EDITOR'S CHOICE

Non-fatal and fatal crash injury risk for children in minivans compared with children in sport utility vehicles

M J Kallan,[1,2] K B Arbogast,[2,3] M R Elliott,[2,4,5] D R Durbin[1,2,3]

[1] Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, USA; [2] Center for Injury Research and Prevention, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, USA; [3] Department of Pediatrics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, USA; [4] Department of Biostatistics, School of Public Health, University of Michigan, Ann Arbor, Michigan, USA; [5] Survey Methodology Program, Institute for Social Research, University of Michigan, Ann Arbor, Michigan, USA

Correspondence to: Michael J Kallan, Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine, 523 Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104, USA; mkallan@mail.med.upenn.edu

Accepted 14 August 2008

ABSTRACT

Objective: To compare the fatal and non-fatal crash injury risk for children in minivans compared with midsize and large sport utility vehicles (SUVs).

Design: Three large population-based sources of US crash data were used—a nationwide cohort of sampled police-reported crashes (NASS-CDS) along with a census of fatal crashes (FARS), plus a large child crash surveillance system, Partners for Child Passenger Safety (PCPS)—collected in 16 states via insurance claim records and validated telephone survey. Each included: 2000–2006 data, occupants aged 0–15 years, traveling in minivan or (midsize/large) SUV, model year 1998–2007. Outcome of interest was parent/driver report of non-fatal injury (Abbreviated Injury Scale scores of 2 or higher) in PCPS and fatal injury in NASS-CDS/FARS.

Results: Compared with children riding in SUVs, those in minivans experienced a similar crude reduction in the relative risk of non-fatal injury (PCPS: unadjusted odds ratio (OR) = 0.55) and fatality (NASS-CDS/FARS cohort: unadjusted OR = 0.58). In PCPS, this reduction in injury risk changed little after adjustment for child, driver, and vehicle factors (adjusted OR = 0.56, 95% CI 0.38 to 0.82). Lower fatality risk in the NASS-CDS/FARS cohort was partially explained by the same factors (adjusted OR = 0.76, 95% CI 0.51 to 1.13).

Conclusions: There may be important safety differences in vehicles during a crash that lead to fewer non-fatal injuries to child occupants of minivans compared with SUVs.

Sport utility vehicles (SUVs) have been the fastest growing segment of the motor vehicle market in the USA through 2007. Between model years 1998 and 2007, sales of SUVs increased 67%, and they accounted for 29% of new passenger vehicle sales during the 2007 model year.[1] This increase in popularity has been due, in part, to their increasing use as family vehicles, because they contain more storage space and seating positions than passenger cars. Much of the previous research on SUV safety has focused on their increased tendency to rollover in a crash, resulting in relatively high fatality rates compared with other vehicles.[2–5] Recent research focusing on the safety of children in SUVs showed that the risk of non-fatal injury to child passengers in SUVs is similar to that in passenger cars in crashes.[6] However, children in crashes in SUVs experience a nearly 50% lower fatal injury risk than children in passenger cars in crashes in which someone dies.[7]

Minivans are an alternative choice as a family vehicle, with similar storage and seating capacity to that of many midsize and large SUVs. As sales of SUVs have increased, those of minivans decreased by 36% over the same period,[1] suggesting that many families choose between these two vehicle types. The objective of this study was to estimate the relative risk of fatal and non-fatal crash injury for children in minivans compared with children in midsize and large SUVs.

METHODS

Crashes involving non-fatal injuries

Study population and data collection

The source of data on non-fatal injury was the Partners for Child Passenger Safety (PCPS) study. PCPS is a 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.[8]

Data for this study were collected from 1 March 2000 to 31 December 2006. Vehicles qualifying for inclusion were State Farm-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 16 states and the District of Columbia, representing three large regions of the USA (East: New York, New Jersey (through November 2001), Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, District of Columbia; Midwest: Ohio, Michigan, Indiana, Illinois; West: California, Nevada, Arizona, Texas (starting June 2003)).

Parent-reported injuries were defined as those with estimated Abbreviated Injury Scale scores of 2 or higher, which includes concussions and more serious brain injuries, facial bone fractures, spinal cord injuries, internal organ injuries, and extremity fractures.[9] Child passengers who suffered a fatal injury (n = 13) were excluded from the analysis.

A stratified cluster sample was designed to select vehicles (the unit of sampling) for the conduct of a telephone survey with the driver. Probability sampling was based on two criteria: whether the vehicle was towed from the scene, 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. A 2.5% sample of crashes in which no medical treatment was received by children was also included to maintain the representativeness of the sample with respect to the population of all children in crashes in State Farm-insured vehicles.

Inj Prev: first published as 10.1136/ip.2008.019224 on 3 February 2009. Downloaded from http://injuryprevention.bmj.com/ on June 9, 2023 by guest. Protected by copyright.

Table 1 Distribution of passenger and vehicle characteristics for child occupants by vehicle type in Partners for Child Passenger Safety

Characteristic	Minivan (n = 2814)	SUV (n = 2350)	p Value*
Child injury	0.50 (226)	0.90 (249)	0.002
Child restraint	97.9 (2713)	98.9 (2239)	0.13
Front row seated	11.6 (405)	13.4 (418)	0.13
Age of child			0.18
0–3 years	28.6 (713)	30.9 (600)	
4–8 years	35.1 (972)	31.8 (722)	
9–12 years	23.4 (705)	22.7 (570)	
13–15 years	12.9 (424)	14.5 (458)	
Sex of child (male)	48.0 (1320)	49.3 (1113)	0.53
Age of driver			0.003
<25 years	3.4 (126)	6.3 (199)	
25–34 years	29.4 (862)	35.5 (852)	
35–44 years	49.0 (1325)	41.6 (927)	
45–54 years	13.5 (359)	12.5 (273)	
55+ years	4.7 (142)	4.0 (99)	
Sex of driver (male)	24.4 (715)	29.7 (721)	0.026
Driver restraint	98.1 (2730)	96.8 (2244)	0.09
Model year			<0.001
1998–1999	33.4 (1026)	26.8 (696)	
2000–2001	35.9 (963)	29.0 (694)	
2002–2007	30.7 (825)	44.3 (960)	
Rollover	1.3 (119)	3.2 (306)	0.001
Tow-away	31.1 (1701)	29.7 (1437)	0.55

Values are weighted % (unweighted n).
*χ^2 test that the proportions are the same in minivans and SUVs.
SUV, sport utility vehicle.

All protocols were approved by the institutional review boards of The Children's Hospital of Philadelphia and the University of Pennsylvania.

Variable definitions

Vehicle type and size classification was obtained from the vehicle identification number (VIN) using VINDICATOR.[10] Vehicles were classified as either minivans or SUVs (limited to midsize and large only). Small SUVs (typically 1701 kg and less) were excluded from this analysis, as were very large SUVs (those typically weighing at least 2609 kg).[11] We grouped midsize and large SUVs together after performing a formal test of heterogeneity and not finding a significant difference in adjusted injury risk between the two classes (p = 0.93). Vehicles were restricted to model year 1998 through 2007 to provide a comparable sample in terms of safety technology availability and crashworthiness. Data were missing in ~0.25% of PCPS cases; for these cases, a single imputation using Imputation and Variance Estimation Software (IVEware) was performed.[12]

Crashes involving fatalities

Study population and data collection

The sources of data for crashes involving fatalities were two automotive crash surveillance systems operated by the National Highway Traffic Safety Administration: the Fatality Analysis Reporting System (FARS) and the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS). FARS is a census of motor vehicle crashes in the 50 States and the District of Columbia that resulted in the death of at least one person (motorist or non-motorist). NASS-CDS is a representative sample of passenger vehicle crashes selected annually from all police-reported crashes that resulted in at least one vehicle having to be towed from the scene for damage. These two data sources were combined using similar methodology to that described previously[13] to create a population-based cohort of children under the age of 16 years involved in police-reported tow-away crashes, with all fatally injured children in the cohort enumerated.

We restricted our analyses to children riding in either SUVs (midsize and large only) or minivans that needed to be towed from the accident scene. Within FARS, we identified 1159 child passenger fatalities in an SUV or minivan between 2000 and 2006. Within NASS-CDS, we identified 1273 child passengers in a minivan or SUV sampled during the same years that were not fatally injured. Because of the complex sample design of NASS-CDS, these 1273 children represented 443 578 children meeting our inclusion criteria.

Variable definitions

As in the PCPS dataset, vehicle type and size classification of the vehicle was obtained from the VIN using VINDICATOR.[10] Midsize and large SUVs were grouped together after a formal test of heterogeneity had been performed and no significant difference in adjusted injury risk had been found between the two classes (p = 0.81). Restraint use (child and/or driver) data were missing in ~0.5% of the NASS-CDS and in more than 9% of the FARS cases. For these cases, multiple imputation using IVEware was performed.[12]

Data analysis

Because sampling was based on the likelihood or severity of an injury, subjects least likely to be injured were under-represented in the study sample in a manner potentially associated with the predictors of interest. To account for this potential bias, case

Table 2 Distribution of passenger and vehicle characteristics for child occupants by vehicle type in NASS-CDS and FARS combined

Characteristic	Minivan (n = 1030)	SUV (n = 1402)	p Value*
Child fatality	0.19 (428)	0.33 (731)	0.010
Child restraint	97.6 (824)	93.1 (933)	0.15
Front row seated	12.8 (128)	23.4 (297)	0.09
Age of child			0.54
0–3 years	25.8 (281)	19.8 (314)	
4–8 years	36.7 (349)	33.9 (382)	
9–12 years	23.8 (239)	26.6 (353)	
13–15 years	13.7 (161)	19.7 (353)	
Sex of child (male)	46.2 (508)	54.0 (692)	0.34
Age of driver			0.026
<25 years	9.8 (104)	12.1 (286)	
25–34 years	15.5 (304)	40.4 (453)	
35–44 years	54.3 (444)	35.6 (463)	
45–54 years	17.2 (124)	10.9 (151)	
55+ years	3.2 (53)	0.9 (49)	
Sex of driver (male)	30.4 (372)	30.6 (589)	0.97
Driver restraint	97.9 (946)	95.9 (1186)	0.37
Model year			0.55
1998–1999	36.4 (361)	32.5 (442)	
2000–2001	31.4 (349)	27.5 (419)	
2002–2007	32.2 (320)	40.0 (541)	
Rollover	11.0 (222)	21.9 (661)	0.20

Values are weighted % (unweighted n).
*χ^2 test that the proportions are the same in minivans and SUVs.
FARS, Fatality Analysis Reporting System; NASS-CDS, National Automotive Sampling System-Crashworthiness Data System; SUV, sport utility vehicle.

Inj Prev: first published as 10.1136/ip.2008.019224 on 3 February 2009. Downloaded from http://injuryprevention.bmj.com/ on June 9, 2023 by guest. Protected by copyright.

weights equal to the inverse of the probability of selection and adjusted to known crash totals were used to account for the over-sampling of severe crashes in both datasets. (Case weights in FARS were set to 1, consistent with the fact that the FARS is a census of all fatalities.) 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[14] of the logistic regression parameter variance were calculated using SAS-callable SUDAAN (Software for the Statistical Analysis of Correlated Data, V9.0.1). Results of logistic regression modeling are expressed as unadjusted and adjusted odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Because fatal and non-fatal injury were relatively rare events in each respective source of data, the odds ratio can be interpreted as a good estimate of relative risk. Adjustments included restraint of the child and driver, seating row of the child (front versus rear), sex of the child and driver, age of the child and driver in years, model year of the vehicle, and whether the vehicle rolled over. For age of child, age of driver, and vehicle model year, we used quadratic splines with linear tails as described by Greenland[15] to minimize assumptions about the functional form.

RESULTS

For the PCPS dataset, complete interview data were obtained on 5164 children representing 111 079 child passengers in the study population. A majority of these children were traveling in minivans (55.5%). Injuries occurred in 475 child occupants representing 748 children or 0.67% of the PCPS study population (table 1). As compared with children in SUVs, child passengers in minivans were less often driven by someone <25 years of age (3.4% vs 6.3%), in a model year 2002 or newer vehicle (30.7% vs 44.3%), or involved in a rollover crash (1.3% vs 3.2%).

In the combined NASS-CDS and FARS cohort, we identified tow-away crashes involving 2432 children representing 444 737 child occupants. In this cohort, just over half the child passengers were in minivans (50.2%). There were 1159 child occupant deaths, representing 0.26% of the combined NASS-CDS and FARS cohort. As seen in table 2, drivers of SUVs in crashes were younger (52.5% were <35 years of age) than the drivers of minivans in crashes (25.3% were <35 years of age).

The proportion of child passengers in this cohort that were in a vehicle that rolled over was much greater (11.0% in minivans and 21.9% in SUVs) than for those in the PCPS study population. This was expected because of the higher average crash severity in the NASS-CDS and FARS cohort, which is restricted to tow-away crashes. For SUVs only, there was a greater proportion of front row seating in the NASS-CDS and FARS cohort (23.4%) than in the PCPS study population (13.4%); this was due in part to the former cohort of children being somewhat older.

In the PCPS data (table 3), there was a 45% crude injury risk reduction for children in minivans compared with children in SUVs (unadjusted OR = 0.55). After adjustment for child and driver restraint, seating row of the child, age of the child and the driver, and model year of the vehicle, PCPS child occupants in minivans still had a 44% lower risk of injury than child occupants in SUVs (adjusted OR = 0.56, 95% CI 0.38 to 0.82). A further adjustment for vehicle rollover explained only a small fraction of the remaining difference in injury risk between minivans and SUVs (adjusted OR = 0.65, 95% CI 0.43 to 0.97).

For the combined NASS-CDS and FARS cohort (table 3), the crude relative risk of death was 42% lower (unadjusted OR = 0.58) in minivans than SUVs, similar to the crude risk of injury reduction in the PCPS data. Adjustment for the set of occupant, driver, and vehicle factors mentioned above (except rollover) accounted for a portion of the difference in fatality risk between the vehicle types (adjusted OR = 0.76, 95% CI 0.51 to 1.13). A final adjustment for vehicle rollover resulted in a non-significant association between vehicle type and risk of death (adjusted OR = 1.19, 95% CI 0.73 to 1.94).

DISCUSSION

Results of this study indicate that children seated in minivans during a crash have a significantly lower crude risk of fatal and non-fatal injury than children seated in SUVs. The differences in risk of non-fatal injury are associated with vehicle type even after adjustment for other child and driver characteristics, vehicle model year, and rollover. The increased proportion of SUV crashes involving rollover explained most of the difference in risk of fatal injury for child occupants in minivans versus those in SUVs.

A previous report by the National Highway Traffic Safety Administration showed a lower risk of fatality for child passengers in crashes of light truck vehicles including SUVs, minivans, and pickup trucks compared with passenger cars.[7] In that study, however, no differentiation was made between specific vehicle types in the light truck vehicle class. The present research extends this previous work by looking at non-fatal injury (PCPS population) and fatality (NASS-CDS and FARS cohort) risk differences between minivans and SUVs specifically.

Previous research has shown that occupants in rollover crashes are more likely to be injured or killed than those in non-rollover crashes.[2 16–18] In addition, although there has been a reduction in rollover risk among newer model year SUVs due in part to both the increased presence of electronic stability control[19 20] and unibody construction (emphasizing a lower center of gravity),[4 21] SUVs are still at higher risk of rollover than minivans of the same model year.[17] Given the relatively low

Table 3 Odds ratios for injury (PCPS) or death (NASS-CDS and FARS combined), minivans versus SUVs, unadjusted and adjusted

	Unadjusted OR (95% CI)	Adjusted* OR (95% CI)	Adjusted† OR (95% CI)
PCPS	0.55 (0.38 to 0.80)	0.56 (0.38 to 0.82)	0.65 (0.43 to 0.97)
NASS-CDS/FARS combined	0.58 (0.38 to 0.87)	0.76 (0.51 to 1.13)	1.19 (0.73 to 1.94)

*Adjusted for restraint of the child and driver, seating row of the child, age of the child and driver, sex of the child and driver, and model year of the vehicle.
†Adjusted for all factors in the above footnote, plus whether the vehicle rolled over.
FARS, Fatality Analysis Reporting System; NASS-CDS, National Automotive Sampling System-Crashworthiness Data System; PCPS, Partners for Child Passenger Safety; SUV, sport utility vehicle.

Inj Prev: first published as 10.1136/ip.2008.019224 on 3 February 2009. Downloaded from http://injuryprevention.bmj.com/ on June 9, 2023 by guest. Protected by copyright.

rollover risk in the PCPS sample (1.3% for minivans and 3.2% for SUVs), and the potentially wide range of scenarios by which children can be injured in non-fatal crashes, rollover crashes accounted for only a small proportion of all injuries (9% of minivan injuries and 19% of SUV injuries). Hence, after a variety of passenger and vehicle characteristics had been controlled for, the final adjustment for vehicle rollover had a minimal effect in explaining the difference in non-fatal injury risk between minivans and SUVs in the PCPS population (adjusted OR changed from 0.56 to 0.65). The remaining association between vehicle type and non-fatal injury risk may be explained by mediators such as other vehicle characteristics (eg, vehicle size, weight, occupant space) as well as unmeasured confounders such as differences in how the vehicles were driven. In particular, previous research hypothesized that differences in occupant space, seating, and restraint geometry would lead to reductions in risk of injury in minivans.[22] The rear rows in minivans may contain captain chairs, which provide a seat and seat belt geometry that may provide better protection than traditional bench seating.[23]

Given the more severe nature of the crashes in the NASS-CDS and FARS cohort (all were tow-away crashes compared with less than one-third of PCPS crashes), we observed a much higher proportion of crashes of both vehicles that involved a rollover (11.0% for minivans and 21.9% for SUV) than were observed in the PCPS population, which were not restricted to tow-away crashes. The rollover crashes accounted for 37% of the minivan fatalities and 66% of the SUV fatalities, indicating that the primary causation scenario for fatal injuries in SUVs involves rollover. Consequently, adjustment for vehicle rollover in the NASS-CDS and FARS cohort explained a large portion of the association between fatality risk and vehicle type (minivan versus SUV adjusted OR climbed from 0.76 to 1.19 after adjustment for rollover).

Our analyses had limitations. We were not able to study or estimate the relative risk of being in a crash, but rather the relative risk of injury given that a crash had occurred. Specific changes in the SUV and minivan fleets over time are addressed globally in the multivariate analyses by adjusting for model year. The specific model year in which particular "cross-over" SUVs that are constructed more like a passenger car than a light truck were introduced was not explicitly captured in this approach. Individual comparisons of specific SUV models with specific minivan models may result in different findings. The PCPS study obtained nearly all of its data via telephone interview with the driver/parent of the child and is therefore subject to potential misclassification, particularly the over-reporting of restraint use by children who were, in fact, unrestrained. Sensitivity analyses determined that over 70% of the unrestrained SUV or minivan passengers would have to be misclassified in order for the difference in risk between SUV and minivan passengers to be explained by misclassification alone. This does not appear plausible. In addition, ongoing comparisons of driver reports of child restraint use and seating positions with evidence from crash investigations, performed as part of the PCPS research project, show a high degree of agreement ($\kappa = 0.99$ for seat row; $\kappa = 0.74$ for restraint use). This degree of agreement is similar to that found in previous research of NASS-CDS data comparing restraint use reported by CDS investigators with that reported by the police.[23] Surveillance data of the nature presented in this study cannot detect precise injury mechanisms. Therefore, more detailed information on the nature and severity of the injuries is needed to further understand how vehicle type and crash characteristics such as rollover lead to specific types of injuries that may be prevented. Finally, this study measured non-fatal and fatal crash injury risk to occupants of the two vehicle types and did not attempt to measure the additional risk of either vehicle type to other vulnerable road users such as pedestrians, cyclists, and occupants of other vehicles involved in the crash. Accounting for these other sources of risk would influence the evaluation of the overall relative safety between these two vehicle types. This was outside the scope of this research, but should be considered in future analyses.

Key points

- Sale of sport utility vehicles (SUVs) is the fastest growing segment of the motor vehicle market in the USA, and sales of minivans have proportionately decreased.
- SUVs have shown an increased tendency to rollover in the event of a crash, resulting in relatively high fatality rates compared with other vehicles.
- Risk of injury to child passengers in SUVs is similar to that in passenger cars in non-fatal crashes, and lower than in passenger cars in crashes in which someone dies.
- This study found a significant crude reduction in risk for child passengers in minivans versus SUVs for both non-fatal (OR = 0.55, 95% CI 0.38 to 0.80) and fatal (OR = 0.58, 95% CI 0.38 to 0.87) injuries.
- Child passengers in minivans were less likely to suffer a non-fatal injury than those in SUVs, after adjustment for child, driver, and vehicle factors (adjusted OR = 0.56, 95% CI 0.38 to 0.82). Adjustment for the same factors resulted in no significant difference in fatal injury risk between vehicle types.
- Child passengers are well protected in both SUVs and minivans, although there may be important safety differences leading to a reduction in non-fatal injuries to child passengers in minivans compared with SUVs.

CONCLUSIONS

Consumers choosing between an SUV and a minivan as a family vehicle should consider the safety of child occupants in addition to other parameters such as fuel economy, storage, and seating configurations. Our results suggest that there may be important differences in the safety of children in these two vehicle types, leading to a decreased risk of non-fatal injury to children seated in minivans compared with SUVs. The increased tendency for SUVs to rollover contributes to a higher overall risk of death of children in these vehicles during more serious crashes. Continued manufacturer improvements that reduce the risk of rollover in SUV crashes, such as electronic stability control and other crash prevention technology, should result in fewer child injuries and deaths.

Acknowledgements: We thank the State Farm Mutual Automobile Insurance Company for their commitment, partnership, and financial support of the Partners for Child Passenger Safety (PCPS) program. We also thank the many State Farm policyholders who consented to participate in PCPS.

Competing interests: None.

REFERENCES

1. **United States Environmental Protection Agency (EPA)**. Light-duty automotive technology and fuel economy trends: 1975 through 2007—appendix D: data stratified by vehicle type. http://www.epa.gov/oms/cert/mpg/fetrends/420r07008d.pdf (accessed 13 Oct 2008)

Inj Prev: first published as 10.1136/ip.2008.019224 on 3 February 2009. Downloaded from http://injuryprevention.bmj.com/ on June 9, 2023 by guest. Protected by copyright.

2. **National Highway Safety Transportation Administration (NHTSA)**. *Initiatives to address the mitigation of vehicle rollover*. Washington DC: NHTSA, 2003.
3. **National Highway Safety Transportation Administration (NHTSA)**. Technical report: characteristics of fatal rollover crashes. Washington DC: NHTSA, 2002; DOT HS 809 438.
4. **Wenzel TP,** Ross M. The effects of vehicle model and driver behavior on risk. *Accid Anal Prev* 2005;**37**:479–94.
5. **Kockelman KM,** Kweon Y-J. Driver injury severity: an application of ordered probit models. *Accid Anal Prev* 2002;**34**:313–21.
6. **Daly L,** Kallan MJ, Arbogast KB, *et al*. Risk of injury to child passengers in sport utility vehicles. *Pediatrics* 2006;**117**:9–14.
7. **National Highway Safety Transportation Administration (NHTSA)**. Child passenger fatalities and injuries, based on restraint use, vehicle type, seat position, and number of vehicles in the crash. Washington DC: NHTSA, 2005; DOT HS 809 784.
8. **Durbin DR,** Bhatia E, Holmes JH, *et al*. Partners for Child Passenger Safety: a unique child-specific crash surveillance system. *Accid Anal Prev* 2001;**33**:407–12.
9. **Association for the Advancement of Automotive Medicine (AAAM)**. *Abbreviated Injury Scale (AIS) 1990: update 98*. Barrington, IL: AAAM, 1998.
10. **Insurance Institute for Highway Safety, Highway Loss Data Institute**. VINDICATOR Version 2008 6.04. Arlington, VA: Highway Loss Data Institute, 2007.
11. **Highway Loss Data Institute**. *Technical appendix*. Arlington, VA: Highway Loss Data Institute, 2006.
12. **Survey Methodology Program, Survey Research Center, Institute for Social Research, University of Michigan**. Imputation and Variance Estimation Software (IVEware). Ann Arbor, MI: University of Michigan, 2007.
13. **Elliott MR,** Kallan MJ, Durbin DR, *et al*. Effectiveness of child safety seats vs. seat belts in reducing risk for death in children in passenger vehicle crashes. *Arch Pediatr Adolesc Med* 2006;**160**:617–21.
14. **Binder DA.** On the variances of asymptotically normal estimators from complex surveys. *Int Stat Rev* 1983;**51**:279–92.
15. **Greenland S.** Dose-response and trend analysis in epidemiology: alternatives to categorical analysis. *Epidemiology* 1995;**6**:356–65.
16. **Rivara FP,** Cummings P, Mock C. Injuries and death of children in rollover motor vehicle crashes in the United States. *Inj Prev* 2003;**9**:76–80.
17. **Kallan MJ,** Arbogast KB, Durbin DR. Effect of model year and vehicle type on rollover crashes and associated injuries to children. *Annu Proc Assoc Adv Automot Med* 2006;**50**:171–84.
18. **National Highway Safety Transportation Administration (NHTSA)**. Table 37: vehicles involved in crashes by vehicle type, rollover occurrence, and crash severity. *Traffic Safety Facts 2006*. Washington DC: NHTSA, 2007.
19. **Dang JN.** Statistical analysis of the effectiveness of electronic stability control (ESC) systems: final report. *NHTSA Technical Report*. Washington DC: NHTSA, 2007;DOT HS 810 794.
20. **Farmer CM.** Effects of electronic stability control: an update. *Traffic Inj Prev* 2006;**7**:319–24.
21. **Walz MC.** Trends in the static stability factor of passenger cars, light trucks, and vans. *NHTSA Technical Report*. Washington DC: NHTSA, 2005;DOT HS 809 868.
22. **Arbogast KB,** Chen I, Nance ML, *et al*. Predictors of pediatric abdominal injury risk. *Stapp Car Crash J* 2004;**48**:479–94.
23. **Schiff MA,** Cummings P. Comparison of reporting of seat belt use by police and crash investigators: variation in agreement by injury severity. *Accid Anal Prev* 2004;**36**:961–5.

Inj Prev: first published as 10.1136/ip.2008.019224 on 3 February 2009. Downloaded from http://injuryprevention.bmj.com/ on June 9, 2023 by guest. Protected by copyright.