

THE EFFECT OF REAR ROW SEATING POSITION ON THE RISK OF INJURY TO BELTED CHILDREN IN SIDE IMPACTS IN PASSENGER CARS

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ABSTRACT

Several studies have characterized the benefits of rear seating on injury outcome in children. While most studies have focused on frontal impacts, our previous work demonstrated that these benefits apply to side impacts as well. In this earlier study, however, results indicated that among those rear seated, the side impact injury risk did not vary by seat position, i.e. those on the struck side had similar injury risk to those on the non-struck side. In that study, the center rear occupants were grouped with the non-struck side occupants, and compared with the struck side. The present analyses built upon that previous work and sought to further explore and explain those results by studying the effect of the three distinct rear seat positions (struck-side, center, non-struck-side) in side impacts in a sample limited to seat belt restrained children. Data were obtained from a probability sample of 592 children, representing 6370 children, 4-15 years of age who were enrolled in an on-going crash surveillance system which links insurance claims data to validated telephone survey and crash investigation data. The sample was limited to children restrained by seat belts involved in side impact crashes and seated in the rear seating rows. The risk of injury was calculated for each seating position - struck, center or non-struck side of the crash. Injuries were defined as scalp and facial lacerations, facial bone fractures, and all other AIS 2 and greater injuries. Risk of injury was lower to children seated on the non-struck-side (1.4%) as compared to those on the struck-side (2.6%) (OR:0.55 95% CI: 0.33 0.93). Of interest, the injury risk to children seated on the struck side (2.6%) was roughly equal to that of those in the center rear position (3.0 %) (OR: 1.15, 95% CI: 0.50, 2.66). Accounting for differences in child age did not change the aforementioned results. These results highlight the elevated injury risk for children in center rear seating position in side impacts, and suggest that the injury mitigation approach is unique to that of the other rear seating positions.

INTRODUCTION

Many researchers have examined the role of seat position on injury outcome for children in motor vehicle crashes. In a study of children in the Fatal Analysis Reporting System (FARS), Braver et al [1] concluded that rear seating offered protective benefit over front seats, and children were 10 to 20 percent less likely to sustain fatal injuries in the rear center than in rear outboard seat positions. Berg et al [2], in a study of a single state database of crashes, found that children seated in the front seat positions were 1.7 times more likely to suffer a serious injury or fatality than those in the rear seat, and also found that the mean inpatient hospital charges were greater for front seat child passengers (\$248.18) than children in the rear (\$194.74). More recent studies have examined the role of seat position on injury outcome in side impacts. Durbin et al. [3], in a study of a large child specific surveillance system, examined side impact crashes involving children and found a protective benefit of rear seat struck-side seating as compared to front seat struck-side seating. Others have chosen to study the effect on struck side seating versus non- struck side. In a study focused on adult occupants in the front outboard seat positions, Farmer et al. [4] examined the National Automotive Sampling System: Crashworthiness Data System (NASS/CDS) database and found that, among non-ejected occupants of vehicles which did not roll over, the likelihood of serious injury was only 3% for those on the near side and 2% for those on the far side. Howard et al [5] conducted a study of children aged 0 to 12 years in all seating rows involved in side impacts. Through analysis of the Fatality Analysis Reporting System (FARS), Howard found that for restrained children, the children seated on the near side were 2.5 times as likely to receive a fatal injury than children seated in the center, and also found through analysis of NASS that among children known to be restrained, severe injury (ISS \geq 16) was much more common for those seated in the near-side seat (7 per 1,000) than for those in the center (2 per 1,000). Neither of these analyses accounted for

restraint type. Using the child specific surveillance system as Durbin et al above, but with a side impact population limited to children in forward facing child restraint systems, Arbogast et al⁶ found that the injury risk was significantly higher for struck-side occupants in the rear row (8.9 injured children per 1000 crashes) as compared to non-struck-side and center seat occupants combined (2.1 injured children per 1000 crashes).

Most of the above analyses either include children restrained in all types of restraints or are limited to children restrained in add-on restraint systems (i.e. child restraints and booster seats). Vehicle and restraint design techniques to mitigate injuries for children in side impact crashes in these varying restraint systems are likely different. In particular, protection of older children who have outgrown, and therefore do not use, add-on child restraints cannot rely on the presence of an add-on restraint system to modulate impact forces. Understanding the injury risk for these seat belt restrained children is a critical first step in injury mitigation efforts. For this reason, the objective of this paper is to examine the injury risk by rear row seating position for children restrained by seat belts alone in side impact crashes. By defining the unique injury risks for the three-rear row seating positions, vehicle design improvements can be facilitated. We have restricted the analysis to passenger cars only, since there are significant structural differences (sill height, seat location, door design) between passenger cars and other vehicles that commonly carry children, such as sport utility vehicles and minivans.

METHODS

Data for the current study were drawn from the Partners for Child Passenger Safety (PCPS) program, collected from December 1, 1998 to November 30, 2002. A description of the study methods has been published previously [7]. PCPS consists of a large scale, child-specific crash surveillance system: insurance claims from State Farm Insurance Co. (Bloomington, IL) function as the source of subjects, with telephone survey and onsite crash investigations serving as the primary sources of data. Vehicles qualifying for inclusion were State FarmTM-insured, model year 1990 or newer, and involved in a crash with at least one child occupant ≤ 15 years of age. Qualifying crashes were limited to those that occurred in fifteen states and the District of Columbia, representing three large regions of the United States (East: NY, NJ, PA, DE, MD, VA, WV, NC, DC; Midwest: OH, MI, IN, IL; West: CA, NV, AZ). After policyholders consented to participate in

the study, limited data were transferred electronically to researchers at The Children's Hospital of Philadelphia and University of Pennsylvania. Data in this initial transfer included contact information for the insured, the ages and genders of all child occupants, and a coded variable describing the level of medical treatment received by all child occupants (no treatment, physician's office or emergency department only, admitted to the hospital, or death). A stratified cluster sample was designed in order to select vehicles (the unit of sampling) for the conduct of a telephone survey with the driver. In the first stage of sampling, vehicles were stratified on the basis of whether they were towed from the scene or not, and a probability sample of both towed and non-towed vehicles was selected at random, with a higher probability of selection for towed vehicles. In the second stage of sampling, vehicles were stratified on the basis of the level of medical treatment received by child occupant(s). A probability sample from each tow status/ medical treatment stratum was selected at random with a higher probability of selection for vehicles in which a child occupant died, was admitted to the hospital, or evaluated in a physician's office or emergency department. In this way, the majority of injured children would be selected while maintaining sample representative of the overall population. If a vehicle was sampled, the "cluster" of all child occupants in that vehicle were included in the survey. Drivers of sampled vehicles were contacted by phone and screened via an abbreviated survey to verify the presence of at least one child occupant with an injury. Surveys were conducted only in English. All vehicles with at least one child who screened positive for injury and a 10% random sample of vehicles in which all child occupants screened negative for injury were selected for a full interview. A 2.5% sample of children untreated as of the crash report was included as well. The full interview involved a 30-minute telephone survey with the driver of the vehicle and parent(s) of the involved children. Only adult drivers and parents were interviewed. The median length of time between the date of the crash and the completion of the interview was six days. The eligible study population consisted of all 430,308 children riding in 288,187 State-FarmTM-insured vehicles newer than 1990 reporting a crash claim between December 1, 1998 and November 30, 2002.

Claim representatives correctly identified 95% of eligible vehicles, and 73% of policyholders consented for participation in this study. Of these, 18% were sampled for interview and an estimated 81% of these were successfully interviewed. Comparing the included sample with known population values from all eligible State Farm claims, little difference is

noted: in both the sample and the population 42%, 34%, and 24% of the vehicles were located in the East, Midwest, and West regions respectively; 52% of the sampled vehicles were model 1996 or newer, compared with 51% of the population; 55% were passenger cars, 20% passenger vans, 16% SUVs, and 7% pickup trucks, compared with 56%, 19%, 16% and 7% in the population; and 33% were towed away, compared with 32% of the population. The mean age of the child in the sample was 7.0 years, compared with 7.2 years in the population. For a subset of cases in which child occupants were admitted to the hospital or killed, in-depth crash investigations were performed. To date, over 600 cases have had field investigations completed. Cases were screened via telephone to confirm the details of the crash. Contact information from selected cases was then forwarded to a crash investigation firm (Dynamic Science, Incorporated, Annapolis, MD), and a full-scale on-site crash investigation was conducted using custom child-specific data collection forms. Crash investigation teams were dispatched to the crash scenes within 24 hours of notification to measure and document the crash environment, damage to the vehicles involved, and occupant contact points according to a standardized protocol. The on-scene investigations were supplemented by information from witnesses, crash victims, physicians, hospital medical records, police reports, and emergency medical service personnel. From this information, reports were generated that included estimates of the vehicle dynamics and occupant kinematics during the crash and detailed descriptions of the injuries sustained in the crash by body region, type of injury, and severity of injury. Delta v , (the instantaneous change in velocity) an accepted measure of crash severity, was calculated using WinSmash and crush measurements of the vehicles involved. For the purposes of this analysis, these cases were used to examine the validity of information obtained from the telephone survey.

Variable definitions

Seating location and restraint use of each child were determined from a series of questions in the telephone survey. Among 170 children for whom paired information on seating position (front versus rear) was available from both the telephone survey and crash investigations, agreement was 99% between the driver report and the crash investigator ($\kappa=0.99$, $p<0.0001$). Among 164 children for whom paired information on restraint use was available from both the telephone survey and crash investigations, agreement was 89% between the driver report and the crash investigator ($\kappa=0.74$,

$p<0.0001$). Direction of first impact was derived from a series of questions regarding the vehicle parts that were involved in the first collision. Survey questions regarding injuries to children were designed to provide responses that were classified by body region and severity based on the Abbreviated Injury Scale (AIS) score [8]. The ability of parents to accurately distinguish AIS 2+ injuries from those less severe has been previously validated for all body regions of injury [9]. Separate verbal consent was obtained from eligible participants for the transfer of claim information from State Farm to CHOP/Penn, for the conduct of the telephone survey, and for the conduct of the crash investigation. The study protocol was reviewed and approved by the Institutional Review Boards of both The Children's Hospital of Philadelphia and The University of Pennsylvania School of Medicine.

Data analysis and study sample

Data were obtained from a probability sample of 592 children, representing 6370 children, 4-15 years of age. The sample was limited to children restrained by seat belts involved in side impact crashes and seated in the rear seating rows of passenger cars. The risk of injury was calculated for each seating position - struck, center or non-struck side of the crash. Injuries were defined as scalp and facial lacerations, facial bone fractures, and all other AIS 2 and greater injuries.

The robust chi-square tests of association were performed. Odds ratios (OR) were obtained from logistic regressions to approximate the relative risk of serious injury. Results of logistic regression modeling are expressed as unadjusted and adjusted OR with corresponding 95% confidence intervals (CI). Because sampling was based on the likelihood of an injury, subjects least likely to be injured were underrepresented in the study sample in a manner potentially associated with the predictors of interest. To account for this potential bias, data were analyzed by using SAS-callable SUDAAN: Software for the Statistical Analysis of Correlated Data, Version 8.0 (Research Triangle Institute, Research Triangle Park, NC, 2001) to account for sampling weights, sampling strata, and sampling units.

RESULTS

Table 1 shows both distributions of child age group by seat position and seat position by child age group for the study sample. Those 4 to 8 years of age were the most common age group in the study sample. 57.3% of the children in the rear outboard struck-side

Table 1.
Distribution of child age by seat position for the study sample and crash side proximity.

	Weighted row % Weighted column % (Unweighted n)			
	4-8 years	9-12 years	13-15 years	Total (seating position)
Rear Outboard Struck-side	57.3 43.7 (112)	29.5 35.4 (90)	13.2 50.1 (45)	100.0 (247)
Rear Outboard Non-struck- side	46.5 34.2 (107)	44.1 51.6 (94)	9.4 34.9 (41)	100.0 (242)
Rear Center	67.1 22.7 (64)	24.1 13.0 (27)	8.8 15.0 (12)	100.0 (103)
Total (age group)	100.0 (283)	100.0 (211)	100.0 (98)	100.0 (592)

position, 46.5% of the children in the rear out-board non-struck side, and 67.1% of the children in the rear center were in the 4 to 8 year old age group (Chi-square test: $p=0.14$). Children seated in the rear center position tended to be younger; 22.7% of 4-8 year olds were seated in the rear center, as opposed to 13.0 % of 9-12 and 15.0% of 13-15 year olds.

Table 2 displays both distributions of seat belt type by seat position/crash side proximity, and seat position/crash side proximity by seat belt type.

Table 2.
Distribution of seat belt type by seat position and crash side proximity.

	Weighted row % Weighted column % (Unweighted n)				
	Lap only	Lap/ Shoulder	Shoulder	Unknown	Total (seating position)
Rear Outboard Struck- side	8.4 17.1 (29)	87.1 47.4 (208)	4.3 68.2 (5)	0.2 7.2 (5)	100.0 (247)
Rear Outboard Non- struck- side	4.4 8.7 (24)	91.9 48.8 (208)	2.0 31.9 (7)	1.6 50.4 (3)	100.0 (242)
Rear Center	81.4 74.3 (85)	15.6 3.8 (15)	0.0 0.0 (0)	3.0 42.4 (3)	100.0 (103)
Total (belt type)	100.0 (138)	100.0 (431)	100.0 (12)	100.0 (11)	100.0 (592)

Children in the rear outboard seating positions were most frequently restrained in lap / shoulder belts (87.1 % to 91.9%, depending on seat position), while children in the rear center position were more frequently in lap only belts (81.4%) (Chi-square test: $p<0.001$).

Injury risk varied by seat position. For all ages combined, those seated in the rear center had similar injury risk (3%) to those in the rear outboard struck-side (2.6%) (Figure 1). These two seating positions were at elevated risk compared to the rear outboard non-struck-side (1.4%). This pattern remained the same for both the 4-8 year olds and the 9-12 year olds. Those 13-15 years, few of which were seated in the center rear, had the highest injury risk when seated on the rear outboard non-struck-side (4.6%) followed by the rear outboard struck-side (3.7%).

Multivariate logistic regression was employed to account for the varying age distribution by seat position highlighted in Table 1. Adjusted for age, the risk of injury was lower to children seated on the non-struck-side as compared to those on the struck-side (OR:0.55 95% CI: 0.33 0.93). Of importance, the injury risk to children seated in the center rear was roughly equivalent to that of those on the struck side (OR: 1.15, 95% CI: 0.50, 2.66).

DISCUSSION

Based on a study of seat belt restrained children in side impact crashes, results of this study confirm previous reports that children seated on the struck-side of the crash have an higher risk of injury than those seated on the non-struck-side. In particular, of children restrained in seat belts, those on the non-struck-side are at a 45% reduction in injury risk as compared those seated on the struck side, even after accounting for the potentially confounding effects of age.

Of most importance, no statistically significant difference in risk of injury was noted between children seated in the center rear and those seated on the struck-side. This finding was relevant for those 4-12 years of age, an age group in which children are transitioning out of add-on child restraints with significant side structure that can be used to mitigate injuries. Children of this age group are typically using either adult seat belts or belt positioning booster seats for their restraint and have an elevated risk of interacting with the vehicle interior surface than their younger counterparts.

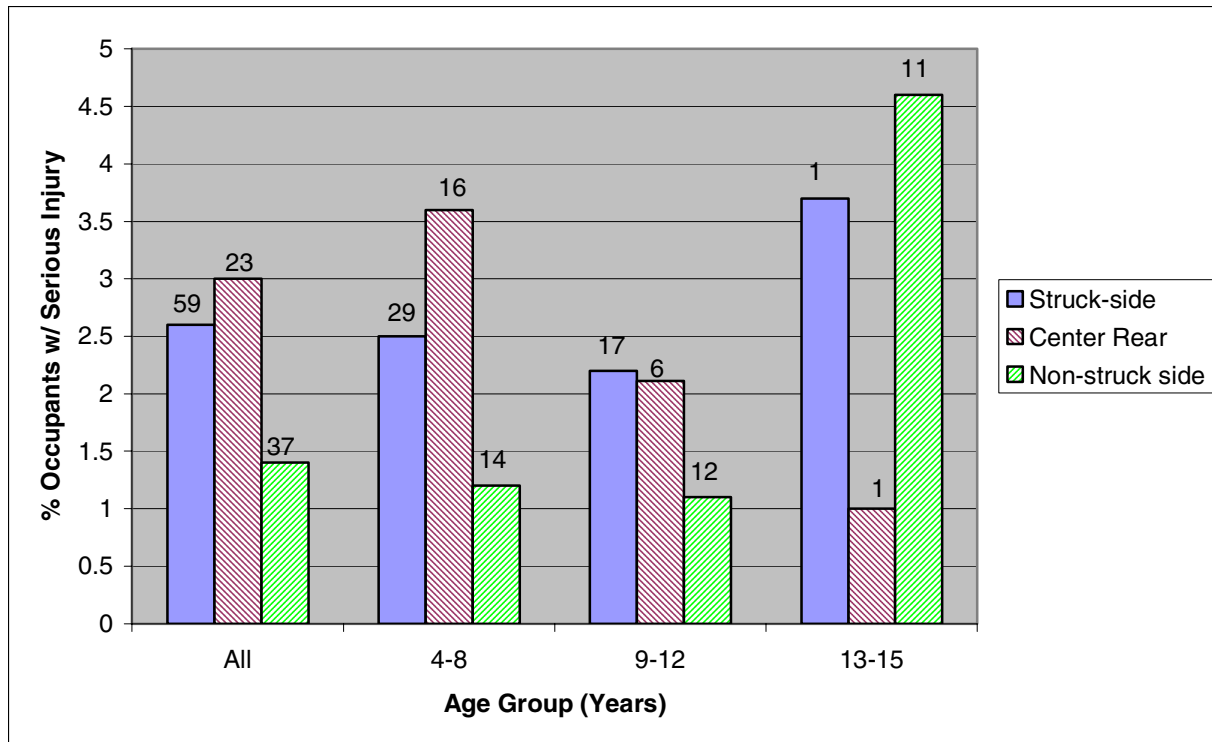


Figure 1 - Risk of Serious Injury by Occupant Age Group and Seat Position on the Rear Row. Numbers above bars are the unweighted sample size.

The present analysis is not the first comparison of the struck-side and center rear side impact environments in a nationally representative sample. Howard et al.⁵ examined the injury risk across the rear seat in restrained children in side impact crashes using NASS-CDS. In contrast to the findings of equal risk between struck-side and center rear in the present study, Howard et al found that serious injury was much more common for those in the struck-side seat position (7 per 1,000 children) than for those in the center (2 per 1,000). There are some methodological differences between the present study and the Howard work that may help explain the contrast in findings. First and foremost, Howard et al included children in all restraint types, whereas the present study includes only seat belt restrained occupants. Research on the effectiveness of child safety seats has found them to reduce fatal injury by 71 percent for infants (less than 1 year old) and by 54 percent for toddlers (1-4 years old) in passenger cars [10], as compared to lap/shoulder belts which reduce the risk of fatal injury to front-seat passenger car occupants by 45 percent [11]. Thus, if the CRS restraint use frequency is higher in the center rear as compared to the outboard rear positions, then the NASS-based finding that the center rear occupant's risk is less than the struck-side occupants risk may be due to a change

to a safer restraint design, as well as the point of impact proximity factors already delineated by Howard et al. Second, Howard et al utilized the National Automotive Sampling System (NASS) dataset that, as described by Newgard and Jolly [12], contains relatively few children for a population-based sampling system, and these limitations may influence NASS-based results. Third, Howard et al assessed serious injury based upon whether or not the occupants Injury Severity Score (ISS) score exceeded 15, whereas the present analysis assigned serious injury if the occupant received an AIS 2 or greater injury and includes injuries ranging in severity from concussions to more serious brain injuries. Whether the range of injury severity varies by seating position within the outcome category of "injury" cannot be determined in the present study. The methodology used for the PCPS crash surveillance system utilized in the present study allows for the enrollment of large numbers of crashes involving children and thus addresses the second limitation highlighted above, however it precludes determination of specific AIS severity for each injury, and thus ISS, so no precise repeat of the Howard et al methods is possible with the PCPS dataset. Future work will extend the results presented herein by using the crash investigation component of the PCPS study to further

elucidate the effects of seating position on risk of injury suggested in these analyses, and to suggest countermeasures to prevent these injuries. In this approach, more detailed information on the nature and severity of the injuries as well as the location and direction of crash impact and crash severity, a critical factor in side impact protection, is obtained. We hypothesize that this future analysis will elucidate differing injured body region patterns between the center and struck-side seat position.

The role of occupant-to-occupant contact in determining injury outcome cannot be discounted in side impact crashes. Sherwood et al [13], in a case study of 37 child-involved side impact fatal crashes, found two cases where the child fatality was caused by contact with other unrestrained (adult) occupants. Cummings and Rivara [14] found a small fatality risk increase for an adult occupant involved in a side impact if there was another unrestrained occupant seated next to them as compared to another restrained occupant. Future analyses will explore the role of this parameter in injury causation within this study sample.

Results presented herein also have relevance to the proposed upgrade to the US side impact standard [15], which notably includes both the 50th percentile male and 5th female size crash test dummies. The 5th female dummy, in particular, is approximately the same size as 50th percentile 12 year old. According to Figure 1 above, the 13 – 15 year old age groups were frequently at the highest injury risk relative to other age groups, and should be similar in size to the 5th female and 50th male dummies proposed in the side impact standard upgrade. However, the current proposed regulatory upgrade is focused on struck side occupants. This data suggests that for this age group in particular the center and non-struck side occupant should also be considered.

In addition to the side impact standard, the regulatory landscape for the rear seat is changing in that lap shoulder belts will now be required for the center rear. Our data set which includes vehicles from model year 1990 to the present, contains both vehicles with a lap only belt in the center rear as well as those with a lap shoulder belt. Our previous work [16] has highlighted the benefits of a lap shoulder belt restraint in the center rear for injury mitigation in crashes of all directions. Effects of this technology change on the results of this study will be considered in future work.

Limitations

This research is conducted on crashes involving State Farm Insurance Co. policyholders only. State Farm is the largest insurer of automobiles in the United States, with over 38 million vehicles covered; therefore, its policyholders are likely representative of the insured public in this country. The surveillance system is limited to children occupying model year 1990 and newer vehicles insured in 15 states and the District of Columbia. Our study sample represents the entire spectrum of crashes reported to an insurance company including property damage only, as well as bodily injury crashes. While our sample included a significant number of vehicles with intrusion into the occupant compartment, it is possible that the PCPS study does not have a representative sample of the most severe crashes. Nearly all of the data for this study were obtained via telephone interview with the driver/parent of the child and is, therefore, subject to potential misclassification. On-going comparison of driver-reported child restraint use and seating position to evidence from crash investigations has demonstrated a high degree of agreement. There may be over-reporting of those using both portions of a lap shoulder belt when in fact, the shoulder portion of the belt was behind their back or under their arm.

CONCLUSION

These results highlight the elevated injury risk for seat belt restrained children in center rear seating position in side impacts, and suggest that the injury mitigation approach in the center seat is unique to that of the other rear seating positions. Vehicle manufacturers and researchers should devote resources to understanding injury mechanisms and injury sources for children restrained in this seat position.

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