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# Increased risk of driver fatality due to unrestrained rear-seat passengers in severe frontal crashes

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ABSTRACT

While belt usage among rear-seat passengers is disproportionately lower than their front-seat counterpart, this may have serious consequences in the event of a crash not only for the unbelted rear-seat passenger but also for the front-seat passengers as well. To quantify that effect, the objective of the study is to evaluate the increased likelihood of driver fatality in the presence of unrestrained rear-seat passengers in a severe frontal collision. U.S.-based census data from 2001 to 2009 fatal motor vehicle crashes was used to enroll frontal crashes which involved 1998 or later year vehicle models with belted drivers and at least one adult passenger in the rear left seat behind the driver. Results using multivariate logistic regression analysis indicated that the odds of a belt restrained driver sustaining a fatal injury was 137% (95% CI = 95%, 189%) higher when the passenger behind the driver was unbelted in comparison to a belted case while the effects of driver age, sex, speed limit, vehicle body type, airbag deployment and driver ejection were controlled in the model. The likelihood of driver fatality due to an unrestrained rear left passenger increased further (119–197%) in the presence of additional unrestrained rear seat passengers in the rear middle or right seats. The results from the study highlight the fact that future advances to front row passive safety systems (e.g. multi-stage airbag deployment) must be adapted to take into account the effect of unrestrained rear-seat passengers.



## 1. Introduction

While rear-seat occupancy in motor vehicle travel has been disproportionately low (less than 13% of annual person-trips traveled in a vehicle in the US (Trowbridge and Kent, 2009)), nevertheless, recent research has emphasized and brought to attention the crash protection and safety measures focused on rear-seat passengers (Forman et al., 2009; Mizuno et al., 2011). In that context, the three-point seat belt is the single most critical safety device available to rear seat passengers in the event of moderate to severe crashes. The effectiveness of the seat belt in reducing fatal and severe injuries among rear-seat passengers is estimated between 32% and 45% based on traffic crash data from countries like the U.S., U.K. and Japan (Cuerden et al., 1997; Morgan, 1999; Shimamura et al., 2004). Interestingly, although the contemporary rear-seat environment lacks advanced restraint technologies such as the airbags, pre-tensioners and force-limiting retractors, the belt effectiveness as determined above is fairly comparable to the front-seat belt effectiveness estimates: 47–67% (USDOT, 1999). While there is potential to offer comparable restrained safety protection to rear-seat passengers, it is worthy of note that belt usage rates among rear-seat passengers is distinctly lower than that of front row occupants. The differences in the behavior between front and rear seat passengers may be attributable to local traffic laws and enforcement criteria in addition to the lack of awareness regarding rear seat belt effectiveness. Among the member countries of the European Union, where seat belt law applies to all seating positions, the average rear-seat belt usage was 53% compared to 85% in the front row. In Japan where it was not mandatory for rear-seat passengers to wear seat belts till 2008, a mere 8% belt usage rate was reported for rear seat passengers (while front-seat usage rate was 92%) in 2005 (JAF, 2006). Traffic data from the US, where 32 out of 50 states have primary enforcement laws for belt use of which only 17 states require rear-seat passengers to be belted, showed that the rear-seat belt usage was 76% against a rate of 85% in the front-seats [IIHS, 2012] (Fig. 1). Guided by the above data, improving the rear-seat belt usage rate appears to be a significant step toward improving the overall protection of vehicle passengers in the developed countries.

The obvious motivation for rear-seat belt use is, as expected, focused on the personal safety of the passenger, however, recent studies have further emphasized on the increased risk of severe injury to the front-seat passengers as well caused by unrestrained rear-seat passengers. Ichikawa et al. (2002) demonstrated that

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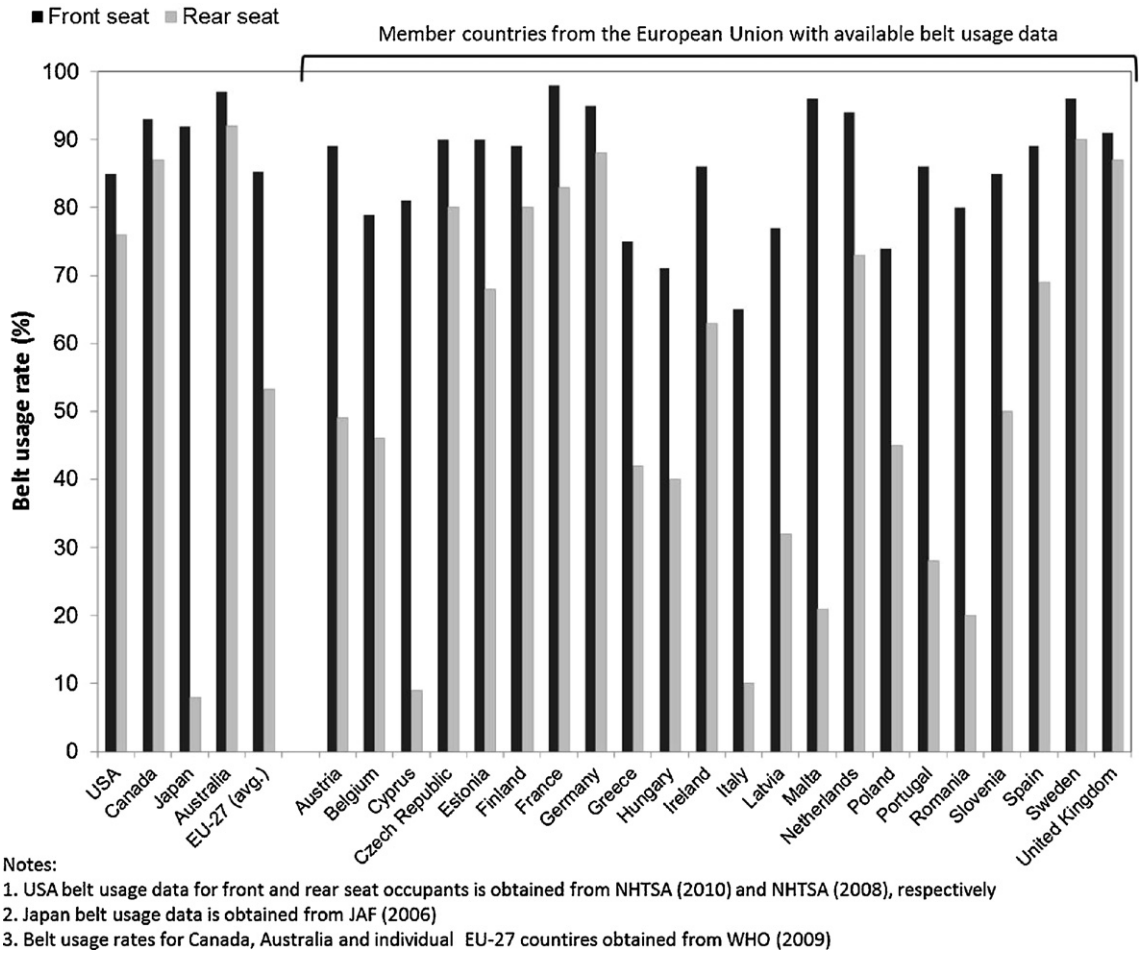


**Fig. 1.** Belt usage rates among front and rear seat passengers in several developed nations with available data.

based on Japanese police data (1995–1999) unrestrained rear-seat passengers increase the risk of fatality for the belted front-seat passengers by five-fold compared to the restrained rear-seat passengers. Similar studies performed by Broughton (2004) and Mayrose et al. (2005) using traffic crash data from Great Britain (1995–1999) and US (1995–2001), respectively, estimated that the risk of fatality to belted driver increased by 75–127% due to the presence of unrestrained rear-seat passengers. While the threat of severe injuries to the driver in the presence of unrestrained rear-seat passengers is well established, opportunities to minimize the risk of injury caused by unrestrained rear-seat passengers by adapting frontal restraint devices is less investigated. For instance, while frontal airbags offer supplemental restraint protection to the belted front-seat occupant, the effect of frontal airbag loading in the presence of unrestrained rear-seat passengers is relatively unclear.

The overall goal of this study was to investigate further into the specific factors responsible for increasing the likelihood of driver fatality in the presence of rear-seat unrestrained passengers. The specific factors analyzed include crash severity, vehicle body type, deployment of frontal airbags, age, sex and anthropometry of the driver and the rear-seat passengers. Further, the effect on driver risk due to the presence of additional rear-seat passengers and their seating location was also studied. The objectives of the study can be summarized as follows:

1. Estimate the risk of a belted driver in a severe frontal crash in the presence of a unrestrained rear-seat passenger seated behind the driver while controlling for confounding factors such as occupant characteristics (e.g. age, sex), vehicle properties (e.g. passenger car vs. SUV, occupancy), crash severity (e.g. delta-v), and restraint characteristics (e.g. airbag deployment).
2. Evaluate the sensitivity of river fatality risk due to unrestrained rear-seat passenger to the presence of additional rear-seat passengers.
3. Determine the effect of airbag deployment in altering the risk of driver fatality due to loading from the unrestrained rear-seat passenger.

## 2. Data and methods

### 2.1. Dataset

U.S. census data on motor vehicle occupants involved in fatal frontal crashes were obtained from the National Highway Traffic Safety Administration's (NHTSA) 2001–2009 Fatality and Analysis Reporting System (FARS) database (USDOT, 2009). FARS database includes cases if at least one fatality occurs within 30 days as a result of a motor vehicle crash on a public roadway. The information in the database is separately tabulated into individual files relating to the crash event, each vehicle involved, and the occupants involved in the crash (including survivors in addition to the fatal victims). For the purposes of this study, a vehicle-level flat database file (each record corresponds to a case vehicle) was created by appropriately merging the crash, vehicle and the transposed occupant level database files for the years 2001–2009. The selection criterion included frontal crashes as identified by the post-crash vehicle damage information. Crashes involving instances of fire and water