)				
0-14	50%	51%	52%	52%
15-24	37%	37%	36%	37%
25+	13%	12%	11%	11%
Multiple Impacts				
Yes	31%	34%	33%	35%
Intrusion Extent (inches)				
Unknown	11%	10%	13%	14%
0	69%	71%	68%	68%
1-5	11%	10%	9%	9%
6-12	5%	5%	6%	5%
12+	4%	4%	4%	4%
Gender				
Female	46%	45%	56%	57%
Belt Use				
Belted	83%	83%	81%	80%
Airbag Deployed				
Deployed	78%	70%	74%	71%
Vehicle Type				
Pass Car	73%	64%	79%	67%
SUV	9%	16%	7%	16%
Van	8%	5%	10%	6%
Pickup	9%	15%	4%	12%

Note: Includes only planar crash involved, non-ejected, airbag protected, MY 1994-2005 vehicle occupants with known airbag type, deltaV, belt use.

Table 2. Unweighted Case Counts for First Generation and Sled Certified Protected Occupants by deltaV availability and injury severity

Population	MAIS 0-1 Injured	MAIS 2+ Injured
Drivers, Frontal Crash Involved First Generation or Sled-certified Airbags Present	11,745	3,594
-Known deltaV	8,473	2,484
- Estimated deltaV available	2,185	650
-Unknown Severity	1,087	460
Passengers, Frontal Crash Involved First Generation or Sled-certified Airbags Present	3,112	808
-Known deltaV	2,200	570
- Estimated deltaV available	640	166
-Unknown Severity	272	72

Table 3. Driver unweighted case counts for low speed crashes by injury severity, belt usage, body region injured and airbag type available.

		Low speed							
		First Generation				Sled Certified			
Body Region	Belt Status	MAIS 0	MAIS 1	MAIS 2	MAIS 3-6	MAIS 0	MAIS 1	MAIS 2	MAIS 3-6
All	Unbelted	64	186	41	27	96	229	44	38
	Belted	875	1,321	152	65	1,159	1,446	177	58
Head	Unbelted	251	46	21	9	330	54	16	12
	Belted	2,285	103	33	11	2,682	131	44	9
Face	Unbelted	225	96	4	2	288	115	6	3
	Belted	2,030	394	6	2	2,544	316	6	-
Chest	Unbelted	276	37	2	12	357	39	2	14
	Belted	2,032	371	20	9	2,396	419	33	18
Abdomen	Unbelted	304	16	4	3	391	16	3	2
	Belted	2,299	122	7	4	2,703	152	8	3
Lower Limb	Unbelted	211	85	21	10	273	106	23	10
	Belted	1,874	476	64	18	2,212	571	66	17
Upper Limb	Unbelted	208	103	10	6	296	97	15	4
	Belted	1,565	791	53	23	2,067	732	48	19

Table 4. Driver unweighted case counts for medium/high speed crashes by injury severity, belt usage, body region injured and airbag type available.

		Medium/High speed							
		First Generation				Sled Certified			
Body Region	Belt Status	MAIS 0	MAIS 1	MAIS 2	MAIS 3-6	MAIS 0	MAIS 1	MAIS 2	MAIS 3-6
All	Unbelted	46	233	103	207	68	271	124	208
	Belted	358	1,130	287	331	512	1,236	312	348
Head	Unbelted	383	93	57	63	454	97	79	56
	Belted	1,825	162	85	49	2,111	144	98	76
Face	Unbelted	350	222	21	3	372	271	35	8
	Belted	1,536	566	15	4	1,888	505	27	9
Chest	Unbelted	411	93	14	78	484	96	24	82
	Belted	1,474	491	30	126	1,681	577	48	123
Abdomen	Unbelted	485	50	36	25	585	45	33	23
	Belted	1,813	232	41	35	2,042	311	48	28
Lower Limb	Unbelted	251	165	80	100	306	190	70	120
	Belted	1,103	631	213	174	1,361	699	203	166
Upper Limb	Unbelted	308	212	51	25	394	213	49	30
	Belted	1,061	842	141	77	1,368	860	133	68

Table 5. Odds of injury and 95% confidence limits for drivers involved in frontal crashes where airbags were available (NASS CDS 1997-2005).

DeltaV	Belt Status	Injury Severity	Odds Ratio	95 % Confidence Limits	
				Lower CL	Upper CL
All	Belted	**MAIS1**	**0.78**	**0.67**	**0.91**
		MAIS 2+	0.86	0.71	1.05
		MAIS 3+	0.97	0.67	1.41
	Unbelted	MAIS1	0.81	0.42	1.55
		MAIS 2+	1.23	0.85	1.80
		MAIS 3+	1.20	0.65	2.25
Low	Belted	**MAIS1**	**0.78**	**0.67**	**0.91**
		MAIS 2+	0.87	0.62	1.23
		MAIS 3+	0.96	0.55	1.67
	Unbelted	MAIS1	0.70	0.33	1.48
		MAIS 2+	0.90	0.51	1.57
		MAIS 3+	--	--	--
Medium/High	Belted	MAIS1	0.79	0.58	1.07
		MAIS 2+	0.87	0.63	1.21
		MAIS 3+	1.00	0.66	1.50
	Unbelted	MAIS1	1.13	0.45	2.81
		MAIS 2+	1.66	0.99	2.80
		MAIS 3+	1.15	0.65	2.02

Controlling for: deltaV category, age, intrusion, gender
--= insufficient data available for analysis

Table 6. Odds of head injury and 95 percent confidence limits for drivers involved in frontal crashes where airbags were available (NASS CDS 1997-2005).

DeltaV	Belt Status	Head Injury Severity	Odds Ratio	95 % Confidence Limits	
				Lower CL	Upper CL
All	Belted	AIS1	0.81	0.56	1.17
		AIS 2+	1.06	0.74	1.52
	Unbelted	AIS1	1.01	0.71	1.43
		AIS 2+	0.94	0.53	1.68
Low	Belted	AIS1	0.77	0.48	1.22
		AIS 2+	0.75	0.42	1.34
	Unbelted	AIS1	0.72	0.46	1.11
		AIS 2+	--	--	--
Medium/High	Belted	AIS1	0.87	0.50	1.53
		AIS 2+	1.39	0.84	2.30
	Unbelted	AIS1	1.48	0.77	2.85
		AIS 2+	1.24	0.68	2.28

Controlling for: deltaV category, age, intrusion, multiple impacts, small stature
--= insufficient data available for analysis

Table 7. Odds of face injury and 95 percent confidence limits for drivers involved in frontal crashes where airbags were available (NASS CDS 1997-2005)

DeltaV	Belt Status	Face Injury Severity	Odds Ratio	95 % Confidence Limits Lower CL	Upper CL
All	Belted	**AIS1**	**0.67**	**0.55**	**0.82**
		AIS 2+	--	--	--
	Unbelted	**AIS1**	**1.66**	**1.16**	**2.39**
		AIS 2+	--	--	--
Low	**Belted**	**AIS1**	**0.68**	**0.52**	**0.88**
		AIS 2+	--	--	--
	Unbelted	AIS1	1.46	0.70	3.02
		AIS 2+	--	--	--
Medium/High	Belted	**AIS1**	**0.66**	**0.47**	**0.94**
		AIS 2+	--	--	--
	Unbelted	**AIS1**	**2.03**	**1.30**	**3.19**
		AIS 2+	--	--	--

Controlling for: deltaV category, intrusion, vehicle body type, multiple impacts
--= insufficient data available for analysis

Table 8. Odds of chest injury and 95 percent confidence limits for drivers involved in frontal crashes where airbags were available (NASS CDS 1997-2005)

DeltaV	Belt Status	Chest Injury Severity	Odds Ratio	95 % Confidence Limits Lower CL	Upper CL
All	Belted	AIS1	0.95	0.71	1.28
		AIS 2+	1.52	0.93	2.48
	Unbelted	AIS1	0.85	0.56	1.29
		AIS 2+	1.76	0.94	3.30
Low	Belted	AIS1	0.93	0.77	1.13
		AIS 2+	--	--	--
	Unbelted	AIS1	0.78	0.42	1.45
		AIS 2+	--	--	--
Medium/High	Belted	AIS1	1.00	0.58	1.75
		AIS 2+	1.47	0.80	2.68
	Unbelted	AIS1	0.84	0.34	2.06
		AIS 2+	**2.07**	**1.09**	**3.90**

Controlling for: deltaV category, intrusion, age, gender
--= insufficient data available for analysis

Table 9. Odds of abdomen injury and 95 percent confidence limits for drivers involved in frontal crashes where airbags were available (NASS CDS 1997-2005)

DeltaV	Belt Status	Abdomen Injury Severity	Odds Ratio	95 % Confidence Limits Lower CL	Upper CL
All	Belted	AIS1	1.27	0.79	2.03
		AIS 2+	0.64	0.24	1.70
	Unbelted	AIS1	0.39	0.16	0.96
		AIS 2+	0.88	0.38	2.03
Low	Belted	AIS1	1.30	0.78	2.17
		AIS 2+	--	--	--
	Unbelted	AIS1	--	--	--
		AIS 2+	--	--	--
Medium/High	Belted	AIS1	1.22	0.56	2.63
		AIS 2+	0.53	0.21	1.38
	Unbelted	AIS1	0.47	0.22	1.00
		AIS 2+	1.00	0.40	2.52

Controlling for: deltaV category, vehicle body type, multiple impacts, gender
--= insufficient data available for analysis

Table 10. Odds of upper limb injury and 95 percent confidence limits for drivers involved in frontal crashes where airbags were available (NASS CDS 1997-2005)

DeltaV	Belt Status	Upper Limb Injury Severity	Odds Ratio	95 % Confidence Limits Lower CL	Upper CL
All	Belted	**AIS1**	**0.74**	**0.61**	**0.90**
		AIS 2+	0.80	0.48	1.32
	Unbelted	AIS1	0.59	0.32	1.11
		AIS 2+	0.75	0.31	1.82
Low	Belted	**AIS1**	**0.75**	**0.60**	**0.93**
		AIS 2+	1.22	0.54	2.74
	Unbelted	AIS1	0.50	0.19	1.27
		AIS 2+	--	--	--
Medium/High	Belted	**AIS1**	**0.74**	**0.57**	**0.96**
		AIS 2+	0.63	0.36	1.11
	Unbelted	AIS1	0.70	0.37	1.34
		AIS 2+	0.51	0.22	1.19

Controlling for: intrusion, vehicle body type, gender
--= insufficient data available for analysis

Table 11. Odds of lower limb injury and 95 percent confidence limits for drivers involved in frontal crashes where airbags were available (NASS CDS 1997-2005).

DeltaV	Belt Status	Lower Limb Injury Severity	Odds Ratio	95 % Confidence Limits	
				Lower CL	Upper CL
All	Belted	AIS1	0.88	0.73	1.07
		AIS 2+	**0.68**	**0.52**	**0.90**
	Unbelted	AIS1	0.84	0.46	1.53
		AIS 2+	1.07	0.64	1.79
Low	Belted	AIS1	0.86	0.67	1.11
		AIS 2+	0.94	0.59	1.50
	Unbelted	AIS1	0.69	0.37	1.27
		AIS 2+	--	--	--
Medium/High	Belted	AIS1	0.91	0.70	1.19
		AIS 2+	**0.62**	**0.45**	**0.85**
	Unbelted	AIS1	1.13	0.58	2.19
		AIS 2+	1.33	0.77	2.31

Controlling for: deltaV category, intrusion, age, vehicle body type, gender
--= insufficient data available for analysis

Table 12. Odds of injury and 95 percent confidence limits for right front passengers involved in frontal crashes where airbags were available (NASS CDS 1997-2005).

DeltaV	Belt Status	Injury Severity	Odds Ratio	95 % Confidence Limits	
				Lower CL	Upper CL
All	Belted	MAIS 1	0.87	0.51	1.49
		MAIS 2+	0.70	0.42	1.15
		MAIS 3+	1.54	0.75	3.16
	Unbelted	MAIS 1	0.65	0.28	1.51
		MAIS 2+	1.00	0.46	2.20
		MAIS 3+	0.85	0.39	1.86
Low	Belted	MAIS 1	0.79	0.49	1.28
		MAIS 2+	0.52	0.27	1.09
		MAIS 3+	--	--	--
	Unbelted	MAIS 1	0.36	0.11	1.20
		MAIS 2+	--	--	--
		MAIS 3+	--	--	--
Medium/High	Belted	MAIS 1	1.19	0.46	3.10
		MAIS 2+	1.01	0.47	2.17
		MAIS 3+	2.05	0.90	3.82
	Unbelted	MAIS 1	1.58	0.54	4.64
		MAIS 2+	1.47	0.50	4.37
		MAIS 3+	1.87	0.50	7.06

Controlling for: gender, age, intrusion, , vehicle body type
--= insufficient data available for analysis

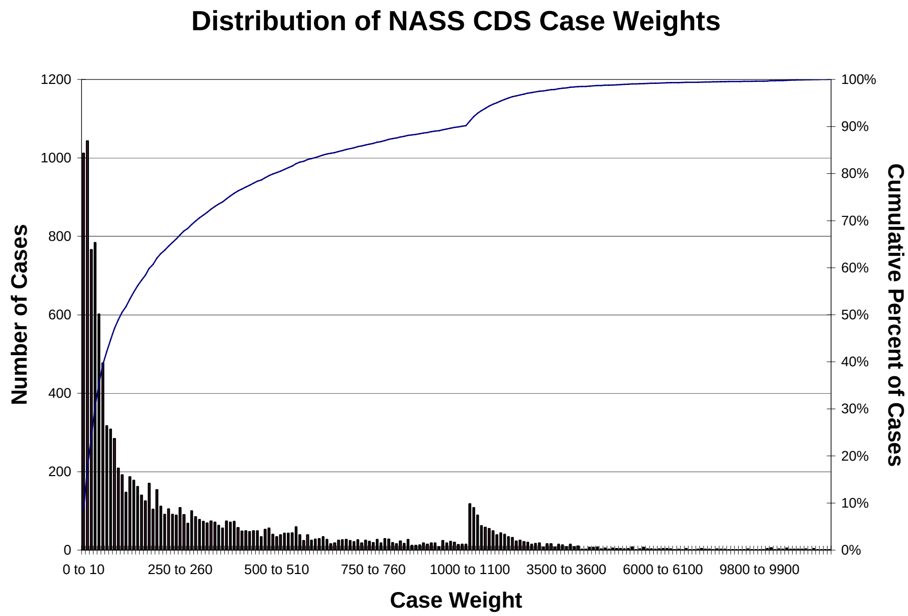

Figure 1. Distribution of sample case weights from NASS CDS 1997-2005 (note: x-axis scale change from 10 unit increment to 100 unit increment after 1,000).