Effects of Booster Seat Laws on Injury Risk among Children in Crashes

Angela H. Eichelberger
Aline O. Chouinard
Jessica S. Jermakian

October 2011

INSURANCE INSTITUTE
FOR HIGHWAY SAFETY
1005 NORTH GLEBE ROAD ARLINGTON, VA 22201
PHONE 703/247-1500 FAX 703/247-1678
www.iihs.org

ABSTRACT

Background: Belt-positioning booster seats have been shown to reduce injury risk among child passengers ages 4-8 in motor vehicle crashes. To encourage the use of booster seats, many states have enacted laws that require the use of either a child restraint with internal harness or a belt-positioning booster seat, but the specific age range covered by the laws varies by state. Previous studies have found evidence that booster seat laws are effective in reducing injury risk among children, but these studies primarily have included states with younger age requirements (e.g., ages 4-6) for booster seats.

Objective: The objective of the present study was to examine the effectiveness of booster seat laws in several states that cover children through age 7 or 8.

Methods: Police-reported crash data from five states — Missouri, North Carolina, Pennsylvania, Wisconsin, and Wyoming — were used to compare population-based injury rates, restraint use, and seating position among children before and after booster seat laws. The pre-law period was comprised of the two calendar years prior to the year of enactment of the booster seat law, and the post-law period was comprised of the two calendar years after the year of the effective start of the booster seat law. Effectiveness estimates were adjusted using a comparison group of children ages 9-12 in the same states who were not covered by the booster seat laws.

Results: Among children in crashes who were affected by law changes in the five study states, the per capita rate of children using child safety seats (either a child restraint or booster seat) increased nearly three times, and the per capita rate of children riding in rear seats increased 6 percent after the booster seat laws were implemented. Booster seat laws were associated with a 5 percent reduction in the per capita rate of children who sustained injuries of any severity and a 17 percent reduction in the per capita rate of children who sustained fatal or incapacitating injuries.

Conclusions: Results provide evidence that booster seat laws are effective in increasing the use of child safety seats, increasing the placement of children in rear seats, and reducing injuries, especially severe injuries, among children covered by the laws.

Keywords: Child passenger safety; Injuries; Children; Legislation; Law upgrade; Belt-positioning booster seat

INTRODUCTION

Booster seats help position vehicle seat belts properly for children who have outgrown forward-facing child restraints with internal harnesses but are too small for adult seat belts. Typically, seat belts alone do not fit children well until they are between ages of 8 and 12 and about 4 feet, 9 inches tall. By raising children up, booster seats help position belts to provide maximum protection in a crash, with the shoulder belt crossing the center of the chest and shoulder and the lap belt low on the hips or over the thighs rather than riding up on the abdomen. Injuries from improperly fitted seat belts, known as "seat belt syndrome," may include hip and abdominal contusions, pelvic fractures, cervical and lumbar spine injuries, and intra-abdominal injuries to solid and hollow organs (see Durbin et al., 2001 for a review). The first study of booster seat effectiveness found that children ages 4-7 were 59 percent less likely to be injured than children using seat belts alone (Durbin et al., 2003). Another study focusing specifically on abdominal injuries found that children ages 4-8 who were restrained only in seat belts were 3.5 times more likely to sustain an abdominal injury than children using booster seats (Nance et al., 2004). Recent studies have found overall injury reductions associated with booster seats ranging from 14 percent (Sivinski, 2010) to 45 percent (Arbogast et al., 2009).

Although almost all children ages 4-7 are too small to be protected adequately by a lap and shoulder belt alone, a national observational survey conducted in 2009 found that 32 percent of 4-7 year olds were restrained only in seat belts, and 13 percent were totally unrestrained (Pickrell and Ye, 2010). Thus, only 55 percent of 4-7 year olds were riding in an appropriate restraint type (i.e., a belt-positioning booster seat or child restraint with internal harness).

All 50 U.S. states and the District of Columbia have laws that require children to be restrained in child safety seats, but not all of these laws reflect current recommended practices for child passenger safety. Early child restraint laws in the 1970s and 1980s were effective at increasing child restraint use and reducing injuries among young children (Zaza et al., 2001). In recent years, most states have strengthened their child restraint laws to require older children to be restrained in forward-facing child restraints or belt-positioning booster seats. These amendments hereafter are referred to as booster seat laws. Currently, the oldest age covered by a booster seat or child restraint requirement varies across states, ranging from 3 in Florida to 8 in Wyoming and Tennessee. Twenty-nine states and the District of

Columbia require booster seats or child restraints for children 7 and younger (Insurance Institute for Highway Safety (IIHS), 2011).

Studies have found that booster seat laws are associated with increases in booster seat use (e.g., Gunn et al., 2007; National Highway Traffic Safety Administration (NHTSA), 2007; Winston et al., 2007). Winston et al. examined a sample of crashes in 16 states and the District of Columbia, finding that children ages 4-7 were 39 percent more likely to be reported as using a forward-facing child restraint or booster seat in states with booster seat laws compared with children in other states. Observational surveys conducted before and after Wisconsin's 2006 booster seat law found that use of a child restraint or booster seat increased among 4-8 year olds from 49 to 58 percent. In Michigan, a neighboring state without a booster seat law, a smaller increase in restraint use from 42 to 48 percent among booster-age children was observed during the same time period (NHTSA, 2007). Tennessee also saw significant improvement in booster seat use among ages 4-8 after a booster seat law was enacted in 2004. Observed booster seat use increased from 29 percent 2-3 months before the law was implemented to 39 percent 1 year after, whereas children younger than 4 showed no change in appropriate restraint use (Gunn et al., 2007).

To the extent that booster seats are effective in reducing the risk of injury in a crash and laws increase their use, laws requiring booster seats would be expected to reduce injuries among the population of booster-age children. A few studies provide some evidence that booster seat laws are associated with reductions in injuries. Pressley et al. (2009) examined hospital data from the Kids Inpatient Database 2003 for 8 states that had booster seat laws in 2003 and 27 states that did not. The study examined motor vehicle occupant injuries as a proportion of total injuries from any source among hospitalized children ages 3-8. The children who were covered by booster seat laws were less likely to be hospitalized for motor vehicle injuries than children who were not covered. Among children hospitalized because of a crash, the types of injuries differed for children by law coverage. Relative to children who were not covered by a booster seat law, the covered children were significantly less likely to have crushing/internal injuries.

Farmer et al. (2009) analyzed 10 years of data on fatal frontal crashes during 1995-2005, using the Fatality Analysis Reporting System (FARS). Children ages 4-8 were 20 percent less likely to die in

fatal frontal crashes in states with booster seat laws compared with states without laws. A limitation of both the Pressley et al. (2009) and Farmer et al. (2009) studies is that they compare two groups of states that may differ in ways other than booster seat laws that are associated with the likelihood of injury or restraint use. For example, socioeconomic status and the proportion of various racial/ethnic groups differ across states, and these variables are related to restraint use among children (e.g., Brixey et al., 2011; Pickrell and Ye, 2010). Therefore, injuries may be overestimated or underestimated due to systematic differences between states that enact booster seat laws compared with those that do not. A research design that would eliminate this problem is comparing injury rates before and after a booster seat law using an appropriate comparison age group.

Sun et al. (2010) studied crash injuries in New York State before and after a booster seat law covering ages 4-6 was implemented in 2005; this was the only study to date examining all injury severities. Using 2003-07 police-reported crash data, the study examined injury rates per 10,000 population among 4-6 year olds. The rate of injuries of all severities among ages 4-6 decreased 18 percent after the law, and use of a booster seat or child restraint increased from 29 to 50 percent among 4-6 year olds involved in crashes. Although not required by the booster seat law, front-seat use decreased from 9 to 6 percent among 4-6 year olds. Injuries also decreased while child restraint use increased among children ages 0-3, but not to the same extent as among the booster-age children.

In 2009, New York raised the age covered by the booster seat law to 7 and younger. In recent years, several states amended child restraint laws to add a booster seat provision or increase the ages covered by an existing booster seat provision, providing additional opportunities to examine the impact of booster seat laws. The purpose of the current study was to examine changes in per capita injury rates among booster-age children in states that have laws requiring child restraints or booster seats for children through age 7 or 8. Because previous studies examined mostly states with younger booster seat requirements, the current study provides useful information to states on the effects of extending booster seat laws to older children.

Research Questions

For each state selected for analysis, the present study investigated the use of restraints, seating position, and per capita injury rates among booster-age child passengers involved in crashes before and

after booster seat laws were implemented, relative to a comparison group of older children in the same states.

The use of appropriate restraint types was expected to increase after the booster seat laws were in effect, and these increases should be reflected among children in crashes. The rate of children using child safety seats, including both booster seats and child restraints, was examined to determine whether there was a change after the booster seat laws.

An indirect positive effect of the booster seat laws might be that fewer children ride in front seats. Research has shown that children younger than 13 are at greater risk of injury in front seats than in rear seats (Braver et al., 1998; Durbin et al., 2005). Most child restraint laws do not state a preference for rear seats, but some laws do require rear seats for certain ages. Only one of the states in the present study required booster-age children to use rear seats. However, parents may believe that children in any type of child safety seat must ride in back or that children who are small enough for safety seats are safer in back. Parents also may find it more convenient to use booster seats in rear seats, so that front seats are readily available for older passengers. In addition, safety seat instruction manuals recommend that children ride in rear seats, and some instruction manuals indicate that booster seats should be secured with vehicle child restraint anchorage systems, which usually are located in rear seating positions. As noted earlier, although New York's booster seat law does not require children to ride in rear seats, the rate of front-seat use declined in New York State after the booster seat law was implemented (Sun et al., 2010). The rate of rear-seat use was examined to determine whether there was a change after the booster seat laws were implemented.

For a law to reduce injury rates, behavior has to change and booster seats have to be effective in reducing injuries in crashes. Thus, a change in injury rates combines the effect of the law on the type of restraint and seating position used, as well as the effectiveness of the booster seat itself. The present study investigated whether the rate of children injured was reduced after the laws were strengthened. The study also examined whether there was a displacement of injury severity. In the event that the injury rate remains the same, the distribution of injuries by severity could change. That is, some children who would have had fatal or incapacitating injuries only in seat belts might have had less severe injuries with booster seats. In addition, if booster seats prevent some minor injuries, some children in seat belts who

would have had minor injuries might not have had any injuries with booster seats. An example of injury displacement was found in an evaluation of the Illinois seat belt law, which reported a small overall reduction in total injury crashes, a decrease in incapacitating injuries, and an increase in minor and moderate injuries (Rock, 1992).

METHODS

Information on injuries, restraint use, and seating position for children in motor vehicle crashes was extracted from the State Data System (SDS), a collection of state crash files coded from police crash reports. In each study state, injury severity was recorded by law enforcement officers using the KABCO injury scale (K = fatal injury, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = no injury). Because data on uninjured passengers was not collected consistently throughout the study period by all states, rates were based on population estimates rather than total crashes. Population estimates by single years of age were obtained for each study state (U.S. Census Bureau, 2011).

Thirty-one states and the District of Columbia were identified as having increased the ages requiring a child restraint or booster seat to 7 or 8 (IIHS, 2011). Of these, eight had at least 2 years of pre-law and post-law crash data available for analysis. Indiana and Illinois were excluded due to changes in the coding of injuries during the study period. Kansas was excluded because the 2 years of post-law data would have included a 12-month warning-only enforcement period. The states included in the study are listed in Table I.

The current study focused on the ages specifically affected by the law changes; these ages varied by state. Missouri, Pennsylvania, and Wisconsin required child restraints for children 3 and younger prior to the amendment adding a booster seat requirement, which expanded coverage to children ages 4-7. North Carolina and Wyoming previously had extended their child restraint laws to cover age 4. Thus, the current study examined more recent amendments that increased the ages covered by the booster seat law through age 7 in North Carolina and through age 8 in Wyoming. In this paper, the term booster-age children refers to the ages affected by the new booster seat laws. None of the study states required booster seats for the comparison group of children ages 9-12, although many children in this age group might benefit from the use of belt-positioning booster seats.

The child restraint and seat belt laws were reviewed in each state to make sure no changes were identified that would have had an effect on relevant behavior in either the booster-age or comparison groups shortly before or during the study periods. In addition to booster seat requirements, some of the laws changed in other ways. In Wyoming, the amended child restraint law required children 8 and younger to use rear seats. In Pennsylvania, the law was amended to close a gap that allowed children ages 4-17 to ride unrestrained in rear seats. This gap affected both the booster-age children and the comparison group of children ages 9-12.

In each state, both the before and after periods were two full calendar years (see Table I). Using full calendar years of data ensured that the same seasons were being compared before and after the new laws. The pre-law period was comprised of the two calendar years prior to the year of enactment of the booster law. The post-law study period began January 1 where the new law went into effect on January 1; where the effective date was in the middle of the year, the post-law study period began January 1 of the year following the effective date. Therefore, the years in which the laws were enacted or were in effect for only part of the year were excluded from analysis. Any time during which police could issue warnings but not citations was excluded from analysis because evidence suggests that compliance rates are lower during warning periods (e.g., Reinfurt et al., 1990).

Comparisons were made of population-based rates of child passengers injured in crashes before and after the enactment and implementation of booster seat laws. The injury rate was calculated by summing the total number of booster-age children injured in each state for each of the 2-year before and after periods and then dividing by the sum of the annual population counts. Counts of injured children included passengers in passenger vehicles, which included cars, SUVs, vans, and pickups.

If the laws had no effect, the expected number of injured children for the 2 years following implementation of the law would be the product of the injury rate for the pre-law period and the population for the post-law period. The rate ratio was defined as the sum of the observed number of injured children during the after period divided by the expected number. To account for time effects that may have influenced injury rates (e.g., general effects of child passenger safety campaigns, changes in driving exposure due to fluctuating gas prices), rate ratios for children ages 9-12 were used to adjust the expected injury counts and derive adjusted rate ratios for booster-age children in each state.

The following example illustrates the calculations using data from Missouri. During the 2 years before the year of the law change, 2,448 children ages 4-7 were injured in crashes and the sum of the 4-7-year-old population was 600,743, so the pre-law injury rate was 40.75 per 10,000 population. If the post-law period had the same rate, based on a population of 613,581, one would expect about 2,500 children ages 4-7 to be injured in the 2 years after the law change. However, children ages 9-12 saw a 22 percent reduction in injuries during the post-law period compared with the pre-law period. Therefore, the expected post-law count of injured children ages 4-7 was decreased to 1,946. The actual count of injured children ages 4-7 was 1,815 for the 2-year post-law period, and the adjusted rate ratio was 0.93.

In this manner, expected and observed counts of injured children were computed for each state and then summed across the five states to derive an estimate of overall effectiveness of the law changes. An adjusted rate ratio significantly less than 1 is evidence that booster seat laws reduce the rate of injury. Ninety-five percent confidence limits for the rate ratios were calculated using the following formulas derived by Silcocks (1994):

$$\text{lower limit} = \beta_{0.025}(O, E + 1)/[1 - \beta_{0.025}(O, E + 1)] \text{ and}$$

$$\text{upper limit} = \beta_{0.975}(O + 1, E)/[1 - \beta_{0.975}(O + 1, E)],$$

where O is the sum of observed injuries, E is the sum of expected injuries, and $\beta_p(x, y)$ is the p^{th} percentile from the beta distribution with parameters x and y.

Separate analyses were completed for two injury severity groupings: all injuries combined (i.e., K, A, B, and C), and fatal or incapacitating injuries only (i.e., K and A). Similar analyses examined changes in the type of restraint use and changes in the use of seating positions, using per capita rates of child safety seat use and per capita rates of children sitting in rear seats. Analyses of restraint use and rear-seat use were conducted for all children in crashes, which included injured, uninjured, and unknown injury severities. Additional analyses of restraint use and rear-seat use were conducted with subsets of the data from the five study states, because Missouri phased in data collection on uninjured passengers during the study period and did not include all passengers until 2007. This change influenced the number of uninjured children included in the data set. Therefore, the additional analyses examined data for all children involved in crashes in the other four study states and data from all five states for only injured children.

RESULTS

Data from five states — Missouri, North Carolina, Pennsylvania, Wisconsin, and Wyoming — were used to compare population-based injury rates, restraint use, and seating positions among child passengers before and after child restraint law changes. Detailed population and injury data for each of these states are listed in Appendix A.

Restraint Use

All five study states recorded restraint use in crashes. In each of the following analyses, child safety seat use included any type of child restraint or booster seat, and seat belt use included lap only or lap and shoulder belts. Although lap and shoulder belts are recommended for children rather than lap-only belts, the state data did not always distinguish which type of seat belt was used. Pennsylvania's restraint use variable had separate categories for recording proper and improper restraint use. These were collapsed into one category, so child safety seat use included both proper and improper use.

Figure 1 shows the percentage of children using each restraint type for all crashes in the five study states (MO, NC, PA, WI, and WY) combined, including all child passengers who were injured, uninjured, or with unknown injury information. Although overall restraint use was similar before and after the law changes, child safety seat use among booster-age children in crashes increased from 17 to 50 percent. There was little change in restraint use among children ages 9-12, with overall restraint use at 88 percent before and after the law changes.

Table II shows the observed and expected counts of children using child safety seats after the law change for all children in crashes in the five study states. For the five states combined, the per capita rate of booster-age children using child safety seats in crashes after the law was 2.91 times the rate before the law changes (95% confidence interval [CI] = 2.84-2.97). Children in Wisconsin showed the least improvement in the per capita rate of child safety seat use in crashes, whereas children in Wyoming showed the greatest increase. However, these differences among states may reflect differences in baseline child seat use. Changes in the percentage of booster-age passengers in child safety seats between the pre-law and post-law change periods were as follows: Missouri (15 to 49 percent), North Carolina (14 to 50 percent), Pennsylvania (14 to 47 percent), Wisconsin (27 to 53 percent), and Wyoming (7 to 36 percent). Among the study states, Wyoming had the lowest percentage of children using child

safety seats before the law change, providing a greater opportunity for improvement in restraint use compared with the other study states.

When the analysis of child safety seat use was limited to the four states that did not change the reporting criteria during the study period (i.e., NC, PA, WI, and WY), results were very similar (adjusted rate ratio = 2.86, 95% CI = 2.78-2.93). When the analysis of child safety seat use was limited to only children with injuries in the five study states, results did not differ from those of the analyses based on all children in crashes in these states (adjusted rate ratio = 2.99, 95% CI = 2.80-3.19).

Seating Position

All of the study states recorded seating position in crashes. For each of the following analyses, front-seat use included passengers in any front seating position, and rear-seat use included passengers in any rear seating position (including second and third rows). States varied in the other categories recorded (e.g., cargo area, positions outside the vehicle). All categories other than front or rear seating positions were combined with unknown seating position into an "other" category.

Figure 2 shows the percentage of children using front and rear seating positions before and after the laws were strengthened. Among children in crashes in the five states combined, the percentage of booster-age children riding in rear seats was 78 percent before and 88 percent after the law changes. The percentage of children ages 9-12 in rear seats was 60 percent before and 63 percent after the law changes.

Table III shows the counts of children using rear seating positions in crashes in the five states. The analysis included children who were injured, uninjured, and with unknown injury severity. For the five states combined, the per capita rate of children using rear seats increased 6 percent for booster-age children under the new laws compared with the prior laws (adjusted rate ratio = 1.06, 95% CI = 1.05-1.07). The greatest increases in the per capita rates of rear-seat use were found in Wyoming and Missouri. Wyoming was the only study state with a child restraint law that required booster-age children to use rear seating positions when available. Changes in the percentage of booster-age passengers in rear seats between the pre-law and post-law change periods were as follows: Missouri (74 to 88 percent), North Carolina (79 to 88 percent), Pennsylvania (73 to 85 percent), Wisconsin (86 to 91 percent), and Wyoming (67 to 78 percent).

When the analysis of rear-seat use was limited to the four states that did not change the reporting criteria during the study period, the increase in use was slightly smaller and statistically significant (adjusted rate ratio = 1.02, 95% CI = 1.00-1.03). When the analysis of rear-seat use was limited to only children with injuries in the five states, results also showed a small increase in rear-seat use, but the increase was not statistically significant (adjusted rate ratio = 1.03, 95% CI = 1.00-1.06).

Injuries

Table IV shows that fewer booster-age and fewer older children were injured in crashes in the post-law period compared with the pre-law period for the five study states combined. Both age groups showed declines in every injury severity category. For booster-age children, the total number who were injured declined from 11,721 in the 2 years before the law changes to 8,995 in the 2 years after the law changes. During the same time period, the total number of children ages 9-12 who were injured declined from 14,610 to 11,286.

Analysis of all injured children: Table V shows the counts of children injured in crashes for all injury severities in the five states combined after the law changes. Uninjured children and those with injuries of unknown severity were excluded from these counts. In the five states combined, there were 8,995 booster-age children who were injured in the 2 years after the law, compared with 9,469 expected injured children. Across the five states, amendments strengthening child restraint laws were associated with a 5 percent reduction in the per capita rate of children injured among the booster-age children, after adjusting for reductions in a comparison group of children ages 9-12 (adjusted rate ratio = 0.95, 95% CI = 0.92-0.98). The pattern of results was fairly consistent across the study states, with the exception of Wyoming, where there was a nonsignificant increase in the injury rate. The reductions in injured children were significant only in Missouri and for the states combined.

After adjusting for changes in the comparison group, there were reductions in the rate of children injured for all severity levels, but not all the reductions were significant. Reductions in the per capita rate of booster-age children injured after law changes in the five states were statistically significant for children with incapacitating injuries (adjusted rate ratio = 0.82, 95% CI = 0.70-0.95) and those with possible injuries (adjusted rate ratio = 0.95, 95% CI = 0.92-0.99). An 11 percent reduction in the rate of fatally injured booster-age children was not statistically significant (adjusted rate ratio = 0.89, 95% CI = 0.57-

1.39), likely due to the small number of fatal crashes, and the small reduction in the rate of booster-age children with nonincapacitating injuries was not significant (adjusted rate ratio = 0.96, 95% CI = 0.90-1.02).

Analysis of children with fatal or incapacitating injuries: Table VI shows observed and expected counts of children who had fatal or incapacitating injuries. In the five states combined, there was a total of 345 booster-age children who experienced fatal or incapacitating injuries in the 2 years after the law, compared with 413 expected injured children for this group. Across the five states, amendments strengthening booster laws were associated with a statistically significant 17 percent reduction in the rate of children with fatal or incapacitating injuries among the targeted age groups, after adjusting for reductions in a comparison group of children ages 9-12 (adjusted rate ratio = 0.83, 95% CI = 0.72-0.97). Missouri and Wisconsin showed significant reductions in the rate of children with fatal or incapacitating injuries after the laws were strengthened. North Carolina experienced a small, nonsignificant increase.

DISCUSSION

Appropriate restraint types for almost all children ages 4-8 include child restraints with internal harnesses or belt-positioning booster seats. The five states included in this study — Missouri, North Carolina, Pennsylvania, Wisconsin, and Wyoming — sought to increase the numbers of appropriately restrained children by enacting booster seat laws that extended the required use of child restraints or booster seats to older ages. Although overall restraint use changed little among booster-age children in crashes before and after the law changes in these states, child safety seat use (including child restraints and booster seats) rose significantly, after adjusting for changes in an older comparison group of children. It should be noted that the analysis was not able to distinguish whether restraints were used correctly, but rather analyses were based on the type of restraint that the child was reported to be using.

The current study found a threefold increase in child safety seat use associated with child restraint law changes; this increase was larger than those found in previous studies. However, the research methodology differed among the studies. Observational studies of restraint use before and after law changes have found smaller increases in child safety seat use (Gunn et al., 2007; NHTSA, 2007). These studies sampled passenger vehicles on the road, whereas the present study examined children in

crashes. The only previous study to use state crash data before and after strengthening a law (Sun et al., 2010) showed a 72 percent increase in child safety seat use among crash-involved children in New York State. This increase was not as large as in the current study and was not adjusted for a comparison group; however, the New York State study had higher baseline child seat use than in this study (29 vs. 17 percent). In a cross-sectional study of children with moderate or more severe injuries in crashes in 16 states and the District of Columbia, Winston et al. (2007) found that children ages 4-7 were 39 percent more likely to be appropriately restrained in states with booster seat laws compared with those without the laws. However, the effect of the laws varied by age. Relative to states without booster seat laws, older children ages 6-7 were twice as likely to be appropriately restrained in states with laws, whereas children ages 4-5 were 23 percent more likely to be appropriately restrained in states with the laws (Winston et al., 2007).

Of the five study states, only Wyoming upgraded its law to require that booster-age children sit in rear seats. There was a significant increase in the per capita rates of children in rear seats in Wyoming. Missouri also showed an increase in the rate of rear-seat use similar to that found in Wyoming, and North Carolina experienced a smaller increase. An unintended effect of booster seat laws could be increased use of rear seats. Publicity surrounding the new laws may increase the general awareness of child passenger safety among parents, including advice that children younger than 13 should sit in rear seats. In addition, the instruction manuals for booster seats include instructions to use rear seats. Therefore, if parents read these instructions, they might decide to move children to rear seating positions even if it is not required by law. After adjusting for changes in seating position use in the comparison group, the rate of rear-seat use increased 6 percent among all booster-age children in crashes. This effect is consistent with results found among children ages 4-6 in New York (Sun et al., 2010), where the law did not require children to ride in rear seats.

Results of the current study provide evidence that amendments in child restraint laws adding a booster seat requirement or strengthening a pre-existing booster seat requirement to include older children are effective in reducing injuries among children affected by the new provisions. After adjusting for injury reductions in the comparison group, booster-age children experienced a 5 percent reduction in the rate of children injured overall. When the analysis was limited to fatal or incapacitating injuries only,

law changes were associated with a 17 percent reduction in the rate of children injured, after adjusting for reductions in the comparison group of children.

In the only other previous study of crash injuries before and after child restraint law upgrades, Sun et al. (2010) found an 18 percent reduction in children sustaining injuries of all severities and a 21 percent reduction when only visible injuries were examined. These estimates are larger than those found in the present study; however, the estimates reported by Sun et al. (2010) were not adjusted for a comparison group.

In the current study, the effectiveness estimate based on total children injured (5 percent) was substantially smaller than the effectiveness estimate for more serious injuries (17 percent). This finding suggests that boosters were most effective in preventing the most serious injuries. A displacement of injury severity also may have occurred. Police officers recorded injury severity based on the most severe injury observed. Some injuries may have been more severe without a booster seat, whereas some minor injuries may occur regardless of restraint type. However, it also is possible that the estimate based on all injury severities underestimated the effect of booster seat laws because of limitations in police-reported injury severity, particularly for the "possible" injury category. Some injuries that are caused by improperly positioned seat belts may not be visible and therefore be underreported. The possible injury category also could be a "catch all" category for any case in which the officer is unsure of injury severity.

There are some limitations to the present study that should be noted. The study relied on police-reported injury data, and it is possible that injuries were overreported or underreported, particularly less severe, nonvisible injuries. Restraint use and seating position also could have been reported inaccurately. However, given that child restraints and booster seats typically are add-on devices, the reporting of child seat use is likely to be more accurate than seat belt use.

Children ages 9-12 in the same states were used to adjust the effectiveness estimates for the booster-age children. However, there may be factors that could have changed over time that influenced restraint use, seating position, or injuries among the booster-age children and that were not fully accounted for by using the older age group as a comparison. For example, booster seat use has been the focus of national educational campaigns such as "Don't Skip a Step" and "4 Steps for Kids" (NHTSA, 2002). Any effects that these or similar campaigns may have on booster seat use are unknown. To rule

out the possibility that national campaigns are responsible for the reductions in injuries, a group of same-age children in other states was explored as a comparison. This approach proved unfeasible because many of the adjacent or nearby states either did not have crash data available or had strengthened their child restraint laws soon after the study states.

In summary, the results provide evidence that stronger child restraint laws are effective at increasing the use of child safety seats, increasing the placement of children in rear seats, and reducing injuries, especially serious injuries, among children covered by the laws. Thus, booster laws that cover older children appear to be an effective way to keep child passengers safer.

ACKNOWLEDGEMENTS

The authors would like to thank our colleagues at the Institute, including Laurel Sims for obtaining information on booster seat legislation and the history on child restraint laws, Michele Fields for reviewing this information, and Anne McCartt for her input on the analyses and write-up. This work was supported by the Insurance Institute for Highway Safety.

REFERENCES

Arbogast KB, Jermakian JS, Kallan MJ, Durbin DR. Effectiveness of belt positioning booster seats: an updated assessment. *Pediatr.* 2009.;124:1281-1286.

Braver ER, Whitefield R, Ferguson SA. Seating positions and children's risk of dying in motor vehicle crashes. *Inj Prev.* 1998;4:181-187.

Brixey SN, Corden TE, Guse CE, Layde PM. Booster seat legislation: Does it work for all children? *Inj Prev.* 2011;17:233-237.

Durbin DR, Arbogast KB, Moll EK. Seat belt syndrome in children: a case report and review of the literature. *Pediatr Emerg Care.* 2001;17:474-477.

Durbin DR, Chen I, Smith R, Elliott MR, Winston FK. Effects of seating position and appropriate restraint use on the risk of injury to children in motor vehicle crashes. *Pediatr.* 2005;115:e305-e309.

Durbin DR, Elliott MR, Winston FK. Belt-positioning booster seats and reduction in risk of injury among children in vehicle crashes. *J Am Med Assoc.* 2003;289:2835-2840.

Farmer P, Howard A, Rothman L, Macpherson A. Booster seat laws and child fatalities: a case-control study. *Inj Prev.* 2009;15:348-350.

Gunn VL, Phillippi RM, Cooper WO. Improvement in booster seat use in Tennessee. *Pediatr.* 2007;119:e131-e136.

Insurance Institute for Highway Safety. *Child Restraint Laws*. Arlington, VA. Available: http://www.iihs.org/laws/childrestraint.aspx. Accessed: September 16, 2011. Arlington, VA: Insurance Institute for Highway Safety; 2011.

Nance ML, Lutz N, Arbogast KB, Cornejo RA, Kallan MJ, Winston FK, Durbin DR. Optimal restraint reduces the risk of abdominal injury in children involved in motor vehicle crashes. *Ann Surg.* 2004;239:127-131.

National Highway Traffic Safety Administration. *Improving the Safety of Child Restraints, Booster Seat Study: Report to Congress*. Washington, DC: National Highway Traffic Safety Administration; 2002.

National Highway Traffic Safety Administration. *Preliminary Data Indicate That Booster Seat Laws Increase Child Safety Seat Use*. *Traffic Tech* no. 331. Washington, DC: National Highway Traffic Safety Administration; 2007.

Pickrell TM, Ye TJ. *The 2009 National Survey of the Use of Booster Seats*. Report no. DOT HS-811-377. Washington, DC: National Highway Traffic Safety Administration; 2010.

Pressley JC, Trieu L, Barlow B, Kendig T. Motor vehicle occupant injury and related hospital expenditures in children aged 3 years to 8 years covered versus uncovered by booster seat legislation. *J Trauma.* 2009;67(1 Suppl):s20-9.

Reinfurt DW, Campbell J, Stewart JR, Stutts JC. Evaluating the North Carolina safety belt wearing law. *Accid Anal Prev.* 1990;22:197-210.

Rock SM. Impact of the Illinois seat belt use law on accidents, deaths, and injuries. *Eval Rev.* 1992;16:491-507.

Silcocks P. Estimating confidence limits on a standardized mortality ratio when the expected number is not error-free. *J Epidemiol Community Health.* 1994;48:313-317.

Sivinski R. *Booster Seat Effectiveness Estimates Based On CDS and State Data*. Report no. DOT HS-811-338. Washington, DC: National Highway Traffic Safety Administration; 2010.

Sun K, Bauer MJ, Hardman S. Effects of upgraded child restraint law designed to increase booster seat use in New York. *Pediatr.* 2010;126:484-489.

U.S. Census Bureau. State single year of age and sex population estimates: April 1, 2000 to July 1, 2009 - resident. Available: http://www.census.gov/popest/states/asrh/stasrh.html. Accessed: August 26, 2011. Washington, DC: U.S. Department of Commerce; 2011.

Winston FK, Kallan MJ, Elliott MR, Xie D, Durbin DR. Effect of booster seat laws on appropriate restraint use by children 4 to 7 years old involved in crashes*. Arch Pediatr Adolesc Med.* 2007;161:270-275.

Zaza S, Sleet DA, Thompson RS, Sosin DM, Bolen JC, Task Force on Community Preventive Services. Reviews of evidence regarding interventions to increase use of child safety seats. *Am J Prev Med.* 2001;21(4S):31-47.

Table I Ages covered by law changes, dates of booster seat law changes, and years of crash data for study states

State	Age groups required to use child restraint or booster seats: Prior law	New law	Affected by change	Dates of new law: Enactment	Effective	Years of crash data: Before change	After change
Missouri	3 and younger	7 and younger	4-7	6/28/2006	8/28/2006	2004-05	2007-08
North Carolina	4 and younger	7 and younger	5-7	8/17/2004	1/1/2005	2002-03	2005-06
Pennsylvania	3 and younger	7 and younger	4-7	12/23/2002	2/21/2003	2000-01	2004-05
Wisconsin	3 and younger	7 and younger	4-7	2/6/2006	6/1/2006	2004-05	2007-08
Wyoming	4 and younger	8 and younger	5-8	3/7/2003	7/1/2003	2001-02	2004-05

Table II Observed and expected numbers of booster-age children in crashes using child safety seats after child restraint law changes in five states

State	Observed	Expected*	Adjusted rate ratio	95% confidence limits: Lower	Upper
Missouri	7,819	2,551	3.07	2.93	3.21
North Carolina	12,070	3,637	3.32	3.20	3.44
Pennsylvania	4,886	1,372	3.56	3.35	3.78
Wisconsin	6,188	3,184	1.94	1.86	2.03
Wyoming	594	117	5.09	4.16	6.26
Total	31,557	10,862	2.91	2.84	2.97

*Adjusted for changes in rate of restraint use for comparison group of children ages 9-12

Table III Observed and expected numbers of booster-age children in crashes using rear seating positions after child restraint law changes in five states

State	Observed	Expected*	Adjusted rate ratio	95% confidence limits: Lower	Upper
Missouri	14,015	11,618	1.21	1.18	1.24
North Carolina	21,148	20,815	1.02	1.00	1.04
Pennsylvania	8,837	8,712	1.01	0.98	1.04
Wisconsin	10,575	10,499	1.01	0.98	1.03
Wyoming	1,281	1,114	1.15	1.06	1.25
Total	55,856	52,759	1.06	1.05	1.07

*Adjusted for changes in rear seating position use for comparison group of children ages 9-12

Table IV Counts of children injured in crashes by severity and percent changes before and after child restraint law changes in five study states combined

	Injured 4-8 year olds who were targeted by law upgrades*			Injured 9-12 year olds*		
Severity	Pre-law	Post-law	Percent change	Pre-law	Post-law	Percent change
Fatal	54	41	-24.07	66	50	-24.24
Incapacitating	488	304	-37.70	616	452	-26.62
Non-incapacitating	2,616	1,974	-24.54	3,165	2,358	-25.50
Possible	8,563	6,676	-22.04	10,763	8,426	-21.71
Total	11,721	8,995	-23.26	14,610	11,286	-22.75

*All counts are unadjusted

Table V Observed and expected counts of booster-age children with injuries in crashes after child restraint law changes in five states

				95% confidence limits	
State	Observed	Expected*	Adjusted rate ratio	Lower	Upper
Missouri	1,815	1,946	0.93	0.87	0.99
North Carolina	3,799	3,971	0.96	0.91	1.00
Pennsylvania	1,798	1,905	0.94	0.88	1.01
Wisconsin	1,351	1,433	0.94	0.87	1.02
Wyoming	232	215	1.08	0.89	1.31
Total	8,995	9,469	0.95	0.92	0.98

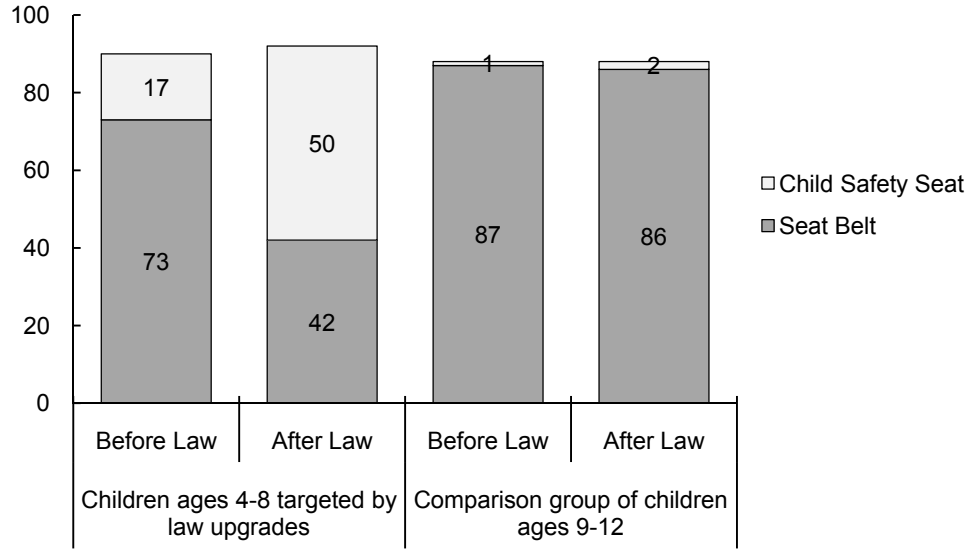
*Adjusted for per capita changes in injury rate for comparison group of children ages 9-12

Table VI Observed and expected counts of booster-age children with fatal or incapacitating injuries in crashes after child restraint law changes in five states

				95% confidence limits	
State	Observed	Expected*	Adjusted rate ratio	Lower	Upper
Missouri	126	161	0.78	0.61	0.99
North Carolina	79	73	1.08	0.78	1.51
Pennsylvania	78	82	0.95	0.69	1.32
Wisconsin	47	69	0.68	0.46	1.00
Wyoming	15	28	0.54	0.27	1.04
Total	345	413	0.83	0.72	0.97

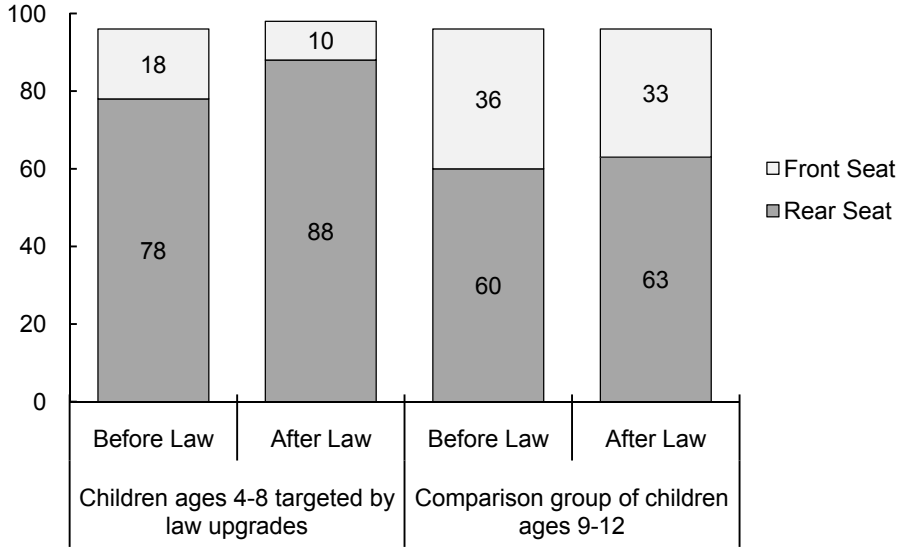
*Adjusted for per capita changes in injury rate for comparison group of children ages 9-12

Figure 1
Percentage of restraint use types among children in crashes 2 years before and after child restraint law changes in five study states (MO, NC, PA, WI, and WY)



Note: All percentages are unadjusted

Figure 2
Percentage of front- and rear-seat position use among children in crashes 2 years before and after child restraint law changes in five states (MO, NC, PA, WI, and WY)



Note: All percentages are unadjusted

APPENDIX A

Population, counts of children injured, and injury rates per 10,000 population for each state before and after amendments strengthening child restraint laws

				Children with fatal or incapacitating injuries*				Total children with injuries of any severity*			
		Average annual population		2-year counts		Rate per 10,000 population		2-year counts		Rate per 10,000 population	
State	Group	Before	After	Before	After	Before	After	Before	After	Before	After
Missouri	Ages 4-7	300,371.5	306,790.5	213	126	3.55	2.05	2,448	1,815	40.75	29.58
	Ages 9-12	316,498.0	307,117.0	261	188	4.12	3.06	2,634	1,989	41.61	32.38
North Carolina	Ages 5-7	328,281.5	351,027.0	88	79	1.34	1.13	4,209	3,799	64.11	54.11
	Ages 9-12	467,544.5	460,477.0	132	101	1.41	1.10	6,097	5,298	65.20	57.53
Pennsylvania	Ages 4-7	623,562.5	581,534.0	125	78	1.00	0.67	3,260	1,798	26.14	15.46
	Ages 9-12	696,151.0	646,997.0	132	86	0.95	0.66	3,807	2,217	27.34	17.13
Wisconsin	Ages 4-7	279,577.0	282,746.5	92	47	1.65	0.83	1,604	1,351	28.69	23.89
	Ages 9-12	299,700.5	285,226.0	116	82	1.94	1.44	1,835	1,543	30.61	27.05
Wyoming	Ages 5-8	25,592.5	25,298.5	24	15	4.69	2.96	200	232	39.07	45.85
	Ages 9-12	28,705.5	26,675.0	41	45	7.14	8.43	237	239	41.28	44.80
Total	Booster-age	1,557,385.0	1,547,396.5	542	345	1.74	1.11	11,721	8,995	37.63	29.06
	Ages 9-12	1,808,599.5	1,726,492.0	682	502	1.89	1.45	14,610	11,286	40.39	32.68

*All counts and rates are unadjusted.