Light-Vehicle Occupancy and Severe Injury by Vehicle and Crash Type

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Received 21 May 2013, Accepted 11 August 2013

Purpose: This study investigated the number of occupants involved and severely injured in light-vehicle crashes by vehicle and crash type.

Methods: 1994–2010 NASS-CDS data were analyzed to estimate the risk of severely injured occupants involved in motor vehicle crashes. Crashes were grouped by front, side, rear, and rollovers. The effect of occupancy and vehicle type was investigated. Light vehicles were less than 4536 kg with model year 1994+. The annual number of Maximum Abbreviated Injury Scale (MAIS) 4+F injuries was estimated and the risk was determined using all occupants with known injury (MAIS 0–6+F).

Results: There were 21,869 MAIS 4+F injuries annually, with 62.7 percent involving passenger cars, 15.9 percent sport utility vehicles (SUVs), 15.3 percent trucks, and 6.1 percent vans. In 36.6 percent of van crashes, MAIS 4+F occurred when there were 4+F occupants and 13.0 percent with 7+F occupants in the vehicle. Overall, 12.8 percent of severely injured were in crashes involving 4+F occupants and 1.4 percent with 7+F occupants. In addition, 30.1 percent of MAIS 4+F occurred in rollovers and only 5.8 percent of crashes were rollovers. Rollovers had the highest injury risks, irrespective of the number of occupants. There was a trend for an increased fraction of injury in frontal crashes and a lower fraction in rollovers. There were high risks in side and rear crashes with 5+F occupants.

Conclusions: On average, there were 1.35 occupants involved in a crash per vehicle. Severely injured occupants were uncommon in 5+F occupancy vehicles. There was a trend for increased injury risks with occupancy. The risk was 1.65 times higher in vehicles with 7+F occupants compared to those with a driver only.

Keywords: occupancy, injury, motor vehicle crashes

Introduction

Various studies have shown substantially higher risks for crash involvement and serious injury with increased vehicle occupancy. Factors include greater risk for distraction, vehicle instability, and other occupant loading.

Stutts et al. (2001) found that distraction from other occupants in the vehicle accounted for more than 10 percent of all types of distraction in tow-away crashes. The authors reported that young drivers were the most likely to be involved in distraction-related crashes. Simons-Morton et al. (2005) found that young driver crash rates were higher in the presence of teen passengers, in particularly for speed-related fatal crashes. Gonzalez et al. (2005) reported that young drivers were involved in more fatal crashes when driving with 2 or more occupants.

The effect of number of occupants on vehicle stability has been studied for rollover crashes. Strashny (2007) reported that higher occupancy was associated with a higher rollover rate. They reported a rollover rate of 54 percent in pickup trucks with 6+F occupants and 17 percent with 1 or 2 occupants. They postulated that higher occupancy raised the vehicle’s center of mass, making it less stable.

Huelke et al. (1987) reviewed tow-away accident data and reported an increase in injury risks due to other occupant loading. Huelke et al. (1976) investigated individual crash cases and reported that 1 out of 9 cases with multiple occupants involved occupant-to-occupant contact. They found that unrestrained occupants can increase the risk of injury severity to other occupants in the vehicle because of additional loading. Additional loading included pushing another occupant into the vehicle interior and/or directly impacting the other occupant. Mackay et al. (1992) showed that seat belt loading contributed to 12 percent of fatal injuries in belted front occupants. They also suggested that unrestrained rear seat occupants contributed to the loading. Ichikawa et al. (2002) showed that the injury risks to belted front seat occupants were 5 times higher with unbelted rear occupants. MacLennan et al. (2004) reported that the injury risk increased by 40 percent for
occupants seated between unbelted occupants and the vehicle impact location. It increased by 90 percent when belted. The fatality risk for belted occupants was 4.8 times higher. Cummings and Rivara (2004) showed that the risk of fatality for belted front seat occupants increased by 20 percent if someone behind them was unrestrained. Similarly, the risk of fatality for rear seat occupants increased by 22 percent if someone in front of them was unrestrained. Mayrose et al. (2005) showed that belted drivers were more than twice as likely to be fatally injured in head-on crashes when the occupants sitting behind them were unbelted. Lack of belt use also affected the rear occupants. The injury risk was 2.71 times higher when the rear occupant was unbelted compared to being belted.

This descriptive study investigates the risk of severe-to-fatal injury (Maximum Abbreviated Injury Scale [MAIS] 4+F) by number of occupants, vehicle, and crash type. The effect of belt usage was not investigated and statistical comparisons were not made.

Methodology

**NASS-CDS Data**

NASS-CDS is a stratified sample of crashes that are prospectively selected for in-depth investigation. Most of the vehicles are towed from the scene because of damage. The data include information based on crash investigation teams, vehicle registration, medical records, police reports, and interviews. The data were extrapolated to national estimates using weighting factors.

This study was carried out to determine the occupancy in light vehicle crashes and to assess the relevance of crash injuries to 1 to 7+ occupants by accident type. Field data from the 1994–2010 (calendar year) NASS-CDS database (http://www.nhtsa.gov) were analyzed. The study included all crashes and all occupants. Only light vehicles (passenger cars, light trucks, sport utility vehicles [SUVs], and vans’ 0 < body type < 50) model years 1994+ were included. The data for calendar years 2009–2010 are representative of model year 2000+.

**Crash Types**

Crash types were defined by general area of damage (GAD) as follows:

- **Front:** Vehicles involved in frontal impacts where the greatest damage was to the front (GAD1 = F). Collisions in which a rollover occurred were excluded from the sample (rollover ≤ 0).
- **Side:** Vehicles involved in side impacts where the greatest damage was to the left or right side (GAD1 = L or R). Collisions in which a rollover occurred were excluded from the sample (rollover ≤ 0).
- **Rear:** Vehicles involved in rear impacts where the greatest damage was to the rear (GAD1 = B). Collisions in which a rollover occurred were excluded from the sample (rollover ≤ 0).

- **Rollover:** Vehicles involved in rollover were those with a rollover > 0.
- **Other:** Vehicles involved in other impacts where the greatest damage was to the top or undercarriage (GAD1 = U or T). Collisions in which a rollover occurred were excluded from the sample (rollover ≤ 0).
- **Unknown:** Vehicles involved in impacts with unknown damage information

**Vehicle Types**

Vehicle types were defined as:

- **Passenger cars:** This included passenger cars (0 < body type < 10) with a gross vehicle weight rating (GVWR) less than 10,000 pounds (<4536 kg):
  - 1: Convertible (excludes sunroof, t-bar)
  - 2: 2-Door sedan, hardtop, coupe
  - 3: 3-Door/2-door hatchback
  - 4: 4-Door sedan, hardtop
  - 5: 5-Door/4-door hatchback
  - 6: Station wagon (excluding van and truck based)
  - 7: Hatchback, number of doors unknown
  - 8: Other automobile type (specify):
  - 9: Unknown automobile type

- **SUV (Sport utility vehicles):** This included passenger cars (9 < body type < 20) with a gross vehicle weight less than 10,000 pounds (<4536 kg):
  - 10: Mini-SUV
  - 11: Compact SUV
  - 12: Mid-size SUV
  - 13: Large SUV

- **Vans (19 < body type < 30).** This included passenger cars (19 < body type < 30) with a gross vehicle weight less than 10,000 pounds (<4536 kg):
  - 20: Minivan
  - 21: Large van
  - 22: Step van or walk-in van (<4536 kg GVWR)
  - 23: Van based motorhome (<4536 kg GVWR)
  - 24: Van based school bus (<4536 kg GVWR)
  - 25: Van based other bus (<4536 kg GVWR)
  - 28: Other van type (Hi-Cube Van, Kary) (specify):
  - 29: Unknown van type

Light trucks: This included trucks with a gross vehicle weight less than 10,000 pounds (<4536 kg). Light trucks were defined using the “body type” variable (29 < body type < 49) and included the following:

- 30: Compact pickup trucks with a width of 70 inches or less (<178 cm)
- 31: Large pickup trucks with a width greater than 70 inches (>178 cm)
- 38: Other pickup trucks including pickups with slide-in camper and convertible pickups
- 39: Unknown pickup style light conventional trucks
- 45: Other light trucks including rescue vehicles, light stakes, dump trucks, tow trucks, truck-based panel
trucks, light truck–based motorhomes, chassis-mounted and other light conventional truck types

- 48: Unknown light truck types

### Injuries Severity

Injury severity of the occupant was assessed using the MAIS and the “TREATMNT” variable. MAIS represents the assessment of life-threatening injuries at the time of first medical evaluation and not long-term consequences. It ranges from MAIS 0 to 9. MAIS 4–6 represents a severe-to-unsurvivable injury. Fatality was also used to determine whether the occupant died of injuries in the accident prior to hospitalization or injury. Fatality was also used to determine whether the occupant died of injuries in the accident prior to hospitalization in the treatment using the TREATMNT variable (TREATMNT = 1). Because the injury severity could be coded despite the fatality, severely injured occupants were defined as those with MAIS 4–6 or fatality. The shorthand notation for this is MAIS 4+F.

MAIS calculations:

- MAIS 0+F = if (0 ≤ MAIS ≤ 6 or (TREATMNT in (1)))
- MAIS 0–3 = if (0 ≤ MAIS ≤ 3 and (TREATMNT not in (1)))
- MAIS 4+F = if (4 ≤ MAIS ≤ 6 or (TREATMNT in (1)))

### Weighted Data

National estimates for the number of occupants and injuries in each category were made using the Ratio Weight (ratwgt) variable in NASS-CDS. All calculations were based on weighted values.

### Risk Analysis

The risk of severely injured occupants was determined by dividing the number of severely injured or killed (MAIS 4+F) by the number of occupants with known injury status MAIS 0–6 or F (MAIS 0+F).

### Results

There were 2,406,964 vehicles involved in tow-away crashes annually in the United States based on the 17 years of NASS-CDS data from 1994 to 2010 (Table A1, see online supplement). In the crashes, there were 3,239,781 occupants, or 1.35 occupants exposed per vehicle, on average. About 60 percent of the exposed occupants were in passenger cars, 18.3 percent were in SUVs, 13.2 percent were in trucks, and 8.5 percent were in vans. There were 21,869 occupants severely injured or killed (MAIS 4+F) annually, with 62.7 percent in passenger car crashes, 15.9 percent in SUVs, 15.3 percent in trucks, and only 6.1 percent in vans. There were 4908 severely injured in crashes involving 3 or more occupants and 298 in crashes with 7+ occupants in the vehicle.

Table 1 shows the risk of severe injury per vehicle type and exposed occupants. Overall, the MAIS 4+F injury risk was 0.92 percent, with the highest risk in trucks (1.27%) and the lowest in vans (0.68%). The injury risks were high in driver-only and driver plus passenger truck crashes, at 1.29 and 1.44 percent, respectively. The relative risk of severe injury is determined with respect to the overall risk of injury in all vehicles. The highest relative risks were with 7+ occupants in any type of vehicle at 1.77 with a relative risk of 2.41 in SUVs. The relative risk of severe injury is determined with respect to the overall risk of injury in all vehicles.

### Table 1. Risks of severe injury by number of occupants and vehicle type based on 17 years of 1994–2010 NASS-CDS (the grey cells indicate risks based on sample size ≤ 10 when unweighted)

| Vehicle type | 1 | 2 | 3 | 4 | 5 | 6 | 7+ | All |
|--------------|---|---|---|---|---|---|----|-----|
| Risk MAIS 4+F/vehicles | 0.69% | 1.38% | 1.49% | 2.48% | 5.34% | 6.80% | 10.34% | 0.96% |
| Cars | 0.54% | 0.98% | 1.42% | 1.71% | 2.32% | 7.37% | 10.97% | 0.79% |
| SUV | 0.43% | 0.69% | 0.89% | 1.44% | 2.02% | 3.67% | 8.03% | 0.76% |
| Van | 0.71% | 1.59% | 1.38% | 2.58% | 3.07% | 13.80% | 3.83% | 0.95% |
| Truck | 0.65% | 1.27% | 1.41% | 2.20% | 3.59% | 5.45% | 8.36% | 0.91% |

### Fig. 1. Fraction of MAIS 4+F injury by vehicle type and year (NASS-CDS 1994–2010).
and the lowest was in vans (38.8%). Overall, 12.8 percent of severely injured were in crashes involving 4+ occupants and 1.36 percent with 7+ occupants. Van crashes often involved 2 or more occupants. In 38.1 percent of van crashes, there were 3 or more occupants and 4.4 percent involved 7+ occupants in the vehicle. For those severely injured, half (50.5%) of the crashes involved only a driver and 27.0 percent involved a driver and passenger. The highest fraction of driver-only crashes was in trucks (62.6%) and the lowest was in vans (38.8%). In addition, 46.3 percent of the severely injured occupants were in vans with 3 or more passengers. There were 7+ occupants in 13.0 percent of crashes with MAIS 4+

Figure 2 shows the trend over the 17 years by crash type. The fraction of severe injury has increased in frontal crashes with a decline in rollovers. The fraction in side and rear impacts has remained relatively constant.

The annual occupancy of vehicles by the type of crash based on 17 years of NASS-CDS is provided in Table A3 (see online supplement). The “all” crash type includes other and unknown, which is the difference between 100 percent and the sum of the data by front, side, rear, and rollover crashes. The largest fraction of occupant exposure was in frontal crashes (37.4%), with a smaller fraction in side (17.1%), rear (8.9%), and rollover (6.5%) crashes. The type of crash was important to the risk of severe injury. In terms of MAIS 4+, 30.1 percent occurred in rollovers, 28.6 percent in side impacts, and 25.7 percent in frontal crashes. About half of the severely injured occupants included drivers without passengers in the vehicle.

The percentage of occupancy and injury by crash type is provided in Table A4 (see online supplement): 37.4 percent of occupants were involved in frontal crashes and 25.7 percent were severely injured. The largest fraction of severely injured with more than 3 occupants in the vehicle involved rollover and frontal crashes. Annually, there were 1.4 percent of occupants (298) with severe injury involving 7+ occupants in the vehicle and 1.4 percent (298) with 6 occupants in the vehicle.

Table 2 shows the risk for severe injury based on exposed occupants and vehicles involved. The highest risks were in rollovers (3.47%) and side impacts (1.37%). Rollovers posed a high risk for drivers alone as well as rollovers involving one or more passengers.

Figure 3 plots the relative risk of MAIS 4+F compared to the risk in all crashes. The highest relative risk was with 5 or more occupants in rollover crashes. The lowest overall relative risk was in rear impacts (0.30). The relative risk was low except in rear crashes with 5 or 6 occupants.

The effect of crash type and belt use on occupancy was assessed by reviewing individual NASS-CDS cases. Appendix A (see online supplement) lists the individual NASS-CDS cases involving severely injured occupants in modern vehicles (MY 2002+) with 5+ occupancy. There were 60 cases reviewed and tabulated by vehicle type, belt use, crash type, and occupancy. There were 26 cases in passenger cars, 8 in vans, 22 in SUVs, and 4 cases in a pickup. Most severely injured occupants were unbelted and involved in a rollover (56 out of 109 occupants).

![Figure 2](image-url) Fraction of MAIS 4+F injury by crash type and year (NASS-CDS 1994–2010).

![Figure 3](image-url) Relative risk of MAIS 4+F injury by number of occupants and crash type compared to the overall risk of MAIS 4+F (NASS-CDS 1994–2010).

| Crash type | 1 | 2 | 3 | 4 | 5 | 6 | 7+ | All |
|------------|---|---|---|---|---|---|----|-----|
| Risk MAIS 4+F/veh | | | | | | | | |
| Rear | 0.10% | 0.39% | 0.27% | 0.06% | 1.42% | 4.42% | 0.49% | 0.19% |
| Side | 1.15% | 2.01% | 3.31% | 3.97% | 4.87% | 2.43% | 15.93% | 1.59% |
| Front | 0.52% | 0.85% | 0.97% | 1.57% | 1.22% | 1.41% | 0.88% | 0.64% |
| Rollover | 3.44% | 6.31% | 6.54% | 7.49% | 24.22% | 21.46% | 36.67% | 4.47% |
| All | 0.65% | 1.27% | 1.41% | 2.20% | 3.59% | 5.45% | 8.36% | 0.91% |
| Relative risk MAIS 4+F | | | | | | | | |
| Rear | 0.26% | 0.43% | 0.14% | 0.02% | 1.28% | 2.96% | 0.08% | 0.27% |
| Side | 1.52% | 1.23% | 1.38% | 1.17% | 1.09% | 0.48% | 3.26% | 1.37% |
| Front | 0.65% | 0.51% | 0.40% | 0.46% | 0.30% | 0.26% | 0.18% | 0.55% |
| Rollover | 3.91% | 3.42% | 2.41% | 2.02% | 5.70% | 3.91% | 5.22% | 3.47% |
| All | 0.99% | 0.92% | 0.69% | 0.77% | 1.04% | 1.34% | 1.64% | 0.92% |

Table 2. Risks of severe injury by number of occupants and vehicle type based on 17 years of 1994–2010 NASS-CDS (the grey cells indicate risks based on sample size ≤ 10 when unweighted).
Though occupant–occupant contact was noted in 5 of the cases, none of the severe injuries were attributed to occupant contact as the injury source.

There was one case involving 5 severely injured occupants with 3 rear occupants younger than 14 years in a light truck (NASS-CDS 2009-73-85B). The case was unusual and involved a 2004 Dodge Ram sandwiched and overridden between 2 heavy trucks following rear and then frontal impacts. The 5 occupants died as a result of the heavy trucks overriding the Dodge Ram’s occupant compartment and a fire. The crash was very severe and involved extensive damage to the occupant compartment (Figure A1, see online supplement).

Discussion

Occupancy

The results of the study showed that they were 1.35 exposed occupants per crash vehicle on average. Drivers only accounted for more than 52 percent of exposed occupants and 50 percent of severely injured occupants in all crashes. Six or more occupants were uncommon and accounted for 2.8 percent of severely injured occupants in all crashes. The data showed a trend for an increasing risk of severely injured occupants as the occupancy in the vehicle increased, in particular in rollover crashes. The increase in injury risk may be from occupant-to-occupant interactions. The effect of occupant interaction was not assessed in this study. Because most vehicles in the study were passenger cars, the vehicles typically did not offer a restraint system for 6 and more occupants. The results suggest that lack of belt use and seat sharing are factors in crashes involving 6 or more occupants.

Vehicles

Six or more occupants were least common in passenger cars and in trucks and accounted for only 0.81 and 1.13 percent of severely injured occupants, respectively. The incidence of severe injury was very low for crashes with more than 2 occupants in a truck.

Crash Types

The type of crash was important to the risk of severe injury. Most severely injured occupants were involved in rollover, side impact, and frontal crashes. Most were with drivers alone in the vehicle. The overall relative risk of severe injury was higher with 5+ occupants than with drivers alone. It was highest in rear impacts where the risk was 3.26 times higher with 5+ occupants than with drivers alone. The data showed that few exposed occupants in rear crashes experience severe-to-fatal injuries. Severe injury in rear impacts accounted for 1.9 percent of all MAIS 4+F occupants and is often associated with intrusion (Viano and Parenteau 2012). In this study, there were few cases involving 6+ occupants in a rear crash. For rear impacts, there were no cases of severely injured occupants with 4, 6, and 7+ occupants in SUVs and no cases with 3, 4, or 6+ occupants in light trucks.

In conclusion, the occupancy analysis of 1994–2010 NASS-CDS with model year 1994+ light vehicles showed that (1) most severely injured occupants were in passenger crashes, followed by SUV, truck, and van crashes; (2) more than 12.8 percent of severely injured occupants were in vehicles with 4+ occupancy; (3) more than 30 percent of severely injured were in rollovers; (4) occupants involved in rollovers have the highest risk of severe injury, irrespective of occupancy; and (5) for vehicles with 5+ occupancy the risk of severe injury increased in side, rear, and rollover crashes. These descriptive findings suggest that the effect of occupancy may need to be considered when assessing occupant protection.

Supplemental Material

Supplemental data for this article can be accessed on the publisher’s website.

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