Effectiveness of Automatic Shoulder Belt Systems in Motor Vehicle Crashes

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Various strategies have been developed to improve motor vehicle occupant protection, including an automatic shoulder belt, combined with a manual lap belt or a knee bolster. Since 1987, more than 27 million cars have been manufactured with automatic 2-point belt systems and more than 10 million are still in use. Studies have found that drivers do not use the manual lap belt 50% to 71% of the time. Prior studies examining the effectiveness of automatic systems have produced conflicting estimates. Numerous studies also report injuries from use of the shoulder harness alone.

The purpose of this study was to examine the effectiveness of automatic shoulder belts when used with and without a manual lap belt.

METHODS
The 1993-1996 National Highway Traffic Safety Administration’s Crashworthiness Data System was the source of data, a national probability sample of light passenger vehicles (passenger cars, light trucks, vans, and sport utility vehicles) involved in police-reported tow-away crashes. About 5000 cases are chosen annually in a 3-stage sampling system. It is the most comprehensive, nationally representative system available and has among the most accurate reporting of belt use, based on vehicle inspection, interviews, and police, autopsy, and hospital records. Outboard front-seat occupants older than 15 years were included. Injury severity data were coded using the Abbreviated Injury Scale.

The 4 categories of restraint use were unrestrained, manual lap and shoulder belt, automatic 2-point shoulder belt with a manual lap belt or an automatic 3-point lap-shoulder belt, and automatic 2-point shoulder belt used without a lap belt. All other restraint systems (0.3% of known belt use) were excluded. Belt-use information was missing on 22.5% of crashes. Compared with occupants for whom this information was present, cases with missing information were similar in age, estimated change in vehicle speed during the crash (delta-V), principal direction of force, and case-fatality rate, but these cases were slightly more likely to involve men who were in some-what older cars. These cases were excluded.

Context Approximately 10 million cars with automatic shoulder belt systems are currently in use in the United States. However, reports on the effectiveness of such restraints have yielded conflicting results.

Objective To determine the effectiveness of automatic shoulder belt systems in reducing the risk of injury and death among front-seat passenger vehicle occupants.


Main Outcome Measures Death and serious injury to specific body areas by use of manual lap and shoulder belts, automatic shoulder belts with manual lap belts, or automatic shoulder belts without lap belts, compared with no restraint use.

Results Use of automatic shoulder belts without lap belts was associated with a decrease in the risk of death vs no restraint use but was not statistically significant for all crashes (odds ratio [OR], 0.66; 95% confidence interval [CI], 0.42-1.06) or for frontal crashes (OR, 0.71; 95% CI, 0.38-1.35) after adjustment for occupant age, sex, vehicle year, airbag deployment, estimated change in vehicle speed during the crash, and principal direction of force. This association was significantly weaker than the 86% lower risk observed for use of automatic shoulder belts with lap belts (OR, 0.14; 95% CI, 0.07-0.26 vs no restraint; P<.05). Use of automatic shoulder belts without lap belts was associated with an increased risk of serious chest (OR, 2.66; 95% CI, 1.11-6.35) and abdominal (OR, 2.06; 95% CI, 1.004-4.22) injuries for all crashes.

Conclusions These data indicate that improperly used automatic restraint systems may be less effective than properly used systems and are associated with an increased risk of serious chest and abdominal injuries. Given the continued widespread use of these automatic systems, educational programs may be warranted.

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Information was missing on delta-V for 47.6% of the remaining cases and on principal direction of force for 17.2%. Because these characteristics appeared to be important potential confounders, multiple imputation was used by an adaptation of the approximate Bayesian bootstrap method. Imputation groups were formed by simultaneous stratification on survival, restraint use, sampling weight, and other characteristics found to be strongly associated with the variable to be imputed when its value was known. Ejection was an additional variable used to impute principal direction of force. Injury severity score and principle direction of force (after imputation) were additional variables used to impute delta-V. Five complete data sets were generated by this method; parallel analyses were then carried out on all 5 sets.

Outcome variables were survival to 30 days and presence of an Abbreviated Injury Scale score of 2 or more. Each outcome was modeled as a function of restraint use and covariates using multiple logistic regression, using survey data analysis commands in STATA statistical software version 5.0 (STATA Corp, College Station, Tex). Results obtained from analysis of each of the 5 complete data sets were combined using methods described by Rubin and Schenker to obtain final point estimates and confidence intervals (CIs) that account for both the multistage sampling design and the imputation process.

RESULTS

Data were available for 25811 crashes involving outboard front-seat occupants, representing an estimated total of 11963796 such crashes nationally. Among occupants, 21.9% were unrestrained, 60.3% were restrained with a manual 3-point system, 15.1% were restrained with an automatic shoulder belt and a manual or automatic lap belt, and 2.7% were using an automatic shoulder belt without the lap belt.

Occupant and crash characteristics of the 4 seat belt restraint groups are displayed in TABLE 1. There were 1226 fatal injuries in the sample, representing 71387 fatalities in the national set of crashes from which it was derived, for a rate of 6.0 deaths per 1000 front seat occupants in crashes. After adjustment for important confounders, automatic shoulder belts worn with a manual lap belt were associated with at least a large reduction in fatality risk as 3-point manual belts (TABLE 2). Automatic shoulder belts with no lap belt appeared to be somewhat protective in all crashes (odds ratio [OR], 0.66; 95% CI, 0.42-1.06) and frontal crashes (OR, 0.71; 95% CI, 0.38-1.35), although the CI included 1. The adjusted OR for automatic shoulder belts without use of a lap belt was significantly closer to 1 than that for automatic shoulder belts with use of the lap belt (P<.05).

Users of automatic shoulder belts without lap belts had a risk of head injury in all crashes and in frontal crashes, which was not significantly different from that of unbelted occupants, and a 2.7-fold higher risk of chest injury in all crashes and more than 7-fold higher risk of chest injury in frontal crashes compared with no belt use (TABLE 3). Similar patterns were found in relation to risk of abdominal injury, with the risk of injury 2-fold higher in all crashes and more than 3.7-fold higher in frontal crashes. There was no sig-

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significant difference between restraint systems in the risk of injuries to the spine or the extremities (data not shown).

**COMMENT**

Using automatic belts without a manual lap belt, while probably better than no restraint, appeared to convey less protection against death than did using 3-point restraints. Use of an automatic shoulder belt by itself was associated with a significant increase in the risk of serious thoracic and abdominal injury.

Prior studies have focused on the impact of automatic restraints on risk of fatal injury. Evans' estimated that improperly used systems decreased the risk of death by 29%, similar to our observation of a 34% reduction for all crashes and 29% for frontal crashes.

This study has certain limitations. We examined only those automatic systems using an automatic shoulder harness and a manual or automatic lap belt. The CIs around many estimates were wide given the sample size available in the Crashworthiness Data System data set. There is also the potential for misclassification of seat belt use. The categorization of proper belt use was made from a combination of interviews, police reports, medical records, and field inspections. However, some misclassification may still have occurred.

Because data on delta-V and the principal direction of force were missing for many crashes, we used multiple imputation to allow using these potential confounders in multivariate analyses. Restricting analysis to cases without missing data leads to valid inferences only if data are missing completely at random. In contrast, multiple imputation substitutes a weaker assumption that data are missing at random conditional on the values of variables used to form the imputation groups. Nonetheless, we cannot rule out residual bias due to associations between other unmeasured aspects of crashes and missing data on delta-V or principal direction of force. Finally, the number of crashes involving automatic systems was limited. Hence for all crashes, the true effect of the restraint configuration on risk of death could lie anywhere from a 58% reduction to a 6% increase and still be reasonably compatible with the data.

Given the still widespread use of these automatic systems, educational programs that encourage vehicle occupants to buckle up their lap belts may be warranted.

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**REFERENCES**


Table 3. Crude and Adjusted Risks of Abbreviated Injury Scale Score of 2 or Higher*  

<table>
<thead>
<tr>
<th>Variables</th>
<th>Unrestrained</th>
<th>Manual Shoulder Plus Lap</th>
<th>Automatic Shoulder Plus Lap</th>
<th>Automatic Shoulder Without Lap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head injury</td>
<td>Rate per 100 occupants</td>
<td>6.16</td>
<td>0.94</td>
<td>0.69</td>
</tr>
<tr>
<td>All crashes†</td>
<td>1.00 (reference)</td>
<td>0.19 (0.13-0.27)</td>
<td>0.12 (0.08-0.18)</td>
<td>0.74 (0.44-1.24)</td>
</tr>
<tr>
<td>Frontal crashes‡</td>
<td>1.00 (reference)</td>
<td>0.21 (0.15-0.32)</td>
<td>0.08 (0.05-0.12)</td>
<td>0.98 (0.41-2.13)</td>
</tr>
<tr>
<td>Chest injury</td>
<td>Rate per 100 occupants</td>
<td>2.42</td>
<td>0.77</td>
<td>1.46</td>
</tr>
<tr>
<td>All crashes†</td>
<td>1.00 (reference)</td>
<td>0.48 (0.36-0.65)</td>
<td>1.07 (0.47-2.43)</td>
<td>2.66 (1.11-6.35)</td>
</tr>
<tr>
<td>Frontal crashes‡</td>
<td>1.00 (reference)</td>
<td>0.42 (0.26-0.66)</td>
<td>2.02 (0.72-5.72)</td>
<td>7.74 (4.03-14.87)</td>
</tr>
<tr>
<td>Abdominal injury</td>
<td>Rate per 100 occupants</td>
<td>1.23</td>
<td>0.90</td>
<td>0.19</td>
</tr>
<tr>
<td>All crashes†</td>
<td>1.00 (reference)</td>
<td>0.40 (0.23-0.71)</td>
<td>0.26 (0.14-0.47)</td>
<td>2.06 (1.004-4.22)</td>
</tr>
<tr>
<td>Frontal crashes‡</td>
<td>1.00 (reference)</td>
<td>0.39 (0.19-0.82)</td>
<td>0.33 (0.17-0.68)</td>
<td>3.75 (1.75-8.06)</td>
</tr>
</tbody>
</table>

*Data are presented as adjusted odds ratio (95% confidence interval).
†Adjusted for occupant sex and age, vehicle model year, airbag deployment, delta-V, principal direction of force.
‡Adjusted for all variables above except principal direction of force.