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Injuries to belted older children in motor vehicle crashes

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ABSTRACT

Context: The American Academy of Pediatrics and the National Highway Traffic Safety Administration currently recommend that, unless they are under 57 in. in height, 8–12-year-old children use seat belts and all should ride in the rear seats of vehicles. These recommendations assume that the vehicle seat belt should provide adequate protection for these older children in the event of a crash.
Objectives: To describe characteristics of older children in the rear seat using seat belts in crashes, to estimate their risk and body region distribution of injury, and to identify risk factors for injury.
Methods: A representative sample of 6680 seat belt-restrained occupants, 8–12 years of age, seated in the rear seat during crashes involving insured vehicles in 16 US states between December 1998 and December 2007. A telephone interview was conducted with the driver of each vehicle. The main outcome was the parent-reported injury defined as Abbreviated Injury Scale (AIS) 2 or greater injuries.
Results: The risk of injury for belted 8–12 year olds in the rear seat was 1.3%. Head injury was the most common injury (60%), followed by injuries to the face (9%), upper extremity (9%) and abdomen (9%). One out of five (21%) 8–12 year olds either did not use the shoulder portion of the vehicle seat belt or placed it incorrectly behind their back or under their arm. Bivariate analyses indicated a higher risk of injury for these children (1.8%) as compared to children using both the lap and shoulder portions of the seat belt (1.1%). However, this difference was not statistically significant when other risk factors such as crash severity and characteristics of the driver were considered.
Conclusions: Injuries to the head, face, abdomen and upper extremity are the most common injuries to target for improved protection among 8–12 year olds in seat belts. Driver and crash characteristics are important risk factors for injury. A recent federal motor vehicle safety standard requiring lap and shoulder belts in all rear seat positions has the potential to further decrease the risk of injury to older children using seat belts.

1. Introduction

For several years child passenger safety researchers focused most of their attention on children under age 8. Evidence of the safety benefits of child restraints for these younger children is robust (Arbogast et al., 2004a; Durbin et al., 2003, 2005; Elliott et al., 2006a; Henary et al., 2007). As a result, the use of age-appropriate restraints by younger children has increased markedly over the past 9 years (The Children's Hospital of Philadelphia, 2007; Durbin et al., 2001a; Winston et al., 2003, 2004, 2007). Comparatively little attention has been paid to the safety of older children, those aged 8–12 (Aitken et al., 2007). This is principally due to the assumption that the vehicle seat belt should provide adequate protection for these older children in the event of a crash (Miller et al., 2002) and that school-age children are at least as well-protected as adults (Halman et al., 2002). This age group of children has often been dubbed "tweens." The name takes into account not only the pre-teen age of the group, but also the gap between the younger group of children requiring child restraints and the older adolescent group who may benefit from vehicle restraint systems that are designed for adults.

The American Academy of Pediatrics (2008) and the National Highway Traffic Safety Administration (NHTSA) (2008a) currently recommend all children under age 13 in the rear seats of vehicles and that 8–12-year-old children, unless they are under 57 in. in height, use the vehicle seat belts. One 8–12-year-old passenger is killed in a motor vehicle crash every day (356 in 2006) and almost

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70,000 (69,166 in 2006) are injured (NHTSA, 2006; CDC, 2008). Of the tweens killed in crashes, 56% were unrestrained and 31% were riding in the front seat (NHTSA, 2006). Recently, NHTSA has supported efforts to develop and validate a 10-year-old anthropometric test device (i.e., crash test dummy) in order to provide an age-appropriate instrument that would enable restraint suppliers and automobile manufacturers to better protect these older children (NHTSA, 2007).

One of the initial steps in achieving optimal protection for these older children is to better understand how current restraint systems perform. Therefore, the objective of this study was to characterize the experience of older children in motor vehicle crashes whose restraint use (seat belts) and seating position (rear seats) were consistent with current recommendations. Specifically, we aimed to determine the risk and body region distribution of injury for children aged 8–12 using vehicle seat belts in the rear seat in order to identify priorities for enhancing their protection and to identify important risk factors for injury.

2. Method

2.1. Study design

The source for this study's data was the Partners for Child Passenger Safety (PCPS) study. PCPS is a large scale, child-specific crash surveillance system. Insurance claims from State Farm function as the source of subjects, with telephone survey and on-site crash investigations serving as the primary sources of data. A description of the study methods has been published previously (Durbin et al., 2001b). Data for this study were collected from 1 December 1998 to 31 December 2007. Passenger vehicles qualifying for inclusion were State Farm-insured, model year 1990 or newer, and involved in a crash with at least one child occupant less than 16 years of age. Qualifying crashes were limited to those that occurred in 16 states and the District of Columbia, representing three large regions of the United States (East: NY, NJ [through November 2001], PA, DE, MD, VA, WV, NC, DC; Midwest: OH, MI, IN, IL; West: CA, NV, AZ, TX [starting June 2003]).

After policyholders consented to participate in the study, limited data were transferred electronically to researchers at The Children's Hospital of Philadelphia and the University of Pennsylvania School of Medicine. 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 hospital or death).

A stratified cluster sample was used 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 a 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 Also selected was a 2.5% sample of crashes where no medical treatment was received. The full interview involved a 30-min telephone survey with the driver of the vehicle and parent(s) of the involved children. The median length of time between the date of the crash and the completion of the interview was 6 days, with 95% of interviews completed within 47 days of the crash.

For the current analysis, the study sample consisted of vehicles with 8–12-year-old occupants restrained with seat belts and seated in the rear of the vehicles. This accounted for 6680 children in 5325 vehicles, representing 102,670 children in 82,356 vehicles.

2.2. Variable definitions

The seating row, seating position, and restraint status for each child were reported by the parent/driver in the telephone survey. The second and third rows of seats in the vehicle were combined and defined as the rear row(s). Two levels of restraint use were defined: use of only a lap belt or any lap/shoulder belt used incorrectly (i.e., the shoulder belt behind the back or under the arm) vs. the recommended use of both the lap and shoulder portions of the seat belt. Seating position was defined as: center vs. outboard. Crash severity was determined both by the drivable status of the vehicle (i.e., whether or not the vehicle was towed from the crash scene) as indicated in the insurance claims data, as well as by driver report of any intrusion into the occupant compartment of the vehicle via the telephone survey (i.e., the integrity of the vehicle structure was lost and the interior space was reduced). A three-level categorization of crash severity was then created (from highest to lowest severity): (1) intrusion, (2) no intrusion and non-drivable, and (3) no intrusion and drivable. Driver responses regarding injuries to children were classified by body region and severity, based on the Abbreviated Injury Scale (AIS) score and have been validated for their ability to distinguish injuries with AIS scores of $\geq$2 from less severe injuries (Durbin et al., 1999). Children were classified as injured if a parent/driver reported any injury with an Abbreviated Injury Scale score of 2 or greater, which includes concussions and more serious brain injuries, all internal organ injuries, spinal cord injuries, facial bone fractures, and extremity fractures.

Separate verbal consent was obtained from eligible participants for the transfer of claim information from State Farm and for the conduct of the telephone survey. 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.

2.3. Data analysis

The primary purpose of these analyses was to describe characteristics of older children using seat belts in the rear seats of vehicles in crashes and to estimate the risk of injuries, the body region distribution, and to investigate risk factors for injury among these children. In particular, we were interested in determining the association between restraint type, demographic characteristics, seating position, vehicle characteristics, driver characteristics, and crash severity with injury risk. Robust χ^2-tests of association were used to compute p-values under the null hypothesis of no association between the mentioned risk factors and risk of injury. Risk factors showing an association at the α level of 0.15 were included into a multivariable logistic regression and adjusted odds ratios (OR) with 95% confidence intervals (CI) estimated. Because of the overall low risk of injury (1.3%), these ORs were considered good approximations of the relative risk. 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 (Korn and Graubard, 1995). To account for this potential bias and to adjust inferences to account for stratification of subjects according to medical treatment and clustering of subjects according to vehi-

Table 1
Distribution of belted rear row seated passengers and vehicle characteristics

Characteristic	Weighted % (unweighted *N*)	% injured	*p*[a]
Total	100(6680)	1.3 (761)	
Gender			
Male	47.3 (3081)	1.2 (351)	0.325
Female	52.7 (3599)	1.4 (410)	
Age (years)			
8	23.4 (1521)	1.3 (183)	0.506
9	22.1 (1462)	1.1 (173)	
10	20.9 (1392)	1.0 (144)	
11	17.8 (1193)	1.7 (132)	
12	15.8 (1112)	1.4 (129)	
Belt type			
Lap and shoulder belt	79.3 (4943)	1.1 (487)	0.021
Lap only belt or shoulder belt under arm or behind back	20.7 (1737)	1.8 (274)	
Seating			
Outboard	88.0 (5809)	1.2 (636)	0.107
Center	12.0 (871)	1.9 (125)	
Age of driver (years)			
<25	3.4 (404)	2.7 (75)	0.004
≥25	96.6 (6268)	1.2 (685)	
Relationship of driver			
Parent	72.5 (4660)	1.3 (518)	0.188
Not parent	27.5 (2020)	1.1 (243)	
Driver restrained			
Yes	97.3 (6479)	1.2 (718)	0.117
No	2.7 (198)	3.4 (43)	
Model year of vehicle			
1990–1997	37.3 (3184)	1.5 (373)	0.360
1998–2001	38.7 (2327)	1.2 (264)	
2002–2007	24.0 (1169)	1.1 (124)	
Vehicle type			
Passenger car	39.2 (3047)	1.7 (399)	0.0004
Large van	2.8 (171)	0.6 (11)	
Pickup truck	4.5 (292)	2.8 (45)	
SUV	25.9 (1450)	1.1 (158)	
Minivan	27.6 (1720)	0.7 (148)	
Crash severity			
Intrusion	7.3 (1357)	6.0 (316)	0.0001
No intrusion (non-drivable)	26.6 (2893)	2.2 (389)	
No intrusion (drivable)	66.1 (2430)	0.4 (56)	
Airbag deployment			
Yes	7.2 (1476)	5.8 (323)	0.0001
No	92.8 (5204)	0.9 (438)	
Direction of impact			
Frontal	42.8 (2981)	1.4 (353)	0.0001
Right side	11.7 (849)	1.9 (134)	
Left side	10.3 (769)	2.1 (114)	
Rear	32.3 (1865)	0.6 (130)	
Other/unknown	2.9 (216)	1.4 (30)	

[a] *p*-value is calculated for the difference in risk of injury among categories of each variable.

cle, robust χ^2-tests of association and Taylor series linearization estimates of the logistic regression parameter variances were calculated by using SAS-callable SUDAAN: Software for the Statistical Analysis of Correlated Data, version 9.1 (Research Triangle Institute, Research Triangle Park, NC).

3. Results

The complete PCPS data showed that 71% of 8–12 years olds rode in the rear seats and that this proportion decreased with age: 83% at age 8; 78% at age 9; 70% at age 10; 65% at age 11; and 57% at age 12. Of the 7285 children in the rear rows, 6680 were wearing seat belts (the current study sample), 114 were in belt-positioning booster seats, and 491 were unrestrained. Unrestrained tweens had an AIS 2 + injury risk of 3.1%, while those in belt-positioning booster seats had an injury risk of 0.3%.

Characteristics of the study sample (restricted to rear-seated children in seat belts) are shown in Table 1, which provides the distribution of the demographic features, belt type and seating position, driver attributes, vehicle type, and crash severity among 8–12 year olds restrained in seat belts in the rear. The same table shows the proportion of children who sustained an AIS 2 + injury by the various characteristics of the sample. 53 percent of the sample was female, and more than 45% of the sample were children younger than 10. Lap only belts were used by 12.8% of children. Lap/shoulder belts were used by 87.2% of children; 80.1% used them appropriately, and 7.1% were reported to have placed the shoulder portion under their arm or behind their back. Only 12.0% of children were seated in the center position on the rear row(s) of the vehicle. Most drivers were restrained (97.3%) during the crash; were older than 24 years of age (96.6%); and were the parents (72.5%) of the child occupant. Bivariate analyses showed that injury risk among children was significantly lower when children used both the lap and shoulder portion of the seat belt (1.1% vs. 1.8% when they used a lap only belt or incorrectly used the lap and shoulder belt), were driven by older (age ≥25 years) drivers, were riding in mini or full-size vans, and were involved in less severe and non-side impact crashes.

Table 2 shows adjusted ORs with 95% CI derived from the logistic regression model. The risk of injury for children not using both portions of the seat belt properly was slightly higher and did not

Table 2
Adjusted odds ratios for injury risk. Belted children seated in the rear of the vehicle

Characteristic	Odds ratio	95% CI
Belt type		
Lap and shoulder belt	1.00	–
Lap only belt or shoulder belt under arm or behind back	1.20	0.84–1.66
Seating position		
Outboard	1.00	–
Center	1.29	0.80–2.08
Age of driver (years)		
<25	1.58	0.97–2.58
≥25	1.00	–
Driver restrained		
Yes	1.00	–
No	2.90	1.03–8.16
Vehicle type		
Passenger car	1.00	–
Large van	0.43	0.18–1.04
Pickup truck	2.88	1.12–7.39
SUV	0.79	0.46–1.36
Minivan	0.56	0.38–0.82
Crash severity		
Intrusion	12.75	5.99–27.16
No intrusion (non-drivable)	4.53	2.24–9.18
No intrusion (drivable)	1.00	–
Airbag deployment		
Yes	1.00	–
No	0.36	0.24–0.55
Direction of impact		
Frontal	1.00	–
Right side	1.50	0.82–2.78
Left side	1.38	0.74–2.60
Rear	0.77	0.48–1.26
Other/unknown	0.98	0.49–2.00

Table 3
Distribution of injuries by body region among rear-seated children by type of seat belt used

Injuries	Total	Lap and shoulder seat belt used (unweighted $N = 487$)	Lap only seat belt used (unweighted $N = 274$)[a]	p-Value
Overall	1.27	1.14	1.77	0.021
Head	0.84	0.76	1.13	0.142
Face	0.12	0.08	0.26	0.003
Chest	0.10	0.11	0.05	0.277
Abdomen	0.12	0.09	0.24	0.014
Neck/spine/back	0.02	0.01	0.07	0.200
Upper extremity	0.13	0.12	0.16	0.222
Lower extremity	0.07	0.06	0.08	0.483

[a] Includes shoulder belt placement under arm or behind back.

reach statistical significance compared with children using both the lap and shoulder portions of the seat belt (adjusted OR = 1.20; 95% CI = 0.84–1.66). Among this restrained rear-seated population there was a lower risk of injury in minivans (adjusted OR = 0.56; 95% CI = 0.38–0.82) as compared to children in passenger cars. Children riding with drivers less than 25 years old were at an increased risk of injury (adjusted OR = 1.58; 95% CI = 0.97–2.58) as were children riding with unrestrained drivers (adjusted OR = 2.90; 95% CI = 1.03–8.16) or in pickup trucks (adjusted OR = 2.88; 95% CI = 1.12–7.39). As expected, children who experienced more severe crashes had significantly higher risk of injury.

Table 3 provides the distribution of the body regions of injury for restrained children in the rear seat. Head injury was the most common injury (60%), followed by injuries to the face (9%), upper extremity (9%), and abdomen (9%). Children using both portions of the seat belt properly had a lower risk of facial ($p = 0.003$) and abdominal ($p = 0.014$) injuries as compared to children using only the lap portion of the seat belt. The data suggests a lower risk of spinal injuries (0.1% vs. 0.7%) as well, although this difference did not achieve statistical significance.

4. Discussion/conclusion

Results of this study indicate that, among 8–12-year-old children using seat belts in the rear seats of vehicles, the overall risk of injury in crashes is 1.3%. Injuries to the head, face, abdomen and upper extremity were most common. Risk factors for injuries to these restrained children were similar to those found for younger children in crashes and included several indicators of crash severity.

Using results of previous studies as a comparison, our results suggest that older children using seat belts do not derive similar protection in crashes as younger children using child restraints. While the overall risk of injury found in the current study (1.3%) appears low, several prior studies on children ranging in age from 1 to 7 years consistently demonstrate risks of injury under 1% for children in child restraint systems including booster seats (Arbogast et al., 2004a; Durbin et al., 2003). For example, Arbogast found that injuries occurred to only 0.4% of 1–3 year olds in child restraint systems (Arbogast et al., 2004a). The assumption that older children will be adequately protected in vehicle seat belts must, therefore, be questioned.

Available data regarding the fit of seat belts in children (Klinich et al., 1994) suggest that the benefits of booster seats seen through age 7 years likely continue for many of the 8–12 year olds. A recent study found that 80% of 8 year olds, 60% of 9 year olds, 45% of 10 year olds, 15% of 11 year olds, and 5% of 12 year olds do not meet the requirements – sitting all way back against the auto seat; knees bent comfortably at the edge of the auto seat; belt crossing the shoulder between the neck and arm; and the lap portion of the belt as low as possible, touching the thighs – to use a seat belt without a booster seat (Cameron et al., 2006). Our PCPS dataset contains information on 114 older children in booster seats. Despite the small sample size, their very low risk of injury (0.3%) suggests that many tweens may benefit from the use of a belt-positioning booster seat.

Results of the current study indicate that injuries to the head, face, abdomen and upper extremity are the most common injuries to target for improved protection among older children. Poorly fitting seat belts provide inadequate support of the trunk, enabling excessive movement of the head/face in the event of a crash (Campbell et al., 2003; Winston et al., 2000). PCPS data previously identified rear-seated children in seat belts as a scenario in which facial fractures commonly occurred (Arbogast et al., 2002; Elliott et al., 2006b). Similarly, prior analyses on younger seat-belted children have consistently identified head injuries as the most common to occur (Campbell et al., 2003; Durbin et al., 2003), with abdominal injuries occurring more commonly among improperly restrained children (Campbell et al., 2003; Lutz et al., 2003, 2004; Nance et al., 2004). When compared to adults, restrained child passengers aged 5–14 were more likely to sustain an AIS 2 + abdominal injury (Javouhey et al., 2006).

As noted previously, NHTSA recently developed a 10-year-old anthropometric test device that can be utilized in restraint system design, vehicle design, and testing (NHTSA, 2007). This study's findings can be used to prioritize the most common injuries to target for enhanced protection. In addition, lap shoulder belts have been required in forward facing rear outboard positions since 1989 (Arbogast et al., 2004b), but only recently, NHTSA announced a final rule requiring that rear center seats in all new passenger vehicles be equipped with lap/shoulder seat belts. All passenger vehicles will be required to comply with the new rule by 2008 (NHTSA, 2008b). This recent federal motor vehicle safety standard requiring lap and shoulder belts in all rear seat positions has the potential to further decrease the risk of injury to older children using seat belts.

This study is not without limitation. It relied on driver reports for information on injuries, restraint use, and seating position of children and might, therefore, be subject to information bias. However, ongoing comparisons of driver reports of child restraint use and seating positions with evidence from crash investigations, performed as part of the PCPS research project, have demonstrated a high degree of agreement ($\kappa = 0.99$ for seat row; $\kappa = 0.74$ for restraint use). In addition, the current study included children involved in crashes of newer insured vehicles, and therefore generalizability of results is limited to insured vehicles in the States represented and vehicles that are 1990 or newer.

Vehicle seat belts (injury risk of 1.3%) are better than no restraint at all (injury risk of 3.1%), and parents should ensure that their 8–12-year-old children are restrained in the rear seat on every trip. However, tweens using vehicle seat belts in the rear of the vehicle have a higher risk of injury (1.3%) as compared to younger children in child restraint systems. This greater level of protection has been achieved for younger children only after significant research, public education, safety regulation and legislative advocacy. Similar attention and focus should now be placed on enhancing the safety of older child passengers.

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