ABDOMINAL INJURY RISK FOR CHILDREN SEATED IN BELT POSITIONING BOOSTER SEATS

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ABSTRACT

Previous studies have demonstrated that booster seats reduce the risk of seat belt syndrome, in particular the occurrence of abdominal organ injuries, by improving the fit of the seat belt on young children and encouraging better posture and compatibility with the vehicle seat itself. However, other researchers have shown that abdominal injuries are still prevalent even with the use of booster seats. In the US, as booster seat use increases and more data become available, particularly on older children in booster seats, the abdominal injury risk to these children should be revisited. Therefore the objective of this study was to quantify the time trend increase in appropriate restraint for rear row(s) seated children age 4 to 7 years old and define the prevalence of abdominal injuries in those restrained by belt-positioning booster seats. A probability sample of 4,517 crashes involving 5,259 children, weighted to represent 89,588 children in 77,153 crashes was collected from an on-going child specific crash surveillance system between December 1, 1998, and December 31, 2005. Appropriate restraint, including the use of belt positioning boosters, increased from 17% to 67% among 4 to 7 year olds during the time period of data collection. In frontal impacts, abdominal injuries occurred among 0.25% of all 4- to 7-year-olds, including 0.32% of those in seat belts and 0.04% of those in belt-positioning booster seats. Among children restrained in belt positioning booster seats, we were not able to detect a difference in the risk of abdominal injuries between the age groups This study, conducted on a dataset with increased booster use by 6 and 7 year olds, confirms previous analyses that point to a reduced abdominal injury risk for children in belt-positioning booster seats. Abdominal injuries still occurred in some booster-seated children, however, suggesting the need for further in-depth study into the circumstances surrounding these injuries.

INTRODUCTION

Abdominal injuries are the second to head and face injuries in young children using adult seat belts. [1] Reported injuries to this region focus on "seat-belt syndrome", which consists of belt-induced abdominal injuries and lumbar spine fractures. [2-6] While all children are at risk of developing seat belt syndrome, the poor fit of the belt in younger children likely places them at higher risk than older children. In a study of abdominal injuries in belted children, the scenarios resulting in injury involved several vehicle and child factors such as seat belt geometry not ideal for children (e.g. a shallow lap belt angle), position of the shoulder belt behind the back or slouched posture to position the knees over the edge of the seat. [7]

The use of a belt positioning booster seat (BPB) improves these factors by improving the fit of the seat belt on young children and encouraging better posture and compatibility with the vehicle seat itself. They are the recommended restraint for 4 to 8 year old children according the American Academy of Pediatrics and National Highway Traffic Safety Administration. Booster seats are designed to improve lap and shoulder belt fit on children, minimizing the factors that result in abdominal injury. Our previous research has confirmed this in real world crashes by showing booster seats reduce the risk of injury to children age 4-7 years old by 59% compared to similar age children in adult seat belts. This reduction in injury risk was particularly evident in the abdomen, resulting in 0 injuries per 1,000 booster seat restrained children in crashes versus 4.4 per 1,000 for children in belts. [1] This analysis conducted on data from 1998 to 2002 was based primarily on children age 4 and 5 years of age due to the usage practices during that time period. In the time since this research was published, however child restraint use including booster seats among children age 4 to 8 years of age has improved by 54% [8] and, as more children, in particular older children, are appropriately restrained in booster seats,

continued monitoring of their real world experience is paramount.

Recently, other researchers have questioned the issue of abdominal injury prevention by booster seats. Several studies have reported the occurrence of these injuries in other field studies. In France, a study of 1629 children under 10 years old involved in crashes during 1992 and 1993 revealed that abdominal and pelvic injuries represented 13% of AIS 2 and greater injuries sustained by booster-seated children. [9] Using data from this study, Trosseille reported on the abdominal injuries sustained by nine booster-seated children but reported few crash or restraint use details such as impact type, severity, booster seat type or presence of misuse. [9] More recently, Johannsen used data from the European CHILD (CHild Injury Led Design) project to reconstruct real world crash events in an effort to validate newly designed abdominal sensors for the Q family of ATDs. In his study, he reconstructed and reported on four cases of frontal impacts involving abdominal injury in booster-seated children. [10] In a recent study of booster-seated children in Australia, Brown reported on 2 children who sustained abdominal injuries, one as the result of a frontal impact and one as the result of a side impact. [11]

Due to the changing nature of the booster use landscape and these case series reports of abdominal injuries in booster seat restrained children, this issue deserves further investigation. Therefore the objective of this study was to quantify the time trend increase in appropriate restraint for rear row(s) seated children aged 4 to 7 years old and define the prevalence of abdominal injuries in those restrained by belt-positioning booster seats.

METHODS

Study Population and Data Collection

Data collected from December 1, 1998 to December 31, 2005 as part of Partners for Child Passenger Safety (PCPS) were used in this analysis. Detailed descriptions of the study population and methods involved in data collection and analysis have been previously published. [12] PCPS consists of a large scale, population based, child-specific crash surveillance system in which insurance claims from State Farm Insurance Co. (Bloomington, IL) function as the source of subjects. Crashes qualifying for inclusion were those involving at least one child occupant < 15 years of age riding in a model year 1990 or newer State Farm-insured vehicle. Qualifying crashes were limited to those that occurred in fifteen states and the District of Columbia, representing three large regions of the United States (East: NY, NJ [until 11/01], PA, DE, MD, VA, WV, NC, DC; Midwest: OH, MI, IN, IL; West: CA, NV, AZ, TX [starting 6/03]). On a daily basis, data from qualifying and consenting claims were transferred electronically from all involved State Farm field offices to researchers at The Children's Hospital of Philadelphia and University of Pennsylvania. 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 medical treatment received by all child occupants. 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 as reported by the policyholder (no treatment, physician's office or emergency department only, admitted to the hospital, or death).

A stratified cluster sample was designed in order to select vehicles (the unit of sampling) for the conduct of a telephone survey with the driver. Vehicles containing children who received medical treatment following the crash were over-sampled 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 phone and, if medical treatment had been received by a passenger, screened via an abbreviated survey to verify the presence of at least one child occupant with an injury. All vehicles with at least one child who screened positive 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 where 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 six days, with 95% of interviews completed within 47 days of the crash.

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 (BPB), or child safety seat (CRS). Among the 169

children aged 4-7 for whom paired information on restraint use was available from both the telephone survey and crash investigations, agreement (child restraint vs. no child restraint / unrestrained) was 96% between the driver report and the crash investigator (kappa value for agreement beyond chance=0.86, $p<0.001$). Seating location of each child was determined from the telephone survey. Among the 170 children for whom paired information on seating position (front versus rear) was available from both the telephone survey and crash investigations, agreement was 99% between the driver report and the crash investigator (kappa value for agreement beyond chance=0.99, $p<0.001$).

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, and have been previously validated for their ability to distinguish AIS 2+ from less severe injuries. [13] For the purposes of this study, children were classified as injured if a parent/ driver reported a clinically significant injury: 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).

Separate verbal consent was obtained from eligible participants for the transfer of claim information from State Farm to CHOP/Penn, for the conduct of the telephone survey, and for the conduct of 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 increase in appropriate restraint for children 4 to 7 years of age over the time period of study and the relative risk of abdominal injury for those restrained in belt positioning booster seats compared with seat belts. Chi-square tests of association were used to compute p-values under the null hypothesis of no association between restraint type and risk of injury. Logistic regression modeling was used to compute the odds ratio (OR) of injury for those seated in belt-positioning booster seats versus seat belts, both unadjusted and adjusted for several potential confounders including differences in driver age (< 25 years vs. 25 and older), seating position (front vs. rear), crash severity (intrusion, towaway/no intrusion, non-towaway), 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. [14] 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 chi-square tests of association and Taylor Series linearization estimates of the logistic regression parameter variances were calculated using SAS-callable SUDAAN: Software for the Statistical Analysis of Correlated Data, Version 9.0 (Research Triangle Institute, Research Triangle Park, NC, 2006). Results of logistic regression modeling are expressed as unadjusted and adjusted odds ratios (OR) with corresponding 95% confidence intervals (CI).

RESULTS

This analysis includes 5,259 restrained 4 to 7 year old children in 4,517 crashes, weighted to represent 89,588 children in 77,153 crashes. Overall, 41% of children were appropriately restrained in child restraints or belt positioning booster seats during the time period of data collection. Eighteen percent were restrained by harness-based child restraint systems (CRS), 23% by belt positioning booster seats (BPB), and 59% by the vehicle seat belts. The overall risk of AIS 2 or greater injuries to all body regions was 1.13% for all restrained children, and 0.70% and 1.43% for appropriately and inappropriately restrained children, respectively.

Table 1 shows the distribution of the study sample in terms of the child's seat position, driver characteristics, crash severity and vehicle type. Appropriately restrained children were more likely to be seated in the outboard positions and be driven by a parent at the time of the crash. Inappropriately restrained children were more likely to be in crashes resulting in intrusion or vehicles towed from the scene.

Trends in Appropriate Restraint Use

During the time period of data collection, appropriate restraint increased from 17% to 67% for 4 to 7 year old children, a three-fold increase during the seven-year period. For the older children, 6 to 7 years of age, appropriate restraint increased from 3% in 1999 to 50% in 2005. For the younger children, 4 to 5 years of age, appropriate restraint increased from 30% to 82% in the same time period. Figure 1 shows the time trend increase in appropriate restraint for 4

to 5 year old and 6 to 7 year old children, stratified by CRS, high back BPB and low back BPB use.

Table 1.
Characteristics of Crashes Involving Children Aged 4 to 7 Years by Appropriate and Inappropriate Restraint Use*

Characteristics	Appropriate Restraint (%) (unweighted n=1613)	Inappropriate Restraint (%) (unweighted n=3646)	P Value
Seat position			
Left rear	46.2	38.9	<0.001
Center rear	9.7	18.4	
Right rear	44.1	42.7	
Driver			
Aged <25 yrs	5.4	5.3	0.90
Parent of child	87.1	79.5	<0.001
Crash severity			
Intrusion	7.1	8.4	0.011
Towaway, no intrusion	23.6	28.1	
Not towaway, no intrusion	69.2	63.5	
Vehicle type			
Passenger car	42.9	44.1	0.66
SUV	24.3	22.2	
Minivan	26.8	27.4	
Large van	1.6	2.3	
Pickup truck	4.4	4.0	

*Data presented as weighted percentages

In 1999, 65% of appropriately restrained 4 to 5 year old children were using a harness-based CRS, 28% in a high back BPB, and the remaining 8% in a low back BPB. By 2005, a larger proportion of 4 to 5 year olds were in booster seats, with 41% and 24% in high and low back BPB, respectively. Thirty-five percent remained in CRS. For 6 to 7 year old children, few children were appropriately restrained in 1999 (3%), 80% of which were in a harness-based CRS. By 2005, the appropriately restrained 6 to 7 year old children (50%) were primarily in booster seats, 42% and 39% in high and low back BPB, respectively. The remaining 19% were in CRS.

Abdominal Injury Risk

In order to examine abdominal injury risk of those restrained in belt positioning booster seats, the analysis was further restricted to the subset of children in frontal impacts, who were restrained by BPB (high back or low back) or seat belts at the time of the crash. This resulted in 2,102 children in 1,789 crashes, weighted to represent 34,301 children in 29,061 crashes. The overall abdominal injury risk was 0.25% for all 4 to 7 year olds, including 0.30% for 4 to 5 year old children and 0.20% for 6 to 7 year old children. Table 2 shows the abdominal injury risk by age group for children restrained by BPB and vehicle seat belts.

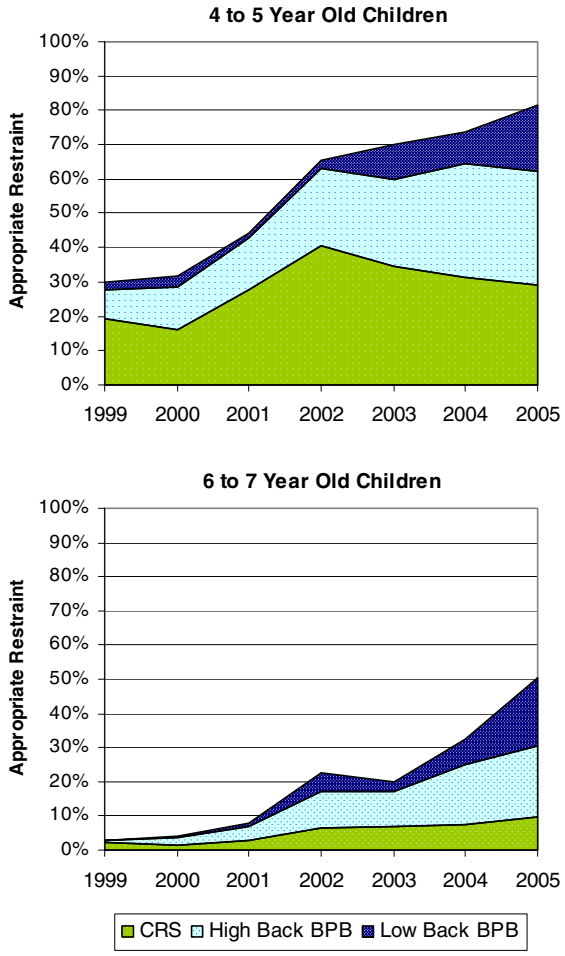

Figure 1. Time trend increase in appropriate restraint for 4 to 5 year old and 6 to 7 year old children.

Children aged 4 to 7 using the vehicle seat belt were more likely to sustain abdominal injuries than similarly aged children using belt positioning booster seats (OR 9.22, 95% CI, 2.01-42.36). The younger age group, children 4 to 5 years of age, showed a significant increase in abdominal injury risk when using seat belts (OR 13.99, 95% CI, 1.66-117.8). The older age group, children 6 to 7 years of age, also showed an increased abdominal injury risk when using seat belts but this finding did not reach statistical significance (OR 5.61, 95% CI, 0.65-48.2). Among children restrained in belt positioning booster

seats, we were not able to detect a difference in the risk of abdominal injuries between the age groups (OR 0.82, 95% CI, 0.07-9.23). When stratified by seat belt type, the results were similar with a reduction in abdominal injury risk for booster seated 4 to 7 year olds over both lap belted children (OR 5.16, 95% CI, 1.37-19.42) and lap/shoulder belted children (OR 10.20, 95% CI, 2.05-19.42).

Table 2.
Abdominal Injury Risk for 4 to 7 Year Old Children by BPB and Seat Belt Use

Age Group (yrs)	BPB (%) (unweighted n=388)	Seat belt (%) (unweighted n=1,714)	P Value
All 4 to 7	0.04	0.32	0.004
4 to 5	0.03	0.46	0.015
6 to 7	0.04	0.23	0.116

*Data presented as weighted percentages

Table 3 shows the abdominal organ injured by restraint type. The table shows a count of injured organs, therefore it may sum to greater than the number of children injured. . Injuries to children in seat belts occurred more commonly to the stomach and intestines than the solid organs such as liver and spleen. Only three children in BPB were injured in this study sample, resulting in one injury to the liver, stomach/intestines and other organ.

Table 3.
Distribution of Injured Abdominal Organ by Restraint Type

Organ of Injury	BPB (n=3)	Lap Belt Only (n=9)	Lap and Shoulder Belt (n=22)
Liver	1	1	2
Spleen	0	2	3
Stomach/Intestines	1	5	9
Other Organ	1	1	4
Unknown	0	0	4

DISCUSSION AND CONCLUSIONS

Our research findings confirm those of previously published studies indicating an increase in appropriate restraint among children aged 4 to 7 years old. [15, 16] This percentage continues to increase over time; however in 2005, 20% of 4 and 5 year old children and 50% of 6 and 7 year old children continued to be inappropriately restrained in vehicle seat belts. This points to the need to continue education and legislative efforts toward appropriate restraint in this age range. . Recent research has shown that, in the United States, appropriate restraint increases in states that amended child restraint laws to mandate booster seat use up through age 7 years. [15]

Appropriately restrained children were using a combination of CRS, high back and low back booster seats. CRS and high back BPB are the most common restraints for the younger age group but the proportion of low back BPB continues to increase. Most appropriately restrained children in the older age group are in belt positioning booster seats, also demonstrating a rise in the proportion of low back boosters. While all booster seats have guides to position the lap portion of the belt low and flat across a child's upper thighs, high back boosters also provide head support and upper belt guides to optimize the position of the shoulder portion of the belt. As low back booster use increases, research to better understand the experience of children in these restraints should continue.

This study extends previous reports that belt-positioning booster seats reduce the risk of abdominal injury in children 4 to 7 years of age by studying a greater percentage of 6 and 7 year olds. [1] While children in BPB are at significantly decreased risk of these injuries, some abdominal injuries still occurred. These included injuries to both the solid and hollow organs, including some injuries that may be associated with seat belt syndrome. Abdominal injuries in booster-seated children continue to be rare events but deserve more detailed examination through review of in-depth investigations.

Limitations

This research is conducted on crashes involving State Farm Insurance Co. policyholders only. State Farm is the largest insurer of automobiles in the United States, with over 38 million vehicles covered; therefore, its policyholders are likely representative of the insured public in this country. The surveillance system is limited to children occupying model year 1990 and newer vehicles insured in 15 states and the District of Columbia. Our study sample represents the entire spectrum of crashes reported to an insurance company including property damage only, as well as bodily injury crashes. While our sample included a significant number of vehicles with intrusion into the occupant compartment, it is possible that the PCPS study does not have a representative sample of the most severe crashes. Nearly all of the data for this study were obtained via telephone interview with the driver/parent of the

child and is, therefore, subject to potential misclassification. On-going comparison of driver-reported child restraint use and seating position to evidence from crash investigations has demonstrated a high degree of agreement. Some misclassification of seat type may occur due to the changing market of child restraints such that many are combination seats that may be used with a harness or a lap and shoulder belt. In addition, misuse of the booster seat and the lap and shoulder belt may not be fully accounted for in these analyses.

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