CHILD SAFETY IN LIGHT VEHICLES

Linda B. McCray
National Highway Traffic Safety Administration
United States

John Brewer
Volpe National Transportation Systems Center
United States
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ABSTRACT

In the last 30 years, our nation has achieved significant gains in child passenger safety. Child restraint systems (child safety seats and booster seats) have saved thousands of children. Even though child restraint systems have proven to be an excellent concept for injury mitigation, Congress directed the Secretary of Transportation to initiate a rulemaking for the purpose of improving the safety of child restraints. The National Highway Traffic Safety Administration (NHTSA) was able to conduct extensive research within the mandated timeframe. Many consumer information programs were developed, and some improved upon, to provide better consumer information on child safety restraints, usage, etc. Federal Motor Vehicle Safety Standards were upgraded and are currently being upgraded to continue improvements in child safety. This paper provides a status on recent analyses and proposed child safety research efforts.

INTRODUCTION

Motor vehicle crashes are the leading cause of death for children of every age from two to 14 years old. During 2003, 8,089 passenger vehicle occupants under 15 years of age were involved in fatal crashes. For those children, where restraint use was known, 30 percent were unrestrained; among those who were fatally injured, 53 percent were unrestrained. In 2003, 471 children under the age of five died as occupants in light passenger vehicle crashes. Of those 471 fatalities, an estimated 167 (35 percent) were totally unrestrained. Research shows that child restraint systems (CRS), when used correctly, can reduce fatalities among infants (children less than one year old) by 71 percent in passenger cars and among toddlers (one to four years old) by 54 percent.[1] That makes child safety seats one of the most effective safety innovations ever developed. Use of CRS is now required in all 50 states and the District of Columbia. Data indicate that the increased use of these restraints, as a result of mandatory usage laws, have significantly reduced the risk of child fatality in motor vehicle crashes.

In 2003, an estimated 446 children under age five were **saved** as a result of CRS use. That 2003 figure would have been 550 children saved if all motor vehicle occupants under 5 years old were protected by CRS. During that year, there were 185 fatalities among children in CRS. About 28 percent (52 fatalities) were in frontal non-rollover crashes, 28 percent (51 fatalities) were in non-rollover side impacts, and 26 percent (48 fatalities) were in rollover crashes.

The data show that the national injury problem remains an issue for children and requires further definition. Given the many crash types, crash severity levels, child occupant ages and child restraint categories, the child safety research area is very complex. Organization of the child safety research base is a major task itself, as is finding a vehicle-based countermeasure focus for maximum benefit across ages. Maximum benefits may not be realized by only focusing on the child restraint system improvements, but by possibly developing vehicle improvements. Further benefits may be realized through crash mitigation with advanced technologies.

BACKGROUND

Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act

On November 1, 2000, Congress enacted the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act (Pub. L. 106-414, 114 Stat. 1800) which, in part, requires the Secretary of Transportation to initiate a rulemaking for the purpose of improving the safety of child restraints.[1]

Section 14(a) of the TREAD Act mandated that the agency ‘‘initiate a rulemaking for the purpose of improving the safety of child restraints, including minimizing head injuries from side impact collisions.’’ Section 14(b) of the Act identified specific elements that the agency must consider in its rulemaking. The Act gave the agency substantial discretion over the decision whether to issue a final rule on the specific elements. Section 14(c) specified that if the agency does not incorporate any element described in 14(b) in a final rule, the agency shall explain in a report to Congress the reasons for not incorporating the element in a final rule.[2] Various Sections of the Act addressed consumer information improvements such as labeling, availability of compliance test data and CRS ratings. In response to Section 14, the agency examined possible ways of improving consumer information on child safety restraints, revising and updating its child restraint standard.

NHTSA published a final rule on June 24, 2003 (68 FR 37620), to address Section 14(b) of the TREAD Act. The rule incorporated five elements into FMVSS No. 213: (a) an amendment to make labels and instructions clearer and simpler; (b) an updated bench seat used to dynamically test add-on child restraint systems; (c) a sled pulse that provides a wider test corridor; (d) improved child test dummies; and (e) expanded applicability to child restraint systems recommended for use by children weighing up to 65 pounds. Child restraints will be tested using the most advanced test dummies available today and tested to conditions representing current model vehicles.[3] Although changes were made to the child safety standard, Congress further directed the Secretary of Transportation to make additional improvements to the Standard to address larger children.

Anton's Law

On December 4, 2002, the President signed "Anton's Law" (Public Law 107-318, 116 Stat. 2772) which in part calls for improvement of the safety of child restraints in passenger motor vehicles for larger, older children. Anton's Law mandated the Secretary of Transportation to 1) initiate a rulemaking proceeding to establish performance requirements for child restraints, including booster seats, for the restraint of children weighing more than 50 pounds; 2) develop and evaluate an anthropomorphic test device that simulates a 10-year old child for use in testing child restraints used in passenger motor vehicles; 3) require a lap and shoulder belt assembly for each rear designated seating position in a passenger motor vehicle with a gross vehicle weight rating of 10,000 pounds or less; and 4) initiate an evaluation of integrated or built-in child restraints and booster seats.

In response to Anton's Law, NHTSA published a report to Congress on built-in child safety restraints. The study found no additional benefits with built-in child restraints when compared to add-on child safety seats. More detailed results of the study can be found in the Report to Congress: Anton's Law Section 6 – Evaluation of Integrated Child Safety Systems.[4] In response to Anton's Law, on December 8, 2004, a final Rule was published requiring lap and shoulder belt assemblies for each rear designated seating position.[5] This rulemaking was instituted, in part, to offer comparable safety protection for larger, older rear center seated child occupants. The agency is continuing research efforts with the 10 year-old anthropometric test device which would be required in order to upgrade the child safety standard to evaluate restraint systems developed for use by children weighing more than 60 pounds.

RESEARCH APPROACH

During the last four years, extensive research efforts have been undertaken to revise Federal Motor Vehicle Safety Standard (FMVSS) No. 213, "Child Restraint Systems" (49 CFR §571.213) and improve consumer information on child safety restraints. Timely program, resource and funding decisions were required in order to address the mandates. In order to better focus the agency's resources and funding for research, a research approach needed to incorporate the concept of preliminary estimations of benefits based on engineering judgment. Preliminary estimate of benefits is used to help direct the agency on immediate and future activities in a more efficient manner. A 9-step research approach has been undertaken for the child safety research program.

[1] This followed an agency announcement in its November 2000 Draft Child Restraint Systems Safety Plan (Docket NHTSA–7938) that the agency would be undertaking rulemaking on these and other elements of Standard No. 213 (65 FR 70687; November 27, 2000).

The approach includes the following steps:

1. Select and define a crash problem
2. Set countermeasure functionality
3. Survey technology for functions
4. Create countermeasure concepts
5. Estimate preliminary costs and benefits
6. Select the most promising concept(s)
7. Develop and conduct objective tests
8. Refine costs and benefits
9. Agency decision on next steps

Step 9 is an agency decision-making step. In this phase of the process, the research results, along with cost and benefits, are then assessed by the agency to determine the next action to be undertaken. While research efforts are conducted within the framework of steps 1 – 8, agency involvement occurs throughout the entire process.

While the agency finalizes meeting the child safety Congressional mandates, a reassessment of the child safety data must be undertaken. As public knowledge has increased regarding child safety due to public programming, new state laws and joint partnerships, real-world requirements have changed/improved for children. For example, more children of appropriate ages and size are using booster seats and younger children are being appropriately restrained in child safety restraint systems.

Problem Definition

During the last four years, extensive data analyses have been conducted by the agency. To date, no compilations or summaries of these analyses have been completed. The intent of current analyses is to build, or expand, on previous analyses and to potentially develop new analytical approaches.

Multi-Dimensional Crash Assessment

The child safety problem has numerous relevant dimensions. The effects in an individual case can be measured by injury severity data (such as Maximum Abbreviated Injury Scale (MAIS) values as used in the Crashworthiness Data System (CDS) or fatality from the Fatality Analysis Reporting System (FARS)). The inputs that yield these results include crash type (e.g., front, rear, side, rollover), crash sub-type (e.g., offset frontal, far side impact), closing velocity, seating position, occupant age, restraint type, restraint appropriateness (e.g., premature graduation to seatbelts) and vehicle characteristics of all vehicles in the crash.

As no two crashes are the same and detailed analysis of large numbers of case studies is beyond the scope of this study, inferences must be made from large groups of similar crashes. Only after significant subgroups of crash parameters are identified can attempts be made to "drill down" to discover those for which countermeasures can provide effective benefits.

A case can be made for examining every recorded parameter, but the authors chose to limit the initial analysis to four major dimensions: crash type, occupant age, general restraint level (restrained/unrestrained/unknown), and injury severity. The years 1995-2003 (except 1997) were used. It should be noted that CDS provides data from tow-away crashes that can then be "weighted" to account for the overall prevalence of those crash conditions.

The total weighted or unweighted counts (normalized by year) provide useful insight into "hotspots" of child injury. An alternative is to estimate "fatality equivalents" associated with each age, crash type, and restraint level. A fatality equivalent factor is assigned to each Abbreviated Injury Scale (AIS) severity level. While the definition of fatality equivalents for children is beyond the scope of this study, the relative weight for each level can be approximated using the [injury-based] weightings in the Blincoe report.[6] When estimating fatality equivalents, it was decided to use FARS data for fatalities and to eliminate non-survivors from CDS data. That is, those data points that indicated an MAIS level of less than 6 but a finite survival period were removed from the CDS counts to avoid double counting. This technique has been used to analyze injury patterns on various crash types and sub-types.

Child Safety Research Inventory

A key aspect of the Child Safety Research Program is coordination and collaboration with other researchers. A specific effort has been made to avoid duplication of effort. The purpose of the newly created database is to provide a cross-reference for identified "hot spots" found in the initial data analysis. This allows analytical resources to be more efficiently allocated. Relevant research studies five years old or less have been entered into a relational database. Important characteristics of each study (e.g., the age groupings and crash types considered) were entered, as well as a summary of results. The database contains information regarding which child safety issues the study address (e.g., which specific age groups were considered, if any at all). A typical study is shown in Figures 1 and 2. The database will facilitate the identification of "holes" in the child safety problem that have been under-analyzed as well as current research and schools of thought for those that are being examined.

The prototype database includes recent governmental studies. Data regarding external studies will be added at a later date.

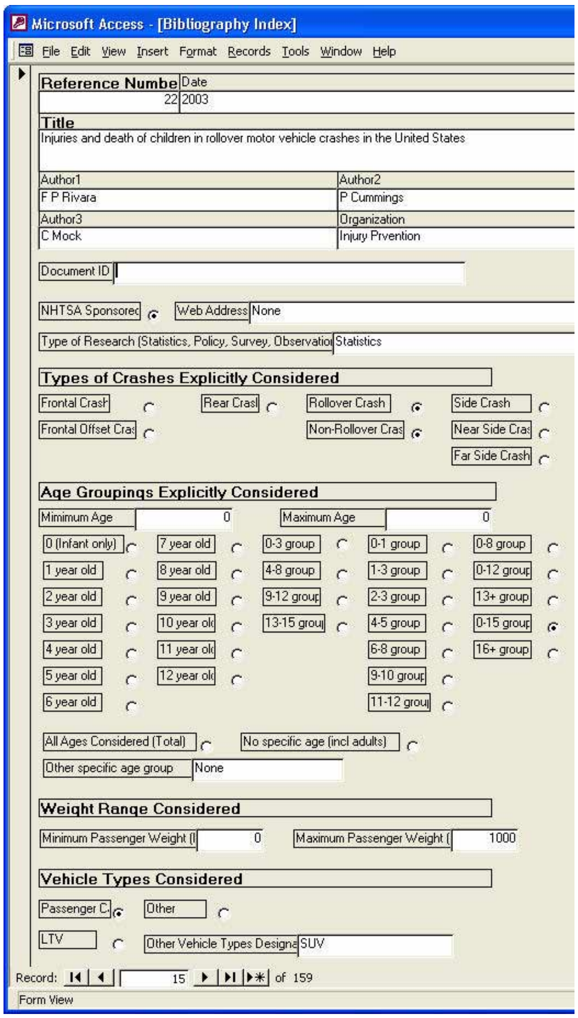

Figure 1 Screen Capture A of Inventory Database

Status of Injury to Children in Motor Vehicle Crashes - Exposure

Understanding the effectiveness of child safety initiatives requires data on both the number of child injuries as well as the number of opportunities or "exposure." One measure of exposure is the number of passenger miles traveled (PMT). Estimating exposure for children is difficult. An approximate method is proposed that relies on potentially questionable assumptions that injury rates and patterns of both drivers and occupants are independent of the age and total number of vehicle occupants. Nonetheless, it is hoped that the trends developed using this method can yield some insight into injury rates for important age groups.

It is tempting to estimate the relevant exposure of a certain age group by comparing the total count of injured and uninjured passengers (the sum of Maximum AIS value of 0 to 6) of an age group in a

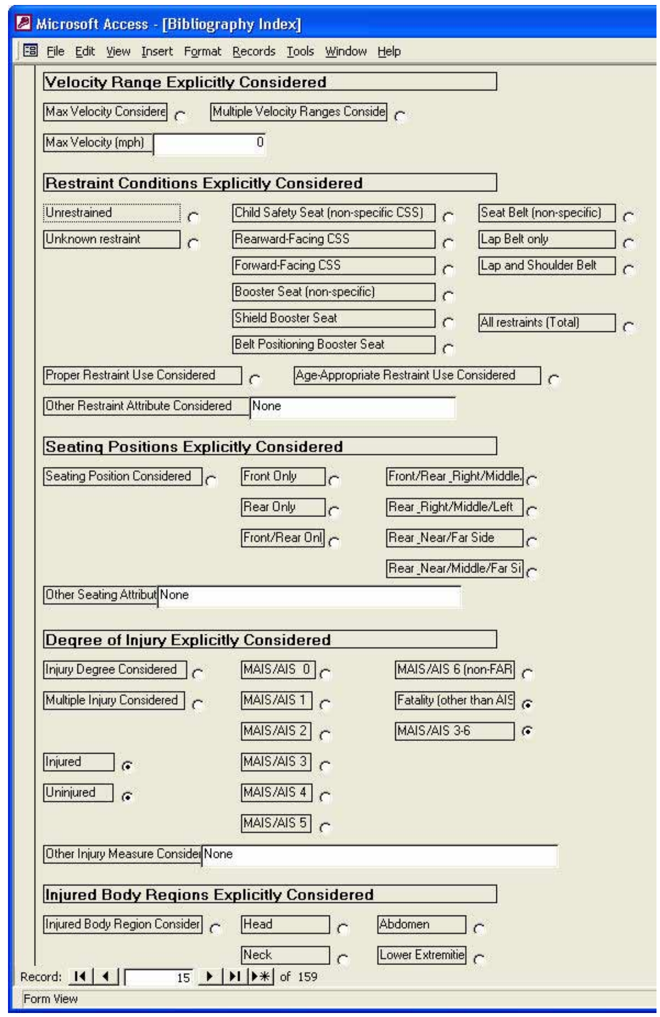

Figure 2 Screen Capture B of Inventory Database

large database (e.g., CDS of the National Automotive Sampling System [NASS]) to the total number of injured and uninjured drivers. Assuming the database contains information on every driver and passenger in every crash considered, the ratio of child occupants in the database to drivers in the database should be the ratio of passenger (child occupant) miles traveled to vehicle (driver) miles traveled. For the purposes of this paper, a "load factor" for a particular age group is defined as this ratio of passenger miles traveled (PMT) to vehicle miles traveled (VMT). The inherent assumption with this definition is that drivers' propensity for being involved in a crash is independent of the presence or the number and age of passengers.

A similar approach which yields some insight into the relative injury profiles of children and drivers involves determining the relative number of injuries of each severity level (e.g., the police injury severity rating where injury is classified from killed [K] to uninjured [O]) for crashes in the NASS General Estimates System (GES)) in which there is one driver and exactly one child passenger. For each severity level, there is a particular ratio of total children to total drivers. It is unlikely that this ratio will be exact unity. When there are more children than drivers at lower injury levels, one might infer that children are safer than drivers. At any given injury level, one can use this ratio and the ratio of total driver injuries to total child injuries to estimate a load factor. A sample calculation is given below:

In the years 1994-2003, GES estimates that there were 179,000 crash vehicles involving only a driver and a single infant (child occupant less than one year old). In those crashes, 154,100 children and 133,600 drivers were uninjured (severity level O). The ratio of these tow numbers is 1.15. Thus, infants were 15% more likely to be uninjured (i.e., have a severity level of O) than drivers. For these same years, the estimated total number of uninjured drivers in all crashes was 88,063,000 and the estimated total number of uninjured infants was 570,000. Since infants are 15% more likely to appear in this injury category, the estimated load factor is given by:

$$LF \cong (570{,}000/1.15)/88{,}063{,}000 = 0.56\%$$

This load factor analysis requires the assumption that injury distribution for children and for drivers in NASS crashes are completely independent of the presence of other occupants. This is unlikely to be the case. At the very least, seating location will be a function of the number of adult and child occupants. Hence, for infants, it is not surprising to find that the calculated load factors range from 0.52% to 0.91%, depending on the injury severity used. When all involved infants (levels K, A, B, C, and O combined) were considered, the computed load factor was 0.61%. The load factors calculated for level K (killed) varied most widely, given the relatively few occurrences compared with other injury levels. When the geometric mean was computed for levels A, B, C, and O, it was found to be 0.67%. Although no rigorous estimate of confidence level was made, it is likely that the actual load factor for infants is between 0.6% and 0.7%. That is, for every 100 vehicle miles traveled, there are approximately 0.6 to 0.7 passenger miles traveled for infants. While some uncertainty exists for each estimate, a consistent calculation method can be used to expose certain trends.

Figure 3 shows the calculated load factors for important age groups and subgroups using all the GES data. Some interesting patterns do emerge. First, infants have a relatively low load factor. One might presume that mothers of newborns avoid taking them on routine errands for several months. Second, load factors drop off as children enter school. Finally, load factors rise again as children enter their early teens.

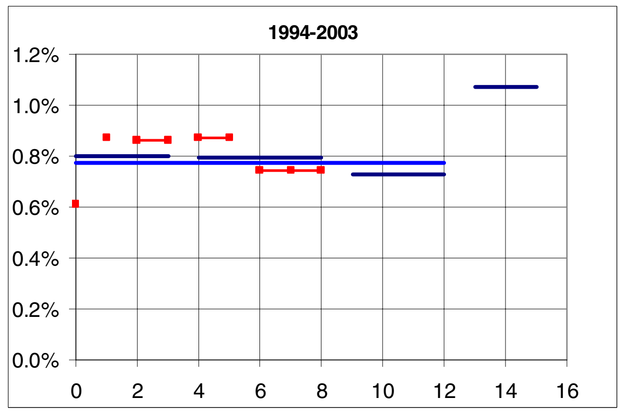

Figure 3 Load Factor vs. Age

These estimated load factors can be used to calculate estimated injury rates relative to PMT. The injury count for the years in question was estimated from MAIS data in CDS. The PMT for each age group was estimated by multiplying the load factor by the VMT reported by the Bureau of Transportation Statistics. Once again, the statistical sensitivity to low incident counts was higher for the more extreme injury levels. The estimated incidence rate is shown for various age groups in Figure 4.

This figure also shows some interesting trends. First, children over 8 years old seem to be far more vulnerable to injuries at all severity levels. This might be a result of diminished parental insistence on proper restraint at these ages. Second, infants and one-year-olds show lower injury rates at the middle severities. The implication is that young children are either well protected in a particular crash or susceptible to severe injury. How well this susceptibility correlates with proper restraint use is a subject for further research. Finally, the trends identified at the MAIS 6 level should be verified by applying FARS fatality data.

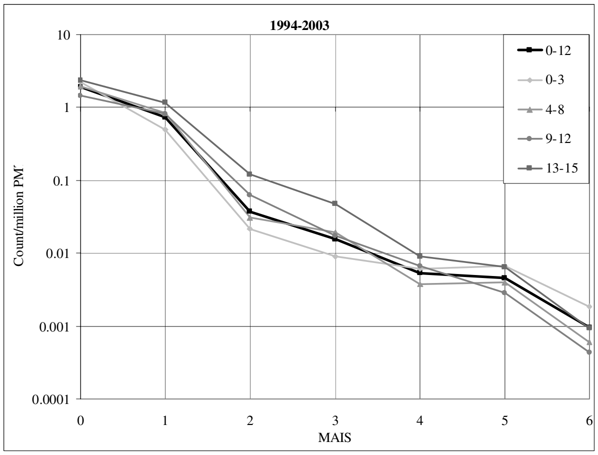

Figure 4 Incidence of MAIS level per Million Passenger Miles Traveled (by age group)

Next Steps

Once the data have been completely reviewed and analyzed, an assessment of countermeasures will be made. Countermeasure candidates will possibly be considered by age and restraint type. Based on each restraint type for the various child age populations, some countermeasure candidates may be vehicle-based. The countermeasure selection approach will then be determined by the applicable parameters. The estimated cost benefits approach will be based on the countermeasure(s) selection. Once the estimated benefits are determined, objective tests will be developed and conducted. These efforts will be undertaken within the framework of steps 1 - 8.

SUMMARY

This paper sought to describe the status of child safety in light passenger vehicles. Child safety in light vehicles is a complex problem area. The data show that child restraint systems are very effective when used. However, continued efforts are warranted to get the unrestrained children into the appropriate restraint systems. Although child restraint systems generally are performing well in real-world crashes, children are still sustaining injuries. Considerations may need to be given to improving the vehicle for occupant protection for children. Benefits may be realized not just for smaller children but older children as well. Nonetheless, further research is warranted. The authors will continue their work to identify opportunities for increased safety.

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