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Effectiveness of Booster Seats Compared With No Restraint or Seat Belt Alone for Crash Injury Prevention

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Abstract

Objectives—The objective was to evaluate the effectiveness of belt-positioning booster seats, compared with no restraint use and with seat belt use only, during motor vehicle crashes among U.S. children.

Methods—This was a retrospective matched cohort study with data from the 1998 through 2009 National Automotive Sampling System (NASS) Crashworthiness Data System (CDS). The study sample consisted of children aged 0 to 10 years who were not seated in the front seat of the vehicle. We used Cox proportional hazards models to estimate the risk of overall, fatal, and regional body injury.

Results—Children using seat belts in belt-positioning booster seats experienced less overall injury (Injury Severity Score [ISS] > 0, adjusted risk ratio [RR] = 0.73, 95% confidence interval [CI] = 0.55 to 0.96; Abbreviated Injury Scale [AIS] score of 2 or higher, adjusted RR = 0.30, 95% CI = 0.16 to 0.58; ISS > 8, adjusted RR = 0.19, 95% CI = 0.06 to 0.56), and less injury in most body regions except the neck (adjusted RR = 4.79, 95% CI = 1.43 to 16.00) than did children with no restraint use. Children using seat belts in belt-positioning booster seats had an equal risk of injury but higher risks of neck (adjusted RR = 1.86, 95% CI = 1.02 to 3.40) and thorax (adjusted RR = 2.86, 95% CI = 1.33 to 6.15) injury than did children restrained by seat belts only.

Conclusions—Children using belt-positioning booster seats appear to experience a higher risk of AIS > 0 injury to the neck and thorax than do children using seat belts only. Future research should examine whether the observed increase in neck and thorax injuries can be attributed to improper use of booster seats.

Motor vehicle collisions (MVCs) are the leading cause of injury death among children aged 4 to 7 years in the United States.¹ Belt-positioning booster seats have been recommended as restraints for these children, who have outgrown forward-facing safety seats but are too small to properly fit in seat belts.^{2,3} By December 2008, the use of booster seats in the United States had been legislated as mandatory in 43 states and the District of Columbia.⁴

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With advocacy efforts and government legislation over the past decade,^{5,6} the prevalence of booster seat use increased from 11.5% in 2000 to 43.0% in 2008.^{7,8}

Children graduating from forward-facing safety seats may be too small to fit adult seat belts; thus, booster seats were designed to improve the fit of seat belts and to protect against potential abdominal injury caused by poorly fitting lap belts.^{9,10} The effectiveness of belt-positioning booster seats over seat belts only was first examined by Durbin et al.,^{11–13} and to date the primary evidence supporting the value of booster seats has come from a series of studies by this research group. In the recent analysis by Durbin et al., the authors replicated previous findings that booster seats reduced the risk of injury during MVCs among children aged 4 to 8 years.¹⁴ On the basis of the estimates by Durbin et al., Miller et al.¹⁵ performed a cost-outcome analysis of booster seats and found an apparent financial return on investment. However, the supportive studies for booster seat use over other types of restraint (e.g., seat belt only) have limitations. For example, most of these studies were based on regional data collected by telephone survey,^{11,12,14} and most of the data were from 1998 to 2003, when only a small proportion of parents chose to put their children in booster seats.^{11–13} Thus, the analysis needed to be replicated with the use of more recent national data. In addition, the previous findings do not appear to be consistent across different databases or for different severities of injury. A recent matched cohort study using the Fatality Analysis Reporting System (FARS) examined the effectiveness of booster seats on the risk of death, and found that seatbelts used with booster seats appeared to be no better at preventing death than seatbelts used alone.¹⁶

In our study published recently, we compared overall nonfatal and fatal injury between appropriate and inappropriate restraint use according to recommendations from the National Highway Traffic Safety Administration. For children aged 4 to 7 years, we found that those restrained by appropriate restraint (seat-positioning booster seats) experienced higher risk of nonfatal but not fatal injury than did those restrained with seat belts only.¹⁷ To further understand the effectiveness of booster seats, as a follow-up to our previous findings, we designed this study to examine the effectiveness of the combination of seat belts and belt-positioning booster seats over no restraint use and seat belts alone in preventing both fatal and nonfatal injury and both overall and regional body injury.

METHODS

Study Design

This was a retrospective cohort study using the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS). The institutional review board of the Medical College of Wisconsin (Milwaukee, WI) granted approval for this study.

Study Sample

Data from the NASS CDS from 1998 to 2009 were used for the analysis. The NASS CDS is a nationwide probability sample of police-reported MVCs in which at least one vehicle was towed from the crash scene. Twenty-four field research teams investigate approximately 5,000 MVCs per year, including information on the occupant, vehicle, crash, and environment. Details of the NASS CDS can be found elsewhere.^{18,19}

Because the purpose of the current study was to assess the effectiveness of booster seats in reducing injuries to children during MVCs, we included children aged 0 to 10 years old in the matched analysis to increase sample size. The inclusion of children aged outside the recommended age range of 4 to 7 years for booster seats, although few in number in the study sample, is warranted because the inclusion represents the “real-world” experience of

children in booster seats and is an important aspect of the effect of booster seats on MVC-related injuries among children.

In a supplemental analysis, we limited our all-subject analysis to children aged 4 to 7 years because belt-positioning booster seats have been recommended by the National Highway Traffic Safety Administration and the American Academy of Pediatrics for children aged 4 to 7 years.^{2,3} Because of differences in airbag equipment and car design, we limited our analyses on all children to only those seated in rear seats. In the NASS CDS sample from 1998 to 2009, a total of 2,476 children aged 4 to 7 years were seated in rear seats in passenger cars involved in motor vehicle crashes, representing 1,139,545 children involved in MVCs during this time period in the United States.

Variable Definitions

Information regarding demographic (e.g., age and sex), vehicle, occupant, and collision characteristics was collected for each entry. In the matched analysis, seating position was defined as rear-driver-side, rear-middle, and rear-passenger-side. Vehicle body type was defined as passenger car, SUV/van, or light pickup truck. Vehicle curb weight was categorized as <2,499 lb, 2,500 to 3,000 lb, and >3,000 lb. Model year was coded as 1987 through 1993, 1994 through 1997, 1998 through 2004, and 2005 through 2010. Collision impact was defined by the direction of primary impact in relation to the center of the front of the car, with frontal impact defined as a primary impact of no more than 45° to the left or right of the front center, a rear impact between 135° and 225° from the front center, and a side impact between 226° and 314° or 46° and 134° for left- and right-side impact, respectively. Side impacts were further classified as near- or far-side in relation to the seating position of the occupant. The severity of the collision was measured by ΔV , which was defined as the maximum change in velocity attained during the collision and the maximum crush of the vehicle exterior. Vehicle crush was categorized as 0 to 39, 40 to 59, 60 to 79, and ≥80 cm. ΔV was defined in two ways: first, it was categorized as 0 to 24, 25 to 49, and ≥50 km/hour, and second, a dichotomous variable was created for whether ΔV was missing. The second definition was created because collisions missing ΔV are likely missing this variable owing to catastrophic damage, which prevents investigators from being able to estimate ΔV . Thus, not accounting for missing ΔV would result in these collisions being excluded from the analysis. Occupants were also classified as to whether the vehicle rolled over at least one-quarter turn along its horizontal axis.

The main exposure of interest was the type of restraint used. Each child was classified as having no restraint, restrained by seat belt only (shoulder belt only), or restrained by a combination of a belt-positioning booster seat and seat belt. The three main outcomes in this study were overall injury, regional body injury, and fatal injury. For the current study, injuries were classified according to eight body regions, including the head, face, neck, thorax, abdomen and pelvis, spine, upper extremity, and lower extremity. Injury severity was classified according to the Abbreviated Injury Scale (AIS) score, which ranges from 1 (i.e., minor injury) to 6 (i.e., highly unsurvivable injury).²⁰ Because many of the injuries with an AIS score of 1 are minor (e.g., abrasions, contusions), separate categories for each body region were created for AIS 1+ (i.e., any injury) and AIS 2+ injury. Overall injury was defined as an Injury Severity Score (ISS) of more than 0. The ISS, based on the AIS, is the sum of the squares of the highest AIS severity score in each of the three most severely injured body regions. The ISS score ranges from 1 to 75 (i.e., AIS scores of 5 for each category). If any of the three scores is a 6, the score is automatically set at 75, because a score of 6 indicates unsurvivable injury.²¹ Because most children involved in MVCs sustained only minor injuries with an AIS of 1, we also defined severe injury by an ISS of more than 8 (i.e., at least one AIS 3 injury or two AIS 2 injuries with one additional

injury).²² Fatal injury was defined by outcome of treatment from emergencies or hospitals (no treatment, fatal, nonfatal).

Data Analysis

Children restrained with a combined seat belt and belt-positioning booster seat were matched to two unexposed children: one with a seat belt only and another with no restraint, on children's age, vehicle body type, and sampling weight of $\pm 2,500$. The sampling weight is calculated as the inverse of the probability of selection and is corrected to ensure that the estimated collision totals match the actual collision totals.¹⁸ The sampling weight provided in the variable RATWGT in the NASS data ranges from 0.77 to 57,870. Matching by sampling weight ensured that exposed children were matched to unexposed children of an equally severe MVC and allowed the use of unweighted analyses. Because NASS oversamples severe collisions, it is imperative that the two exposure groups have a similar probability of selection to avoid any selection biases that may occur owing to the differential chance of being in a severe collision. That is, for example, if the children in the booster seat exposure group were more likely to be in a higher-severity collision, the association between booster seat use and injury would be biased away from the null. By matching the exposure groups on sampling weight, this selection bias is minimized. Given that age and vehicle type may be very strong confounders of the association between injury and booster seat use, and that these confounding associations may not be linear, inclusion of these variables into a statistical model may not eliminate any bias resulting from the confounding (i.e., there may be residual confounding). Thus, matching was used on these characteristics to ensure that the bias was minimized.

Demographic, vehicle, occupant, and collision characteristics were compared between the exposed and unexposed groups by using chi-square tests and t-tests for categorical and continuous variables, respectively. PROC PHREG in SAS version 9.2 (SAS Institute, Cary, NC) was used to create a conditional Cox proportional hazards model, assuming an equal time at risk was used to calculate risk ratios (RRs) and associated 95% confidence intervals (95% CIs) to estimate the association between restraint type and injury risk. Models were stratified by matched set to account for the matching performed and were adjusted for whether the V for the MVC was missing and for model year.

For the supplemental analysis based on all subjects in the cohort, characteristics of the child passenger, driver, vehicle, and crash were summarized and compared by different restraint groups. Means ($\pm$ standard deviation [SD]) for continuous variables and proportions for categorical variables were compared by using t-tests and chi-square tests, respectively. The percentages of overall injury, fatal injury, and regional body injury are presented and compared by different restraint types by use of chi-square tests. Logistic regression models were used to estimate the risk of injury for belt-positioning booster seats compared with seat belts. Three sets of models were performed for each injury outcome: unadjusted model, adjusted model, and V-adjusted model. In the adjusted models, all covariates in the above matched analysis, as well as age and vehicle type, were controlled for to remove the potential effects of confounding factors. V was additionally controlled in the V-adjusted model.

Height was an important variable in that the booster recommendations were based on not just age but also height. In the matching analysis, we matched by age, which was found to be closely correlated with height according to the NASS CDS data ($p < 0.001$). In the all-subjects analysis, height was controlled in the logistic regression models to avoid potential bias, and the results remained similar (data not shown). However, we did not control for height in the final analyses because data on height were missing for more than 30% of the children in the database.

All analyses were weighted to produce nationally representative estimates. Weighted means, percentages, odds ratios (ORs), and all statistical analyses in this study were calculated by use of the survey procedure in STATA software (version 10.0, StataCorp, College Station, TX).

RESULTS

From 1998 through 2009, a total of 514 children seated in the rear of vehicles involved in MVCs were restrained by combined seat belts and belt-positioning booster seats. Of these, 381 were matched to children who were unrestrained. The median absolute difference in sampling weight between the matched pairs was 13.6 (interquartile range = 2.4 to 104.5), suggesting that sampling weights were similar among exposure groups. The mean age of the children included in this study was 4.7 years old, and approximately 72% of the children were aged 4 to 8 years old. In this analysis, there were no significant differences in sex or vehicle curb weight between exposed children and those with no restraint (Table 1). Children with no restraint, however, were more likely to be seated in the middle of the rear row ($p < 0.001$), be involved in a frontal impact collision ($p = 0.002$), be involved in a rollover ($p < 0.001$), and be in a higher-speed collision ($p < 0.001$) that resulted in a higher vehicle exterior crush ($p < 0.001$). Additionally, unrestrained children were more likely to have passenger compartment intrusion of ≥ 15 cm ($p < 0.001$).

Of the 514 exposed children, 475 were matched to children restrained with seat belts only. In this analysis, there were no significant differences between these two groups in regards to sex, seat position, vehicle curb weight, collision impact, ΔV , vehicle crush, or intrusion (Table 2). Children restrained by seat belts only were more likely to be in rollovers and to have missing values for ΔV .

Compared with children with no restraints, those with combined seat belts and booster seats were 27% less likely to have any injury (RR = 0.73, 95% CI = 0.55 to 0.96; Table 3). Stronger decreased associations were observed for AIS 2+ injury (RR = 0.30, 95% CI = 0.16 to 0.58) and severe injury (ISS > 8 ; RR = 0.19, 95% CI = 0.06 to 0.56). No significant difference was found for fatal injury. By body region, decreased risks were observed for AIS 1+ head injury (RR = 0.51, 95% CI = 0.30 to 0.86), face injury (RR = 0.54, 95% CI = 0.36 to 0.80), upper extremity injury (RR = 0.53, 95% CI = 0.30 to 0.97), and lower extremity injury (RR = 0.41, 95% CI = 0.24 to 0.69). By contrast, however, children restrained with combined seat belts and booster seats had more than a threefold increased risk of AIS 1+ neck injury (RR = 4.79, 95% CI = 1.43 to 16.00). For AIS 2+ injuries, a similar association for the head region was observed (RR = 0.31, 95% CI = 0.11 to 0.87), but no AIS 2+ neck injuries were observed. Decreased risks were also noted for AIS 2+ lower extremity injury (RR = 0.07, 95% CI = 0.01 to 0.50), although it should be noted that the latter association was based on a low number of injuries, resulting in limited statistical precision.

When children with combined seat belts and booster seats were compared with children restrained by seat belts only, no association was observed for any injury or for severe and fatal injury (Table 4). By body region, no decreased risks were observed for AIS 1+ injury, but increased risks were observed for AIS 1+ neck injury (RR = 1.86, 95% CI = 1.02–3.40) and thorax injury (RR = 2.86, 95% CI = 1.33–6.15). No statistically significant associations were observed for AIS 2+ injuries, although possible associations of note were AIS 2+ abdomen injury (RR = 0.47, 95% CI = 0.11–2.06) and face injury (RR = 3.26, 95% CI = 0.23–45.70).

It should be noted that, for purposes of allowing results from Tables 3 and 4 to be comparable, we chose to report results from models adjusted for whether ΔV was missing

and model year despite the fact that other variables were differently distributed between restraint groups (e.g., rollover). We did, however, include these variables in models in part of our analysis, and the point estimates and interpretation of the associations did not change appreciably.

Regarding the analysis of all children aged 4 to 7 years in the cohort, the prevalence of booster seat use increased gradually from approximately 1% in 1998 to 8% in 2003 and to 46% in 2009. Compared with the use of seat belts only, the use of belt-positioning booster seats was much more common in younger ages (47.4% of 4-year-olds used belt-positioning booster seats, whereas 14.7% used seat belts; $p = 0.010$), in the white race group (87.4% vs. 69.2%), and in crashes involving drug use (2.8% vs. 0.9%; Data Supplement S1, available as supporting information in the online version of this paper). The percentages of overall injury, fatal injury, and regional body injury by restraint type are shown in Data Supplement S2 (available as supporting information in the online version of this paper). Compared with children restrained by seat belts only, children seated in belt-positioning booster seats had higher percentages of thorax injury (10.84% vs. 4.32%; $p = 0.004$) and severe lower extremity injury (1.07% vs. 0.13%; $p = 0.001$). As expected, children with no restraints showed higher percentages of injury for most injury outcomes than did those with restraints. The results of the logistic regression models are presented in Data Supplement S3 (available as supporting information in the online version of this paper). No protective effect was found for belt-positioning booster seat over seat belt only. Children using belt-positioning booster seats experienced a significantly higher risk of thorax injury (unadjusted OR = 2.70, $p = 0.026$; adjusted OR = 1.98, $p = 0.037$; V-adjusted OR = 2.03, $p = 0.064$) and severe lower extremity injury (unadjusted OR = 9.45, $p = 0.060$; adjusted OR = 8.72, $p = 0.028$; V-adjusted OR = 9.79, $p = 0.014$) than did those using seat belts only.

DISCUSSION

After matching by age, vehicle body type, and sampling weight, children using seat belts in belt-positioning booster seats, compared with children with no restraints, had a lower risk of both any injury and severe injury but a higher risk of AIS 1+ neck injury. When compared with children using seat belts only, children using booster seats had an equal risk of injury and had a higher risk of AIS 1+ injury to the neck and thorax. From the analysis based on all subjects in the cohort, we found that children using booster seats were more likely to experience thorax injury (AIS 1+) and severe lower extremity injury (AIS 2+) than were children using seat belts only.

Although these results confirm previous findings on the effectiveness of booster seats over no restraint use,³ the significantly increased risk of minor neck injury in children using booster seats compared with those with no restraint use is contrary to previous evidence. For unrestrained children in the current study population, minor neck injury is concomitant with injuries in other body regions such as the head, upper extremity, and thorax, the risk of which was higher in the present study and which have been identified as the most frequently injured body regions during MVCs.²¹ However, children using seat belts in belt-positioning booster seats were more likely to experience minor injuries in the body regions in contact with the belts, such as the neck and thorax. Another possible explanation for this increased risk of neck injury was the raised center of gravity among children boosted by the booster seats. In our recent study based on adult data, we demonstrated that center of gravity played an important role in crash injury.²³ Higher center of gravity was associated with increased risk of injury during MVCs. However, no data in children have been published to test this hypothesis.

In the current study, children using booster seats experienced a significantly higher risk of injury to the neck and thorax than did children using seat belts only. In further analysis based on all children aged 4 to 7 years, we found a higher risk of thorax injury and marginally higher risk of neck injury for children using booster seats compared to those using seat belts only. These results are inconsistent with previous findings.^{12,14} This inconsistency could be due to the use of a different database in the present study. That is, Durbin et al. performed their analyses on a 16-state crash database in which the data were collected by telephone survey from the child passengers' parents and insurance claim records. As noted by those authors, data collection via telephone survey might cause misclassification of restraint use and bias.^{12,14} In the present study, the NASS CDS database was used, and all injury records were reported by medical professionals; additionally, child seat type was reported by trained investigators, thus minimizing the probability of exposure misclassification compared with previous research. Matched study design in the present study might be another reason for the inconsistency of results. In other studies, the factors used for matching in this study were usually controlled as covariates in the models. For instance, prior studies have included vehicle type as a confounder by including the covariate in statistical models; however, this may not be valid, as it may be possible that the ability of booster seats to prevent injury is differential by vehicle type. Thus, we matched the samples by vehicle type and we also limited our analysis among passenger cars only in the supplemental analysis. In the NASS CDS data, there was no information on the misuse of booster seats. With lack of such data, we would not know whether the increased risks of minor neck and thorax injury were due to general use of the device or misuse of the device. However, children in both booster seat and seat belt groups were restrained by the seat belts. In this situation, even for children seated in belt-positioning booster seats that were installed inappropriately, they might not be benefited from the devices, but should not experience more risks of injury than those using seat belts only. Furthermore, the misuse of the booster seats likely could not account for the increased of minor neck injury comparing to no restraints use. Future research is needed to examine the effects of misuse of the devices on crash injury.

A possible explanation for this increased risk of neck and thorax injury is changes in position and elevated center of gravity relative to the floor of the vehicle in the vehicle space after boosting by booster seats in the vehicles, as discussed above. In our study of obesity and MVC injury among adults, obese male drivers experienced more upper-body injuries than did obese female drivers, a difference that might be explained by the higher center of gravity in obese men (more fat accumulated in abdominal region) than in obese women (more fat accumulated in hip or thigh region).²³ In another study that also used NASS CDS data, obesity was associated with a more than twofold increased risk of thorax injury for children aged 2 to 9.²⁴ To control for such effects caused by center of gravity, we designed the present study by matching for age, which is highly correlated with sitting height. Additionally, we tried to control for height in the analysis, even though it had 30% missing data in the data set; however, the significantly higher risk of injury to the neck and thorax remained (data not shown).

In our supplemental analysis based on all children aged 4 to 7 years in the cohort, we also found higher risks of thorax injury (AIS 1+) and severe lower extremities injury (AIS 2+) for booster users compared to seat belt users. In the supplemental analysis, most significant ORs were marginal, especially after adjusting for V. However, because most ORs were more than one in both the unadjusted and the adjusted models, a significant difference could be expected between booster seat use and seat belt use only with a larger sample size. For the higher risk of lower extremity injury (AIS 2+) in the supplemental results, the 95% CI range was very wide owing to the limited injured cases in this subgroup. Further research is

needed to study the regional body injuries of various restraint devices with larger sample sizes.

Evidence for the risk of fatal injury in children restrained by belt-positioning booster seats compared with seat belts only was limited in previous studies. The effectiveness of child safety seats in protecting against death during MVCs has been evaluated in several studies;^{10,13} however, booster seats were not examined separately in those studies because of small sample sizes. A recent study using FARS to compare the effectiveness of booster seats and seat belts in preventing death among children aged 4 to 8 years did not report a significant difference between the two restraints in protecting against fatal injury, which was similar to the results of the present study. The lack of significant difference between booster seats and seat belts in the present study might have been due to the sparse data on fatal injury in restrained children (less than 0.2%) in the NASS CDS. However, this does not explain the results in the study using FARS, in which the fatality rate was approximately 32%.¹⁶ The nonsignificant results in the FARS study can be partly explained by the proportion of observations with missing information on child safety seat use. Moreover, FARS is generalizable only to fatal MVCs and thus is not representative of all MVCs.

LIMITATIONS

The results of our study should be interpreted in light of several limitations. First, the NASS CDS is a sample of tow-away MVCs; thus, the prevalence and pattern of restraint use does not represent all child passengers traveling in vehicles on the road. Second, information on the proper use of booster seats was not available for a large portion of the children included in the NASS CDS. The National Highway Traffic Safety Administration estimated in their report that child safety seats are misused in up to 72.6% of observed child restraint systems.²⁵ It has been estimated that approximately 68% of shield boosters and 20% of belt-positioning boosters are misused.²⁶ Therefore, the higher risk of injury for children using booster seats compared with seat belts only might be due not to their use in general but rather to their misuse.

Third, the restraint type was unknown for 14.4% (weighted) of the children in the database. We excluded these children in the analysis, which may have affected the results of injury frequencies. Also, there were children in booster seats who did not have a match. This is problematic if those who did not match were systematically different than those who did match. Examining characteristics from Table 1 between those who did and did not match, there was no difference in regards to strong correlates of injury risk (sex, V, maximum crush, impact type, rollover, seat position, and intrusion). Those who did not match were more likely to be in SUVs or vans; however, body category was not associated with injury risk among those in booster seats, suggesting that the resulting bias had a minimal effect on the observed results.

Furthermore, these data were collected retrospectively and therefore unmeasured confounders may be present. In addition, we could not fully adjust for patient height because 30% of the data were missing and this has proved to be important in prior studies. Last, there were no AIS 2 or higher neck injuries in the sample; thus, conclusions can only be drawn regarding mild or AIS 1 neck injuries.

CONCLUSIONS

Children using booster seats were more likely to sustain AIS 1+ neck injury and thorax injury than were children using seat belts only. Future research should examine whether the observed increase in neck and thorax injuries can be attributed to improper use of booster seats and whether the association is influenced by the type of booster seat or some other

factors. In addition to real-world data, computer simulations may be a good alternative for confirming the results in the present study. Establishing the mechanisms leading to these potential injuries would provide a basis for designing new safer restraints for children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Comparison of Demographic, Vehicle, and Collision Characteristics by Type of Child Restraint Used (Booster Seat + Seat Belt Versus No Restraint)

	Booster Seat + Seat Belt	No restraint	p-value*
No.	381	381	
Male	46.8	49.0	0.56
Seat position			
Driver-side	44.6	30.3	<0.001
Middle	7.4	21.3	
Passenger-side	48.0	48.4	
Curb weight (lb)			
2,499	65.6	63.0	0.49
2,500–3,000	20.2	19.7	
>3,000	14.2	17.3	
Model year			
1987–1993	10.0	37.3	<0.001
1994–1997	16.8	27.2	
1998–2004	55.1	32.2	
2005–2010	18.1	3.3	
Impact			
Frontal	61.7	77.2	0.002
Near-side	11.5	7.8	
Far-side	12.3	7.1	
Rear	14.6	7.8	
Rollover	6.6	16.3	<0.001
Total V (km/hour)			
0–24	69.7	54.2	<0.001
25–49	28.3	37.3	
50+	2.0	8.4	
Missing V	34.1	40.9	0.05
Vehicle crush (cm)			
0–39	79.9	64.6	<0.001
40–59	12.3	19.2	
60–79	4.1	6.9	
80+	3.7	9.2	
Intrusion 15 cm	18.4	37.0	<0.001

Data are reported in percentages, except for *n*.

* Based on chi-square test.

Table 2

Comparison of Demographic, Vehicle, and Collision Characteristics by Type of Child Restraint Used (Booster Seat + Seat Belt Versus Seat Belt Only)

	Booster Seat + Seat Belt	Seat Belt Only	p-value*
No.	475	475	
Male	46.2	47.9	0.60
Seat position			
Driver-side	44.6	45.1	0.37
Middle	6.7	9.0	
Passenger-side	48.6	45.9	
Curb weight (lb)			
<2,499	70.7	68.8	0.81
2,500–3,000	17.3	18.1	
>3,000	12.0	13.1	
Model year			
1987–1993	8.8	16.9	<0.001
1994–1997	14.9	26.6	
1998–2004	55.0	49.3	
2005–2010	21.3	7.2	
Impact			
Frontal	60.2	67.5	0.28
Near-side	10.9	8.4	
Far-side	13.3	10.5	
Rear	15.5	13.6	
Rollover	7.4	13.7	0.001
Total V (km/hour)			
0–24	70.2	64.6	0.17
25–49	27.8	31.4	
50+	1.9	4.1	
Missing V	34.9	42.9	0.01
Vehicle crush (cm)			
0–39	80.4	71.9	0.05
40–59	12.3	20.2	
60–79	3.9	3.8	
80+	3.3	4.1	
Intrusion 15 cm	17.7	21.1	0.19

Data are reported in percentages, except for *n*.

* Based on chi-square test.

Table 3

RRs and 95% CIs for the Association Between Type of Child Restraint and MVC-related Injury (Booster Seat + Seat Belt Versus No Restraint)

	No Restraint [*] Risk (per 100)	Booster Seat + Seat Belt Risk (per 100)	uRR [†] (95% CI)	aRR [‡] (95% CI)
Injury (ISS > 0)	52.39	37.53	0.72 (0.58–0.89)	0.73 (0.55–0.96)
Injury (AIS 2+)	18.90	6.04	0.32 (0.20–0.51)	0.30 (0.16–0.58)
Severe injury (ISS > 8)	11.29	3.41	0.30 (0.16–0.56)	0.19 (0.06–0.56)
Fatal injury	3.41	1.57	0.46 (0.18–1.21)	0.21 (0.02–1.92)
AIS 1+ body region				
Head	18.90	9.71	0.51 (0.35–0.76)	0.51 (0.30–0.86)
Face	32.28	14.70	0.46 (0.33–0.62)	0.54 (0.36–0.80)
Neck	2.10	7.61	3.62 (1.66–7.93)	4.79 (1.43–16.00)
Thorax	8.14	6.82	0.84 (0.50–1.41)	1.23 (0.57–2.63)
Abdomen	7.09	5.77	0.81 (0.46–1.43)	0.53 (0.20–1.37)
Spine	8.40	3.94	0.47 (0.25–0.87)	0.72 (0.29–1.82)
Upper extremity	15.22	13.12	0.86 (0.59–1.26)	0.53 (0.30–0.97)
Lower extremity	20.47	9.45	0.46 (0.31–0.69)	0.41 (0.24–0.69)
AIS 2+ body region				
Head	9.45	3.15	0.33 (0.17–0.64)	0.31 (0.11–0.87)
Face	2.62	1.57	0.60 (0.22–1.65)	1.00 (0.20–4.95)
Thorax	3.67	1.05	0.29 (0.09–0.87)	0.32 (0.05–1.97)
Abdomen	2.36	0.79	0.33 (0.09–1.23)	2.00 (0.07–54.2)
Spine	2.10	1.31	0.63 (0.20–1.91)	Undefined
Upper extremity	3.67	2.10	0.57 (0.24–1.36)	0.20 (0.03–1.20)
Lower extremity	5.77	0.52	0.09 (0.02–0.39)	0.07 (0.01–0.50)

Results of neck injury (AIS2+) were not presented because no neck AIS2+ injuries were observed.

AIS = Abbreviated Injury Scale; aRR = adjusted risk ratio; ISS = Injury Severity Scale; MVC = motor vehicle collision; RR = risk ratio; uRR = unadjusted risk ratio.

^{*} No restraint children matched to booster seat + seat belt children on the basis of exact age, type of vehicle, and sample weight.

[†] Based on proportional hazards regression assuming equal time at risk and stratified by matched-pair set.

[‡] Adjusted for whether V was missing and model year.

Table 4

RRs and 95% CI for the Association Between Type of Child Restraint and MVC-related Injury (Booster Seat + Seat Belt vs. Seat Belt Only)

	Seat Belt Only* Risk (per 100)	Booster Seat + Seat Belt Risk (per 100)	uRR [†] (95% CI)	aRR [‡] (95% CI)
Injury (ISS > 0)	36.63	37.05	1.01 (0.82–1.25)	1.04 (0.84–1.30)
Injury (AIS 2+)	4.63	5.68	1.23 (0.70–2.15)	1.52 (0.79–2.93)
Severe injury (ISS > 8)	3.37	3.16	0.94 (0.46–1.90)	1.15 (0.51–2.58)
Fatal injury	0.21	1.26	6.00 (0.72–49.8)	Undefined
AIS 1+ body region				
Head	8.00	9.26	1.16 (0.75–1.79)	1.40 (0.85–2.33)
Face	18.95	14.32	0.76 (0.55–1.04)	0.77 (0.55–1.09)
Neck	3.79	7.16	1.89 (1.07–3.34)	1.86 (1.02–3.40)
Thorax	2.74	6.95	2.54 (1.34–4.82)	2.86 (1.33–6.15)
Abdomen injury	6.11	4.63	0.76 (0.44–1.32)	0.72 (0.37–1.43)
Spine	4.42	4.00	0.90 (0.49–1.68)	0.92 (0.45–1.91)
Upper extremity	8.42	11.37	1.35 (0.90–2.03)	1.42 (0.91–2.21)
Lower extremity	9.47	9.68	1.02 (0.68–1.54)	1.01 (0.63–1.63)
AIS 2+ body region				
Head	1.68	2.95	1.75 (0.73–4.17)	2.57 (0.80–8.28)
Face	0.63	1.68	2.67 (0.71–10.1)	3.26 (0.23–45.70)
Thorax	0.42	1.05	2.50 (0.49–12.9)	Undefined
Abdomen	1.68	0.63	0.38 (0.10–1.41)	0.47 (0.11–2.06)
Spine	0.84	1.26	1.50 (0.42–5.32)	0.88 (0.16–4.86)
Upper extremity	0.84	1.68	2.00 (0.60–6.64)	Undefined
Lower extremity	1.68	0.63	0.38 (0.10–1.41)	0.72 (0.14–3.62)

Results of neck injury (AIS 2+) were not presented because no neck AIS 2+ injuries were observed.

AIS = Abbreviated Injury Scale; aRR = adjusted risk ratio; ISS = Injury Severity Scale; MVC = Motor Vehicle Collision; RR = risk ratio; uRR = unadjusted risk ratio.

* Seat belt only children matched to booster seat + seat belt children on the basis of exact age, type of vehicle, and sample weight.

[†] Based on proportional hazards regression assuming equal time at risk and stratified by matched-pair set.

[‡] Adjusted for whether V was missing and model year.