Effectiveness of Child Safety Seats vs Safety Belts for Children Aged 2 to 3 Years

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Objective: To compare the effectiveness of child safety seats and lap-shoulder belts in rear passenger vehicle seats for 2- to 3-year-old crash survivors.

Design: Cohort study.

Setting: The January 1, 1998, to December 31, 2004, US data on a nationally representative sample of crashes that resulted in at least 1 vehicle being towed away.

Participants: Toddlers who were sitting in rear vehicle seats and using lap-shoulder belts or child seats when involved in highway crashes.

Intervention: Child safety seat vs safety belt.

Outcome Measure: Presence of any injury after a crash.

Results: The adjusted odds of injury were 81.8% lower (95% confidence interval, 58.3%-92.1% lower) for toddlers in child seats than belted toddlers.

Conclusions: Child safety seats seem to be more effective rear seat restraints than lap-shoulder safety belts for children aged 2 to 3 years. Laws requiring that children younger than 4 years travel in child safety seats have a sound basis and should remain in force.

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I n a 2005 National Bureau of Economic Research working paper1 and a companion article2 in the New York Times, researchers found that lap-shoulder safety belts were as protective as child safety seats for children aged 2 to 6 years and were far less expensive. The publications question the wisdom of state child safety seat laws that mandate use beyond the age of 1 year.

This work is out of step with the literature. It contrasts with the literature establishing the effectiveness of child safety seats relative to unrestrained travel. More important, subsequent analysis by Elliott et al3 found that child restraints for children aged 2 through 6 years, when not seriously misused, reduce the risk of death by 28% compared with seat belts. Prior studies4,5 also found that child safety seats were more effective against fatalities than safety belts. Relative to unrestrained travel, child safety seat restraints reduced the risk of death by an estimated 47% for toddlers aged 1 to 4 years.4 At most, though, for this age group, they offered a modest fatality risk reduction vs safety belts, which were estimated to be 45% effective against deaths among people 12 years and older and 36.3% to 39% effective for toddlers.4,6

The analyses by Levitt1 and Dubner and Levitt2 have 3 major limitations. First, it included children up to the age of 6 years, meaning it confounded seat effectiveness for children of appropriate weight and stature for a child seat and larger children whose restraint in a child seat constitutes misuse. Second, it used a fatal crash data file that lacked a good control variable for crash severity. Third, it largely restricted its analysis to fatalities, with some glancing attention to nonfatal injuries coded by police using a coarse inaccurate severity measurement system.7 Fully analyzing the appropriateness of child safety seat laws for toddlers, however, also requires considering the relative impacts of child safety seats and lap-shoulder belts against nonfatal injury. A few studies8-10 have examined the effects on nonfatal injuries to specific body regions (eg, severe abdominal injuries) but not on total injuries. Only 2 studies11,12 used a design similar to that used by Levitt and co-worker to analyze effects on nonfatal injury. One limited the analysis to significant injuries, which were defined as an Abbreviated Injury Scale (AIS) score of 2 or more.13 Neither distinguished lap-shoulder from lap-only belts. One found that children aged 2 to 5 years in seat belts had a 3.5 times higher relative risk of signifi-

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cant injuries than those in child restraint systems.12 The other found an odds ratio of 0.22 (95% confidence interval, 0.11-0.45) of significant injury in a child seat vs a safety belt, but found no difference in the odds of minor injury.13 Our study covers all nonfatal injuries and, like the work by Levitt and coworker, it specifically examines lap-shoulder belts. It addresses the probability of being injured, analyzes crashes that resulted in at least 1 vehicle being towed away, and is restricted to passenger vehicles with occupants aged 2 to 3 years.

CRASH DATA

We pooled January 1, 1998, to December 31, 2004, National Highway Traffic Safety Administration data from the Crashworthiness Data System (CDS) investigations of a nationally representative sample of all crashes that resulted in at least 1 vehicle being towed away, including those without injury.14 The CDS is a stratified random cluster sample. The sampling scheme deliberately oversamples more serious crashes to get more information about seriously injured people. We considered children as injured if the CDS coded any injury diagnosis, including those having all the relevant information available. More than 99% of vehicles in the sample were towed from the crash site. No children in the sample died of their injuries.

We excluded children aged 2 to 3 years riding in passenger vehicles (passenger cars, sport-utility vehicles, pickup trucks, and vans) and using either a shoulder-lap belt or a child safety seat were included in the analysis. We used restraint use as determined by trained CDS crash investigators. We excluded children aged 4 to 6 years from the sample because some unknown portion of them, because of their height and weight, do not need child safety seats, and height and weight information is missing on roughly half of the relevant CDS records. We also restricted the analysis to children in rear vehicle seats because of the few children seated in the front (34 total, 11 belted with an air bag available, 7 belted only, 6 in child seats with an air bag available, and 10 in child seats only). At the end of the selection process, we had a file of 579 records on restrained 2- to 3-year-old children, with 463 of them having all the relevant information available. More than 90% of vehicles in the sample were towed from the crash site. No children in the sample died of their injuries.

REGRESSION MODEL

We used logistic regression to model the probability of injury. The explanatory variable was a dichotomous variable that took the value of 0 if the toddler was belted and 1 if the toddler was sitting in a child seat. We controlled for vehicle weight (in 10 kg) and vehicle type (van/passenger car or sport-utility vehicle/pickup truck). As proxies for crash severity, we used driver injury costs (in thousand dollars) and controlled for driver restraint use, air bag availability, sex, and age group. We also controlled for the seating position of the child in relation to the driver and for the main crash impact angle.

To identify driver air bag availability, we used the Highway Loss Data Institute's 2004 software (VINDICATOR; Highway Loss Data Institute, Arlington, Va). It provides vehicle characteristics based on the vehicle identification numbers (VINs). The following process was used to identify air bag availability for 43 vehicles (of 44 used in the regression analysis) whose VINs could not be translated using the software (generally because of a missing VIN). First, all vehicles in the entire CDS data set with the same make, model, and model year as the vehicles with missing VINs were extracted from the 1998-2004 files. This resulted in 1093 vehicles (most of them without child occupants) with translatable VINs indicating if air bags were available for their front seating positions. Next, we tabulated the frequency of air bag installation per vehicle make, model, and year. Finally, at the end of this single imputation process, the consensus air bag status for all translatable VINs for the appropriate platform was substituted for each vehicle whose VIN could not be translated.

To estimate driver injury costs, we merged published crash costs by body part, AIS score, and involvement of a fracture or dislocation onto the pooled files.7,15 The costs included medical costs, work loss, travel delay, police and other resource costs, and the value of pain, suffering, and lost quality of life. All estimates were in 2004 dollars. Following the reference case guidance prescribed by the Panel on Cost-effectiveness in Health and Medicine, we chose crash cost data that used a 3% discount rate to compute the present value of future costs.10

To explore if driver injury cost is a good proxy for crash severity, we estimated an augmented regression model restricted to the 307 crashes that included the CDS crash investigator's estimate of the change in occupant velocity resulting from the crash. This change is not coded for rollovers and was missing for 85 other crashes.

To control for the seating position of the child in relation to the driver and the main crash impact angle, we created 7 dummy variables: frontal collision, rear collision, collision on child's side only, collision on driver's side only, collision on driver's and child's shared side, collision on the opposite side of the driver and the child, and rollover. There were no crashes with side collision and with children seating in the middle seat.

We controlled using an ordinal regression model by AIS level to estimate the impact of child seats vs seat belts on injury severity. However, because the data included only 23 belted injured children and just 3 had injuries with an AIS score of 2 or more (moderate to critical threat to life), they were too sparse to expect an ordinal model to produce reliable results. Adding older data (1993-1997) would not solve the problem because the total sample only would increase to 41 belted injured children, with 4 having injuries with an AIS score of 2 and more.

Regression analyses and standard errors were run using computer software (Stata, version 8.2; StataCorp, College Station, Tex) and accounted for sample design/weighting using linearization methods.17

Table 1 gives the distribution of the variables used in the analysis by type of restraint used. It shows that the unadjusted probability of injury for toddlers in severe crashes was 46% lower if they were restrained in a child safety seat vs a lap-shoulder belt. However, confidence intervals for the unadjusted probabilities indicate that this difference was not statistically significant at the 95% confidence level. When we controlled for vehicle weight, vehicle type, crash severity (obtained by proxy × driver injury costs × driver restraint use, air bag availability, sex, and age group), and seating position of the child in relation to the driver and to the main crash impact angle (Table 2), the adjusted odds of injury were 81.8% lower (95% confidence interval, 38.3%-92.1% lower) for child-seated than belted toddlers.

In preliminary analysis, we included dummy variables for child age and sex and for vans/minivans, and a continuous variable for vehicle length. Because these vari-
This study suggests that child safety seats are more effective than lap-shoulder safety belts for children aged 2 to 3 years seated in the rear. Controlling for vehicle characteristics, crash characteristics, and crash severity, child seats are associated with an estimated 80% reduction in the odds of injury relative to a safety belt. That finding is consistent with the results of crash dummy testing and with the better fit of a seat than a belt to a child's body, increasing the likelihood that it reflects causation.

Our study was limited by the little data on crash-involved children aged 2 to 3 years who were belted. This limitation prevented us from analyzing the relative severity of injury by restraint type for restrained children who were injured. Fortunately, that question has been addressed with other data. It would be desirable to repeat our analysis for children aged 4 to 6 years of proper stature to use a child safety seat if an appropriate data set with reliable information on height and weight were available.

Table 1. Descriptive Statistics on Restrained Toddlers Aged 2 to 3 Years Involved in Severe Crashes From 1998 to 2004, by Type of Restraint

<table>
<thead>
<tr>
<th>Variable</th>
<th>Child Seated in the Rear</th>
<th>Child Lap-Shoulder Belted in the Rear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study Sample Count</td>
<td>Estimates for Study Population (95% Confidence Interval)</td>
</tr>
<tr>
<td>No. of toddlers aged 2-3 y</td>
<td>409</td>
<td>314,887 (144,580-485,095)</td>
</tr>
<tr>
<td>Injured</td>
<td>178</td>
<td>17.2 (10.5-23.8)</td>
</tr>
<tr>
<td>Male driver</td>
<td>136</td>
<td>24.3 (8.6-40.0)</td>
</tr>
<tr>
<td>Driver aged ≥40 y</td>
<td>75</td>
<td>12.9 (7.7-18.0)</td>
</tr>
<tr>
<td>Driver belted and air bag available</td>
<td>264</td>
<td>66.6 (49.9-83.3)</td>
</tr>
<tr>
<td>Driver belted only</td>
<td>78</td>
<td>25.6 (9.3-42.0)</td>
</tr>
<tr>
<td>Driver unbelted and air bag available</td>
<td>31</td>
<td>2.6 (0.1-5.0)</td>
</tr>
<tr>
<td>Driver unbelted and no air bag</td>
<td>36</td>
<td>5.2 (1.3-9.0)</td>
</tr>
<tr>
<td>Sport-utility vehicle or pickup truck</td>
<td>82</td>
<td>15.6 (8.9-22.4)</td>
</tr>
<tr>
<td>Rollover</td>
<td>64</td>
<td>5.0 (1.3-8.8)</td>
</tr>
<tr>
<td>Frontal collision</td>
<td>250</td>
<td>51.9 (41.8-62.0)</td>
</tr>
<tr>
<td>Collision on child’s side only</td>
<td>12</td>
<td>2.0 (0.1-3.8)</td>
</tr>
<tr>
<td>Collision on driver’s and child’s side</td>
<td>22</td>
<td>4.2 (1.3-7.1)</td>
</tr>
<tr>
<td>Collision on the opposite side of both</td>
<td>12</td>
<td>7.4 (1.3-13.6)</td>
</tr>
<tr>
<td>Collision on driver’s side only</td>
<td>14</td>
<td>12.9 (0.8-25.0)</td>
</tr>
<tr>
<td>Rear collision</td>
<td>35</td>
<td>16.6 (19-31.3)</td>
</tr>
<tr>
<td>Driver injury cost (in 2004 dollars)</td>
<td>409</td>
<td>33,303 (12,739-53,867)</td>
</tr>
<tr>
<td>Vehicle curb weight (in 10 kg)</td>
<td>409</td>
<td>141 (134-149)</td>
</tr>
</tbody>
</table>

*Data are given as percentage unless otherwise indicated.

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The sign on vehicle weight was contrary to expectations. This is a minor issue because the coefficient was not statistically significant and the variables for driver cost and sport-utility vehicle, both of which were correctly signed, partially captured some of the effects of vehicle weight. In addition, decreasing vehicle weight entirely did not change the value or significance of the child seat coefficient rounded to 2 decimal points.

Our findings that children aged 2 to 3 years have an 80% lower odds of being injured in child safety seats than in safety belts are consistent with those of prior studies showing seats are associated with 78% lower odds of serious injury than belts for children aged 1 to 4 years,11 with a 28% reduction in mortality risk relative to belts for children aged 2 to 6 years3 and with a 75% lower relative risk of serious injury (AIS score ≥2) for children aged 2 to 3 years.12 Our results also were robust across a range of sensitivity analyses. Although all these studies were correlational, they confirmed the differential effectiveness predicted by crash tests on dummies.18 Thus, we believe they are reasonably definitive; they confirm that, as their designers intended, child safety seats offer children aged 2 to 3 years greater protection than safety belts. Taken together, these studies suggest that the study by Levitt1 is out of kilter with the literature. They largely lay to rest the concerns that Levitt1 raised with respect to mandatory child safety seat use laws for child occupants aged 2 to 3 years. Laws requiring children aged 2 to 3 years to travel in child safety seats seem to have a sound basis and should remain in force.

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REFERENCES