Belt-Positioning Booster Seats and Reduction in Risk of Injury Among Children in Vehicle Crashes

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Context Although more than a dozen states have ratified laws that require booster seats for children older than 4 years, most states continue to have child restraint laws that only cover children through age 4 years. Lack of booster seat effectiveness data may be a barrier to passage of stronger child restraint laws.

Objectives To quantify the association of belt-positioning booster seats compared with seat belts alone and risk of injury among 4- to 7-year-old children and to assess patterns of injury among children in booster seats vs seat belts.

Design, Setting, and Population Cross-sectional study of children aged 4 to 7 years in crashes of insured vehicles in 15 states, with data collected via insurance claims records and a telephone survey. A probability sample of 3616 crashes involving 4243 children, weighted to represent 56593 children in 48257 crashes was collected between December 1, 1998, and May 31, 2002.

Main Outcome Measure Parent report of clinically significant injuries.

Results Injuries occurred among 1.81% of all 4- to 7-year-olds, including 1.95% of those in seat belts and 0.77% of those in belt-positioning booster seats. The odds of injury, adjusting for child, driver, crash, and vehicle characteristics, were 59% lower for children aged 4 to 7 years in belt-positioning boosters than in seat belts (odds ratio, 0.41; 95% confidence interval, 0.20-0.86). Children in belt-positioning booster seats had no injuries to the abdomen, neck/spine/back, or lower extremities, while children in seat belts alone had injuries to all body regions.

Conclusion Belt-positioning booster seats were associated with added safety benefits compared with seat belts to children through age 7 years, including reduction of injuries classically associated with improper seat belt fit in children.

JAMA. 2003;289:2835-2840 www.jama.com

Advocates have long recommended belt-positioning booster seats for children who have outgrown their child safety seats.[1,2] A belt-positioning booster, either with or without a high back, raises the child up to improve the fit of both the lap and shoulder portions of the seat belt. Rapid, "jackknife" bending about or sliding beneath a poorly positioned vehicle seat belt increases the risk of intra-abdominal and spinal cord injuries, also known as "seat belt syndrome," as well as injuries to the face and brain due to impact of the head with the child's knees or the vehicle interior.[3-8]

Previously, we demonstrated the effectiveness of child restraints, including booster seats, compared with seat belts among 2- to 5-year-old children.[6] Given the relatively limited sample size of children in booster seats at the time of that study, the effectiveness of booster seats for 4- to 7-year-old children could not be assessed. Furthermore, belt-positioning booster seats were combined with shield-type booster seats in analyses. These 2 seats function differently, and belt-positioning boosters are considered by the American Academy of Pediatrics to be the optimal form of restraint when children outgrow their child safety seats.[2]

Initial data on the benefits of child restraints helped to inform discussions in many states regarding upgrades to child restraint laws to include the use of booster seats. To date, 15 states have passed laws to include the use of booster seats for children older than 4 years.[9] Individual states have chosen various upper age limits as a requirement for booster seat use, ranging from 6 to 8 years. Specific data on the effectiveness of booster seats for children older than 5 years might encourage more uniformity in these upgraded laws. Therefore, the objective of this study was to assess the relative effectiveness of belt-positioning booster seats compared with seat belts alone in reducing risk of injury to children 4 to 7 years of age. In addition, we sought

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to examine differences in patterns of injury among children in boosters vs seat belts.

METHODS

Study Population and Data Collection

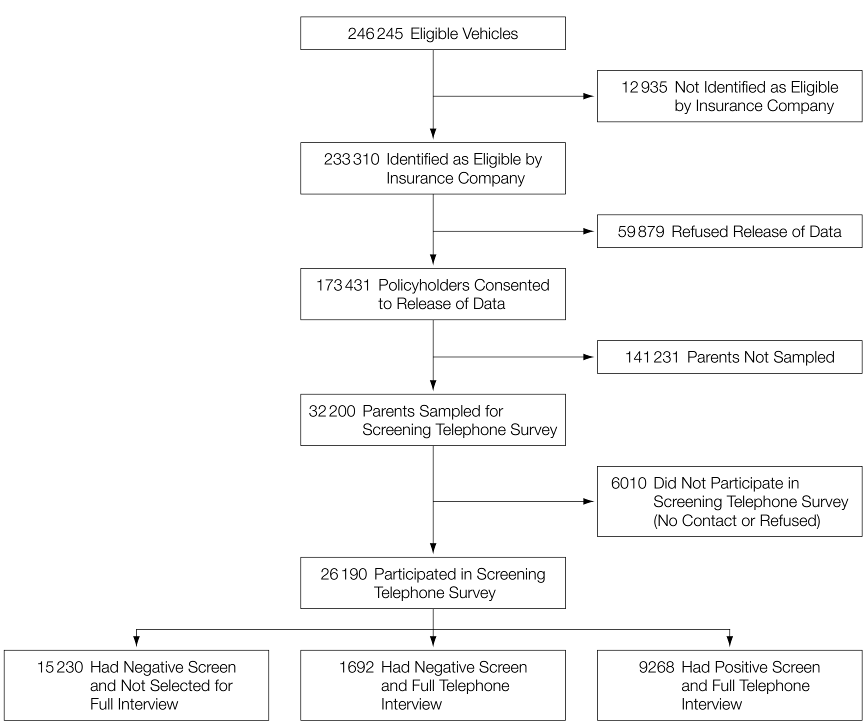
Data were collected from December 1, 1998, through May 31, 2002. A description of the study methods has been published previously.[10] The project consists of a large-scale, child-specific crash surveillance system; insurance claims from State Farm Insurance Co (Bloomington, Ill) function as the source of subjects, with telephone survey and onsite crash investigations serving as the primary sources of data.

Vehicles qualifying for inclusion were State Farm insured, model year 1990 or newer, and involved in a crash with at least 1 child occupant no more than 15 years of age. Qualifying crashes were limited to those that occurred in 15 states and the District of Columbia, representing 3 large regions of the United States (East: New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, District of Columbia; Midwest: Ohio, Michigan, Indiana, Illinois; West: California, Nevada, Arizona). After policyholders consented to participate in the study, limited data were transferred electronically to researchers at the Children's Hospital of Philadelphia and University of Pennsylvania. Data in this initial transfer included contact information for the insured, age and sex of all child occupants, and a coded variable describing the level of medical treatment received by all child occupants as reported by the policyholder (no treatment, physician's office or emergency department only, hospital admission, or death).

A stratified cluster sample was designed to select vehicles (the unit of sampling) for the conduct of a telephone survey with the driver. Vehicles containing children who received medical treatment after the crash were oversampled so that the majority of injured children would be selected while maintaining the representativeness of the overall population. If a vehicle was sampled, all child occupants in that vehicle were included in the survey. Drivers of sampled vehicles were contacted by telephone and, if a passenger had received medical treatment, screened via an abbreviated survey to verify the presence of at least 1 child occupant with an injury. All vehicles with at least 1 child who had a positive screen for injury and a 10% random sample of vehicles in which all child occupants who were reported to receive medical treatment but screened negative for injury were selected for a full interview; a 2.5% sample of crashes in which no medical treatment was received were also selected. The full interview involved a 30-minute telephone survey with the driver of the vehicle and parent(s) of the involved children. Only adult drivers and parents were interviewed. The median length of time between the date of the crash and the completion of the interview was 10 days, with 95% of interviews completed within 51 days of the crash.

The eligible study population consisted of all 367 020 children riding in 246 245 State Farm–insured vehicles newer than 1990 reporting a crash claim between December 1, 1998, and May 31, 2002. Claim representatives correctly identified 95% of eligible vehicles, and 74% of policyholders consented to participation in this study. Of these, 19% were sampled for interview and an estimated 81% of these were successfully interviewed (Figure). Comparing the included sample with known population values from State Farm claims, we observed little difference: in both the sample and the population, 40%, 36%, and 24% of the vehicles were located in the East, Midwest, and West regions, respectively, and 58% of the sampled vehicles were model 1996 or newer. In the sample, 53% were passenger cars, 20% minivans, 18%

Figure. Derivation of Study Sample From Initially Eligible Population



A total of 10 960 respondents completed the full interview. Our analysis was restricted to the 3616 respondents who were in a crash with a child occupant between 4 and 7 years old.

sport utility vehicles, 6% pickup trucks, and 2% large passenger/cargo vans compared with 55%, 18%, 18%, 7%, and 2% in the population, respectively; 32% were nondriveable after the crash compared with 30% of the population. The mean age of the child occupants in the sample was 6.9 years compared with 7.3 years in the population.

For cases in which child occupants were seriously injured or killed, in-depth crash investigations were performed. Cases were screened via telephone to confirm the details of the crash. Contact information from selected cases was then forwarded to a crash investigation firm (Dynamic Science Inc, Annapolis, Md), and a full-scale on-site crash investigation was conducted using custom child-specific data collection forms. Among cases selected for investigation, 97% were completed. For the purposes of this analysis, these cases were used to examine the validity of information obtained from the telephone survey.

Variable Definitions

Restraint status of children was determined from the telephone survey. Children were classified as unrestrained or restrained, with the restraint type further classified as seat belt, belt-positioning booster, shield booster, or child safety seat. Among the 161 children for whom paired information on restraint use was available from both the telephone survey and crash investigations, agreement was 88% between the driver report and the crash investigator (κ=0.74; P<.001). Crash severity was categorized both by the towaway status of the vehicle (ie, whether the vehicle was towed from the crash scene), as indicated in the insurance claims data, and by driver report via the telephone survey of intrusion into the occupant compartment of the vehicle. Seating location of each child was determined from the telephone survey. Among the 170 children for whom paired information on seating position (front vs rear) was available from both the telephone survey and crash investigations, agreement was 99% between the driver report and the crash investigator (κ=0.99; P<.001).

Survey questions regarding injuries to children were designed to provide responses that were classified by body region and severity based on the Abbreviated Injury Scale (AIS) score[11] and have been previously validated for their ability to distinguish AIS scores of 2 or more from less severe injuries.[12] For the purposes of this study, children were classified as injured if a parent/driver reported a clinically significant injury, ie, any injury with an AIS score of 2 or greater (concussions and more serious brain injuries, all internal organ injuries, spinal cord injuries, and extremity fractures) or facial lacerations.

Separate oral consent was obtained from eligible participants for the transfer of claim information from State Farm to The Children's Hospital of Philadelphia and University of Pennsylvania for the conduct of the telephone survey and the crash investigation. The study protocol was reviewed and approved by the institutional review boards of both The Children's Hospital of Philadelphia and the University of Pennsylvania School of Medicine.

Data Analysis

The primary purpose of these analyses was to compute the relative risk of injury for children aged 4 to 7 years restrained in belt-positioning booster seats compared with seat belts. Age 4 years was chosen as the lower bound for our analyses because current recommendations for optimal restraint indicate that children younger than 4 years should be restrained in child safety seats.[1,2] χ^2 Tests of association were used to compute P values based on the null hypothesis of no association between restraint type and risk of injury. Logistic regression modeling was used to compute odds ratios (ORs) of injury for those seated in belt-positioning booster seats vs seat belts, both unadjusted and adjusted for several potential confounders, including differences in driver age (<25 vs ≥25 years), seating position (front vs rear), crash severity, and vehicle type.

Because sampling was based on the likelihood of an injury, subjects least likely to be injured were underrepresented in the study sample in a manner potentially associated with the predictors of interest.[13] To account for this potential bias and to adjust inference to account for the stratification of subjects by medical treatment and clustering of subjects by vehicle, robust χ^2 tests of association and Taylor series linearization estimates of the logistic regression parameter variances were calculated using SAS-callable SUDAAN version 7.5 (Research Triangle Institute, Research Triangle Park, NC). Results of logistic regression modeling are expressed as unadjusted and adjusted ORs with corresponding 95% confidence intervals (CIs). Because of the small number of injuries to certain body regions, differences in risk of injury by body region were assessed using a nonparametric permutation test[14] based on the null hypothesis of no injury risk difference by restraint type by body region.

RESULTS

This analysis is restricted to the 3616 crashes involving 4243 children aged 4 to 7 years, weighted to represent 56593 children in 48257 crashes. Among all 4- to 7-year-olds, 3519 were using either a seat belt or belt-positioning booster seat, representing 45701 children, or 81% of all 4- to 7-year-olds in the study population. As expected, restraint use of the children varied by age. Seat belts were used by 42% of 4-years-olds, 72% of 5-year-olds, and 89% of 6- and 7-year-olds; belt-positioning booster seats were used by 16% of 4-year-olds, 13% of 5-year-olds, and 4% of 6- and 7-year-olds. The majority of children in belt-positioning booster seats (81%) were in high-backed booster seats.

TABLE 1 provides the distribution of driver age, seating row, crash severity, and vehicle type among 4- to 7-year-olds restrained in seat belts (unweighted n=3282; weighted n=40389) and in belt-positioning booster seats (unweighted n=237; weighted n=5312). Children in belt-positioning booster seats were less likely to be in vehicles driven by younger drivers and more likely to be rear-seated than children in seat belts.

Injuries occurred in 1.81% of all 4- to 7-year-olds, including 1.95% of those in seat belts and 0.77% of those in belt-positioning booster seats. There were 5 deaths identified among children in seat belts, while no children in belt-positioning booster seats died. The unadjusted odds of injury were 61% lower for children aged 4 to 7 years in belt-positioning boosters than in seat belts (OR, 0.39; 95% CI, 0.20-0.77). The unadjusted odds of injury reduction ranged from 56% among 4-year-olds (OR, 0.44; 95% CI, 0.15- 1.31) to 81% for 6-year-olds (OR, 0.19; 95% CI, 0.04-0.83). Despite the appearance of variable effectiveness by age, there was no significant difference in the effectiveness of booster seats by individual year of age (*P*=.66).

Children in seat belts were more likely to be in vehicles driven by young drivers and more likely to be located in the front seat (Table 1), both factors that increase risk of injury. Adjustment for these factors, together with crash severity, vehicle type, and age of the child, yielded an estimated adjusted reduction in risk of 59% for children in boosters (OR, 0.41; 95% CI, 0.20-0.86; *P*=.02). The adjusted odds of injury reduction did not vary significantly by age (*P*=.44), ranging from 46% among 4-year-olds (OR, 0.54; 95% CI, 0.17-1.74) to 85% among 6-year-olds (OR, 0.15; 95% CI, 0.03-0.80). Restricting our analysis to rear-seated children only did not substantially alter the booster seat protective effect (adjusted OR, 0.40; 95% CI, 0.18-0.89; *P*=.03). Comparing booster seat users with lap-shoulder belt users only had no effect (adjusted OR, 0.39; 95% CI, 0.17-0.86; *P*=.02). Airbag exposure was rare for both belted and booster children, and adjusting for it as well had no effect (adjusted OR, 0.40; 95% CI, 0.19-0.83; *P*=.01).

Table 2 provides the distribution of the body regions of injury for children in belt-positioning booster seats and seat belts. Children in seat belts had injuries to every body region. However, children in belt-positioning booster seats had injuries only to the head, face, chest, and upper extremities. Of particular note among children in belt-positioning booster seats is the lack of injuries to the abdomen and neck/back/spine—part of the body regions characterized by the "seat belt syndrome" constellation of injuries—although these differences were statistically significant only for abdominal injuries.

Table 1. Characteristics of Vehicle Crashes Involving Children Aged 4 to 7 Years by Seat Belt vs Belt-Positioning Booster Seat Use*

Characteristics	Belt-Positioning Booster Seat (Unweighted n = 237)	Seat Belt (Unweighted n = 3282)	*P* Value†
Driver aged <25 y	3.5	8.2	.008
Child passenger in front seat	3.6	15.7	<.001
Intrusion into occupant compartment of vehicle	6.6	8.7	.26
Towaway	27.2	32.0	.22
Airbag exposed	0.8	0.7	.86
Vehicle type			
Passenger car	46.3	48.0	.99
Sport utility vehicle	18.3	18.3	
Minivan	26.0	24.6	
Large van	2.6	2.7	
Pickup truck	6.8	6.4	

*Data are presented as weighted percentages.
†*P* values were calculated based on the null hypothesis of no difference between children aged 4 to 7 years restrained in seat belts vs belt-positioning booster seats, accounting for potential clustering of multiple children in a single vehicle.

Table 2. Distribution of Injuries by Body Region Among Children in Belt-Positioning Booster Seats vs Seat Belts*

Injuries	Belt-Positioning Booster Seat (Unweighted n = 237)	Seat Belt (Unweighted n = 3282)	*P* Value
Overall	0.77	1.95	.006
Head	0.62	1.16	.35
Face	0.23	0.40	.07
Chest	0.09	0.03	.47
Abdomen	0	0.44	.05
Neck/spine/back	0	0.17	.31
Upper extremities	0.02	0.10	.12
Lower extremities	0	0.05	.18

*Data are presented as weighted percentages. Subjects may have had injuries to more than 1 body region.

COMMENT

This study confirms that belt-positioning booster seats are associated with a reduced risk of injury compared with seat belts in children aged 4 to 7 years. As noted previously, belt-positioning booster seats function by raising a child up on the vehicle seat so that his seated height is more like that of an adult, allowing both portions of the belt to fit more properly. Belt-positioning booster seats have small handles, guides, or a slot that help to position the lap portion of the belt low and flat across a child's upper thighs.[15] Many boosters have high backs that not only provide the child with head support but also have upper belt guides to optimize the position of the shoulder portion of the belt.[15] The bottom cushions of belt-positioning boosters are also shallower than the vehicle seat, allowing the child's knees to bend comfortably at the edge of the booster. This encourages a child to sit up straight in the seat with his back against the seat back.[16]

Our results provide the first real-world evidence that this optimal positioning of the belt is associated with significantly fewer injuries classically associated with seat belt use in young children. Belt-positioning booster seats appeared to significantly reduce the risk of injuries to the abdomen. In addition, children in belt-positioning booster seats in our sample had no injuries to the abdomen, spine, or lower extremities, while children in seat belts had injuries to every body region.

At present, 15 states have passed legislation upgrading child restraint laws to include the appropriate restraint of children aged 4 years or older in booster seats, with several other states actively considering similar upgrades to their child restraint laws.[9] Federal legislation has also recently been passed to encourage states to upgrade their child restraint laws to include the use of booster seats for children aged 4 years or older.[17] Parents rely on state laws for guidance about properly restraining their children.[18] Laws that are in closer alignment with current best-practice recommendations may help reduce confusion among parents regarding the most effective way to protect their children. We have previously reported significant increases in booster seat use, particularly among 4-year-old children.[19] Previous research suggests that parental knowledge of booster seats has increased during the period of this study.[20] These results may assist state and federal policymakers by demonstrating the current level of interest on the part of parents to optimally restrain their older children. Our data suggest that the safety benefits of booster seats are present through age 7 years.

We found that children in belt-positioning booster seats were more likely to sit in the rear seats of vehicles than children in seat belts. This may indicate that many parents link the concepts of child restraint use and seating position or it may be an indicator of safer drivers. Rear-seated children in booster seats derive safety benefits not only from appropriate restraint but also by optimal seating position.[21,22] Our estimate of the effectiveness of booster seats remained unchanged when restricted to children in the rear seats of vehicles.

Booster effectiveness was also unchanged when restricted to children using both the lap and shoulder portion of the seat belt (as opposed to the lap belt only). It is possible that children using booster seats as well as those in seat belts used only the lap portion of the seat belt, either because that is all that was available or because they placed the shoulder belt behind their back or under their arm. We included these children in the primary analysis to evaluate effectiveness of boosters compared with belts in the "as used" real-world situation. We combined high-back and backless belt-positioning booster seats for our analyses. Further research will be required to evaluate whether one design or the other may offer an important incremental safety benefit.

This study relied on parent report of restraint use by children, which, if differentially reported by restraint type, might have biased the results. To determine some potential effects of restraint misclassification, we assumed that those identified as unrestrained were indeed unrestrained and that the observed risk of injury among the unrestrained correctly estimates their risk for each year of age. If we further assume that all children reported as restrained in belt-positioning booster seats were correctly classified, 50% of those reported as restrained in seat belts would have to be unrestrained for the risk differences between those reported as being in belt-positioning booster seats and those reported as being in seat belts to be eliminated. Since the maximum misclassification rate among those in seat belts (which requires the risk of injury among those correctly reported to be 0) is 62%, this is highly unlikely. Assuming that 20% of those reported to be in booster seats were actually unrestrained (the maximum possible is 25%), a misclassification rate of 60% would be required among those reported to be in seat belts to nullify risk differences. It is highly unlikely that differential misclassifications this large exist. Similar results were obtained in analyses stratified by year of age.

The National Highway Traffic Safety Administration currently recommends that all children who have outgrown child safety seats should be restrained in booster seats until they are at least 8 years old, unless they are 57 in (145 cm) tall.[1] In the overall Partners for Child Passenger Safety population, booster seat use by 8-year-olds is negligible; therefore, they were not included in the analysis. The difference in height between 50th-percentile 7- and 8-year-olds is approximately 2 in (5 cm), with more than 95% of 8-year-olds expected to be less than 57 in (145 cm).[23] Based on available data regarding the fit of seat belts in children,[16] there is no reason to suspect that the benefits of booster seats demonstrated through age 7 years would not remain through age 8 years. Recent data suggest that restrained children older than age 7 years are at a higher risk of injury than younger children in crashes, suggesting that seat belts alone may not provide optimal protection to older children as well.[24] Further research is needed to identify characteristics of optimal restraint devices for children of all ages.

CONCLUSION

Belt-positioning booster seats are associated with added safety benefits over seat belts for children through age 7 years. Pediatricians should educate parents regarding current recommendations for optimal restraint, including the use of belt-positioning booster seats within their practice. In addition, state child restraint laws should be revised to include the use of booster seats for children through age 7 years. Pediatricians can play an important role in advocating for this legislation in their state.

Author Contributions: *Study concept and design, acquisition of data, obtained funding, and study supervision:* Durbin, Winston.

Analysis and interpretation of data: Durbin, Elliott, Winston.
Drafting of the manuscript and statistical expertise: Durbin, Elliott.
Critical revision of the manuscript for important intellectual content: Elliott, Winston.
Administrative, technical, or material support: Winston.

Funding/Support: State Farm Insurance Co provided financial support of this work through the Partners for Child Passenger Safety project.

Acknowledgment: We thank the many dedicated claim representatives and personnel from State Farm, the research team on the Partners for Child Passenger Safety project and at TraumaLink who devoted countless hours to this study, and the parents who generously agreed to participate in the study. We also thank Susan Ferguson and Anne McCartt from the Insurance Institute for Highway Safety and Kathleen Weber, formerly of the University of Michigan Transportation Research Institute, for their review and comments on an early version of the manuscript.

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Truth is not only violated by falsehood; it may be outraged by silence.
—Henri Frederic Amiel (1821-1881)

