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The effect of seating location on the injury of properly restrained children in child safety seats

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Abstract

Properly restrained child passengers in the National Automotive Sampling System (NASS), General Estimates System (GES), were studied for the effect of seating position on the risk of injury. The analysis focused on children seated in a child safety seat in a rear seat location. A multiple logistic regression model was used to assess whether the center rear seat is a safer seating position than either of the outboard rear seats. Standard errors for the odds ratios (ORs) of injury for several correlates of injury including seating position were obtained using a jackknife procedure. This analysis of the data showed that the center rear seat is not a safer seating position than either of the outboard rear seats in terms of odds of injury (left seat OR = 0.88, 95% CI = 0.73–1.03; right seat OR = 1.03, 95% CI = 0.85–1.20). These results do not agree with those of previous studies that suggested the center rear seat is the safest position for parents to place a child safety seat.

Keywords: Children; Child safety seats; Injury; Seating position; Logistic regression

1. Introduction

In the year 2001, for children aged 1–5 years, motor vehicle accidents were the leading cause of death and the ninth most common cause of non-fatal injury in the United States (Centers for Disease Control and Prevention, 2002). Seating position and the usage of proper restraints are factors that can easily be controlled by parents and may affect the risk of injury and fatality of child passengers.

There is evidence in the literature documenting the decreased risk of injury and fatality in automobile accidents due to proper restraint usage. See, for example, Bédard (2002) and Johnston et al. (1994), of which the latter specifically addressed the benefit of proper restraint systems in reducing the odds of injury for children. The National Highway Traffic Safety Administration (NHTSA) estimated that child restraints reduce the risk of fatality by about 71% for infants and by 54% for toddlers in passenger vehicles (NHTSA, 2001). Existing literature also suggests that seating position has an effect on the injury and fatality rate of motor vehicle passengers. Several studies have shown that occupants in rear seating positions have a reduced risk of fatality and injury when compared to front seated occupants (Williams and Zador, 1977; Glass et al., 2000; Evans and Frick, 1988). Most recently, Smith and Cummings (2004) estimated that a rear seating position reduces the risk of death by about 39% and the risk of death or serious injury by 33%. Their result was similar to those of previous studies. This research validates the recommendation of NHTSA that all children under the age of 12 years be properly restrained in a rear seat (NHTSA, 2002).

Although the literature suggests that the optimal seating location for passengers is in the back seat of a vehicle and that children should use an age-appropriate restraint system, it is unclear what the optimal location in the back seat is for a properly restrained child. Fatality risk ratios computed by Evans and Frick (1988) showed that for unrestrained occupants, the center rear seat was the safest location and that there was no practically significant difference between the left and right rear seats. They estimated that the left rear seat versus the center rear seat has a fatality risk ratio of 1.17,

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while the ratio for the right rear seat versus the center rear is 1.19. Braver et al. (1998) analyzed the risk of fatality for child passengers aged 0–12 years by seating location and restraint use. They found that among restrained children seated in the rear, the outboard seat had a relative risk of fatality of 1.31 when compared to the center seat. It is unclear whether the above results extend to properly restrained child passengers seated in child safety seats, and whether the risk of injury instead of fatality follows a similar pattern.

Though NHTSA does not promote the center back seat as the optimal location, some less authoritative organizations do advocate the placement of the child safety seat in the center rear seat. For example, an article in the publication Westways, affiliated to the Automobile Club of Southern California, stated, "For most safety seats, the preferred position is the center of the backseat" (Yap, 2002). No explicit citation was given to substantiate their assertion. The aim of the present study is to determine whether there is, in fact, a significant safety benefit for seating a child in the center rear seat versus one of the outboard seats, when properly restrained in a child safety seat.

2. Methods

2.1. Data source

The General Estimates System (GES) of the National Automotive Sampling System (NASS) was used for the analysis. The GES data has been collected annually since 1988 by the National Center for Statistics and Analysis, a component of NHTSA. The data is a nationally representative sample of all police-reported crashes, and is an appropriate set of data from which to estimate risk of injury in an automobile crash. Though the sample does not include data from crashes that are not reported to the police, it is generally accepted that the vast majority of accidents that lead to substantial property damage or injury are reported to the police (Johnston et al., 1994), and it is these accidents that are of interest in the present study.

2.2. Study sample

The GES consists of data with variables on the accident, vehicle, and person level. The present study used data for the years 1992–2000, as these years provided the availability and consistent coding of the variables of interest. To restrict to records concerning the target population of the study, and to reduce the effect of confounding variables and the complexity of the models necessary for the primary analysis, a subset of the GES data was taken. The body types of vehicles included were automobiles, utility vehicles, mini-vans, and large vans with gross vehicle weight rating at most 4536 kg. Vehicles that were not emergency or special use were included. Vehicles were required to have been involved in a collision accident, with the initial point of impact being one of the sides, the front or the back of the vehicle. In an effort to identify properly restrained children, the analysis was further restricted to occupants classified as passengers, aged 5 years and younger, seated in the second or third row of the vehicle, and restrained by a child safety seat. The number of GES records relevant to the study was 11,872. All data management and subsequent analyses were performed using SAS statistical software (SAS, 1999).

2.3. Descriptive and inferential statistics

The outcome measure of interest was the injury versus non-injury of a child passenger. In the GES, injury is defined by the police-reported injury severity. For the present study, the following police-reported injury severity classifications lead to a coding of injured: possible injury, non-incapacitating injury, incapacitating injury, fatal injury, injured—severity unknown. A police-reported injury severity classification of no-injury leads to a coding of non-injured in the present study. As the outcome measure of interest was binary, an appropriate way to model the response, given a set of predictor variables, was multiple logistic regression (Hosmer and Lemeshow, 2000).

Accident level predictors for passenger injury were: year of crash (1992–2000), type of roadway (interstate highway, not interstate highway), and the posted speed limit (5-mph increments). Speed limit was included to serve as a proxy measurement for vehicle speed upon impact. Vehicle level predictors were: age of vehicle (5-year increments), body type (passenger vehicle, utility vehicle, van), role of vehicle (striking, struck or both striking and struck), and initial point of impact (left side, right side, front or back). Less than 3% of the records had initial point of impact coded as one of the corners of the vehicle. These records were assigned either the left or right side as initial point of impact. Person level predictors were: age of passenger (1-year increments, 0–5); gender of passenger; number of additional passengers seated in the same row as passenger; seating position, in terms of the center, left, and right seating position.

Any records with missing values for at least one of the above independent variables or the response variable injury were omitted from all analyses, leaving an analytic sample size of 9894. The distribution of seating position for properly restrained child passengers was estimated from these records, and descriptive statistics were computed for the correlates of injury as well as the injury response variable. Univariate logistic regression models predicting child passenger injury from the various independent variables were fit (univariate analysis), followed by a multiple logistic regression model using all of the predictors simultaneously (adjusted analysis). The latter analysis was used to obtain adjusted odds ratios (OR) of injury for the outboard seating positions relative to the center.

The NASS GES data set is a nationally representative sample of automobile accidents. As such, it contains a weighting variable that should be used to estimate population parameters such as means, proportions, regression model coefficients, and odds ratios. To obtain accurate standard errors for the estimated odds ratios obtained from the multiple logistic regression model, a jackknife procedure that accounts for the complex survey design was used as described by Rust and Rao (1996). To apply the jackknife, several strata with only one primary sampling unit were collapsed into one new stratum before beginning the algorithm.

3. Results

3.1. Descriptive statistics

Table 1 presents accident, vehicle, and passenger characteristics by seating position for the 9894 records with complete data. Adjusted for population weights, it was found that among properly restrained children in the rear seat, 32.8% were seated in the left rear seat, 24.8% in the center, and 42.5% in the right rear seat. There was a non-uniform distribution of crash year, reflecting the fact that there has been an increase in the proportion of properly restrained children over time, and an increase in the proportion of children seated in the rear seat (Glass and Graham, 1999), two criteria for inclusion in the study sample. It was found that 61.0% of children restrained in the left rear seat had additional passengers seated in the same row, while this proportion was only 42.8% for children restrained in the center seat, and 46.4% for children in the right rear seat. The risk of injury for children seated in a child safety seat in the center rear was 0.13, 0.12 for children in the left, and 0.14 for children in the right rear seat.

3.2. Estimated odds ratios of injury

Table 2 presents the results of the univariate and multiple logistic regression models predicting odds of child injury. The effect of seating position was found to be similar with and without adjusting for the possible confounding variables. The multiple logistic regression model estimated that the odds of injury is not reduced for children seated in the center rear seat versus those in an outboard seat. The computed odds of injury was lower for children seated in the left rear seat versus those in the center rear seat (OR = 0.88; 95% CI = 0.73–1.03), and slightly elevated for those in the right rear seat versus the center (OR = 1.03; 95% CI = 0.85–1.20).

4. Discussion

In terms of fatality, Evans and Frick (1988) showed that the center rear seat was the safest seating location for unrestrained passengers and that there was no practically significant difference between the two outboard rear seats. Braver et al. (1998) found that an outboard rear seating position had an increased risk of fatality over the center rear seat position for restrained child passengers aged 0–12 years. These results are not replicated in the present study.

There are important differences between the outcomes and populations studied in the two aforementioned studies and the current one. First, Evans and Frick (1988) and Braver et al. (1998) studied the risk of fatality while the present study focused on the risk of injury. Their fatality studies used

Table 1
Accident, vehicle, and passenger characteristics by seating location

Variables	Seating location		
	Left	Center	Right
Analysis sample counts	3251	2435	4208
Population counts	388635	294000	503946
Crash year (%)			
1992	6.2	5.5	6.1
1993	7.8	7.9	9.2
1994	9.4	9.4	8.9
1995	11.9	10.3	10.7
1996	11.7	11.8	11.3
1997	10.5	11.3	12.5
1998	12.4	13.0	13.0
1999	14.5	15.1	13.0
2000	15.7	15.6	15.3
Roadway (%)			
Not interstate highway	94.4	93.5	94.9
Interstate highway	5.6	6.5	5.1
Speed limit, mean	41.2	40.9	40.6
Vehicle age, mean	7.1	6.9	7.3
Body type (%)			
Passenger	76.9	80.6	81.7
Utility	9.1	10.3	8.7
Van	14.0	9.1	9.6
Vehicle role (%)			
Striking	49.5	48.9	48.5
Struck	44.6	45.7	46.5
Both striking and struck	5.9	5.5	5.0
Initial point of impact (%)			
Front	43.9	41.9	41.6
Right	15.5	13.8	15.1
Left	16.7	17.7	18.3
Back	24.0	26.6	25.0
Passenger age in years (%)			
Under 1	20.0	26.6	20.0
1	29.2	32.8	32.3
2	25.8	21.2	25.4
3	16.1	12.7	14.5
4	6.9	4.6	5.9
5	1.9	2.0	1.8
Gender (%)			
Male	50.4	53.4	52.3
Female	49.6	46.6	47.7
Number of additional passengers in row (%)			
0	39.0	57.2	53.6
1	49.1	23.6	37.2
2 or more	11.9	19.1	9.2
Injury (%)			
Non-injured	87.9	86.6	86.0
Injured	12.1	13.4	14.0

Table 2
Univariate and adjusted odds ratios of injury

Variables	Univariate OR	Adjusted	
		OR	95% CI
Crash year			
1-year increment	1.01	1.01	0.97–1.05
Roadway			
Not interstate highway	1.00	1.00	
Interstate highway	1.09	0.67	0.44–0.90
Speed limit			
5-mph increment	1.13	1.16	1.12–1.21
Vehicle age			
5-year increments	1.05	1.04	0.97–1.12
Body type			
Passenger	1.00	1.00	
Utility	0.75	0.73	0.55–0.92
Van	0.75	0.76	0.59–0.93
Vehicle role			
Both striking and struck	1.00	1.00	
Striking	0.55	0.40	0.28–0.52
Struck	0.59	0.58	0.42–0.75
Initial point of impact			
Front	1.00	1.00	
Right	1.12	0.87	0.66–1.08
Left	1.14	0.88	0.66–1.10
Back	0.93	0.61	0.44–0.78
Passenger age			
1-year increment	1.02	1.02	0.97–1.08
Gender			
Male	1.00	1.00	
Female	1.12	1.13	0.99–1.26
Number of additional passengers in row			
0	1.00	1.00	
1	0.84	0.84	0.72–0.96
2 or more	0.73	0.70	0.54–0.87
Seating position			
Center	1.00	1.00	
Left	0.88	0.88	0.73–1.03
Right	1.05	1.03	0.85–1.20

the Fatality Accident Reporting System (FARS), a census of accidents involving fatalities in the United States. The data source used in the present study was the NASS GES, which contains information about accidents that may not have resulted in a fatality. Thus, the accidents sampled in the NASS GES represent a population of accidents that includes those contained in FARS. Another important difference between the populations studied is that the present study focused on children aged 5 years and younger who were seated in a child safety seat; Evans and Frick (1988) focused on unrestrained adults; Braver et al. (1998) studied children aged 12 years and younger, restrained, but not necessarily seated in a child safety seat.

These differences may account for the discrepancy in the results obtained previously and herein. The relative risk of being ejected from a vehicle for outboard-seated passengers versus center-seated passengers is much less when passengers are restrained than when they are unrestrained. This could account for why the present study did not find the outboard seats as hazardous as Evans and Frick (1988) did.

Furthermore, it could be argued that being seated in the center is disadvantageous with respect to injury because the passenger is in close proximity to the position of impact when the point of impact is on either side of the vehicle, while if a passenger is seated in an outboard position, he or she may be seated further away from the point of impact, if this point is on the other side of the vehicle. Since the present analysis did not take into account injury severity, it is possible that the center seat is more prone to injury than the left seat, but that the resulting injuries are less severe, not as lethal, on average. Since Evans and Frick (1988) and Braver et al. (1998) studied fatality instead of injury, this could explain why they found the center seat much safer than the outboard seats and the present study did not.

This study has several limitations, which may also account for the discord with previous results. Though the intent here was to restrict the study sample to children properly restrained in a child safety seat, it is uncertain whether a child coded as being restrained in a child safety seat in the NASS GES was indeed properly restrained. Many vehicles' center rear seats are not compatible with certain child safety seats. Since the contour of the center rear seat and the type of seatbelt provided for this seating position makes it more prone to an improper child seat installation than an outboard seating position (NHTSA, 2002), it could be conjectured that the benefit of being seated in the center did not materialize in this study because some children in the center seating position were not actually in properly installed child safety seats.

Another limitation deals with the degree to which the present study was able to account for confounding variables. As with any observational study, there is the chance that observed effects are actually caused by confounding variables. This could explain differences between results of the present study and those of Evans and Frick (1988), since their matched-pair analysis was less susceptible to confounding variables. In particular, the present study's results may be confounded by crash severity. Posted speed limit was used as a proxy for travel speed, but this is likely insufficient to fully account for crash severity. On the other hand, Braver et al. (1998) also used speed limit as a proxy for travel speed to account for crash severity, and their results still differed from what was seen here.

Selection bias may be present in the current study due to missing data. When selecting the analysis sample from the 1992–2000 GES data, records were retained that conformed to the various accidents, vehicle, and passenger characteristics discussed in Section 2.2. Of the entire 1992–2000 GES data set, 31.2% of the records had a missing value for at least one of the variables used to arrive at the study sample. Most egregious, in this respect, were age (8.7% missing) and restraint use (23.9%). Omitting these cases due to missing values could have resulted in a selection bias if the data were not missing completely at random.

A final limitation that might be affecting the results of the current study is that injury may have been under-reported, especially for the younger children in the sample. It may be that the crying of a child was initially interpreted as a sign of being emotionally upset, not a manifestation of injury (Johnston et al., 1994), and hence, the child was incorrectly noted as uninjured in the police report for the accident.

In addition to safety considerations, parents will inevitably weigh convenience factors when deciding where to place the child safety seat. Placing a child in the left rear seat makes it more difficult for a parent driver to monitor the child. In some smaller vehicles, a left rear seat placement may also limit the legroom of the driver, since some rear-facing infant seats require substantial space when installed at the proper angle. Entering the car from the curb is usually more convenient than entering from the street, especially when holding a child. Parents may choose to place the child safety seat in the right seating position to avoid reaching over to the center or left side to seat their child when entering from the curb.

Though the results of this study should be viewed with caution, given the limitations discussed above, it did find that when young children were restrained in a child safety seat, the center rear seat was not a safer seating position than the outboard rear seats. This study suggests that parents should not feel obligated to seat their children in the center seating position, especially when the contour of the rear seat is such that the child safety seat cannot be installed properly in the center position. Future research should focus on whether the results of this current study are an artifact of the aggregate measure of injury used, or because parents are overly anxious to place a child in the center while not ensuring that the seat can, in fact, be properly installed in this position.

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