REAR SEAT OCCUPANTS IN FRONTAL CRASHES - ADULTS AND CHILDREN - THE EFFECTS OF RESTRAINT SYSTEMS

Donald F. Huelke
and
Charles P. Compton
University of Michigan Transportation Research Institute

ABSTRACT

Data on passenger cars in frontal crashes were reviewed using NASS 1980-1991. Crashes with one or more rear seat passengers were included. Combinations (pairs) were made based on restraint use: lap-shoulder belts in the front seat (or no belts worn) and lap belts, or (no belts worn) in the rear seat. Crashes wherein passive restraints were worn or restraints for children were not included. The AIS was used for injury severity. The data indicate the rear seat is a safer environment. Lap belted rear seat occupants, children and adults, most always fared better than their front seat counterparts.

THE EFFECTS OF SEAT BELT RESTRAINT SYSTEMS have been well documented and need not be repeated here. For the most part, studies on the effectiveness of restraint systems only included the front seat occupant(s). In the rear seat, data are sparse, and generally only involve the use of lap belts (Gikas and Huelke, 1966, Huelke, 1978a, b, NTSB Safety Study, 1986, Evans, 1987, Huelke, et al, 1987, Huelke, 1987, Campbell, 1988, Evans, 1988a, b, Huelke,1988a,b, Krafft, 1990). The National Transportation Safety Board (NTSB, 1986) reported on selected cases of lap belt induced injuries, cases where the investigators specifically searched for crashes with injuries to lap belted occupants.

In a crash the advantages of being a rear seat occupant has been identified by many authors. Those restrained in the rear seat faired much better under all belting conditions. (Ashton, et al, 1977, Lowne, 1977, Williams and Zadore, 1977, Huelke, et al, 1987, Huelke, 1987, Padmanaban and Ray, 1993, Cooper, et al., 1994, Huelke and Compton, 1994) The requirements for proper restraint of rear seat occupants varies, for rear seat occupancy includes more children and adolescents than in the front passenger seat (Huelke, 1978, 1987 a, b, Mackay, 1992, Norin, 1980).

Children also fit the above, a lower frequency of the more serious injuries in the rear seat than in the front, with younger belted passengers having even a lower injury severity frequency (Lowne, 1977, Williams and Zador, 1977, Norin, et al, 1980, Krafft, et al, 1990, Lane, 1993,).

MATERIALS AND METHODS

For this study, the National Accident Severity Study (NASS) data, was reviewed for the years 1980 -1991. From these data, only frontal collisions of passenger cars (11-1 o'clock impact direction) were studied, cars without major secondary collision damage. Additionally, only cars equipped with an active belt system were selected; no cars with passive restraints (automatic shoulder belts or airbags) were included. "Adult" (15 years or older) front seat occupants were either unbelted or lap-shoulder belt restrained. In each crash there was at least one rear seat occupant, 15 years or older, either unbelted or lap belted. Occupant pairs were then formed, based on seating location (front and rear), and the various belt combinations. A pair consists of a rear seat occupant with the driver, and, if there was a front seat passenger, then another pair was made. Similarly, if there was a second rear seat occupant, another pair (or two) was identified. There are few lap-shoulder belted rear passengers and therefore they are not included in this analysis. In a similar manner, separately studied were rear seat children 5-14 years of age.

The Abbreviated Injury Scale (AIS) was used and the highest or most severe injury level, the Maximum Abbreviated Injury Scale (MAIS) was tabulated.

Table 1

Variables Used

- •Frontal crashes (11-1 o'clock-primary CDC)
- •Passenger cars
- •No major secondary damage
- •No rollovers
- •No passive restraints or child restraints included
- •Adult front seat occupants-15 years or older
- •Rear seat occupants-5-14 years, ≥ 15 years
- •Known injury level (AIS)

RESULTS

Data derived from the front seat-rear seat adult pairs are shown in Table 2 where the frequency of *all* MAIS levels is presented along with the MAIS 2+ injury frequency shown in parenthesis.

In Table 2 the MAIS frequencies indicate that the rear seat adult occupants have a lower frequency of injury than those in the front seat. For example, when both the unbelted front and rear seat adult occupants were reviewed, 29% of the front seat occupants have a higher MAIS compared to those in the rear (11%). This holds true for all belting combinations except for the front lap-shoulder belted and rear unbelted occupant pairs where the frequency of the MAIS is the same (17%).

In all belting combinations the majority of MAIS of front and rear occupants were at the 0-1 level. Eliminating the MAIS 0 & 1, the sets with an injury level of MAIS 2+ for both front and rear seat adult occupants were separately reviewed (Table 2). Again, more adult front seat occupants had a higher MAIS level (2+) in all belting combinations except one--the rear unbelted adult occupants had a higher frequency of MAIS 2+ (55%) than the front lap-shoulder belted occupants (44%).

Table 2
MAIS Frequency
Adult Front and Rear Occupants With Various Belting Combinations

Combinations	Front		Rear		Same		No. of Sets	
	All MAIS %	(MAIS 2+) %	All MAIS %	(MAIS 2+) %	All MAIS %	(MAIS 2+) %	All MAIS %	(MAIS 2+) %
Front-unbelted & Rear-unbelted	29	(58)	11	(31)	60	(11)	5259	(946)
Front-unbelted & Rear-lap belted	31	(56)	6	(33)	63	(11)	258	(27)
Front-lap shoulder belted Rear-unbelted	17	(44)	17	(55)	66	(1)	564	(73)
Front-lap shoulder belted Rear lap belted	21	(64)	8	(23)	71	(13)	543	(52)

The 5-14 year old rear seat children have a lower frequency of injury at all MAIS levels (Table 3), even when they are lap belted with the front adults restrained by lap-shoulder belts. The sets of MAIS 2+ for rear seat 5-14 year old children are few in number indicating the protection offered by the rear seat areas as well as the use of the lap belt.

Table 3
Injury Frequency
Front Seat Adults and Rear Seat Children (5-14 Years)

Combinations	All MAIS Levels Front	Rear	Same	No. of Sets
	%	%	%	
Front-unbelted & Rear-unbelted	31	8	61	1249
Front-unbelted & Rear-lap belted	25	5	70	107
Front-lap shoulder belted Rear-unbelted	36	14	50	138
Front-lap shoulder belted Rear lap belted	20	7	77	190

DISCUSSION

The lower injury frequency at all MAIS levels, in most all of the belted (or unrestrained) sets, indicate that the rear seat occupants fare better than their front seat counterparts. This is also true when front seat adults are compared to younger rear seat passengers-5-14 year olds-for all belted combinations. Our data disagree with Nygren, et al (1982) and Norin, et al (1980) that the injury severity for unbelted front and rear seat occupants is similar. Our findings indicate that the unrestrained rear seat occupant injury frequency is about 63% lower than unrestrained front seat occupants.

Previous data have shown that lap belts provide protection for children (Morris, 1983, Partyka, 1987, Orsay, et al, 1989, Krafft, et al, 1990, Corben and Herbert, 1991).

The incidence of the seat belt syndrome in children is not high. Lane (1993) indicated that children appear to be less at risk for the seat belt syndrome than adults in the same seating position, including the rear outboard seats. Agran, et al, (1985, 1987a,b, 1989, 1990) did not find any pattern of significant injuries in their studies of pediatric car crash patients. In their study of belted children, Langweider and Hummel, (1989) did not find an increase in lumbar spine injuries.

These data that we present on passenger cars in frontal crashes with various belt use in the front and in the rear seats indicate that the rear seat is a much safer location than is the front seat in this set of frontal crashes, agreeing with citations mentioned earlier in this paper. The

data further indicate that there is no overall enhancement of injuries to occupants in the rear seat who were wearing lap belts.

Additionally, one would hope that the lap-shoulder belt in the rear seat will offer even further protection over that of the lap belt only. It is the supposition of some that if lap-shoulder belts are worn in the rear seat, the injury reducing effectiveness of the 3-point restraint would be similar to that in the front seat. Although we do not have data on lap-shoulder belted rear occupants, other studies should be mentioned that have indicated the lap-shoulder belted rear seat occupant is susceptible to seat belt injuries. Padmanaban and Ray, (1993) using two independent analysis did not find any measurable differences between rear seat lap or lap shoulder belt effectiveness. Because of the variety of sizes of individuals in the rear seat, it is unsure at this time whether a lap-shoulder belt will properly fit the anatomy of all ages of rear seat occupants, especially children who have different body portions than adults (Burdi, Huelke and Snyder, 1969). A slight deviation from the upright position laterally can degrade the effectiveness of the upper restraint system as well as a slouched precrash position of the rear passenger. Also, less leg room is often noted in the rear seat area versus the front seat area, and the belt conformity to the anatomical anchor points, especially of children, may be less than optimal, depending on the size of the individual.

Lane (1993) concluded that, "of adults restrained by three point belts, rear outboard occupants have a greater liability to SBS (seat belt syndrome) than left front occupants (passengers)". Our data agree with the study of Evans and Frick (1988b) on fatal risk, where they stated, "Hence when all occupants use the most commonly provided restraint systems, no difference is indicated in the fatality risk to front and rear outboard occupants. Using data from the Folksam Insurance Company, a low frequency of "injured" rear passengers, of all ages, using the lap or lap-shoulder belts, was found (Krafft, et al, 1990). Lane (1993), indicated that for children in the rear the relative risk of the seat belt syndrome (SBS) is twice as high for lap belt users than for those using the 3-point restraint. Yet, rear seat lap-shoulder belt users have nearly three times the risk of front seat passengers in 3-point belts. Twice as many children sustained SBS when 3-point restrained in the rear seat.

CONCLUSION

In this unique study of frontal crashes with front and rear seat occupants either belted or unrestrained in the same crash, the rear seat was identified as a safer environment, agreeing with other studies. It appears that unbelted rear passengers fare as well as lap-shoulder belted front seat occupants in the same frontal crashes. Lap belted rear occupants have a higher level of injury severity less often than lap-shoulder belted front seat occupants in the same crash. The exception to this is at the higher MAIS levels (2+) in adults when the rear passenger is unbelted and the front seat occupant is lap-shoulder belted. The 5-14 year old rear seat passengers have a lower frequency of injury at all MAIS levels when compared to front seat occupants.

REFERENCES

Agran, P.F., Dunkle, D.E., Winn, D.G. Motor vehicle Accident Trauma and Restraint Usage Patterns in Chilcren Less Than 4 Years of Age. *Pediatrics*, 76:382-386, 1985.

Agran, P.F., Dunkle, D.E., Winn, D.G. Injuries To a Sample of Seat-belted Children Evaluated and Treated in a Hospital Emergency Room. *J Trauma*, 27:8-64, 1987.

Agran, P.F., Winn, D.G. Traumatic Injuries Among Children Using Lap Belts and Lap/Shoulder Belts in Motor Vehilce Collisions. *Proc 31st Conf Amer Assn for Auto Med,* 283-296, 1987, Des Plaines, IL.

Agran, P.F., Winn, D.G., Dunkle, D.E. Injuries Among 4 to 9 Year Old Restrained Motor Vehicle Occupants By Seat Location and Crash Impact Site. *Am J Diseases of Children,* 143: 1317-1321, 1989.

Agran, P.F., Castillo, D., Winn, D.G. Childhood Motor Vehicle Occupant Injuries. *Am J Diseases of Children,* 144:653-662, 1990.

Ashton, S.J., Mackay, G. M. and Gloyns, P.F. Trauma to Children as Car Occupants. *Proc Intl Mtg on Biomech of Trauma in Children,* Intl Research Committee on the Biokinetics of Impacts, Lyon, FR, 83-100, 1977.

Burdi, A.R., Huelke, D.F., Snyder, R.G., et al Infants and Children in the Adult World of Automobile Safety Design: Pediatric and Anatomical Considerations for Design of Child Restraints. *J Biomech* 2:267-280, 1969.

Campbell, B. J. The Effectiveness of Rear-Seat Lap-Belts in Crash Injury Reduction. UNC Highway Safety Research Center, Publ. No. A-125, 1986.

Cooper, K.D., Proctor, S.M., Ragland, D.R. and Barkan, H. Seat Belt Syndrome-An Examination of Patterns of Injury Associated With Seat Belt Use. *Proc. 38th Assoc. for the Advancement of Auto Med.,* Lyon, FR, 11-23, Des Plaines, IL 1994.

Corben, C.W., Herbert, D.C Children Wearing Approved Restraints and Adult's Belts in Crashes. Traffic Accident Research Unit Report 1/81. Department of Motor Transport, New South Wales, Australia, 1981.

Evans, L. Rear Compared to Front Seat Restraint System Effectiveness in Preventing Fatalities. SAE No. 870485, Warrendale, PA, 1987.

Evans, L. Rear Seat Restraint System Effectiveness in Preventing Fatalities. *Acc Analy & Prev* 20:129-136, 1988.

Evans, L. and Frick, M.C. Seating Position in Cars and Fatality Risk. *Am J Pub Health,* 78:1456-1458, 1988.

Gikas, P. and Huelke, D. F., Pathogenesis of Fatal Injuries to Rear Seat Occupants of Automobiles. *Ninth Stapp Car Crash Conf,* University of Minn, 355-366, 1966.

Huelke, D.F.; Lawson, T.E., The rear seat automobile passenger in frontal crashes. *Proc 22nd Am Assn for Auto Med,* Ann Arbor, MI, 1978, University of Michigan Printing, Ann Arbor, MI, 141-150, 1978.

Huelke, D.F., Sherman, H.W., and Elliott, A.F., The Rear Seat Occupant From Data Analysis of Selected Clinical Case Studies. SAE No. 870487, In: Restraint Technologies:Rear Seat Occupant Protection - SP-691, 53-63, Warrendale, PA, 1987.

Huelke, D.F. The Rear Seat Occupant in Car Crashes. *J Am Assoc Auto Med*, 9:21-24, 1987.

Huelke, D.F., and Compton C.P. The Effects of Seat Belts on Injury Severity of Front and Rear Seat Occupants in the Same Frontal Crash. *Proc 38th Assoc for the Advancement of Auto Med.*, Lyon, FR, 1-10, Des Plaines, IL, 1994.

Krafft, M., Nygren, C., and Tingvall, C. Rear Seat Occupant Protection. A Study of Children and Adults in the Rear Seat of Cars in Relation to Restraint Use and Car Characteristics. *J Traffic Med*, 18:51-60, 1990.

Lane, J.C. The Seat Belt Syndrome in Children. In: Child Occupant Protection-SP-986, 159-164, 1993.

Langwieder, K. Hummel, T. Children in Cars-Their Injury Risks and the Influence of Child Protection Systems. *12th International Conf on Exp Safety Vehicles*, NHTSA, US Department of Transportation, Section 3, 39-49, 1989.

Lowne, R.W. Injuries to Children Involved in Road Accidents. *Proc Intl Mtg on Biomech of Trauma in Children*, Intl Research Committee on the Biokinetics of Impacts, Leone, FR, 19-29, 1977.

Mackay, G.M. The Effectiveness and Limitations of Seat Belts in Collisions. Birmingham University, Accident Research Unit, England, 15 pp, 1992, Dunbar, Proc of Intl Symposium, Riyadh, Security Forces Hospital, pp 95-109, 1992.

Morris, J.B. Protection for 5-12 Year Old Children. SAE Paper 831654, *SAE Child Injury and Restraint Conf Proc*, P-135, 89-100, 1983.

National Transportation Safety Board Safety Study, Performance of Lap Belts in 26 Frontal Crashes. NTSB/SS-85/03, 1986.

Norin, H., Nilsson-Ehle, A., Jareton, E., Tingval, C. The Injury- Reducing Effect of Seat Belt Use on Rear Seat Passengers. Volvo-TSV Report, 1980.

Nygren, A., Aldman, B., Gustafsoon, H., et al. The Use of an Insurance Material to Study Traffic Safety. *Proc 9th Intl Conf on Exp Safety Vehicles*, 1982.

Orsay, E.M. Turnbull, T.L., Dunne, M., et al The Effect of Occupant Restraints on Children and the Elderly in Motor Vehicle Crashes. *12th Intl Conf on Exp Safety Vehicles*, 2:1213-1215, 1989.

Padmanaban, J., and Ray, R.M. Safety Performance of Rear Seat Occupant Restraint Systems. *Proc 36th Stapp Car Crash Conf*, 193-201, 1993.

Partyka, S. Lives savey by Child Restraints from 1982 through 1987. Technical report HS 807 371, NHTSA, Department of Transportation, 1988.

Williams, A.F., and Zador, P. Injuries to Children in Automobiles in Relation to Seating Location and Restraint Use. *Accid Anal & Prev* 9:69-76; 1977.