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# Epidemiology of injuries sustained by rear-seat passengers in frontal motor vehicle crashes

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ABSTRACT

*Objective:* Advanced occupant protection systems in motor-vehicles (e.g., seat belts and airbags), while widely adopted for front-seat passengers, are either absent or offer disproportionally lower safety to rear-seat passengers in similar crashes. Optimization of advanced restraint systems for the rear-seat environment will require a detailed understanding of epidemiology and associated risk factors for injuries sustained by rear-seat passengers. Thus, the objective of the study is to use national level motor-vehicle travel and crash data to quantify rear-seat travel exposure, and determine the descriptive characteristics and the injury outcomes for rear-seat passengers involved in frontal collisions.

*Methods:* While U.S. travel data from the 2009 National Household Travel Survey was used to determine rear-seat travel estimates, crash data from 2001 to 2010 National Automotive Sampling System Crash Worthiness Data System was used to enroll rear-seat passengers injured in a frontal crash. The descriptive epidemiology of rear-seat crash victims was separately done for the three age-groups: children (8–15 years old), adults (16–59 years old), and senior adults (60+).

*Results:* The study indicated that senior adults in rear-seats were associated with a significantly higher rate of sustaining fatal (6%) and severe injuries (16% for MAIS 3+ injuries) in comparison to the younger cohorts. The distribution of severe injuries further indicated that the thorax was the most frequently injured region across all age groups irrespective of the belt-use status.

*Conclusions:* Findings of the study conclude that while rear-seat travel in the U.S. is still very low and improving belt usage is a primary concern among rear-seat passengers; however, the epidemiology supports the need for adapting rear-seat restraint performance for effective protection for all groups of rear-seat passengers.



## 1. Introduction

As traffic data suggests, rear-seat travel among motor vehicle passengers in the U.S. continues to be relatively low,

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compared with Europe or other developed countries: less than 13% of total annual person-trips in a motor-vehicle involve a rear-seat passenger (Trowbridge and Kent, 2009), and rear seat occupants are present in approximately 13–17% of all tow-away collisions (Parenteau and Viano, 2003). As a result of low-exposure, rear-seat passengers are responsible for less than 10% of overall fatalities and injured victims (USDOT, 2010). Consequently, this cohort of vehicle passengers has traditionally received less attention than front seat occupants in terms of targeted injury countermeasures and understanding of the relative risk factors applicable to the rear-seat environment (Trowbridge and Kent, 2009).

Various studies indicate that for children, a car's rear seat is safer than the front seat (Smith and Cummings, 2004; Kuppa et al., 2005). Moreover, recent research indicate that the fatality and injury-reducing efficacy of the rear seat highly depends on the passenger's age since the rear seat has been reported to be less safe than the front seat for older persons. Kuppa et al. (2005) reported a greater fatality risk for rear seat passengers than front seat passengers over the age of 50. Similarly, Bilston et al. (2010) found that the rear seat carried a higher risk of AIS 3+ injuries compared to the front seat for restrained passengers over the age of 50.

In newer automobile models – from 1997 until 2007 – improvements were made resulting in an even lower injury risk for all restrained passengers in the front seat over the age of 16 compared to rear seat passengers. Similar tendencies have been mentioned by other researchers (Esfahani and Digges, 2009; Kent et al., 2007). Nevertheless, Sahraei et al. (2010) observed that in models from 1990 to 1999, the rear seat was safer than the front seat for all fastened passengers over the age of 25. However, this trend changed for models from 2000 until 2009, where the risk of fatality for all fastened passengers over the age of 25 was greater for rear seat than front seat passengers. These field observations are consistent with several recent frontal crash test studies where greater thoracic injury risks were observed with adult dummies seated in the rear seat compared to dummies seated in the front (Mizuno et al., 2011; Tylko and Dalmotas, 2005; Sahraei et al., 2010).

The growing disparity between rear seat and front seat safety for adults suggests a reexamination of the rear seat environment to identify potential areas for improvement. While for the front-seat occupants, upper-body (head, neck and chest) and knee excursion in the event of a frontal collision can be effectively controlled for safety using supplementary restraint devices like the air bags, such provisions are almost unavailable in the rear-seat. Even widely adopted advanced belt systems which control the belt payout in the event of a crash (e.g., pre-tensioners and force-limiting retractors) are not standard features in the rear-seats (Kent et al., 2007). As occupant age increases, the distribution of AIS2+ and 3+ injuries in restrained rear seat occupants tends to shift from predominantly head injuries (in young occupants) to thoracic injuries resulting from interaction with the seatbelt (in older occupants; Kuppa et al., 2005). Recent computational (Kent et al., 2007) and experimental (Forman et al., 2008, 2009) studies have indicated that thoracic injury risk in adult rear seat occupants may be reduced through the use of pre-tensioning, force-limiting seatbelt prototypes designed for use in the rear seat environment.

The studies above indicate a disparity between front seat and rear seat safety, and a “proof of concept” regarding the incorporation of advanced and customized belt restraint technologies into the rear seat environment. To refine and implement these countermeasures, it is necessary to understand the epidemiology, demographics, and causal risk factors affecting the severity of injury outcome to identify targets for intervention. With belt usage rates among U.S. rear-seat passengers steadily improving (currently at 76%, IIHS, 2012), additional risk factors such as passenger characteristics (e.g., body type, sex, age), seating posture, use of special restraints (e.g., child seats), vehicle characteristics (e.g., interaction with front-seat back), and crash attributes (e.g., crash pulse, vehicle deformation) must be analyzed. With the goal of describing the characteristics of passenger, vehicle, crash and injury severities applicable to rear-seat passengers and subsequently identifying the associated risk factors, the objectives of this research are outlined as:

1. Compare overall vehicle-travel exposure and crash characteristics among rear-seat passengers involved in moderate to severe frontal crashes at all injury severities.
2. Perform stratified descriptive analyses applicable to three distinct age groups among rear-seat passengers (children, 8–15 years old; adults, 16–59 years old; and senior adults 60 years and older). Further, investigate the characteristics of the three age groups as a function of the injury severity rates sustained by the victim in frontal crashes.
3. Evaluate the distribution of moderate and serious injuries to the different body regions for all three age groups of rear-seat passengers.

## 2. Data and methods

### 2.1. Dataset

Sampled cases of rear-seat passengers involved in a motor vehicle frontal crash in the US were obtained from the National Highway Traffic Safety Administration's (NHTSA) 2001–2010 National Automotive Sampling System Crashworthiness Data System (NASS CDS). NASS CDS provides nationally representative data regarding motor vehicle crashes based on a weighted annual sample of approximately 5000 police reported tow-away crashes (NHTSA, 2008). The dataset includes detailed information about the occupant, vehicle, crash kinematics, restraint usage and injury outcome including incidence of fatality and injury severity codes for each individual injury based on the 1998 Abbreviated Injury Scale (AIS) (AAAM, 1990). Sampled cases were screened from the NASS-CDS 2001 to 2010 database where the case occupant was seated in