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Booster Seat Effectiveness Estimates Based on CDS and State Data

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16. Abstract

Statistical analyses based on NASS CDS data from 1998-2008 and 17 combined years of State data from Kansas, Washington, and Nebraska estimate the effects of early graduation from child restraint seats to booster seats and of early graduation from booster seats to lap and shoulder belts. The principal findings are that among 3- and 4-year-olds there is evidence of increased risk of injury when restrained in booster seats rather than with the recommended child restraints. This increase depends on injury severity, and may be as large as 27 percent for non-disabling to fatal injuries. This effect may be more pronounced in the 3-year-olds, although sample sizes are too small to draw statistical conclusions. Among 4- to 8-year-olds there is strong evidence of reduced risk of injury when restrained by booster seats rather than lap and shoulder belts. The magnitude of this effect for the combined database is a 14 percent reduction in risk of any type of injury, but the effect varies depending on data source and injury severity. Estimates varied from no effect to a 45 percent reduction of MAIS ≥ 2 injuries based on CDS data.

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Introduction:

Booster seats are recommended to improve seat belt fit for children from age 4 to at least 8, or until they reach a height of 4 feet 9 inches. Early graduation from booster seats to adult belts may present safety risks to children involved in motor vehicle crashes. By lifting the child, booster seats provide a better fit for the shoulder strap and move the lap belt lower on the child's body. If the shoulder strap is too high, it may do a poor job of containment or may be removed by the child due to discomfort. A lap belt that is positioned too high may fail to engage the pelvis and instead cause internal injury to the abdomen.

Forward-facing (convertible or combination) child seats are recommended for children age 1 to 4, or until they reach 40 lbs. Early graduation from child restraint seats (CRS) to booster seats may also present safety risks. Child restraint seats may offer more lateral support and better containment for smaller children. This report uses the double-pair comparison to evaluate the effects of both types of early graduation by estimating reduction in injury for children age 4 to 8 in booster seats compared to adult belts, and children age 3 and 4 in child restraint seats compared to booster seats.

Methods:

The effectiveness of booster seats in preventing injury was estimated using data from the Crashworthiness Data System (CDS) and from three States that record the use of booster seats in their reported crash data as a distinct category separate from other types of child safety seats. Unfortunately, the Fatality Analysis Reporting System (FARS) and many of the States in the State Data System (SDS) system do not record the use of booster seats as a distinct category. Cases were selected at the vehicle level based on the following criteria:

- Vehicle has a driver's side air bag;
- Driver (age 14 to 97) wearing an adult belt (lap and shoulder belts);
- Child passenger(s) age 4 to 8 in the second or third row of seating in either a booster seat, or an adult seat belt (lap and shoulder belts); or
- Child passengers age 3 or 4 in the second or third row of seating in either a booster seat or a child restraint seat;
- Injury severity information for both the driver and the child passenger(s).

In these analyses, each child in the selected vehicle is paired with the adult driver of the vehicle. For each injury cutoff, each injured member of these pairs who meets or exceeds the injury cutoff is placed into one of four possible groups in a 2x2 table (see Table 1). If there is more than one child in a vehicle, the driver of that vehicle will be counted multiple times, once for each child. The purpose of arranging the data this way is to conduct a double-pair comparison, a method that allows one to estimate the effect on risk of injury of a single binary treatment factor (in this case booster seats versus adult belts) without having to model the diverse confounding factors or exposure rates that may be affecting injury risk.[1] Instead, the driver of the vehicle is used as a comparison "control" to account for exposure, severity and other confounding factors. Since drivers are used as a comparison control, only vehicles with driver's side air bags and belted drivers were included in order to standardize the control group and avoid potential bias.

The effectiveness estimates are given in percentage injury reduction versus belts and come from comparing the ratio of injured children to injured drivers when the children are in booster seats to the ratio of injured children to injured drivers when the children are in adult belts. For KABC (any injury type) in Table 1, as an example:

$$risk\ ratio = \frac{(\#\ of\ injured\ kids\ in\ boosters\ /\ \#\ of\ injured\ drivers\ of\ kids\ in\ boosters)}{(\#\ of\ injured\ kids\ in\ belts\ /\ \#\ of\ injured\ drivers\ of\ kids\ in\ belts)}$$

$$risk\ ratio = \frac{(1493/2275)}{(4056/5298)} = 0.86$$

$$\%\ injury\ reduction = (1 - risk\ ratio) = (1 - 0.86) = 14\%$$

This means that in the sample children in booster seats were 14 percent less likely to sustain injury than children in adult belts when using driver injury as a control.

Once an effectiveness estimate is computed, two different confidence intervals are constructed. The confidence intervals indicate the reliability of the effectiveness estimates and are more informative in this application than simple p-values. They give the range in which the true unknown value of the parameter of interest (here the percentage injury reduction) is likely to be based on the sample taken. Both intervals are computed at the 95 percent confidence level.

The first confidence interval is a Cochran-Mantel-Haenszel (CMH) interval based on the chi-squared test of independence. This method is analogous to those used in previous NHTSA reports for analyzing double-pair comparison data. It is described in the SAS/STAT 9.1 documentation and has several drawbacks in this application, the largest of which is that we are forced to "throw out" information. The chi-squared analysis does not take into account the driver/child pairs, but combines the data without regard to vehicle. Also, this method assumes that the underlying distribution is chi-squared when constructing the intervals. Because of these drawbacks, one should consider the CMH method a conservative approach that is likely to overestimate the variance of the risk ratios, and therefore provide confidence intervals that may be too large.

A more sophisticated method of evaluating the reliability of the risk ratio estimates is given by the stratified bootstrap.[2 3] This is a resampling method that takes into account factors that the chi-squared method ignores. It preserves the driver/child pairs by vehicle and it stratifies the sample based on type of restraint. It makes no a priori assumptions about the distribution of the response and instead uses the empirical distribution generated by the data itself. With this

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[1] Evans, L. (1986). Double Pair Comparison - A New Method to Determine How Occupant Characteristics Affect Fatality Risk in Traffic Crashes, *Accident Analysis and Prevention*, Vol. 18, pp. 217-227.

[2] Efron, B., and Tibshirani, R. (1994). *An Introduction to the Bootstrap.* Boca Raton, FL: Chapman and Hall.

[3] Pons, O. (2007). Bootstrap of Means Under Stratified Sampling, *Electronic Journal of Statistics*, Vol. 1, pp. 381-391.

method we consider the population of vehicles in which children are in booster seats to be different from the population of vehicles in which children are restrained by adult belts, and further posit that we can post-stratify the sample accordingly. Because this method assumes that we can remove between strata variance, it should be considered a more liberal approach that is likely to underestimate the variance of the risk ratios and therefore provide confidence intervals that may be too small. Both of these methods simply compute variance; they will have no effect on the point estimates derived by the double-paired comparisons.

Results: Booster Seats Versus Adult Belts in Children Age 4 to 8

Combined CDS and State Data

CDS data for the last 10 calendar years (1999-2008) and State data from Washington (2002-2007), Kansas (2003-2007), and Nebraska (2002-2007) were included in the analysis.

Table 1 shows the data and results for each of four different injury cutoffs. The injury scale is an on-the-scene police-reported measure of injury. "K" is killed, "A" is disabling injury, "B" is non-disabling injury and "C" is possible injury. Each estimate considers injuries of a given severity level or higher – i.e., fatalities are included in every estimate, disabling injuries are included in all but the "K" estimate, and so on. The "KABC" category therefore includes all recorded injuries. Since this variable is determined by responding police officers, it may have some repeatability and/or validity issues; the same injury might be coded "B" in one case and "C" in another.

**Table 1: Effectiveness of Booster Seats Versus Seat Belts
Combined Unweighted CDS and State Data Results
(KABC Scale)**

Injury Level	Child Restrained By	# of Injured Drivers[1]	# of Injured children[2]	% Fewer Injuries vs. Belts	95% CMH Chi-Square Interval	95% Bootstrap Confidence Interval
KABC	Adult Belt	**5298**	**4056**			
KABC	Booster	**2275**	**1493**	14%	(7%, 21%)*	(10%, 19%)*
KAB	Adult Belt	**1700**	**1387**			
KAB	Booster	**594**	**474**	2%	(-13%, 15%)	(-8%, 13%)
KA	Adult Belt	**340**	**231**			
KA	Booster	**107**	**65**	11%	(-27%, 37%)	(-22%, 35%)
K	Adult Belt	**32**	**23**			
K	Booster	**11**	**8**	-1%	#	#

[1] Drivers: Age 14 to 97

[2] Passengers: Age 4 to 8; 2nd & 3rd row outboard

Insufficient sample size for statistical inferences

* Statistically significant reduction of injury for boosters versus adult belts

This analysis shows a significant 14-percent reduction (the 95% intervals do not include 0%) in all injury types for children in booster seats compared to children in adult belts. The χ^2 p-value associated with this estimate is <.0001, which along with the associated confidence intervals can be taken as strong statistical support for the effectiveness of booster seats in reducing all injury. The stricter injury cutoffs do not show significant reductions, but it should be noted that the sample sizes decrease quickly when only more severe injuries are included. It is also important to consider that more than half of the sample comes from Washington State data. Notice that in this table both methods of confidence interval construction result in the same conclusions on the significance of the point estimates. Although there are a few cases in other tables where the bootstrap intervals will identify an estimate as significant while the CMH interval will not, in general the two methods result in similar statistical conclusions. However, the bootstrap intervals are more likely to reflect the actual range of expected safety benefits since they retain the driver/passenger pairs in the variance estimation. Also, the CDS data used here is unweighted. This will be discussed in the following section on CDS data.

CDS:

Table 2 shows the results from conducting the same analysis on only the CDS data. These results are based on unweighted CDS data. The most severe injury cutoff, fatal injury, did not have a sufficient sample size to make any statistical inference.

Table 2: Effectiveness of Booster Seats Versus Seat Belts (KABC)
1999-2008 Unweighted CDS Data

Injury Level	Child Restrained By	# of Injured Drivers[1]	# of Injured children[2]	% Fewer Injuries vs. Belts	95% CMH Chi-Square Interval	95% Bootstrap Confidence Interval
KABC	Adult Belt	**505**	**425**			
KABC	Booster	**157**	**98**	26%	(2%, 44%)*	(13%, 40%)*
KAB	Adult Belt	**313**	**240**			
KAB	Booster	**79**	**50**	17%	(-22%, 44%)	(-3%, 44%)
KA	Adult Belt	**163**	**111**			
KA	Booster	**43**	**23**	21%	(-38%, 55%)	(-8%, 69%)
K	Adult Belt	**8**	**6**			
K	Booster	**2**	**1**	33%	#	#

[1] Drivers: Age 14 to 97

[2] Passengers: Age 4 to 8; 2nd & 3rd row outboard

Insufficient sample size for statistical inferences

* Statistically significant reduction of injury for boosters versus adult belts

Using only the unweighted CDS data gives much larger effectiveness estimates for booster seat effectiveness, with a significant 26-percent reduction in overall injury (χ^2 p-value =

.04). Although the estimates from the stricter injury cutoffs are not significant, they are of similar magnitude.

When interpreting these results it is important to note that the data used is unweighted. Customarily, CDS analyses are based on weighted, not unweighted data. The weighting system for CDS data is designed to give nationally representative rates of injury per 100 crashes. As a result, larger weights are given to non-injury crashes which are under-sampled by design. However, since a criterion for inclusion in this double-paired comparison analysis is that a vehicle occupant is injured in the crash, the population of interest is less influenced by low-severity crashes. Also, by using the driver as a control we shift the focus of the analysis from estimating injuries per crash to comparative likelihood of injury for the driver given that a child has been injured in the crash. Thus, at least the first-order bias in analyses of injury rates based on unweighted data is not present in the double-paired comparison analysis – and under those circumstances, the greater precision of the analysis based on unweighted data may compensate for the second-order biases introduced by not weighting. Ideally (when there is sufficient data), the weighted and unweighted analyses will have consistent results. In this situation where there are few data points, the results from the weighted data are inconsistent both internally and with the results from the unweighted data. For example, for the two largest injury cutoffs the point estimates of percent injury reduction from the weighted data are ("KABC": -1%, "KAB": -46%). These estimates were not significant, and had very large confidence intervals. The CDS analysis cannot be considered authoritative until sample sizes are sufficient to give fairly consistent results from both the weighted and the unweighted data. Until then, the unweighted results are likely more accurate than the weighted results. Accordingly, unweighted data are used in the reported analyses that include CDS data.

CDS is the only data source that also reports Maximum Abbreviated Injury Scores (MAIS) for each observation. This is a score that is assigned by CDS investigators after reviewing case files and patients' medical records, based on a list that assigns a specific AIS rating to each particular type of injury. It should be less susceptible to the validity and repeatability concerns than the KABC scale. Table 3 gives results for each of five different injury levels based on MAIS; MAIS $\geq$ 1 (minor), MAIS $\geq$ 2 (moderate), MAIS $\geq$ 3 (serious), MAIS $\geq$ 4 (severe), and fatal injury.

Table 3: Effectiveness of Booster Seats Versus Seat Belts (MAIS) 1999-2008 Unweighted CDS Data						
Injury Level	**Child Restrained By**	**# of Injured Drivers[1]**	**# of Injured children[2]**	**% Fewer Injuries vs. Belts**	**95% CMH Chi-Square Interval**	**95% Bootstrap Confidence Interval**
MAIS ≥ 1	Adult Belt	**552**	**374**			
MAIS ≥ 1	Booster	**202**	**115**	16%	(-9%, 35%)	(3%, 31%)*
MAIS ≥ 2	Adult Belt	**96**	**61**			
MAIS ≥ 2	Booster	**40**	**14**	45%	(-10%, 72%)	(16%, 84%)*
MAIS ≥ 3	Adult Belt	**42**	**28**			
MAIS ≥ 3	Booster	**18**	**9**	25%	#	#
MAIS ≥ 4	Adult Belt	**16**	**13**			
MAIS ≥ 4	Booster	**9**	**2**	73%	#	#
Fatal	Adult Belt	**9**	**8**			
Fatal	Booster	**6**	**2**	63%	#	#
[1] Drivers: Age 14 to 97						
[2] Passengers: Age 4 to 8; 2nd & 3rd row outboard						
# Insufficient sample size for statistical inferences						
* Statistically significant reduction of injury for boosters versus adult belts						

Although the bootstrap confidence intervals for the two least severe injury cutoffs do not contain 0, neither the χ^2 test nor the CMH interval confirmed this significance. Since the bootstrap intervals are likely to underestimate variance, these results should be treated somewhat skeptically (note that confidence intervals for these estimates are quite large).

As with the KABC scale, a corresponding analysis using the weighted CDS data yielded point estimates for injury reduction that were not consistent with the unweighted estimates. The confidence intervals that were obtained using the weighted data and sampling structure were again extremely large. For example, the point estimate and 95-percent interval for MAIS ≥ 2 is (-45% [-1679%, 88%]). Given the inconsistency of the weighted and unweighted estimates, it is impossible to state with certainty that booster seats are more effective than adult belts at reducing injury in the CDS sample.

State Data:

Washington, Kansas, and Nebraska are the three State data files in NHTSA's State Data System that have reported booster seat use in crashes and have accumulated enough data to conduct statistical analyses. All of the State data files are unweighted data. The results for the individual State data files are given in Tables 4-6 below.

Table 4: Effectiveness of Booster Seats Versus Seat Belts (KABC)
2002-2007 Washington State Data

Injury Level	Child Restrained By	# of Injured Drivers[1]	# of Injured children[2]	% Fewer Injuries vs. Belts	95% CMH Chi-Square Interval	95% Bootstrap Confidence Interval
KABC	Adult Belt	**3026**	**1915**			
KABC	Booster	**1486**	**838**	11%	(1%, 20%)*	(4%, 18%)*
KAB	Adult Belt	**677**	**499**			
KAB	Booster	**303**	**237**	-6%	(-30%, 14%)	(-23%, 14%)
KA	Adult Belt	**72**	**32**			
KA	Booster	**34**	**15**	1%	(-107%, 52%)	(-51%, 91%)
K	Adult Belt	**7**	**8**			
K	Booster	**4**	**5**	-9%	#	#

[1] Drivers: Age 14 to 97 Years

[2] Passengers: Age 4 to 8; 2nd & 3rd row outboard

Insufficient sample size for statistical inferences

* Statistically significant reduction of injury for boosters versus adult belts

Of the three States, Washington has the largest sample and shows a significant 11-percent reduction of injury at the least severe injury cutoff. Although other estimates in this table suggest a slight negative effect, the large 95-percent confidence intervals for these estimates show them to be unreliable and they should be considered to show no effect.

Kansas State data (Table 5 below) gives similar estimates for the benefit of booster seats over adult belts, with an 11-percent injury reduction at the least severe injury cutoff. There appears to be a large increase in severe (KA) injuries associated with booster seats in this sample, but examination of the confidence intervals shows this estimate to be unreliable. Note that the bootstrap interval, based on the empirical distribution, is centered near zero.

Table 5: Effectiveness of Booster Seats Versus Seat Belts (KABC) 2003-2007 Kansas State Data						
Injury Level	**Child Restrained By**	**# of Injured Drivers[1]**	**# of Injured children[2]**	**% Fewer Injuries vs. Belts**	**95% CMH Chi-Square Interval**	**95% Bootstrap Confidence Interval**
KABC	Adult Belt	**1171**	**875**			
KABC	Booster	**425**	**283**	11%	(-6%, 25%)	(1%, 23%)*
KAB	Adult Belt	**516**	**340**			
KAB	Booster	**149**	**99**	-1%	(-35%, 24%)	(-21%, 26%)
KA	Adult Belt	**71**	**34**			
KA	Booster	**19**	**13**	-43%	(-323%, 37%)	(-118%, 91%)
K	Adult Belt	**12**	**5**			
K	Booster	**4**	**2**	-20%	#	#
[1] Drivers: Age 14 to 97 Years						
[2] Passengers: Age 4 to 8; 2nd & 3rd row outboard						
# Insufficient sample size for statistical inferences						
* Statistically significant reduction of injury for boosters versus adult belts						

The third State to provide data on booster seat use in crash data is Nebraska. It has the smallest sample size of any of the data sources.

Table 6: Effectiveness of Booster Seats Versus Seat Belts (KABC) 2002-2007 Nebraska State Data						
Injury Level	**Child Restrained By**	**# of Injured Drivers[1]**	**# of Injured children[2]**	**% Fewer Injuries vs. Belts**	**95% CMH Chi-Square Interval**	**95% Bootstrap Confidence Interval**
KABC	Adult Belt	**596**	**841**			
KABC	Booster	**207**	**274**	6%	(-16%, 24%)	(-2%, 15%)
KAB	Adult Belt	**194**	**308**			
KAB	Booster	**63**	**88**	12%	(-27%, 39%)	(-9%, 40%)
KA	Adult Belt	**34**	**54**			
KA	Booster	**11**	**14**	20%	(-97%, 67%)	(-93%, 109%)
K	Adult Belt	**5**	**4**			
K	Booster	**1**	**0**	#	#	#
[1] Drivers: Age 14 to 97 Years						
[2] Passengers: Age 4 to 8; 2nd & 3rd row outboard						
# Insufficient sample size for statistical inferences						

None of the estimates from the Nebraska data are statistically significant, but the point estimates show a possible injury reduction for the less severe cutoffs with booster seat use.

Results: CRS versus Booster Seats in Children Age 3-4

The analyses presented in Table 7 below compare the effectiveness of child restraint seats to booster seats in 3- and 4-year-old child passengers and use the same data sources and years of collection as the adult belt comparison. Because the sample sizes are smaller for this narrow age range, the only estimates presented will be for the combined results from the four data sources. In this analysis the injury risk for a child in a child restraint seat is compared to the injury risk of a child in a booster seat. A positive estimate indicates that the booster seats are less effective than child restraint seats at reducing injury in the sample.

Table 7: Effectiveness of Booster Seats Versus Child Restraint Seats
Children aged 3-4
Combined Unweighted CDS and State Data Results

Data Source	Child Restrained By	# of Injured Drivers[1]	# of Injured children[2]	% More Injuries in Boosters	95% CMH Chi-Square Interval	95% Bootstrap Confidence Interval
Combined (KABC)	CRS	**3050**	**1614**			
	Booster	**1086**	**627**	9%	(-3%, 22%)	(0, 18%)
Combined (KAB)	CRS	**713**	**412**			
	Booster	**310**	**228**	27%	(3%, 57%)*	(6%, 46%)*
Combined (KA)	CRS	**128**	**48**			
	Booster	**75**	**39**	39%	(-17%, 131%)	(-33%, 85%)

[1] Drivers: Age 14 to 97 Years

[2] Passengers: Age 3-4; 2nd & 3rd row outboard

* Statistically significant increase in injury for boosters versus CRS

These results appear to confirm expectations that child restraint seats will be more effective at reducing injury than booster seats. The larger estimates are more volatile (larger confidence intervals) and would benefit from more years of data collection and a larger sample.

Three and 4-year-olds from the above table were analyzed separately to explore a possible age effect within the group. Since 4 is the age of recommended graduation, one might expect to see a larger comparative benefit to the 3-year-olds than the 4-year-olds. Again to preserve adequate sample size only combined results are given and the strictest injury cutoff is omitted. Table 8 presents results for the 3-year-olds and Table 9 presents results for the 4-year-olds.

Table 8: Effectiveness of Booster Seats Versus Child Restraint Seats Children Age 3 Combined Unweighted CDS and State Data Results						
Data Source	**Child Restrained By**	**# of Injured Drivers[1]**	**# of Injured children[2]**	**% More Injuries in Boosters**	**95% CMH Chi-Square Interval**	**95% Bootstrap Confidence Interval**
Combined (KABC)	CRS	**1837**	**919**			
	Booster	**452**	**259**	15%	(-4%, 36%)	(0%, 30%)
Combined (KAB)	CRS	**427**	**234**			
	Booster	**136**	**94**	26%	(-7%, 72%)	(0%, 71%)
Combined (KA)	CRS	**86**	**36**			
	Booster	**34**	**18**	26%	(-37%, 152%)	(-71%, 84%)
[1] Drivers: Age 14 to 97 Years						
[2] Passengers: Age 3; 2nd & 3rd row outboard						

Table 9: Effectiveness of Booster Seats Versus Child Restraint Seats Children Age 4 Combined Unweighted CDS and State Data Results						
Data Source	**Child Restrained By**	**# of Injured Drivers[1]**	**# of Injured children[2]**	**% More Injuries in Boosters**	**95% CMH Chi-Square Interval**	**95% Bootstrap Confidence Interval**
Combined (KABC)	CRS	**1223**	**722**			
	Booster	**641**	**381**	1%	(-14, 18%)	(-11%, 12%)
Combined (KAB)	CRS	**286**	**178**			
	Booster	**174**	**134**	24%	(-8%, 66%)	(-16%, 38%)
Combined (KA)	CRS	**42**	**12**			
	Booster	**41**	**21**	79%	(-22%, 311%)	(-124%, 171%)
[1] Drivers: Age 14 to 97 Years						
[2] Passengers: Age 4; 2nd & 3rd row outboard						

The results for any type of injury show a large difference between the 3- and 4-year-olds, with the older children showing almost no difference in injury rate between the two restraint types and the 3-year-olds showing a 15-percent reduction. The more serious KAB injury cutoff shows similar effectiveness for CRS in both the 3 and 4-year-olds, while the KA injury cutoff does not have sufficient sample size to compare the two ages meaningfully. The results for any type of injury support the recommendation for graduation at 4 years or about 40 pounds in general, although it may be the case that more severe injuries are better prevented by CRS even at 4 years old.

Discussion:

When analyzed collectively the data shows a 14-percent reduction in overall injuries for children in booster seats relative to children in adult belts. When the analyses are restricted to more severe injuries, sample sizes are insufficient to make reliable inference about the effectiveness of booster seats. When the available data sources are examined individually, the results appear fairly consistent.

The unweighted CDS analysis suggests that booster seats may be substantially more effective than adult belts at preventing MAIS $\geq$ 2 injuries in children aged 4 to 8. This 45-percent injury reduction estimate, although different from any of the estimates generated from the State data or the CDS KABC data, is very similar to the results from the recent Children's Hospital of Philadelphia (CHOP) study on booster seat effectiveness[4] that used insurance claims data from State Farm to estimate a statistically significant 45-percent reduction in MAIS $\geq$ 2 injuries for children age 4 to 8. It is important to consider limitations of the data and the wide confidence intervals around these estimates. The 95-percent bootstrap CI for the 46 percent estimate from CDS is (16%, 84%) and the 95 percent CI (method of interval construction is not known) for the 45 percent estimate from CHOP is (4%, 68%). Furthermore, the point estimate derived from weighted CDS data is actually negative. Limitations of the data could explain why the estimates differ from one another and are discussed in the following section.

While the analysis comparing booster seats to child restraint seats in children 3 and 4 years old needs more data before drawing any firm statistical conclusions, it suggests that there is an increase in overall injury for this age group when restrained by booster seats rather than CRS. The point estimate is a 9-percent reduction and the 95 percent confidence interval is (0%, 18%) for the bootstrap method and (-3%, 22%) for the CMH chi-square interval method. This effect may be more pronounced for the 3-year-olds than for the 4-year-olds in the sample.

Limitations:

Several aspects of the sampling and coding of the data used in this analysis could introduce bias to the estimates. Due to sampling methods and data sources the results cannot be considered nationally representative or randomly sampled.

For the State data, the injury coding may be inconsistent or inaccurate. Notice that in the Nebraska data there are more injured child passengers than injured drivers, a unique and

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[4] Arbogast, K. B., Jermakian, J. S., Kallan, M. J., & Durbin, D. R (2009). Effectiveness of Belt-Positioning Booster Seats: An Updated Assessment, *Pediatrics*, Vol. 124, pp. 1281-1286, http://pediatrics.aappublications.org/cgi/content/abstract/124/5/1281.

somewhat unlikely scenario since one of the inclusion criteria for children is that they are seated in the second or third row. This could reflect a bias on the part of injury coders for scoring child injuries as more severe than adult injuries, or possibly an underreporting of uninjured child passengers.

Estimates of booster seat effectiveness rely heavily on proper coding of the injured child's restraint type. Error in this variable could easily bias the estimates. To assess the reliability of this variable for the different data sources, the restraint use rates from these sources was compared to the use rates from 2006 and 2007 National Survey of the Use of Booster Seats (NSUBS).[5] Use rates were determined for children 4 to 7 in each of the four data sources used in this analysis and are reported along with the NSUBS rates in Tables 10 and 11 below. NSUBS is a nationally representative and randomly selected sample, while the CDS (unweighted) data and State data are not nationally representative and are pre-selected for crash involvement. This could bias the use rates if, for example, drivers who get into crashes tend to engage in riskier behavior and are therefore less likely to place their child passengers in proper restraints. Accordingly, slight departures from the NSUBS rates should not be considered strong evidence that the coding of booster seat use in crash data is unreliable or invalid.

Table 10: Comparison Child Restraint Use Rates
2006 Age 4 to 7

Source:	NSUBS	CDS	STWA	STKS	STNE
Booster Seat:	**41%**	33%	40%	22%	24%
Seat Belt	**33%**	49%	46%	49%	44%
Child Safety Seat	**17%**	6%	12%	24%	26%
Unrestrained	**9%**	12%	1%	5%	7%

Table 11: Comparison of Child Restraint Use Rates
2007 Age 4 to 7

Source:	NSUBS	CDS	STWA	STKS	STNE
Booster Seat:	**37%**	36%	47%	40%	20%
Seat Belt	**35%**	42%	39%	29%	49%
Child Safety Seat	**13%**	8%	13%	27%	24%
Unrestrained	**15%**	14%	1%	5%	8%

These tables show a fair level of overall agreement, but also some inconsistencies in use rates among the different data sources. There are two main concerns; the first is that child safety seats such as convertible seats are being confused with booster seats and vice versa. This could be true for Nebraska, which shows lower than expected rates for booster seats and higher than expected rates for child safety seats for both years. Nebraska reported that 6 percent and 5

[5] NHTSA. (2009, May). *Booster Seat Use in 2008.* Traffic Safety Facts Research Note. DOT HS 811 121. Washington, DC: National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/Pubs/811121.PDF.

percent of the 8-year-old children in their 2006 and 2007 data files respectively were restrained in child safety seats, or convertible and infant seats, a rather implausible rate for this age group. The second concern is that unrestrained children are being falsely reported as restrained. This seems to be a possibility for the State data sources, especially Washington, which reported few unrestrained children. Although these inconsistencies will affect the accuracy of the estimates, they should not be sufficient cause to invalidate the results of analyses using this data.

Although there are shortcomings and caveats to the data used in this analysis, it is the best data at hand to evaluate the relative benefit of booster seat use in real-world crashes. These analyses will benefit from more years of collection and inclusion of other States as the data become available.

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