Association Between Different Restraint Use and Rear-Seated Child Passenger Fatalities

A Matched Cohort Study

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Objective: To investigate the association between restraint use and death in rear-seated child passengers and to examine whether the estimated association varies by restraint type and age.

Design: Matched cohort study.

Setting: All reported crashed passenger vehicles with at least 2 rear-seated child passengers of whom at least 1 died from the US Fatality Analysis Reporting System for 1998 to 2006.

Participants: Rear-seated child passengers aged 2 to 6 years.

Interventions: Three models of restraint use: (1) no restraint use, any restraint use, recorded improper restraint use (including improper use of seat belts or child restraints, use of shoulder-only seat belts, and use of an unknown type of restraint), any other restraint use; and (3) no restraint use, improper restraint use, seat belts, and child restraints.

Main Outcome Measure: Death within 30 days of a crash.

Results: Compared with no restraint use, being restrained reduced the risk of death in rear-seated child passengers (relative risk [RR], 0.33; 95% confidence interval [CI], 0.22-0.49). Compared with improper restraint use, any other restraint use reduced the risk of death (RR, 0.46; 95% CI, 0.20-0.63). The RR of death for using child restraints compared with seat belts was 0.91 (95% CI, 0.57-1.14). Child restraints performed slightly better in fatality risk reduction in children aged 2 to 3 years (RR, 0.24; 95% CI, 0.09-0.33) than in children aged 4 to 6 years (RR, 0.32; 95% CI, 0.11-0.44) compared with traveling unrestrained.

Conclusions: This study demonstrates the protective effects of restraints for child passengers and highlights the importance of using restraints correctly.


Currently in the United States, as elsewhere, it is recommended that children use appropriate restraints (eg, infant seats, forward-facing child restraints, booster seats, and seat belts) when traveling in motor vehicles.1 Restraint use by child passengers has been reported to reduce the risk of death in crashes compared with traveling unrestrained, for example, a reduction in the risk of death of 46% for children in child restraints,2 54% for child restraints and 47% for seat belts for children aged 1 to 4 years in passenger cars,3 and 47% (relative risk [RR], 0.53; 95% confidence interval [CI], 0.47-0.59) for rear-seated children from birth to 12 years of age in any type of restraint without the presence of a front passenger air bag.4 However, few studies addressed whether the association between restraint use and death varies by the type of restraint use (seat belt vs child restraint) for child passengers. Recently, 2 studies compared the risk of death when using child restraints vs seat belts in children aged 2 to 6 years traveling in passenger vehicles (eg, cars, vans, and utility vehicles). Levitt5 concluded that no evidence suggested that child restraints were better than seat belts after a series of analyses using no restraint use as a common referent. In contrast, Elliott et al6 found evidence that child restraints outperformed seat belts when serious misuse of seat belts and child restraints was removed from the analysis (odds ratio [OR], 0.72; 95% CI, 0.54-0.97). Neither study adjusted for a variety of potential confounders that may affect the risk of death, such as the distance to emergency services, which may be achieved by means of a matched cohort design.7,8

Using the most current data and a matched cohort design, this study aims to estimate the association between restraint use and death in child passengers aged 2 to 6 years and to examine whether that association varies according to the type of restraint (child restraints and seat belts). Given that exposure to different restraint use varies with age 2 to 6 years,9 we also aim to evaluate the extent to which the examined association varies with age.

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The study exposure was restraint use, which was categorized according to 3 classifications. To estimate the association between restraint use and death, we classified restraint exposure into either "no restraint use" or "any restraint use" (model 1). Because restraint misuse may affect the study association, we further distinguished recorded improper restraint use (including improper use of seat belts or child restraints, use of a shoulder-only seat belt, and use of an unknown type of restraint) from the "any restraint use" category (model 2). To determine the association between type of restraint use and death, we classified restraint exposure into 4 categories: no restraint use, seat belt use, child restraint use, and improper restraint use (model 3).

CONFIDENTS OF INTEREST

We treated child age group (2-3 years, suitable for forward-facing child restraints, and 4-6 years, suitable for boosters), sex, seating position (left side [yes/no] and right side [yes/no]), and the interaction between seating position and initial impact point as potential confounding variables in all the analyses. Initial impact point was split into the following categories according to the NHTSA definition: noncollision, front, right side, left side, rear, and other (underride, overide, and unknown). Because no child was exposed to a deployed rear-seat air bag, the presence of rear-seat air bags was not considered in this analysis. We considered several variables (age group, sex, and seating position) that may modify the effect of restraint use in each of the models.

STATISTICAL ANALYSES

We estimated the association between restraint use and death using conditional Poisson regression. To fit the conditional Poisson model, we used the Cox proportional hazard regression method to estimate the mortality RR, stratifying on the matched vehicle and using the Breslow method to handle ties in follow-up time, which we set equal within each matched set. Because the variance estimate for conditional Poisson regression may be too large when data are almost binary, we calculated bootstrap CIs at the 95% level based on 1000 replications by assigning an equal probability to each vehicle to be resampled with replacement.

We used likelihood ratio tests and Akaike Information Criteria to compare nested models (eg, to compare models 1 and 2). The interaction terms involving restraint use were added individually to the regression models, and we retained these if $P < .05$ from a likelihood ratio test. A software program (SAS version 9.1) was used to perform all the data analyses.
RESTRAINT EFFECTS

None of the interaction terms involving restraint use were significant using likelihood ratio tests. Table 2 provides the model comparison results for the 3 models. Compared with no restraint use, any type of restraint use provided a large reduction in the risk of death (RR, 0.33; 95% CI, 0.22-0.49). Improper restraint use affected the association between restraint use and death for rear-seated child passengers aged 2 to 6 years (likelihood ratio test \(P < .01\) for the comparison between models 1 and 2) (Table 2). Compared with improper restraint use, any other restraint use provided a reduction in the risk of death (RR, 0.46; 95% CI, 0.20-0.63).

TYPE OF RESTRAINT

The association between restraint use and death did not vary significantly by type of restraint use (likelihood ratio test \(P = .62\) for the comparison between models 2 and 3); the RR of death for child passengers compared with seat belts was 0.91 (95% CI, 0.57-1.44) (Table 3). The association between restraint use and death did not vary significantly with age (likelihood ratio test \(P = .66\) for testing of the interaction between restraint use and age group in model 3). Child restraints slightly varied in the protective effects by age compared with no restraint use (Table 3).

COMMENT

This study found that a reduction in the risk of death for rear-seated child passengers is associated with the use of a restraint. This is consistent with 2 earlier studies that also used matched cohort study designs to estimate the association between restraint use and no restraint use. Smith and Cummings\(^5\) analyzed FARS data from 1990 to 2001 and estimated a risk reduction for rear-seated child passengers from birth to 12 years of age when no front passenger air bag was present (RR, 0.53; 95% CI, 0.47-0.59). Lardelli-Claret et al\(^\text{14}\) analyzed road crashes in Spain from 1993 to 2002 for child and adult rear-seated passengers and found an RR of death of 0.56 (95% CI, 0.38-0.82). By comparison, we found a larger reduction in the risk of death when using any type of restraint for rear-seated children aged 2 to 6 years (RR, 0.33; 95% CI, 0.22-0.49). Improper use of restraints reduced their protective effects in lowering the risk of death in this study. Valent et al\(^\text{15}\) analyzed National Automotive Sampling System tow-away crash data from 1995 to 1999 for child passengers.
11 years and younger and found a smaller reduction in the risk of death for improper restraint use (risk ratio, 0.74; 95% CI, 0.11-4.98) than for proper restraint use (risk ratio, 0.26; 95% CI, 0.12-0.59) compared with no restraint use. Sherwood et al\textsuperscript{16} also suggested that gross misuse of restraints accounted for 12% of fatalities after examining the most responsible factor for a sample of child passenger fatalities 6 years and younger.

The association between restraint use and death did not vary by type of restraint in this study. Using FARS data from 1975 to 2003, Levitt\textsuperscript{5} found no difference in the risk of death for child passengers aged 2 to 6 years using child restraints and seat belts. After controlling for a variety of potential crash- and vehicle-related confounders, Levitt found an identical regression model coefficient for child restraints and seat belts. After controlling for a variety of potential crash- and vehicle-related confounders, Levitt found an identical regression model coefficient for child restraints and seat belts compared with being unrestrained. However, in a recent NHTSA analysis of FARS restraints and seat belts compared with being unrestrained, Stinson et al\textsuperscript{21} also reported an elevated RR of injury of 3.5 (95% CI, 2.4-5.2) for children aged 2 to 5 years using seat belts compared with those using child restraints from a representative crash sample. Sherwood et al\textsuperscript{16} argued that crashes involving the death of a child passenger using a child restraint were of a so-called unsurvivable crash severity. It is possible that this level of crash severity may be associated with the present study population, with almost all deaths (90.9%) occurring in crashes with disabling deformation of the vehicle.

We did not find evidence that the association between type of restraint use and risk of death varies with age. Although child restraints provided a greater but nonsignificant reduction in the risk of death for children aged 2 to 3 years than for children aged 4 to 6 years compared with no restraint use, our ability to detect whether the association varies with age is limited by the study’s sample size.

Matched designs, such as that used in this study, cannot completely eliminate confounding,\textsuperscript{22} and uncontrolled confounders may affect the association between risk of death and type of restraint use in this study. For example, the location and the extent of intrusion have been suggested as possible causal factors related to the risk of death in child passengers.\textsuperscript{16} However, this information is not available in FARS. Therefore, we could not control for all potential confounders in the present analysis.

Misclassification of restraint type may bias the effect estimates for type of restraint use in children (eg, a belt-positioning booster recorded as a seat belt), although seatbelt use misclassification in a matched cohort study\textsuperscript{23} did...
not substantially affect the risk estimates for study participants 16 years and older. In addition, we observed a discrepancy between the prevalence of improper use of child restraints (12.1%) in the present study population and previously reported prevalence (72.6%) from a sample population in 6 states in 2002. It is possible that misuse is underreported in the FARS data set. If systematic misclassification of this type occurs, it would mask the child restraint effectiveness. Seat belt misuse may also have been underreported because improper use of seat belts by children is commonly found in in-depth crash studies.

Another limitation was that we could not determine whether the mechanism underlying missing data was completely at random. We restricted the analysis to those with complete information and effectively controlled confounding from known risk factors. Because we found no substantial difference regarding age, sex, and death distributions between the present study population and those being excluded due to missing information, it is unlikely that these estimates of the risk of death are biased substantially by missing data.

In conclusion, this study provides support for current recommendations and promotion campaigns about the optimal use of restraints for young child passengers. Given existing evidence that child restraints outperformed seat belts in reducing nonfatal injuries, the lack of evidence indicating that child restraints are better than seat belts in reducing fatalities raises the need for further study of the performance of child restraint systems in fatal crashes.

Accepted for Publication: April 8, 2008.

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Author Contributions: Mr Du had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Du and Hayen. Acquisition of data: Du, Analysis and interpretation of data: Du, Hayen, Bilston, Hatfield, Finch, and Brown. Drafting of the manuscript: Du, Hayen, and Bilston. Critical revision of the manuscript for important intellectual content: Du, Hayen, Bilston, Hatfield, Finch, and Brown. Statistical analysis: Du, Hayen, and Finch. Obtained funding: Bilston and Finch. Administrative, technical, or material support: Bilston. Study supervision: Hayen, Hatfield, and Finch.

Financial Disclosure: None reported.

Funding/Support: This research was supported by a research grant from the Australian Research Council in partnership with the Motor Accidents Authority of New South Wales (NSW) and the Roads and Traffic Authority of NSW; the NSW Injury Risk Management Research Centre, with core funding provided by the NSW Department of Health, the Roads and Traffic Authority of NSW, and the Motor Accidents Authority of NSW (Drs Hayen and Hatfield); the Injury, Trauma, and Rehabilitation National Health and Medical Research Council (NHMRC) Capacity Building Grant in Population Health (Dr Hatfield); an NHMRC Senior Research Fellowship (Dr Bilston); and an NHMRC Principal Research Fellowship (Dr Finch).

Role of the Sponsors: The funding organizations had no role in the design and conduct of the study; the collection, management, analysis, and interpretation of the data; and the preparation, review, and approval of the manuscript.

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