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Seating Patterns and Corresponding Risk of Injury Among 0- to 3-Year-Old Children in Child Safety Seats

Michael J. Kallan, MS^{a,b}, Dennis R. Durbin, MD, MSCE^{a,b,c}, Kristy B. Arbogast, PhD^{b,c}

^aCenter for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; ^bCenter for Injury Research and Prevention, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania; ^cDepartment of Pediatrics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania

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What's Known on This Subject

Child safety seats installed in the rear seat of the vehicle provide excellent protection for young children in motor vehicle crashes.

What This Study Adds

We present up-to-date real-world data identifying the center rear seating position as the one that provides optimal protection for children using child safety seats.

ABSTRACT

OBJECTIVE. Current guidelines for optimal restraint of children in motor vehicles recommend the center rear seating location for installing a child-restraint system. However, recent research on child occupants in child-restraint system has brought this into question. The objective of this study was to describe seating position patterns among appropriately restrained child occupants aged 0 to 3 years in the rear row of vehicles. In addition, we determined the association between rear row seating location and risk of injury.

METHODS. We studied data collected on child occupants from December 1, 1998, to December 31, 2006, via insurance claim records and a validated telephone survey. The study sample included child occupants aged 0 to 3 years seated in a child-restraint system in the rear row of the vehicle, model year 1990 or newer, involved in a crash in 16 states. Children were classified as injured if a parent or driver reported an injury corresponding with Abbreviated Injury Scale scores of ≥ 2 .

RESULTS. Seating position distribution for child occupants was as follows: left outboard (31%), center (28%), and right outboard (41%). There was an inverse relationship between the center position and increasing child age (39% for occupants <1 year old versus 18% for occupants 3 years old), independent of the number of additional row occupants. Child occupants seated in the center had an injury risk 43% less than children seated in either of the rear outboard positions.

CONCLUSIONS. The most common seating position for appropriately restrained child occupants in a child-restraint system is the right rear outboard. The center rear seating position is used less often by children restrained by a child-restraint system as they get older. Children seated in the center rear have a 43% lower risk of injury compared with children in a rear outboard position.

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The results presented in this article are the interpretation solely of the authors and are not necessarily the views of State Farm.

Key Words

accidents, car seats, child passenger safety, injury

Abbreviations

CRS—child-restraint system
CI—confidence interval
AIS—Abbreviated Injury Scale
OR—odds ratio
SUV—sport utility vehicle

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Address correspondence to Michael J. Kallan, MS, Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine, 523 Blockley Hall, 423 Guardian Dr, Philadelphia, PA 19104. E-mail: mkallan@mail.med.upenn.edu

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ALTHOUGH OLDER PASSENGERS using seat belts tend to decide where they sit, a young child's seating position is typically determined by the installation of the child-restraint system (CRS). According to current child-restraint recommendations, the center rear seating position is preferable to outboard positions provided a snug fit of the child restraint can be obtained.¹ These recommendations are based, in part, on research conducted over 10 years ago: Evans and Frick² found an overall 16% decrease in fatality risk for all age occupants when seated in the center as compared with the outboard seat. For restrained children, Braver et al³ found that those seated in the center rear experienced a reduction of 24% in fatality risk when compared with those in the rear outboard seating positions.

Recent advances in vehicle crash-worthiness and child-restraint design, as well as rapidly changing patterns of child-restraint use among children, have prompted the need to reexamine the evidence in support of these recommendations. Recently, Lund⁴ studied children aged 0 to 5 years in crashes occurring between 1992 and 2000 and found that those seated in the center rear position experienced a 12% higher injury risk than those seated in the left outboard position, and a 3% lower injury risk than those seated in the right rear outboard seating position. In an effort to provide more contemporary data to inform current recommendations, the objective of this study was to

describe seating position patterns among appropriately restrained child occupants aged 0 to 3 years in the rear row of vehicles. In addition, we determined the association between rear row seating location and risk of injury.

METHODS

Study Population and Data Collection

The Partners for Child Passenger Safety Study consists of a large-scale, child-specific crash surveillance system: insurance claims from State Farm function as the source of subjects, with telephone survey and on-site crash investigations serving as the primary sources of data. A description of the study methods has been published previously.⁵

Data were collected from December 1, 1998, to December 31, 2006. Passenger vehicles qualifying for inclusion were State Farm-insured, model year 1990 or newer, and involved in a crash with ≥ 1 child occupant < 16 years of age. Qualifying crashes were limited to those that occurred in 16 states and the District of Columbia, representing 3 large regions of the United States (East: New York, New Jersey [through November 2001], Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, and District of Columbia; Midwest: Ohio, Michigan, Indiana, and Illinois; and West: California, Nevada, Arizona, and Texas [starting June 2003]).

A stratified cluster sample was designed to select passenger vehicles (the unit of sampling) for the conduct of a telephone survey with the driver. Probability sampling was based on 2 criteria: whether the vehicle was towed from the scene or not and the level of medical treatment received by the child passenger(s). If a vehicle was sampled, the cluster of all child passengers in that vehicle was included in the survey.

Separate verbal consent was obtained from eligible participants for the transfer of claim information from State Farm to Children's Hospital of Philadelphia/University of Pennsylvania School of Medicine, for the conduct of the telephone survey, and for the conduct of on-site crash investigations on a smaller convenience sample of crashes. The study protocol was reviewed and approved by the institutional review boards of both the Children's Hospital of Philadelphia and University of Pennsylvania School of Medicine.

On the basis of an analysis of data for the time period of this study, claim representatives correctly identified 97% of eligible vehicles, and 80% of policyholders either consented for participation in this study or were not sampled for consent (the procedure to identify participants who required consent changed in June 2003). Of those who consented and were sampled for an interview, 79% were successfully contacted and screened for the full interview, representing an overall inclusion rate of 52% of eligible subjects. The included sample did not differ from known population values from State Farm claims with respect to geographic region, model year of vehicle, tow status of the vehicle, and age of the child occupant.

Variable Definitions

The analysis was limited to those children aged 0 to 3 years in either a rear-facing CRS or a forward-facing CRS in the rear rows of the passenger vehicle. Exclusions included those vehicles with > 3 occupants in a particular rear row, as well as occupants in CRSs used forward facing that were designed for rear-facing use only. Seating position within the rear row for these child occupants was defined as follows: left outboard (driver's side), center, or right outboard. Both seating position and type of restraint used were determined from the telephone survey. Children in the second row of a minivan with a shortened bench seated at the far right of the bench were classified as sitting in the center seat position. Among the 117 children aged 0 to 3 years for whom paired information on seating position was available from both the telephone survey and crash investigations, agreement was 98% between the driver report and the crash investigations (κ statistic for agreement beyond chance = 0.95; 95% confidence interval [CI]: 0.88–1.00). Agreement for restraint type was 92% between the driver report and the crash investigator among these same 117 children (κ statistic = 0.65; 95% CI: 0.43–0.86).

Survey questions regarding injuries to children were classified by body region and severity based on the Abbreviated Injury Scale (AIS) score. The ability of parents to accurately distinguish injuries with AIS scores of ≥ 2 from those less severe has been validated previously for all of the body regions of injury.⁶ For the purposes of this study, injury was defined as all of the injuries with AIS scores of ≥ 2 , including concussions and more serious brain injuries, facial bone fractures, spinal cord injuries, internal organ injuries, and extremity fractures.

Data Analysis

The primary purpose of these analyses was to compute both the unadjusted and adjusted relative risk of injury for child occupants by seating position in the rear row(s). Point estimates of risk with associated 95% CIs were determined. 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. Failing to account for the sample design in the analysis of data would lead to biased estimates of the prevalence of exposures of interest, as well as the outcome, and might also lead to biased estimates of the association between seating position and risk of injury. To account for the stratification of subjects by medical treatment, clustering of subjects by vehicle, and the disproportional probability of selection, Taylor series linearization estimates of the logistic regression parameter variance were calculated using SAS-callable SUDAAN, Software for the Statistical Analysis of Correlated Data, 9.0 (Research Triangle Institute, Research Triangle Park, NC). Results of logistic regression modeling are expressed as unadjusted and adjusted odds ratios (ORs) with corresponding 95% CIs. Because injury is a relatively rare event, the OR can be interpreted as a good estimate of relative risk. Adjustments included CRS type (rear facing and forward fac-

TABLE 1 Distribution of Passenger and Vehicle Characteristics for Rear Row-Seated Children by Seating Position

Characteristic	Weighted % (Unweighted n)	Child Seating Position			P
		Left Outboard %	Center %	Right Outboard %	
Total	100.0 (5358)	30.6	28.2	41.2	
CRS type					<.001
RF CRS	23.2 (1231)	22.2	39.5	38.3	
FF CRS	76.8 (4127)	33.2	24.8	42.0	
Age of child					<.001
<1 y	25.4 (1398)	22.9	39.2	37.9	
1 y	27.2 (1474)	29.2	31.4	39.5	
2 y	26.8 (1404)	34.7	22.4	42.9	
3 y	20.7 (1082)	36.7	18.0	45.3	
Vehicle type					<.001
Passenger car	48.2 (2763)	24.6	33.6	41.8	
Large van	1.5 (83)	34.9	28.0	37.1	
Pickup truck	3.4 (175)	17.3	51.8	30.8	
SUV	25.6 (1215)	31.4	28.6	40.0	
Minivan	21.2 (1122)	45.3	11.5	43.1	
Age of driver					.22
<25 y	15.5 (947)	28.0	31.1	40.9	
≥25 y	84.5 (4411)	31.1	27.6	41.2	
Additional occupants in row					<.001
0	48.5 (2529)	23.1	35.5	41.4	
1	43.0 (2278)	39.5	16.8	43.7	
2	8.5 (551)	29.1	43.5	27.4	
Direction of initial impact					.82
Frontal	45.2 (2415)	29.8	28.2	42.0	
Right side	10.5 (581)	32.6	25.6	41.9	
Left side	9.6 (570)	30.1	27.5	42.3	
Rear	31.7 (1621)	31.2	28.9	39.9	
Other/unknown	3.0 (171)	32.6	31.3	36.1	
Crash severity					.30
Any intrusion	7.3 (948)	31.8	23.2	45.0	
Towed from scene	27.6 (2140)	30.9	28.8	40.3	
None	65.0 (2270)	30.4	28.5	41.1	

Data are from χ^2 test of the distributions across the 3 seating positions. RF CRS indicates rear-facing CRS; FF CRS, front-facing CRS.

ing), age of the child (by year) and driver (<25 and ≥25 years), the number of other occupants seated in the row with the child (0, 1, or 2), crash severity (intrusion, nondrivable without intrusion, or drivable), and the initial direction of crash impact (frontal, right side, left side, rear, or other/unknown).

RESULTS

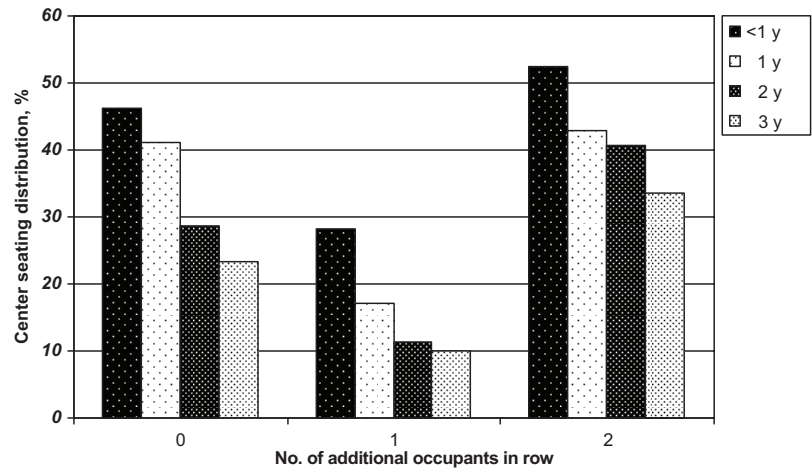
Complete interview data were obtained on 4790 crashes involving 5358 children, representing an estimated 94 735 crashes with 106 580 child passengers in the study population. Table 1 presents the estimated overall passenger and vehicle characteristics of the study population along with their distribution by seating location. The distribution of seating position for child occupants was as follows: left outboard (30.6%), center (28.2%), and right outboard (41.2%). The vast majority of the observed child occupants were either alone in their row (48.5%) or sat with 1 additional passenger in their row (43.0%).

When the child was the only occupant in the row, he or she was more likely to be seated in either the right outboard or center positions (41.4% and 35.5%, respec-

tively) than in the left outboard position (23.1%). Children aged 0 to 3 years were less likely to be in the center position ($P < .001$) when there was 1 additional occupant seated in the same row (16.8%) but more likely to be in the center when 2 additional occupants were in their row (43.5%). Of note, when present, ~9 (87%) of 10 of the additional occupants were <16 years of age. There was an inverse relationship between seating in the center position and increasing child age (39.2% for child occupants <1 year of age versus 18.0% for 3-year-olds; $P < .001$). This finding was independent of the number of additional occupants in the row (Fig 1). Children 0 to 3 years old in rear-facing CRSs were more likely to be in the center (39.5%) than those in forward-facing CRSs (24.8%). Child occupants were also more likely to be seated in the center position in either passenger cars (33.6%) or sport utility vehicles (SUVs; 28.6%) than in minivans (11.5%). This finding is attributed in part to the large variety of seating configurations observed in the second row of minivans.

Injuries were reported in 237 sampled children representing an estimated 268 children or 0.25% of the study population (Table 2). The injury risk was 0.27%,

FIGURE 1
Distribution of age in CRS position stratified according to number of additional occupants.



0.17%, and 0.29% in the left outboard, center, and right outboard positions, respectively. No statistically significant difference in injury risk was found between child occupants in the right and left outboard positions; therefore, they were combined for additional analyses. Child occupants seated in the center seating position had a 43% lower injury risk than those children seated in either of the outboard positions (adjusted OR: 0.57; 95% CI: 0.38–0.86).

In part, the increased injury risk for outboard occupants is related to their proximity to the impact location in side impact crashes. When compared with those in the nearside (on the struck side of the crash) outboard position in a side impact collision, those 0- to 3-year-old children seated in the center were at a 54% decreased risk of injury (adjusted OR: 0.46; 95% CI: 0.28–0.76). Center-seated children still demonstrated a statistically significant decrease in risk of injury compared with outboard-seated children in all of the other impact directions (adjusted OR: 0.60; 95% CI: 0.39–0.91).

DISCUSSION

This analysis confirmed current recommendations that the center rear is the safest seat position for children

restrained in CRS. Children aged 0 to 3 years restrained in the center rear seat had a 43% lower risk of injury compared with the rear outboard positions. This was particularly apparent in side-impact crashes. Our findings are consistent with several previous studies conducted on crash populations of different ages, using both fatal and nonfatal injuries as the outcomes of interest.^{2,3,7,8}

However, our findings are in contrast to those of Lund,⁴ who found that the center rear was not a safer seating position than either of the rear outboard seating positions for children restrained in a CRS. The population studied in the Lund⁴ analysis was derived from National Automotive Sampling System's General Estimates System data from 1992 to 2000, with vehicles that were, on average, 7 years old at the time of the crash. This is a significantly older sample of vehicles than those we analyzed (crashes between 1998 and 2006 and model years no earlier than 1990).⁴ The different time periods of study also yield a different mix of vehicle types, given changes in the vehicle fleet that have taken place over time.^{4,9} Although Lund's⁴ data are dominated by children in passenger cars (~80%), our population shows a more varied vehicle distribution (approximately

TABLE 2 Risk of Injury With AIS Score of ≥ 2 and Both Crude and Adjusted ORs of Injury with AIS Score of ≥ 2 According to Seating Position

Seating Position	Injury Risk % (Unweighted n)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Center	0.17 (47)		
Left outboard	0.27 (76)		
Right outboard	0.29 (114)		
Center vs left outboard		0.61 (0.40–0.92)	0.56 (0.36–0.89) ^a
Center vs right outboard		0.57 (0.38–0.84)	0.58 (0.37–0.90) ^a
All outboard	0.28 (190)		
Center vs. all outboard		0.58 (0.41–0.84)	0.57 (0.38–0.86) ^a
Nearside outboard (side crashes)	0.53 (41)		
Outboard, not nearside (all crash directions)	0.26 (149)		
Center vs. nearside outboard (side crashes)		0.31 (0.20–0.50)	0.46 (0.28–0.76) ^b
Center vs. outboard, not nearside (all crash directions)		0.65 (0.44–0.94)	0.60 (0.39–0.91) ^b

^a Data were adjusted for CRS type, vehicle type, age of child occupant, age of driver, additional occupants in row, crash severity, and direction of impact.

^b Data were adjusted for CRS type, vehicle type, age of child occupant, age of driver, additional occupants in row, and crash severity.

half cars and nearly one-quarter SUVs). Finally, Lund⁴ defined injury as any police-reported injury, which includes those of a relatively minor nature. The threshold for injury is higher in our analysis, resulting in more serious injuries, such as internal organ injuries and extremity fractures. We feel that this is the threshold for injuries that are both clinically significant and typically targeted for prevention by federal motor vehicle safety standards and auto manufacturers. This difference is evident when comparing prevalence estimates of injury (12%–14% for Lund compared with our <0.5%).

Our study further demonstrated that fewer children aged 0 to 3 years in a CRS use the center seating position as they get older. This finding was independent of the number of other occupants seated in the row with the child. Variation in child-restraint size may partly explain this pattern, as convertible CRSs (typically used for toddler-aged children) are larger on average than infant-only CRSs.¹⁰ When placed in the center position, a smaller CRS will allow more room for potential occupants to sit on either side of the child. Parents may need to put the (larger forward-facing) CRS in an outboard position when a second occupant is in the back row with the child.

Center rear seating is likely also influenced by the increased level of difficulty in placing a child in the center position when transitioning from a more portable infant CRS to a stationary forward-facing CRS. When a heavier child has to be maneuvered into the forward-facing CRS, it is physically less stressful if the seat is in one of the outboard positions. In addition, certain vehicle contours in the center rear of some vehicles (particularly in smaller passenger cars) can make it difficult for a tight installation of a CRS in that seat position compared with either of the outboard positions. In addition, the desire of the driver to keep an eye on the child may explain the apparent preference for the right outboard seating position by children >1 year of age in forward-facing CRSs. Those seated in the right outboard position are the easiest for a driver to observe either in his or her rearview mirror or by turning slightly. Finally, the right outboard position is curbside not roadside (on a 2-way street), which is safer during loading and unloading. Resources exist to assist parents on proper CRS installation and use.^{11–13} Practitioners should be aware of these resources and direct patients to their use.

It is important to note that the injury risk for all children aged 0 to 3 years restrained in a CRS in the current study was <5 injured children per 1000 child occupants, indicating remarkable protection for children in CRS regardless of their seat position. This is consistent with the growing body of evidence demonstrating the importance of restraining young children in a CRS.^{14–18} The data from this study do not indicate that a CRS restrained in an outboard position is a poor choice for children of this age but rather that given the available space and the ability to obtain a tight installation, restraining a CRS in the center rear allows for further reductions in injury risk beyond the already excellent protection afforded by CRSs attached in the outboard positions.

This study obtained nearly all of its data via telephone interview with the driver and/or parent of the child and is, therefore, subject to potential misclassification. As noted previously, ongoing comparisons of driver-reported child-restraint use and seating position to evidence from crash investigations have demonstrated a high degree of agreement. In addition, our results on age-specific restraint use and seating position are similar to those of other population-based studies of child occupants.¹⁹ Therefore, it is unlikely that errors in reporting restraint use or seating position would substantially alter the results of this study.

Our study sample covers a representative spectrum of crashes with child occupants traveling in 1990 and newer model year insured passenger vehicles in 16 states and the District of Columbia reported to an insurance company (State Farm). These crashes ranged from those with minor vehicle damage to those with loss of life; however, our results cannot be generalized to an uninsured or older population of vehicles. It should be noted that a 2004 estimate by the Insurance Research Council estimating the proportion of insured motorists ranged from 75% to 93% in the 16 participating states and was ~85% nationally.²⁰

Surveillance data of the nature presented in this study cannot identify precise injury mechanisms. Therefore, more detailed information on the nature and severity of the injuries, occupant kinematics, and characteristics of the vehicle structure and restraint systems is needed to fully understand the mechanism by which the center rear seating position offers enhanced protection.

CONCLUSIONS

Although placement in any rear seating position provides excellent protection for young children in CRSs, those in the center rear have the lowest risk of injury. Children aged 0 to 3 years seated in the center rear position were at approximately half the risk of injury as those restrained in either of the rear outboard positions after adjusting for key vehicle and occupant characteristics. The right rear outboard is the most common seating position for appropriately restrained child occupants in a CRS, and their presence in this position increases as they get older. This trend is in contrast to the center rear seating position, which is less often used by CRS-restrained children as they get older. Recommendations should continue to encourage families to install CRSs in the center of the rear seat.

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