

# Risk of Injury to Child Passengers in Sport Utility Vehicles

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## ABSTRACT

**OBJECTIVE.** The popularity of sport utility vehicles (SUVs) is growing, and they are increasingly being used as family vehicles. Because of the large size of SUVs, relative to passenger cars, parents may perceive that they are safer family vehicles. However, little is known about the safety of children in SUVs, compared with passenger cars. The objective of this study was to determine the relative risk of injury to children involved in crashes in SUVs, compared with those in passenger cars.

**DESIGN.** From an on-going motor vehicle crash surveillance system, a probability sample of 3922 child occupants 0 to 15 years of age, representing 72 396 children in crashes of either SUVs or passenger cars (model year 1998 or newer), from 3 large US regions, was identified between March 1, 2000, and December 31, 2003. Injuries were defined as concussions and other brain injuries, spinal cord injuries, facial fractures and lacerations, internal organ injuries, extremity fractures, and scalp lacerations. Logistic regression modeling was used to compute the odds ratio (OR) of injury for children in SUVs versus passenger cars, both unadjusted and adjusted for several potential confounders, including differences in child seating position, restraint use, vehicle weight, exposure of the child to a passenger airbag, and whether the vehicle rolled over.

**RESULTS.** A total of 38.2% of children were in SUVs and 61.8% were in passenger cars. The average weight of SUVs was 1317 lb greater than the average weight of passenger cars. Among all children in the study, those restrained appropriately were less likely to be injured (OR: 0.25; 95% confidence interval [CI]: 0.15–0.45) and those in the front seat were more likely to be injured (OR: 2.06; 95% CI: 1.33–3.21). In both vehicle types, children exposed to a passenger airbag were more likely to be injured than were those who were not (OR: 4.70; 95% CI: 2.36–9.37). Rollover crashes increased the risk of injury in both vehicle types (OR: 3.29; 95% CI: 1.88–5.76) and occurred more than twice as frequently with SUVs (2.9%, compared with 1.2% with passenger cars). There was a trend for increasing vehicle weight being a protective factor with both vehicle types (OR: 0.86; 95% CI:

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

### Key Words

sport utility vehicles, accidents, motor vehicle safety

### Abbreviations

SUV—sport utility vehicle  
OR—odds ratio  
CI—confidence interval  
PAB—passenger airbag  
AIS—Abbreviated Injury Scale

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0.73–1.01). After adjustment for all of the aforementioned factors, the risk of injury was not significantly different for children in SUVs versus passenger cars (adjusted OR: 1.50; 95% CI: 0.88–2.57). Especially detrimental for children in SUVs was being unrestrained versus restrained in a rollover crash (OR: 24.99; 95% CI: 6.68–93.53).

**CONCLUSIONS.** Despite the greater vehicle weight of SUVs, the risk of injury for children in SUVs is similar to that for children in passenger cars. The potential advantage offered by heavier SUVs seems to be offset by other factors, including an increased tendency to roll over. Age-appropriate child restraint and rear seat positioning are important, particularly for children in SUVs, given the very high risk of injury for children restrained inappropriately in rollover crashes.

**S**PORT UTILITY VEHICLES (SUVs) are growing in popularity in the United States and increasingly are being used as family vehicles.<sup>1</sup> The number of SUV registrations rose 250% between 1995 and 2002.<sup>2</sup> This may be attributable, in part, to a perception that SUVs are safer than other passenger vehicles because of their larger average size.<sup>3,4</sup> Much of the current literature on the performance of SUVs in crashes has focused on adult drivers and has found that any potential safety advantage of the SUVs' increased size and weight is offset by their increased likelihood of rolling over in a crash, compared with passenger cars.<sup>1,5–7</sup> Data from the National Highway Traffic Safety Administration indicate that SUVs are 4 times more likely to roll over in a crash than passenger cars.<sup>1</sup> The propensity for SUVs to roll over has been brandished as a warning to consumers that SUVs are unsafe vehicles to buy.<sup>8,9</sup>

Evaluation of the safety of SUVs for child passengers is complicated by the fact that the characteristics of drivers in child-involved crashes are likely substantially different from those in most existing SUV studies. The typical drivers in such studies of SUV safety are young male drivers who are often unrestrained in single-vehicle crashes of high severity, with alcohol involvement.<sup>1</sup> Furthermore, child occupants have different risks of injury than do adult occupants in similar crashes, because of differences in their sizes and in the restraint systems used. Finally, the performance of safety technologies such as child restraints and passenger airbags (PABs) has not been evaluated specifically for children in SUVs. Therefore, the relative safety performance of SUVs for child occupants is largely unknown, and consumers are faced with incomplete information when considering the purchase of an SUV or a passenger car for their family vehicle.

The objective of this study was to determine the relative risk of injury for children involved in crashes in

SUVs versus passenger cars. We hypothesized that children in SUVs would have a lower risk of injury, compared with children in passenger cars, and that much of the relative safety advantage of SUVs would be attributable to their heavier average weight.

## METHODS

### Study Population and Data Collection

Data were collected as part of the Partners for Child Passenger Safety project, between March 1, 2000, and December 31, 2003. A detailed description of the overall cross-sectional study design and the data collection methods was published previously.<sup>10</sup> The project consists of a large-scale, child-specific, crash surveillance system; insurance claims from State Farm Mutual Automobile Insurance Company function as the source of subjects, with telephone interviews and on-site crash investigations serving as the primary sources of data.

Vehicles qualified for inclusion in the overall Partners for Child Passenger Safety project if they were insured by State Farm, were of model year 1990 or newer, and were involved in a crash with  $\geq 1$  child occupant  $< 16$  years of age. Qualifying crashes were limited to those in 16 states (New York, New Jersey [until November 30, 2001], Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, Ohio, Michigan, Indiana, Illinois, California, Nevada, Arizona, and Texas [beginning June 17, 2003]) and the District of Columbia. After policyholders consented to participate in the study, limited data were transferred electronically to researchers at the Children's Hospital of Philadelphia and the University of Pennsylvania.

In the overall Partners for Child Passenger Safety project, we used stratified cluster sampling to select vehicles (the unit of sampling) for inclusion in the surveillance system. Vehicles containing children who received medical treatment after the crash were oversampled, so that the majority of injured children would be selected while the representativeness of the overall population was maintained. The "cluster" of all child occupants in a sampled vehicle was included in the survey. Drivers of sampled vehicles were contacted via telephone and, if medical treatment had been received by a passenger, were screened with an abbreviated survey to verify that  $\geq 1$  child occupant had been injured. We selected for a full interview all vehicles with  $\geq 1$  child who screened positive for injury, as well as a 10% random sample of vehicles in which all child occupants screened negative for injury. A 2.5% sample of crashes in which no medical treatment was received by any children was also selected. The full interview involved a 30-minute telephone survey with the driver of the vehicle. Only drivers  $\geq 16$  years of age were interviewed. The median time between the date of the crash and completion of the

interview was 6 days, with 95% of interviews being completed within 47 days after the crash.

For the current analysis, we selected all crashes involving an SUV or passenger car with a model year of 1998 or newer. The restriction regarding model year provides a more comparable sample of vehicles with respect to overall crashworthiness and the type of PAB technology with which the vehicles were equipped. Most vehicles made in 1998 and all later models are considered to have “second-generation” PABs, which are designed to deploy with less force than “first-generation” PABs.<sup>11</sup> This change in PAB technology was demonstrated previously to alter the risk of injury for child passengers significantly.<sup>12</sup>

We collected data on the age and gender of involved children and their restraint status, PAB exposure, and seat row position. In addition, the survey assessed several crash characteristics, such as severity (as determined by the presence of intrusion into the occupant compartment), whether there was a rollover, the age of the driver, and whether there was PAB deployment. Vehicle characteristics, such as type (SUV versus passenger car), model year, weight, and whether the vehicle was equipped with a PAB, were determined from the Vehicle Identification Number by using the VINDICATOR program (Insurance Institute for Highway Safety-Highway Loss Data Institute, Arlington, VA).

Survey questions regarding injuries to children were designed to provide responses that were classified according to body region and severity, on the basis of Abbreviated Injury Scale (AIS) scores, and were validated previously for their ability to distinguish injuries with AIS scores of  $\geq 2$  from less-severe injuries.<sup>13,14</sup> For the purposes of this study, children were classified as injured if a driver reported a clinically significant injury, ie, any injury with an AIS score of  $\geq 2$  (concussions and more serious brain injuries, all internal organ injuries, spinal cord injuries, and extremity fractures) or facial and scalp lacerations.

Separate verbal consent was obtained from eligible participants for the transfer of claim information from State Farm to the Children’s Hospital of Philadelphia/University of Pennsylvania and for the conducting of the telephone survey. 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 Analyses

The primary purpose of these analyses was to compute the relative risk of injury for children in SUVs, compared with those in passenger cars;  $\chi^2$  tests of association were used to compute *P* values under the null hypothesis of no association between vehicle type and risk of injury. Logistic regression modeling was used to compute the odds ratio (OR) of injury for those in SUVs versus pas-

senger cars, both unadjusted and adjusted for several potential confounders, including differences in child seating position (front versus rear row), child restraint use (appropriate for age versus inappropriate for age versus unrestrained), vehicle weight (in 500-lb increments), exposure of the child to a PAB, and whether the vehicle rolled over.

Because sampling was based on the likelihood of an injury, subjects who were least likely to be injured were underrepresented in the study sample, in a manner potentially associated with the predictors of interest.<sup>10</sup> To account for this potential bias and to adjust inferences to account for stratification of subjects according to medical treatment and clustering of subjects according to vehicle, robust  $\chi^2$  tests of association and Taylor series linearization estimates of the logistic regression parameter variances were calculated by using SAS software-callable SUDAAN software, version 8.0 (Research Triangle Institute, Research Triangle Park, NC). Results of logistic regression modeling are expressed as unadjusted and adjusted ORs, with corresponding 95% confidence intervals (CIs). Because of the overall low risk of injury (<2%), these ORs are considered reasonable approximations of the relative risk.

### RESULTS

During the study period, data were collected for 3922 children in either SUVs or passenger cars, representing 72 396 children in 49 742 crashes. In the study sample, 38.2% of children were in SUVs and 61.8% were in passenger cars. Table 1 provides descriptive characteristics of the study sample, stratified according to type of vehicle. The age distribution of children did not vary according to vehicle type and included the entire range of children <16 years of age. Most children were restrained with an age-appropriate restraint device, and very few were reported to be unrestrained. Although there was a statistically significant difference in the distribution of restraint use according to vehicle type, the differences noted were of marginal clinical significance. The majority of children in the sample sat in the rear row(s) of the vehicle; this also varied according to vehicle type, with more children in SUVs being seated in the rear. This was likely attributable to the fact that some SUVs have 3 rows of seats and all children seated in either the second or third row were considered rear-seated. In addition, children in SUVs were less likely to be exposed to a PAB, probably because of their overall lower risk of sitting in the front seat. Rollovers represented a minority of crashes for both types of vehicles; however, SUVs had a higher rate of rollover crashes than did passenger cars. As one would anticipate, there was a substantial difference in vehicle weight between SUVs and passenger cars, with the average SUV being >1300 lb heavier than the average passenger car.

The overall injury risk was 1.74% (601 unweighted

**TABLE 1** Characteristics of the Study Sample, According to Type of Vehicle

	Unweighted No. (Weighted %)		P
	Passenger Car	SUV	
Age, y			.19
0–3	576 (29.1)	341 (32.4)	
4–8	784 (32.7)	412 (33.0)	
9–12	673 (22.6)	331 (22.3)	
13–15	567 (15.7)	238 (12.4)	
Restraint status			.018
Appropriate	1693 (67.4)	843 (68.3)	
Inappropriate	773 (29.3)	402 (30.6)	
Unrestrained	134 (3.3)	77 (1.1)	
Seating position			<.001
Front	788 (20.8)	260 (13.0)	
Back	1812 (79.2)	1062 (87.0)	
Driver characteristics			
Age of <25 y	350 (13.5)	78 (7.8)	.010
Male gender	901 (48.3)	445 (52.3)	.13
Rollover crash	93 (1.2)	137 (2.9)	.009
PAB exposure	402 (2.1)	99 (0.7)	<.001
Mean vehicle weight, lb (range)	2938 (2279–3778)	4255 (2987–5564)	<.001
Risk of injury	1.76	1.71	.90

children, representing 1261 weighted children), and findings did not differ according to vehicle type. Multivariate logistic regression modeling was then used to account for the differences in several child and vehicle factors noted above (Table 2). We constructed several models to examine incrementally the effects of distinct child, vehicle, and crash characteristics on the risk of injury to children in each vehicle type. In the first model, we included characteristics that could be controlled by the parent/driver each time the child was placed in the vehicle, namely, appropriateness of restraint and seating position. After adjustment for these factors, there remained no difference in the risk of injury for children in SUVs versus passenger cars (OR: 1.08; 95% CI: 0.66–1.77). It should be noted that children who were restrained appropriately were less likely to be injured than were unrestrained children (OR: 0.25; 95% CI: 0.15–0.45) and children in the front seat were more likely to

be injured than were those in the rear (OR: 2.06; 95% CI: 1.33–3.21).

In the second model, we accounted for the role of vehicle weight, because this is a fixed attribute of the vehicle that is known to be related to the risk of injury in a crash. We found that, for every 500-lb increase in vehicle weight, there was a 14% decrease in the risk of injury. After adjustment for vehicle weight along with restraint use and seating position, children in SUVs continued to be at similar risk of injury, compared with children in passenger cars, although the trend was toward an elevated risk of injury for children in SUVs (OR: 1.62; 95% CI: 0.97–2.70).

The final model added factors related to the performance of specific safety features in the vehicles, namely, PABs and the tendency of the vehicle to roll over. After accounting for all child- and vehicle-related factors, there was a trend toward an increased risk of injury for

**TABLE 2** Results of Multivariate Logistic Regression Modeling

	OR (95% CI)		
	Model 1	Model 2	Model 3
Vehicle type			
SUV	1.08 (0.66–1.77)	1.62 (0.97–2.70)	1.50 (0.88–2.57)
Passenger car	Reference		
Restraint type			
Appropriate	0.25 (0.15–0.45)	0.25 (0.15–0.43)	0.29 (0.17–0.50)
Inappropriate	0.44 (0.23–0.84)	0.43 (0.23–0.82)	0.49 (0.26–0.90)
Unrestrained	Reference		
Seating position			
Front	2.06 (1.33–3.21)	2.05 (1.32–3.20)	1.49 (0.84–2.65)
Rear	Reference		
Vehicle weight (per 500 lb)		0.86 (0.73–1.01)	0.88 (0.75–1.03)
PAB exposure (positive)			4.70 (2.36–9.37)
Rollover (positive)			3.29 (1.88–5.76)



children in SUVs, although this difference was not statistically significant (OR: 1.50; 95% CI: 0.88–2.57). In both vehicle types, children exposed to a PAB were more likely to be injured than were those who were not (OR: 4.70; 95% CI: 2.36–9.37). Rollover contributed significantly to the risk of injury in both vehicle types, with children in rollover crashes being >3 times more likely to be injured, compared with children in nonrollover crashes (OR: 3.29; 95% CI: 1.88–5.76). We examined whether the effect of rollover and PAB exposure on the risk of injury varied according to vehicle type, and we found no evidence of effect modification.

Because of particular concern regarding rollover crashes among SUVs, we explored the impact of restraint use among children in SUVs, especially those in rollover crashes. The overall risks of injury were 1.47% for restrained children and 13.65% for unrestrained children in SUVs. In rollover crashes, the risk of injury to SUV occupants was 2.72% for restrained children, compared with 41.18% for unrestrained children, which reflects a 25-fold increased risk of injury for unrestrained versus appropriately restrained children (OR: 25.0; 95% CI: 6.68–93.53) in a rollover SUV crash.

## DISCUSSION

Children in SUVs had a similar risk of injury, compared with children in passenger cars, both before and after adjustment for several important child and vehicle characteristics, which indicates that, contrary to public perception, SUVs do not provide superior protection to child occupants, compared with passenger cars. The potential safety advantage of SUVs resulting from their heavier weight seems to be offset by other factors, including the greater tendency of SUVs to roll over in a crash. Results of this study also confirm the importance of age-appropriate restraint and rear seating for children in either type of vehicle, as well as the elevated risk of injury to children who are exposed to a deploying PAB.

Similar to our findings, a 2002 report from the National Highway Traffic Safety Administration determined that occupant fatality rates per 100 000 vehicles registered were not significantly different between light trucks and passenger cars (15.99 deaths per 100 000 vehicles vs 16.04 deaths per 100 000 vehicles). In addition, the rate of occupant deaths per 100 million vehicle-miles traveled decreased between 1991 and 2000, from 1.4 deaths per 100 million vehicle-miles to 1.2 deaths per 100 million vehicle-miles for light trucks and from 1.6 deaths per 100 million vehicle-miles to 1.3 deaths per 100 million vehicle-miles for passenger cars.<sup>1</sup> Our findings extend these results by providing previously unavailable, child-specific data on the safety of SUVs, compared with passenger cars.

Much of the current literature on SUV crashworthiness focuses on the issue of rollover crashes. Similar to previous studies, we found a difference in the propor-

tions of crashes involving rollovers between SUVs and passenger cars.<sup>1,15</sup> Although our difference was slightly smaller, we think this is attributable to differing driver characteristics. The typical drivers in most existing studies of SUV safety are young male drivers (often unrestrained) in single-vehicle crashes of high severity, with alcohol involvement.<sup>1</sup> Our drivers were more likely to be older adults of both genders who, on the basis of inclusion in our database, were driving with children (Table 1). The importance of appropriate restraint use for children in crashes was identified previously.<sup>16</sup> However, the situation of a rollover crash makes this choice critical. Our data show a 25-fold increased risk of injury to unrestrained child occupants in an SUV rollover crash. Both of these populations of unrestrained children in SUV crashes (with and without rollover) seem to fare worse than unrestrained adults (below). National Highway Traffic Safety Administration data indicated that, of all occupants in rollover crashes, 72% were unrestrained, one half of whom were ejected from the vehicle. Only 4% of restrained occupants were ejected.<sup>1</sup> Of those ejected, 62% were killed. Malliaris and Digges<sup>15</sup> found overall injury risks in all crash modes of 1.4% for belted occupants and 5.0% for unbelted occupants in SUVs. In rollovers, the injury risks were 2.3% for belted occupants and 10.1% for unbelted occupants. Our child-specific results confirm the importance of appropriate child restraint and seating position, particularly in rollover crashes.

Previous findings from the Partners for Child Passenger Safety study provided insight regarding the differential performance of PABs according to the type of vehicle. Arbogast et al<sup>12</sup> investigated the effects of vehicle type and the differential performance of first- and second-generation PABs on injuries to restrained children in frontal impact crashes. Second-generation PABs have design modifications intended to reduce the aggressiveness and deployment rates of the PABs. Arbogast et al<sup>12</sup> found that the benefit of second-generation PABs was seen in passenger cars and minivans but not in SUVs. In the current study, we found no evidence for modification of the effect of PAB exposure according to vehicle type. Although the current study used the same source of data as did the study by Arbogast et al,<sup>12</sup> the current study covers a more recent time period, which might indicate that improvements in PAB performance are occurring in newer SUVs.

This study relied on driver reports for all child and crash characteristics and might be subject to reporting bias. However, when we compared driver-reported child restraint use and seating position with evidence from crash investigations performed as part of this research project, we found a high degree of agreement ( $\kappa = 0.99$  for seat row and  $\kappa = 0.74$  for restraint use). In addition, our results on age-specific restraint use and seating position were similar to those of other recently reported,

population-based studies of child occupants, in which estimates of 83% to 99% for restraint use among children <8 years of age were noted.<sup>17</sup> Our study included children involved in crashes of newer insured vehicles; results may not be generalizable to children riding in older or uninsured vehicles.

## CONCLUSIONS

Our findings suggest that, despite the larger size of SUVs and the consequent perception of improved safety, children riding in SUVs have a similar risk of injury, compared with children riding in passenger cars. The protective effect of increased vehicle weight offered by SUVs is tempered by their higher risk of rollover crashes. In either vehicle type, age-appropriate child restraint and rear seat positioning are critically important for reducing the risk of injury in a crash. However, because of the higher risk of rollover, pediatricians should reinforce strongly the importance of age-appropriate restraint for all children who ride in SUVs. Furthermore, the increased risk of injury posed by deploying PABs in either vehicle type reinforces the importance of continued education of parents to never place children <13 years of age in the front seat of a PAB-equipped vehicle. This information may assist parents wanting to make fully informed decisions regarding the choice of vehicle for their family or may assist pediatricians called on by families for counseling regarding child passenger safety.

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L.D. completed this work while she was a Fellow in the Division of Emergency Medicine at the Children's Hospital of Philadelphia.

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"Both the American Diabetes Association and the European Association for the Study of Diabetes had never taken a position on metabolic syndrome, and when we did, we found that the emperor wears no clothes," said Richard Kahn, PhD [author of the joint statement] and the ADA's chief scientific officer. "They [supporters of the metabolic syndrome concept] focus on the syndrome and don't concentrate on the disease."

Mitka M. *JAMA*. 2005;294:2010. October 26, 2005

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