Effectiveness of Belt Positioning Booster Seats: An Updated Assessment

AUTHORS: Kristy B. Arbogast, PhD,[a] Jessica S. Jermakian, DSc,[a] Michael J. Kallan, MS,[b] and Dennis R. Durbin, MD, MSCE[a,b]

[a]Center for Injury Research and Prevention, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania; and [b]Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania, Philadelphia, Pennsylvania

KEY WORDS

child passenger safety, booster seats, seat belts

ABBREVIATIONS

AAP—American Academy of Pediatrics
NHTSA—National Highway Traffic Safety Administration
BPB—belt-positioning booster
PCPS—Partners for Child Passenger Safety
AIS—Abbreviated Injury Scale
OR—odds ratio
CI—confidence interval

The results presented in this report are the interpretation solely of the Partners for Child Passenger Safety research team at the Children's Hospital of Philadelphia and are not necessarily the views of State Farm.

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Address correspondence to Kristy B. Arbogast, PhD, Engineering, Center for Injury Research and Prevention, Children's Hospital of Philadelphia, 34th and Civic Center Boulevard, Suite 1150, Philadelphia, PA 19104. E-mail: arbogast@email.chop.edu

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WHAT'S KNOWN ON THIS SUBJECT: Previous research demonstrating the benefits of booster seats over seat belts for children is outdated. Because more children, particularly older children, are now restrained in booster seats, it is important to provide an updated assessment of booster seat effectiveness.

WHAT THIS STUDY ADDS: This study reconfirms that booster seats reduce the risk for injury in children aged 4 through 8 years. BPB seats should continue to be recommended until at least 8 years of age once a child outgrows a harness-based restraint.

abstract

OBJECTIVE: The objective of this study was to provide an updated estimate of the effectiveness of belt-positioning booster (BPB) seats compared with seat belts alone in reducing the risk for injury for children aged 4 to 8 years.

METHODS: Data were collected from a longitudinal study of children who were involved in crashes in 16 states and the District of Columbia from December 1, 1998, to November 30, 2007, with data collected via insurance claims records and a validated telephone survey. The study sample included children who were aged 4 to 8 years, seated in the rear rows of the vehicle, and restrained by either a seat belt or a BPB seat. Multivariable logistic regression was used to determine the odds of injury for those in BPB seats versus those in seat belts. Effects of crash direction and booster seat type were also explored.

RESULTS: Complete interview data were obtained on 7151 children in 6591 crashes representing an estimated 120 646 children in 116 503 crashes in the study population. The adjusted relative risk for injury to children in BPB seats compared with those in seat belts was 0.55.

CONCLUSIONS: This study reconfirms previous reports that BPB seats reduce the risk for injury in children aged 4 through 8 years. On the basis of these analyses, parents, pediatricians, and health educators should continue to recommend as best practice the use of BPB seats once a child outgrows a harness-based child restraint until he or she is at least 8 years of age. *Pediatrics* 2009;124:1281–1286

The American Academy of Pediatrics (AAP) and the National Highway Traffic Safety Administration (NHTSA) recommend the use of child restraint systems to protect children in crashes, including the use of child restraint systems with harnesses for children from birth to at least 4 years of age, followed by the use of belt-positioning booster (BPB) seats until they fit properly in the vehicle seat belt. Despite these recommendations, many children begin using the vehicle belt prematurely,[1] which puts them at an increased risk for serious injuries in a crash.[2–4]

Previous research demonstrated that booster seats reduce the risk for injury to children aged 4 to 7 years by 59% compared with similar-aged children in adult seat belts by improving restraint geometry for children who are too small for the vehicle seat belt.[2] This previous analysis, conducted on data from 1998 to 2002, was based primarily on children who were aged 4 and 5 years because of the usage practices during that period. In the time since that research, appropriate restraint use among children aged 4 through 8 years has increased threefold.[5] This is attributable, in part, to many states passing upgrades to their child restraint laws that require booster seats for children who are older than 4 years. The upper age limit of these booster laws varies by state and ranges from 6 to 8 years. Passage of these laws is associated with a nearly 40% increase in child restraint use among children through age 7.[6]

Because more children, particularly older children, are now appropriately restrained in booster seats, we sought to provide an updated estimate of the effectiveness of BPB seats compared with the use of seat belts alone in reducing the risk for injury for children aged 4 to 8 years. The effectiveness of booster seats by impact direction and booster seat type was also explored.

METHODS

Data Source

Data from the Partners for Child Passenger Safety (PCPS) project from December 1, 1998, and November 30, 2007, were used for these analyses. PCPS consists of a large-scale, child-specific crash surveillance system: insurance claims from State Farm (Bloomington, IL) function as the source of subjects, with a validated telephone survey and on-site crash investigations serving as the primary sources of data.[7] The parent/driver-reported telephone survey served as the source of data for the analyses performed.

Vehicles that qualified for inclusion were State Farm–insured, model year 1990 or newer, and involved in a crash with at least 1 child occupant who was $\leq$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: NY, NJ [until November 2001], PA, DE, MD, VA, WV, NC, and DC; Midwest: OH, MI, IN, and IL; West: CA, NV, AZ, and TX [starting June 2003]). Policyholders from qualifying crashes were contacted by the insurance company and told that they were eligible for a motor vehicle safety study. They were given a very brief description of the study that explained that, with their consent, limited data from their claim would be transferred electronically to researchers at the Children's Hospital of Philadelphia and University of Pennsylvania. They were told to expect a telephone call from these researchers for additional data collection. Data in this initial transfer included contact information for the insured, the ages and genders of all child occupants, and a coded variable describing the level of medical treatment received by all child occupants (no treatment, physician's office or emergency department only, admitted to the hospital, or death).

Sampling and Data Collection

A stratified cluster sample was designed to select vehicles for the conduct of a telephone survey with the driver of the vehicle and parent(s) of the children in the sampled vehicle. Vehicles were stratified on the basis of the initial medical treatment received by child occupants and whether the vehicle was drivable, and a probability sample from each tow status/medical treatment stratum was selected. When a vehicle was sampled, the "cluster" of all child occupants in that vehicle was included in the survey.

Drivers of sampled vehicles in which at least 1 child received medical treatment were contacted by telephone, consented for a telephone interview, and 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 screened positive for injury and a 10% random sample of vehicles in which all child occupants screened negative for injury were selected for a full interview. (The 2.5% of sampled vehicles in which no children were treated were also selected for a full interview.) The full interview involved a 30-minute telephone survey with the driver of the vehicle and parents of the involved children. Often the driver and the parent were the same person; if not, then the interview was conducted with the driver.

On the basis of an analysis of data for the period of this study, claim representatives correctly identified 97% of eligible vehicles, and 80% of policyholders either consented for participation in this study or were not sampled for consent (the procedure to identify participants who required consent changed in June 2003). Of those who consented and were sampled for an interview, 79% were successfully contacted and screened for the full interview, representing an overall inclusion rate of 52% of eligible individuals. The included sample did not differ from known population values from State Farm claims with respect to geographic region, model year of vehicle, tow status of the vehicle, and age of the child occupant.

Data Analysis

Survey questions regarding injuries to children were designed to provide responses that were classified by body region and severity on the basis of the Abbreviated Injury Scale (AIS) score and were previously validated to distinguish AIS 2+ injuries from those less severe.[8] For the purposes of these analyses, children were classified as injured when they had a clinically significant injury generally corresponding to injuries with an AIS score of 2+ (concussions and more serious brain injuries, internal organ injuries, spinal cord injuries, and extremity fractures). Children who sustained only minor injuries generally corresponding to an AIS score of 1, such as lacerations, contusions, and abrasions, were not considered injured for these analyses.

Current child restraint laws vary by state but, collectively, incorporate children up through 8 years of age. Because of low usage rates for children ≥9 years, these analyses were therefore restricted to rear-seated children who were aged 4 to 8 years and were restrained by BPB seats or seat belts. The booster seat–restrained children were additionally categorized as those who used a high-back booster seat or a backless booster seat. Shield boosters were excluded from these analyses because their use is not recommended for this age group.

To account for the potential clustering of multiple children in a single sampled vehicle and the disproportional probability of selection of the study sample design, we used SAS-callable SUDAAN: Software for the Statistical Analysis of Correlated Data 9.0 (Research Triangle Institute, Research Triangle Park, NC) for the data analyses. Frequency distributions of several child, vehicle, and impact characteristics among the sample were determined. Multivariable logistic regression was used to determine the odds of injury for those in BPB seats versus those in seat belts. Because the probability of injury was low in the sample (<5%), these odds ratios (ORs) were interpreted as good approximations of risk ratios. Additional analyses examined risk ratios between the 2 booster seat types.

TABLE 1 Child and Driver Characteristics of the Study Sample

Characteristic	Overall, Weighted % (Unweighted *n*) (*N* = 7151)	BPB Seat, Weighted % (Unweighted *n*) (*N* = 1604)	Seat Belt, Weighted % (Unweighted *n*) (*N* = 5547)	*P*[a]
Child characteristics				
Age, y				<.001
4	16.1 (1131)	30.8 (517)	9.7 (614)	
5	21.5 (1454)	32.0 (495)	16.9 (959)	
6	20.4 (1461)	19.0 (315)	21.0 (1146)	
7	21.3 (1558)	13.6 (208)	24.7 (1350)	
8	20.7 (1547)	4.7 (69)	27.7 (1478)	
4 to 5	37.6 (2585)	62.7 (1012)	26.6 (1573)	<.001
6 to 8	62.4 (4566)	37.3 (592)	73.4 (3974)	
Weight, lb				<.001
<40	9.5 (625)	18.6 (296)	5.5 (329)	
40–59	56.4 (3829)	66.9 (1064)	51.8 (2765)	
60–79	22.0 (1653)	11.6 (192)	26.5 (1461)	
≥80+	7.8 (601)	1.7 (27)	10.5 (574)	
Unknown	4.3 (443)	1.1 (25)	5.7 (418)	
Seating position				<.001
Left outboard	41.7 (2916)	47.3 (747)	39.3 (2169)	
Center	14.1 (1148)	5.4 (96)	17.9 (1052)	
Right outboard	44.2 (3087)	47.3 (761)	42.8 (2326)	
Driver characteristics				
Age <25 y	5.0 (455)	5.5 (93)	4.7 (362)	.370
Male gender	26.8 (1957)	24.2 (411)	27.9 (1546)	.032
Restrained	97.1 (6898)	97.9 (1561)	96.7 (5337)	.070
Parent	81.0 (5721)	87.1 (1394)	78.4 (4327)	<.001

[a] *P* values between BPB seat and seat belt groups where applicable. For categorical (nondichotomous) variables, the *P* values refer to the differences in the distribution of the variables between the BPB seat and seat belt groups.

RESULTS

Between December 1, 1998, and November 30, 2007, interviews were completed on 34 732 children in 21 943 crashes, representing 531 193 children in 346 485 crashes. From the overall PCPS sample, 7151 children in 6591 crashes met the inclusion criteria (rear seated, aged 4–8 years, and restrained in a seat belt or BPB seat), representing 120 646 children in 116 503 crashes. Overall, 70% of the children were restrained by a seat belt; the remaining 30% were in BPBs. Table 1 provides the distribution of age, weight, gender, restraint use, and seating position for the children and driver/parent characteristics, including gender, restraint status, and relationship to the child by restraint type. For the overall sample, the children were approximately evenly divided across the 4- to 8-year age range (20%–22% for each year of age) with slightly fewer 4-year-old children (16%).

Children who were restrained by the seat belt were more likely to be older and heavier than those in boosters, although they remained within the recommended best practice guidelines for booster seat use. Children in both types of restraint were seated primarily in the outboard positions; however, a larger proportion of seat-belted children occupied the center seating position

TABLE 2 Crash Characteristics of the Study Group

Characteristic	Overall, Weighted % (Unweighted n) ($N = 7151$)	BPB Seat, Weighted % (Unweighted n) ($N = 1604$)	Seat Belt, Weighted % (Unweighted n) ($N = 5547$)	P[a]
Vehicle type				.090
Passenger car	41.8 (3333)	41.3 (674)	42.1 (2659)	
Large van	2.0 (161)	1.1 (27)	2.4 (134)	
Pickup truck	4.4 (296)	4.7 (73)	4.2 (223)	
SUV	25.0 (1568)	26.2 (404)	24.5 (1164)	
Minivan	26.7 (1793)	26.7 (426)	26.7 (1367)	
Model year				<.001
1990–1997	37.3 (3275)	23.0 (438)	43.5 (2837)	
1998–2001	38.5 (2547)	38.2 (597)	38.6 (1950)	
2002–2008	24.2 (1329)	38.8 (569)	17.8 (760)	
Crash severity				.032
Any intrusion	7.7 (1454)	6.3 (300)	8.2 (1154)	
Towaway, no intrusion	27.4 (3001)	26.1 (639)	28.0 (2362)	
None	65.0 (2696)	67.6 (665)	63.8 (2031)	
Direction of initial impact				.018
Front	46.6 (3312)	43.8 (695)	47.9 (2617)	
Near side	9.4 (744)	11.9 (228)	8.3 (516)	
Far side	11.6 (943)	12.0 (217)	11.4 (726)	
Rear	30.2 (1952)	30.6 (425)	30.0 (1527)	
Other/miscellaneous/unknown	2.2 (200)	1.8 (39)	2.4 (161)	

[a] P values between BPB seat and seat belt groups where applicable. For categorical (nondichotomous) variables, the P values refer to the differences in the distribution of the variables between the BPB seat and seat belt groups.

compared with booster-seated children (18% vs 5%). Booster-seated children were more likely to be driven by a parent (87% vs 78%; $P < .001$), whereas seat-belted children were driven more often by men (28% vs 24%; $P = .03$).

Table 2 provides the distribution of vehicle type, model year, crash severity, and impact type by restraint type. For children in both booster seats and vehicle seat belts, passenger cars were the most common vehicle type, followed by minivans, SUVs, pickup trucks, and large vans. Children who were restrained by the vehicle seat belt were more likely to be in vehicles of older model year and more likely to be involved in crashes with intrusion present or requiring a vehicle to be towed. In addition, a higher proportion of crashes for children in seat belts were frontal impacts and fewer were side impacts as compared with children in booster seats.

The overall risk for AIS 2 and greater injury was 1.15% for all 4- to 8-year-olds. Children in booster seats had approximately half the injury risk as children in seat belts (0.67% for children in BPB vs 1.36% for children in seat belts). Table 3 shows the unadjusted and adjusted ORs of injury for BPB seats versus seat belts. The adjusted models account for child age, weight, and seating position; driver restraint and relationship to the child; crash severity; model year (if applicable); direction of impact (if applicable); and crash year. After accounting for potential confounders, children who were aged 4 to 8 years and using BPB seats were 45% less likely to sustain injuries than similarly aged children who were using the vehicle seat belt (OR: 0.55 [95% confidence interval (CI): 0.32–0.96]). Children in side impact crashes benefited the most from booster seats, showing a reduction in injury risk of 68% for near-side impacts and 82% for far-side impacts. There was evidence that children in booster seats in frontal impacts were also at a reduced risk for injury compared with those in seat belts; however, we could not exclude the possibility of no difference. Children who were using booster seats in model year 1998 and newer vehicles had the greatest risk reduction compared with children in belts (OR: 0.33 [95% CI: 0.18–0.61]).

A total of 61% ($n = 932$) of the booster-seated children were restrained in high-back booster seats; the remaining 39% ($n = 672$) were in backless booster seats. Among children who were restrained in booster seats, we were not able to detect a difference in the risk for injury between the children in backless versus high-back boosters (OR: 0.84 [95% CI: 0.44–1.61]).

Tables 4 and 5 show the distribution of AIS 2+ injured body regions among 4-

TABLE 3 Unadjusted and Adjusted OR of Injury for BPB Seats versus Seat Belts

Parameter	BPB vs Belts			
	Unadjusted Model		BPB vs Belts Adjusted Model[a]	
	OR	95% CI	OR	95% CI
Overall	0.49	0.31–0.78	0.55	0.32–0.96
Direction of initial impact				
Front	0.43	0.24–0.78	0.59	0.31–1.13
Near side	0.25	0.14–0.46	0.32	0.13–0.79
Far side[b]	0.31	0.12–0.77	0.18	0.06–0.49
Rear	0.59	0.28–1.24	0.97	0.35–2.74
Vehicle model year				
1990–1997	1.12	0.50–2.52	1.33	0.53–3.35
1998–2001	0.33	0.18–0.63	0.31	0.14–0.68
2002–2008	0.35	0.16–0.76	0.54	0.20–1.47
1998 and later	0.32	0.19–0.52	0.33	0.18–0.61

[a] Adjusted for child age, child weight, child seating position, driver restraint, whether driver parent, crash severity, model year (if applicable), direction of impact (if applicable), and crash year.
[b] Far-side impacts include children sitting in the far-side outboard, as well as center seating position.

TABLE 4 Body Region Distribution of Injuries Among 4- to 8-Year-Olds by Restraint Type

Injured Body Region	Overall, Weighted % (Unweighted *n*) (*N* = 7151)[a]	BPB Seat, Weighted % (Unweighted *n*) (*N* = 1604)[b]	Seat Belt, Weighted % (Unweighted *n*) (*N* = 5547)[c]
Head	65.4 (471)	67.4 (78)	65.0 (393)
Face	8.7 (110)	9.4 (14)	8.5 (96)
Chest	2.6 (28)	4.0 (8)	2.3 (20)
Abdomen	10.7 (87)	5.1 (5)	12.0 (82)
Neck/spine	1.5 (14)	1.1 (3)	1.6 (11)
Upper extremity	6.6 (89)	5.4 (15)	6.9 (74)
Lower extremity	4.5 (66)	7.6 (18)	3.8 (48)

[a] Total $n = 722$ with injury (1.15%).
[b] Total $n = 118$ with injury (0.67%).
[c] Total $n = 604$ with injury (1.36%).

TABLE 5 Body Region Distribution of Injuries Among Booster-Seated Children by Booster Seat Type

Injured Body Region	Backless Booster Seat, Weighted % (Unweighted *n*) (*N* = 672)[a]	High-Back Booster Seat, Weighted % (Unweighted *n*) (*N* = 932)[b]
Head	58.9 (42)	72.8 (36)
Face	17.8 (7)	4.1 (7)
Chest	2.8 (3)	4.7 (5)
Abdomen	0.0 (0)	8.3 (5)
Neck/spine	2.8 (3)	0.0 (0)
Upper extremity	4.7 (5)	5.9 (10)
Lower extremity	13.1 (11)	4.1 (7)

[a] Total $n = 57$ with injury (0.63%).
[b] Total $n = 61$ with injury (0.70%).

to 8-year-old children by restraint type. Head injuries were the most prevalent among all injured children, regardless of restraint type, accounting for ~65% of injuries. Among injured children in booster seats, face and lower extremity injuries were the next most common at 9% and 8%, respectively. Injured children in seat belts sustained injuries to the abdomen and face at 12% and 9%, respectively. For both types of BPB seats, head injuries were the most common injury sustained, representing 59% and 73% of injuries for backless and high-back BPB seats, respectively. Head injuries were followed by face injuries for backless BPB seats and abdominal injuries for high-back BPB seats. Of those with an AIS 2+ injury, 9%, 7%, and 14% of children in seat belts, high-back booster seats, and backless booster seats, respectively, sustained an AIS 2+ injury to >1 body region. There was not a significant difference between the percentage of children with multiple injuries between those in high-back versus backless booster seats ($P = .26$).

DISCUSSION

This study used the most recent data available to reexamine the effectiveness of BPB seats and extends previous reports that booster seats reduce the risk for injury in children by studying a greater percentage of older children; 37% of the study sample who used booster seats were 6 to 8 years of age. The analysis confirmed that children who were aged 4 to 8 and used BPB seats were 45% less likely to sustain injuries than similarly aged children who used the vehicle seat belt when considering all crash directions and vehicle model years.

Children in side impacts derived the largest relative protection from booster seats, with a reduction in risk of 68% and 82% for near-side and far-side crashes, respectively. Reductions in injury risk in side impact crashes for children who were restrained in BPB seats were previously reported,[3] and the analyses on this larger data set suggest an even larger protective effect of boosters in this impact direction. Side impact crashes often have a substantial frontal component.[9] The shoulder portion of the seat belt may have better fit on the child's shoulder when the child is in a booster seat and therefore provide better protection than a shoulder belt that fits poorly in the absence of a booster seat. The largest relative benefit was realized for children who were seated far side to the crash, for which the risk for torso rollout from the shoulder belt is greatest.

Of interest, although the OR suggested injury risk reduction for children in boosters in frontal impacts compared with those in seat belts, the results did not reach statistical significance for this data set. One reason may be because of the changing landscape of restraint practices. Our previous analysis reported an injury risk of 1.95% for 4- to 7-year-old children in belts compared with 0.77% for boosters.[2] In this analysis, we report an injury risk of 1.36% for children in belts compared with 0.67% for children in boosters. The reduction in injury risk for children in belts is likely attributable to 2 reasons. First, the previous study included children in both the front and rear rows, whereas this study was limited to those in the rear row. Front seating is associated with an increased risk for injury, and the proportion of seat belt–restrained children in the front row was higher than those in booster seats. Second, because more of the children in the 4- to 8-year age range use boosters, fewer of the smallest children (ie, those most susceptible to injury from poor belt fit) are using belts; therefore, as the population of seat belt users shifts toward the older children, they are more likely to fit better in the vehicle seat belt and their overall injury risk reduced.

Importantly, these results suggest that the effectiveness of booster seats does not vary by the type of booster seat: backless or high-back. Backless booster seats are less costly and often more acceptable to older children because of the absence of a back that makes them look like a toddler child restraint. These results give confidence to parents and health educators that choosing this type of restraint for their child does not represent a compromise in safety.

Head injuries remained the most commonly injured body region for all of the restrained children in this study; however, abdominal injuries were the second most common injuries for belted children as a result of "seat-belt syndrome" injuries. Children who were restrained by booster seats sustained injuries to the face and lower extremity, with a notable absence of abdominal injuries.

This research was conducted on crashes that involved State Farm policyholders only. State Farm is the largest insurer of automobiles in the United States, with more than 38 million vehicles covered; therefore, its policyholders are likely representative of the insured public in the United States. This study obtained nearly all of its data via telephone interview with the driver/parent of the child and is therefore subject to potential misclassification. Ongoing comparison of survey data with crash investigation data has revealed a high degree of agreement between the 2 sources. In previous published analyses of PCPS data regarding risk for injury to children in compact extended-cab pickup trucks[10] and the effectiveness of booster seats,[2] sensitivity analyses that were conducted to quantify the potential impact of misclassification bias indicated that an implausible amount (40%–50% misclassification of restraint use) of misclassification would be required for results of our analyses to lose statistical significance. Although some degree of misclassification likely exists in parent-reported data, we believe that it is of a magnitude that would not alter the conclusions of this report. Our study sample represents the entire spectrum of crashes reported to an insurance company, from those with minor vehicle damage to those with loss of life. It must be noted, however, that given this distribution of crashes, we are looking almost exclusively at nonfatal injuries.

CONCLUSIONS

This study reconfirms previous reports that BPB seats reduce the risk for injury in children 4 through 8 years of age by studying a greater percentage of children aged 6 to 8 years than previous studies. After adjustment for potential confounders, children who were aged 4 to 8 and using BPB seats were 45% less likely to sustain injuries than similarly aged children who were using the vehicle seat belt. Among children who were restrained in BPB seats, there was no evidence of a difference in the performance of backless versus high-back boosters. On the basis of these analyses, parents, pediatricians, and health educators should continue to recommend as best practice the use of BPB seats once a child outgrows a harness-based child restraint until he or she is at least 8 years of age.

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