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Booster Seat Effectiveness Among Older Children: Evidence From Washington State

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Abstract

Introduction—The American Academy of Pediatrics has recommended that children as old as 12 years use a booster seat when riding in motor vehicles, yet little is known about booster seat effectiveness when used by older children. This study estimated the association between booster use and injuries among children aged 8–12 years who were involved in motor vehicle crashes.

Methods—Researchers analyzed data on all motor vehicle crashes involving children aged 8–12 years reported to the Washington State Department of Transportation from 2002 to 2015. Data were collected in 2015 and analyzed in 2016. Children who were in a booster seat were compared with children restrained by a seat belt alone. Logistic regression was used to adjust for potential confounders.

Results—In unadjusted models, booster use was associated with a 29% reduction in the odds of experiencing any injury versus riding in a seat belt alone (OR=0.709, 95% CI=0.675, 0.745). In models adjusted for potential confounders, booster use was associated with a 19% reduction in the odds of any injury relative to riding in a seat belt alone (OR=0.814, 95% CI=0.749, 0.884). The risk of experiencing an incapacitating/fatal injury was not associated with booster use.

Conclusions—Children aged 8–12 years involved in a motor vehicle crash are less likely to be injured if in a booster than if restrained by a seat belt alone. Because only 10% of U.S. children aged 8–12 years use booster seats, policies encouraging their use could lead to fewer injuries.

INTRODUCTION

Motor vehicle crashes (MVCs) are the leading cause of death due to injury among children aged 8–12 years in the U.S.¹ In 2015, the most recent year for which Fatality Analysis

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Reporting System data are available, 242 children aged 8–12 years died as a result of an MVC.²

Prominent groups such as the American Academy of Pediatrics and National Highway Traffic Safety Administration have suggested that children as old as 12 years should use a belt-positioning booster seat when riding in a motor vehicle,^{3,4} and the use of booster seats by older children is, in fact, growing rapidly. According to the 2009 National Survey of the Use of Booster Seats, only 5% of children aged 8–12 years used a booster seat.⁵ By 2013, 10% of children in this age group used a booster seat.⁶

Very little is known about the effectiveness of booster seats among children aged >8 years. Only one previous study, by Ma et al.,⁷ has examined the effectiveness of booster seats compared with seat belts using data on older children. However, this study has been characterized as underpowered and potentially unrepresentative.⁸ Moreover, to increase sample size, Ma and colleagues⁷ combined data on children aged 4–10 years with data on children aged 0–3 years, for whom booster seats are not recommended.

Studies focusing on younger children provide evidence that booster seat use reduces the risk of injury.^{9–12} For instance, Durbin et al.⁹ examined data on children aged 4–7 years involved in an MVC. They found that booster seat use was associated with a 59% decrease in the odds of injury compared with being restrained by a seat belt alone. Using data on children aged 4–8 years involved in a MVC, Arbogast and colleagues¹⁰ found that booster seat use was associated with a 45% decrease in the odds of an injury versus being restrained by a seat belt alone.

Drawing on crash data collected by the Washington State Department of Transportation (WSDOT) for the period 2002–2015, the effectiveness of booster seats compared with seat belts among children aged 8–12 years was examined. Logistic regression was used to adjust for factors such as seating position, direction of the impact, vehicle type, vehicle age, time of day, day of week, weather conditions, and the number of vehicles involved. Booster seat laws in the U.S. typically apply to children aged <8 years; no state currently requires children aged >8 years to use booster seats.¹³

METHODS

Data

Data on MVCs came from WSDOT, were collected in 2015, and analyzed in 2016. The data cover all MVCs on Washington public roadways reported to law enforcement officers during the period from January 2002 through July 2015, and were obtained through a written agreement with WSDOT in accordance with the Public Records Act, RCW 42.56. They contain information on the vehicles involved in the accident, the circumstances surrounding the crash (e.g., weather conditions and time of day), and driver and passenger characteristics. The WSDOT data also include detailed information on restraint device usage and injury severity.

The focus was on occupants aged 8–12 years who rode in a passenger car or a light truck and were restrained by either a booster seat or seat belt alone. Pedestrians and children riding in vehicles such as school buses or motor homes were excluded from the analysis. From 2002 through 2015, nearly 92% of children aged 8–12 years who were involved in an MVC were passengers in a car or light truck. Children who had missing information on age, type of restraint used, or severity of injury were also excluded from the analysis.

A total of 79,859 children aged 8–12 years were observed in the WSDOT data. Of these, 5,932 (7.4%) were in a booster seat at the time of the MVC and 73,927 (92.6%) were restrained by a seat belt alone. Figure 1, which is based on the WSDOT data, shows a steep increase in booster seat use among children aged 8–12 years involved in an MVC. In 2002, only 2% of children aged 8–12 years used a booster seat. By 2015, approximately 14% of children belonging to this age group used a booster seat.

Outcome Measures

Two outcomes were constructed, both of which were based on the 5-point KABCO scale used by WSDOT to characterize injuries sustained by people involved in an MVC. The first was an indicator for experiencing any injury, including so-called “non-evident” injuries such as limping, momentary unconsciousness, nausea, and pain. The second was an indicator of whether the crash caused an incapacitating or fatal injury to the child. Examples of incapacitating injuries include severe lacerations, broken or distorted extremities, significant burns, unconsciousness, and paralysis. There is evidence that responding officers applying the KABCO scale often mistake minor injuries such as abrasions and contusions for incapacitating injuries, especially when there is copious bleeding.^{14–16} However, responding officers are much better at distinguishing between the absence of an injury and non-evident/minor injuries.^{14,15}

Statistical Analysis

Logistic regression analysis was used to estimate the effect of using a booster seat relative to being restrained by a seat belt alone. Estimates were considered to be statistically significant if their 95% CI did not include the value 0. SEs (used to calculate confidence intervals and p-values) were corrected for clustering at the county level. This correction takes into account the fact that parents living in the same county may not behave independently.

Adjusted models included individual-, vehicle-, and crash-level variables. At the individual level, these were indicators for seat position (front, back left, back middle, back right, and “other” seating position), gender, and age. It is particularly important to adjust for seating position because children in a child restraint system (CRS) are more likely to ride in the back than those who are restrained by a seat belt alone.¹⁷ The results of previous studies suggest that sitting in the back of the vehicle reduces the likelihood of being fatally injured, especially for children.¹⁸

Vehicle-level variables included age of the vehicle at the time of the crash and indicators for vehicle type, model year, and vehicle style. Indicators for seat belt use by the driver, injury status of the driver, whether the driver was driving without a license, and whether the driver was listed by the reporting law enforcement officer as at fault were also included and served

as proxies for unobserved driver characteristics. The crash-level variables included the number of people involved in the MVC and indicators for the number of cars involved, the speed limit, direction of impact, whether the crash occurred on a rural road, the time of day, whether the crash occurred on the weekend, weather conditions, the month and year of the crash, and the county where the crash occurred.

RESULTS

Table 1 provides means (with SDs in parentheses) for the full sample and Appendix Table 1 (available online) provides variable definitions. Appendix Table 2 (available online) shows descriptive statistics for subsamples based on restraint type. Descriptive statistics for the month, year, and county indicators were suppressed for the sake of brevity, but are available upon request.

As shown in Appendix Table 2, 11% of children who rode in a booster seat suffered an injury. By comparison, 15% of children restrained by a seat belt were injured. Fatal/incapacitating injuries among children in the data set were rare: Only 0.3% of children in booster seats, and 0.3% of children restrained by a seat belt alone, suffered a fatal or incapacitating injury. Type of restraint was associated with significant differences in observable characteristics. For instance, children who rode in a booster seat were more likely to be positioned in the back and were more likely to be in a newer vehicle.

The first and second columns of Table 2 report unadjusted estimates for any injury and fatal/incapacitating injury, respectively. The use of a booster was associated with a 29% reduction in the odds of any injury relative to being in a seat belt alone (OR=0.709, 95% CI=0.675, 0.745). On the other hand, the use of a booster was not statistically related to the odds of fatal/incapacitating injury relative to being restrained by a seat belt alone.

The third and fourth columns of Table 2 show estimates adjusted for the individual-, vehicle-, and crash-level characteristics listed in Table 1 as well as the month, year, and county in which the crash took place. The use of a booster seat was associated with a 19% reduction in the odds of any injury relative to being in a seat belt alone (OR=0.814, 95% CI=0.749, 0.884). Again, the use of a booster was not statistically related to the odds of experiencing a fatal/incapacitating injury relative to being restrained by a seat belt alone.

In Table 3, adjusted estimates by age group (children aged 8–9 years versus children aged 10–12 years) are reported. Among children aged 8–9 years, the use of a booster seat was associated with a 13% reduction in the odds of any injury relative to being restrained by a seat belt alone (OR=0.869, 95% CI=0.818, 0.923), whereas the use of a booster was not associated with a significant change in the odds of experiencing a fatal/incapacitating injury relative to being restrained by a seat belt alone.

Among children aged 10–12 years, the use of a booster seat was associated with a 33% reduction in the odds of any injury relative to being restrained by a seat belt alone (OR=0.675, 95% CI=0.505, 0.902), whereas the use of a booster seat was not associated with a significant change in the odds of experiencing a fatal/incapacitating injury versus being restrained by a seat belt alone. It should be noted, however, that the 13% reduction in

the odds of any injury among children aged 8–9 years is not statistically distinguishable from the 33% reduction in the odds of any injury among children aged 10–12 years.

DISCUSSION

Using data on all MVCs reported to WSDOT during the period 2002–2015 involving children aged 8–12 years, the effectiveness of booster seats versus seat belts was examined. Type of restraint used (booster seat versus seat belt) was associated with significant differences in variables such as seating position, vehicle type, and vehicle year, all of which could be related to the risk of experiencing an injury in the event of an MVC. After adjusting for these and other factors, booster seats were found to be no more effective than seat belts at preventing fatal/incapacitating injuries, such as severe lacerations, broken or distorted extremities, unconsciousness, and paralysis. By contrast, there was a strong negative association between using a booster seat and the odds of any injury from an MVC. Specifically, the use of a booster seat was associated with a 19% reduction in the odds of experiencing any injury relative to being restrained by a seat belt alone. This estimate suggests that children aged 8–12 years are considerably safer in booster seats than in seat belts.

Booster seats were first introduced in 1978, and have been growing rapidly in popularity since.^{6,19,20} They are designed to improve seat belt fit for children who are too big for a harnessed CRS but too small for vehicle belts to fit properly. During an MVC, the lap belt should engage with the front of the pelvis and the shoulder belt should engage with the clavicle. When properly used, booster seats direct the force of the seat belt onto the skeleton as opposed to soft tissues.^{19,21}

Prominent groups such as the American Academy of Pediatrics and National Highway Traffic Safety Administration suggest that children as old as 12 years should use a belt-positioning booster seat when riding in a motor vehicle. However, very little is known about the effectiveness of booster seats versus seat belts when used by older children. In fact, only one previous study, authored by Ma et al.,⁷ has examined data on children aged 8–12 years involved in an MVC. It found that booster seat use was associated with increased risk of minor neck injury (such as abrasions and contusions) and thorax injury compared with the use of seat belts alone, but combined data on children aged 4–10 years with data on children aged 0–3 years, for whom booster seats are not recommended. Because belt positioning is critical for the safety of the child, premature graduation from a harnessed CRS to a booster seat (or from a booster seat to a seat belt) is thought to be particularly dangerous.⁶

In 2007, Washington passed the Anton Skeen Act, which requires children aged <8 years to be in a CRS, and today every state except for South Dakota requires the use of booster seats. There is evidence that such requirements are effective. For instance, Winston et al.²² found that children aged 4–7 years living in states that had implemented booster seat laws were 39% more likely to be appropriately restrained than their counterparts in states that had not implemented booster seat laws. Eichelberger and colleagues²³ compared booster seat use among children aged 4–8 years involved in an MVC before and after the adoption of a

booster seat law. They found that adoption of a booster seat law was associated with an almost threefold increase in the percentage of children who were restrained appropriately.

Booster seat laws, however, typically apply to children aged <8 years. Only two states (Tennessee and Wyoming) require 8-year-olds to use booster seats, and no state requires children aged >8 years to use booster seats.^{13,23} The estimates of the association between booster seat use and the risk of injury discussed above suggest that extending the coverage of booster seat laws to older children would result in many fewer injuries, but there are several limitations to the current study that should be noted.

Limitations

First, information on the child's height and weight is not available in the WSDOT data, but the decision to use a booster seat should, according to experts, be based primarily on these factors as opposed to age.^{24,25} Many states require children of a certain age to be in a CRS without providing exemptions for children of above-average height and weight.¹³ Collecting information on the height and weight of crash victims could help researchers and policymakers craft such exemptions.

Second, 1.7% of children aged 8–12 years were, according to WSDOT, in a CRS other than a booster seat. These children were coded as being in a booster seat at the time of the accident. However, when they were excluded from the analysis, the estimated ORs reported in Tables 2 and 3 were qualitatively unchanged.

Third, the KABCO scale used by WSDOT does not contain nearly as much information on sustained injuries as was available to Ma et al.⁷ Although these authors found no differences in the risk of experiencing any injury, they did find that the use of booster seats was associated with an increased risk of neck and thorax injuries relative to the use of seat belts. Because the KABCO scale does not include information on where the injury occurred, it cannot be used to explore the effects of booster seats on neck and thorax injuries.

Lastly, the WSDOT data are not nationally representative, and parents in Washington could be better (or worse) at positioning booster seats than parents in other states. A recent field study by the National Highway Traffic Safety Administration found that roughly 10% of children in booster seats had the lap belt sitting too high, across the child's stomach.²⁶ If parents in Washington are somehow less prone to making this mistake than parents elsewhere, then the results could overstate the relative effectiveness of booster seats as compared with seat belts alone.

CONCLUSIONS

Children aged 8–12 years who are involved in a motor vehicle crash are less likely to be injured if they are in a booster seat than if they are restrained by a seat belt alone. No state currently mandates the use of booster seats for children aged >8 years, and only 10% of children aged 8–12 years in the U.S. use booster seats.^{6,13} The present results suggest that the adoption of laws encouraging the use of booster seats among children aged 8–12 years could lead to fewer injuries.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Booster seat use in Washington state.

Table 1Descriptive Statistics^a

	Mean (SD)
Outcomes	
Any injury	0.145 (0.352)
Fatal/Incapacitating injury	0.003 (0.056)
Individual-level characteristics	
Front seat	0.287 (0.452)
Back left seat	0.278 (0.448)
Back middle seat	0.098 (0.297)
Back right seat	0.322 (0.467)
Other seating position	0.014 (0.118)
Male	0.480 (0.500)
Age 8 years	0.203 (0.402)
Age 9 years	0.200 (0.400)
Age 10 years	0.200 (0.400)
Age 11 years	0.199 (0.399)
Age 12 years	0.199 (0.399)
Vehicle-level characteristics	
Car	0.442 (0.497)
Light truck	0.558 (0.497)
Model year 1990	0.089 (0.285)
1990< Model year 1995	0.160 (0.366)
1995< Model year 2000	0.278 (0.448)
2000< Model year 2005	0.301 (0.458)
2005< Model year 2010	0.134 (0.341)
Model year >2010	0.038 (0.191)
Vehicle age	8.414 (5.745)
Coupe	0.028 (0.165)
Convertible	0.004 (0.066)
Hatchback	0.027 (0.162)
Sedan	0.332 (0.471)
Station wagon	0.259 (0.438)
Jeep	0.062 (0.242)
Other vehicle style	0.287 (0.452)
Front-end collision	0.336 (0.472)
Left-side collision	0.019 (0.138)
Right-side collision	0.022 (0.148)
Side collision	0.042 (0.200)
Rear-end collision	0.015 (0.121)
Other collision	0.018 (0.131)
Driver unbelted	0.004 (0.066)

	Mean (SD)
Driver injured	0.208 (0.406)
Driver no license	0.021 (0.145)
Driver at fault	0.376 (0.484)
Crash-level characteristics	
Persons involved	5.310 (2.209)
One-car crash	0.090 (0.286)
Two-car crash	0.742 (0.438)
Three-plus-car crash	0.168 (0.374)
Speed limit <55MPH	0.734 (0.442)
Rural road	0.081 (0.273)
Early morning	0.007 (0.081)
Daytime	0.906 (0.291)
Evening	0.087 (0.282)
Weekend	0.375 (0.484)
Precipitation	0.182 (0.386)
No precipitation	0.807 (0.395)
Other weather	0.009 (0.096)
N	79,859

^a Means (with SDs in parentheses) are based on data from the Washington State Department of Transportation (2002–2015). Means for binary variables can be interpreted as proportions.

MPH, miles per hour

Table 2Unadjusted and AOR of Injury for Booster Seats Relative to Seat Belts^a

	Unadjusted models		Adjusted models ^b	
	Any injury	Fatal/Incapacitating injury	Any injury	Fatal/Incapacitating injury
Booster seat	0.709 [0.675, 0.745]	1.003 [0.691, 1.460]	0.814 [0.749, 0.884]	1.349 [0.907, 2.004]

Notes: Boldface indicates statistical significance (p<0.01).

^aEach column represents results from a separate logistic regression based on data from the Washington State Department of Transportation (2002–2015). ORs are reported with 95% CIs in brackets. Any injury corresponds to K, A, B, and C injuries on the KABCO scale, while Fatal/Incapacitating injury corresponds to K and A injuries.

^bAdjusted for the individual-, vehicle-, and crash-level characteristics listed in Table 1, and the month, year, and county in which the crash occurred.

Table 3AOR of Injury for Booster Seats Relative to Seat Belts by Age Group^{a,b}

	Age 8 to 9 years		Age 10 to 12 years	
	Any injury	Fatal/Incapacitating injury	Any injury	Fatal/Incapacitating injury
Booster seat	0.869 [0.818, 0.923]	1.431 [0.827, 2.478]	0.675 [0.505, 0.902]	1.232 [0.556, 2.731]

Note: Boldface indicates statistical significance ($p < 0.01$).

^a Each column represents results from a separate logistic regression based on data from the Washington State Department of Transportation (2002–2015). ORs are reported with 95% CIs in brackets. Any injury corresponds to K, A, B and C injuries on the KABCO scale, while Fatal/Incapacitating injury corresponds to K and A injuries.

^b Adjusted for the individual-, vehicle-, and crash-level characteristics listed in Table 1, and the month, year, and county in which the crash occurred.