KID IN THE MIDDLE: A DISCUSSION OF EFFECTIVENESS OF CENTER REAR-SEAT RESTRAINT SYSTEMS

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ABSTRACT

This paper examines effectiveness of rear seat restraint systems in reducing injury in frontal and side impacts. Results indicate effectiveness varies by crash configuration and occupant age, with age being the most important factor influencing odds of fatality/serious injury to belted, rear seated occupants in frontal and side crashes. There is no significant difference between center lap and outboard lap/shoulder belts effectiveness; however, field data shows a high percentage of misuse (wearing belts improperly or using age-inappropriate belts) associated with fatalities and serious injuries. Review of NASS/CDS cases on seriously injured belted children shows belt misuse and injury patterns that might be mitigated by booster seats or proper use of adult belts.

For decades, safety researchers around the world have agreed the rear seat environment is the safest for children (Braver et al., 1998; Berg et al., 1999; NHTSA, 1999). Howard (2002: p. 771) opined that “the best advice is to seat the child in the center position whenever possible and to ensure that age-appropriate restraints are used.” In the last few years, several studies have been published examining the effectiveness of various types of rear seat restraint systems for children, including booster seats and child safety seats (Durbin et al., 2003; NHTSA, 1999, 2002; Winston et al., 2000). In December 2004, the National Highway Traffic Safety Administration (NHTSA)

announced a final rule that rear center seats in all new passenger vehicles be equipped with lap/shoulder belts. As of December 2004, 23% of new passenger cars and 51% of new vans and light trucks were equipped with lap belts in rear center seats.

The center position has long been served by a lap-only belt for several reasons, including that this restraint system configuration most easily accommodated a child safety seat in rear center in the early 1980s and 1990s. While studies have shown that rear outboard belts are highly effective in reducing fatalities and injuries to children and adults (NHTSA, 1999; Padmanaban and Besuner, 1999; Padmanaban and Davis, 1999; Padmanaban, 1998; Warner, et al., 1997; Padmanaban, 1992; and Padmanaban and Ray, 1992), very few studies address the effectiveness of belts in rear center seats.

Partyka (1988) estimated that rear seating lowered fatal risk for children (ages 0-4) by 26%. Evans and Frick (1988) examined fatal data and concluded that unbelted rear center occupants (older than 15) had a 15% reduction in mortality risk compared to unbelted rear outboard occupants. Braver et al. (1998) examined the children's risk of dying in crashes by seat position and belt use and concluded that children were about 10-20% less likely to die in rear center than in rear outboard positions. Berg et al. (1999) examined Utah crash records to develop logistic regression models and concluded that the rear seat offers a significant protective effect and that restraint use enhanced this effect. The Center for Auto Safety (2000: p. 2) opined:

> The outboard seating positions are not as safe because in the event of a side-impact crash, the outboard location directly behind the driver or passenger seat is more vulnerable if one side is hit because of its proximity to the point of impact. In addition, many parents and caregivers prefer the rear center position because it is easier to keep an eye on the child.

In addition, several studies have observed improper or age-inappropriate belt use by children in lap or lap/shoulder belts (Green, 1986; German et al., 1999; Winston and Durbin, 2000; Durbin et al., 2003; Simpson et al., 2002). Winston et al. (2000) found that 83% of children between ages 4 and 8 are inappropriately restrained in adult seat belts. A separate study found increases in the use of booster seats and child restraints with harnesses from 1999 to 2002, but notes that a substantial number of children in such restraints exceed the manufacturer's recommended weight limits and concludes "substantial inappropriate restraint still remains and continued investment in outreach efforts is necessary" (Winston et al., 2003: p. 1).

Recently, the Prince of Wales Medical Research Institute (POWMRI) performed a comprehensive study of crash injury to children and observed: "an alarming number of children are being put

at risk through the improper use of seat belts and child restraints" (POWMRI, 2005: p. 1). A key research finding was that "Putting the seatbelt under the arm or behind the back and poor belt fit contributed to some abdominal injuries in children" (POWMRI, 2005: p. 1). Agran et al. (1989) found that significant injuries occurred in 41% of side impacts and 15% of frontal impacts for children 4 to 9 years old.

In this paper, the complex issues and controversies surrounding the injury experience of center rear seat occupants in lap belts (particularly as opposed to outboard rear seat occupants in lap/shoulder belts) are examined. The statistical study reported here undertook to quantify the effectiveness of rear center lap belts versus rear outboard lap/shoulder belts in frontal and side-impact non-rollover crashes. The study encompasses occupants of all ages, but focuses on children (2-14 years old, an age spread chosen to be consistent with other safety research and the group with the highest occupancy rates) and elderly occupants (over 55 years old) in rear seat positions in passenger cars. Children in child safety seats and booster seats were excluded to allow more direct comparison and to remove confounding variables.

The study also examined detailed case reviews for frontal impacts resulting in serious injuries to lap belted children seated in center seats and lap/shoulder belted children seated in outboard positions.

METHOD

Due to paucity of data available on center rear seat occupants, the study first examined occupancy rates. Then simple injury rates were derived using the National Automotive Sampling System (NASS/CDS) and state accident files. Belt misuse was also examined. Next, double pair comparison methods (Evans, 1986) were developed using Fatality Analysis Reporting System (FARS) and state accident data to determine the factors influencing the odds of fatality/serious injury to rear-seated occupants. In addition, effectiveness of center-seat lap belts versus rear outboard lap/shoulder belts in reducing the odds of fatality/injury to children was calculated. Finally, case reviews from NASS/CDS are presented.

The study focused on belted, rear-seated occupants (excluding occupants in child safety seats or booster seats) in passenger cars (1993-2001 model years) involved in frontal and side crashes. The model year range was selected to focus on vehicles with lap/shoulder belts in the rear outboard position and lap belts in the rear center position. By model year 1993, about 80% of vehicles on the road had been equipped with lap/shoulder belts (as opposed to lap-only) in the

rear outboard position, so 1993 was chosen as the starting year for the vehicle models used. Similarly, since 95% of model year 2001 vehicles were still equipped with lap-only belts in the rear center position, 2001 was chosen as the final year in the model year range. The data on children focused on 2-14 year olds to be consistent with published technical literature on injuries to children. Finally, since about 80% of fatal crashes, and 74% of all crashes, involving passenger cars are frontal or side impacts, this study was limited to frontal and side impact crashes.

REAR SEAT OCCUPANCY RATES — NASS General Estimates System (NASS/GES) data for calendar years 1992-2004 was used to determine the rear center and outboard seat occupancy rates. The NASS/GES database is a nationally representative probability sample, selected from all police-reported traffic crashes (to be included, a crash must have had a police report completed for it and must have involved at least one vehicle traveling on a public roadway and have resulted in a death, injury, or property damage). This database is typically used by NHTSA to obtain national estimates of injuries and crashes.

Rear seat occupancy rates were also established using police-reported motor vehicle accident data from nine states: Alabama (1992-1999), Arkansas (1992-1996), Florida (1992-2003), Idaho (1992-2004), Illinois (1996-2003), Maryland (1992-2004), North Carolina (1992-2004), Pennsylvania (1992-2004), and Utah (1992-1995). These states provide information on rear seated occupants (injury severity/belt use/age) and identify crash configuration such as frontal and side impacts. These states also are typically used by NHTSA for their rulemaking activities or assessment of safety standards.

SIMPLE INJURY RATES — To examine the injury risk to belted children and adults in rear seats, NASS Crashworthiness Data System (NASS/CDS) data for the years 1992-2004 was used. The NASS database, which is maintained by NHTSA, is a nation-wide representative sample of tow-away crashes investigated in detail by NASS teams consisting of engineers, biomechanical experts, medical personnel, and statisticians. NASS is widely used by NHTSA to examine injury mechanisms, nature of injuries by body region, and other occupant/vehicle and crash related factors. The NASS/CDS database investigates about 5,000 crashes a year involving passenger cars, light trucks, vans, and utility vehicles. The NASS injury risk analysis included approximately 360,000 (raw count: 710) rear seated (belted and unbelted) children (ages 2-14) involved in frontal and side crashes.

The serious injury risk analyses also used state accident data. State accident data files examined include police-reported motor

vehicle crash files from states that provide large volumes of crash data for rear seated occupants involved in frontal and side crashes. The state injury risk analysis included 104,073 rear seated (belted and unbelted) children (2-14) involved in frontal crashes, and 42,100 children involved in side crashes.

BELT MISUSE —NASS/CDS, NASS/GES, and FARS data were also used to establish rates for improper belt/restraint use. Belt misuse was defined in NASS/CDS as "shoulder belt worn under arm," "shoulder belt worn behind back/seat," "belt worn around more than 1 person," "lap belt worn on abdomen" or "other improper use of manual belts." Also, cases of seriously and fatally injured children, from NASS/GES and FARS (respectively), wearing age-inappropriate belts were defined as misuse of belts.

DOUBLE PAIR MODELS — Double pair comparison methods were developed using FARS and state data for passenger car frontal and side crashes to identify factors influencing the odds of fatality/serious injury to rear seat occupants of the struck vehicle. The FARS database is maintained by NHTSA and is a census of all fatal vehicle crashes occurring on public roads within the 50 states, the District of Columbia, and Puerto Rico that result in death within 30 days of the crash.

Double pair analysis is the method used by NHTSA in the study: "Effectiveness of Lap/Shoulder Belts in the Back Outboard Seating Positions" (NHTSA, 1999). A comprehensive description of double pair comparison method is available in studies performed by Evans and Frick (1988), Evans (1986, 1987), and Kahane (1987), but briefly, it involves focusing on two occupants, a "subject" occupant and an "other" occupant.

In this study, the probabilities of fatality for the "subject" occupant restrained in the rear seat were compared for two conditions: lap belt in center position and lap/shoulder belt in outboard position. The "other" occupant (a belted driver in the same vehicle) serves a normalizing role. The dependent variable for the model is either a "1" or a "0", where "1" represents a frontal or side impact crash involving a car containing a rear occupant that is killed and a restrained driver that is not, and "0" represents the opposite: a frontal or side impact crash involving a car containing a restrained driver that is killed and a rear occupant that is not.

As part of the analyses, effectiveness of center rear seat lap versus outboard lap/shoulder belts was evaluated for occupants 2 years old and over. The statistical models included the following variables:

- vehicle weight
- occupant gender
- occupant age (2-14, 15-54, and 55+ years)

- belt type by seat position (rear center lap belted v rear outboard lap/shoulder belted).

The statistical models were examined for relative importance of variables. Statistical significance of factors and model fit parameters were also examined.

NASS CASE REVIEWS — A review of NASS/CDS frontal crash cases involving seriously injured (MAIS 3 or greater) belted children (2-12 years old) in the rear seat was made. Fifteen such cases (excluding those involving children in child safety or booster seats) are available in NASS/CDS. Of these, 5 cases involved serious injury to rear center seat, lap belted children, and 11 cases involved serious injuries to rear outboard, lap/shoulder belted children (Note: 1 case involved both). All of these cases are summarized herein.

RESULTS

REAR SEAT OCCUPANCY RATES —

NASS/GES Occupancy Rates. NASS/GES data was examined to identify the frequency of rear seat occupancy in passenger cars (1993-2001 model years) involved in frontal and side crashes. There were 13 million frontal-crash-involved occupants (112,675 raw counts) and 9.6 million side-crash-involved occupants (82,506 raw counts) in NASS/GES for the years 1992-2004. Of these, about 9% are rear seat outboard occupants and only 1.5% are rear center-seated occupants (for both frontal and side crashes).

The NASS/GES data also shows that, in about 35% of these frontal and side crashes, the rear center seat was used for child safety seats rather than for a seated occupant.

State Occupancy Rates. State accident data was also examined to address the rear center seat occupancy rates. The state data, encompassing the years 1992-2004, shows 3.5 million frontal-crash-involved occupants and 1.5 million side-crash-involved occupants. The occupancy rates observed in state data are identical to the occupancy rates from NASS/GES. Of all occupants in frontal and side-impact crashes, about 9% are rear seat outboard occupants and only 1.5% are rear center-seated occupants. Hence, the NASS/GES and state accident data files are consistent in terms of rear seat occupancy rates.

SIMPLE INJURY RATES —

NASS Injury Rates. First, in NASS/CDS, injury risk was examined for MAIS 2-6/fatal[1] injuries in frontal and side-impact

[1] The Maximum Abbreviated Injury Severity (MAIS) scale, copyrighted by the AAAM, ranks injury from minor (MAIS 1) to unsurvivable/fatal (MAIS 6).

crashes. Table 1 presents the number and percent of injured children by belt use and seat position.

As seen in Table 1, the risk of MAIS 2-6/fatal injury for children (2-14 years old) involved in frontal or side-impact crashes is 1.8% for rear outboard lap/shoulder belted occupants and 0.5% for rear center lap belted occupants. Injury risk is also shown for unbelted rear outboard occupants (9.1%) and unbelted rear center occupants (20.0%).

Table 1. MAIS 2-6/Fatal Injury Risk for Children (Ages 2-14) in Frontal or Side Crashes (NASS/CDS, 1992-2004)

	Rear Outboard (Lap/Shoulder)	**Rear Center (Lap Only)**
No. Seated in Position Weighted Count (Raw Count)	289,724 (606)	69,436 (104)
No. Belted Weighted (Raw)	246,702 (471)	66,396 (77)
No. Belted and Injured Weighted (Raw)	4,414 (48)	320 (5)
No. Unbelted Weighted (Raw)	43,022 (135)	3,040 (27)
No. Unbelted and Injured Weighted (Raw)	3,918 (48)	607 (9)
Belted Injury Risk (95% confidence bounds)	1.8% (0.8%, 2.8%)	0.5% (0.0%, 1.0%)
Unbelted Injury Risk (95% confidence bounds)	9.1% (2.3%, 15.9%)	20.0% (4.2%, 35.7%)

The table shows that (even with limited data) the center lap belts and outboard lap/shoulder belts are highly effective in reducing injuries to children. The seemingly lower rates for center lap belted children (compared to outboard lap/shoulder belted) are not statistically significantly different.

State Injury Rates. The state data was also used to examine the serious injury risk to children in rear center and outboard seats. Police-reported serious and fatal injuries were examined by seat position. For frontal crashes, data from eight states included approximately 14,400 belted children (2-14 years old) in rear center seats, about 80,400 belted children in rear outboard seats, and about 9,300 unbelted children in rear seats. For side-impact crashes, the data included approximately 5,800 belted children in rear center seats, about 32,300 belted children in rear outboard seats, and about 4,000 unbelted children in rear seats.

Figure 1 presents state data for children with fatal/serious (KA^2) injuries in frontal crashes. The frontal crash data shows no difference in injury rates for rear outboard lap/shoulder belted (1.0%) and rear center lap belted (1.1%) children. The figure also shows that an unbelted child in rear seat in a frontal crash is about 4 times more likely to sustain serious/fatal injuries compared to a belted child in

Figure 1. Serious (KA) Injury Risk for Children (2-14) in Frontal Crashes (State Data)

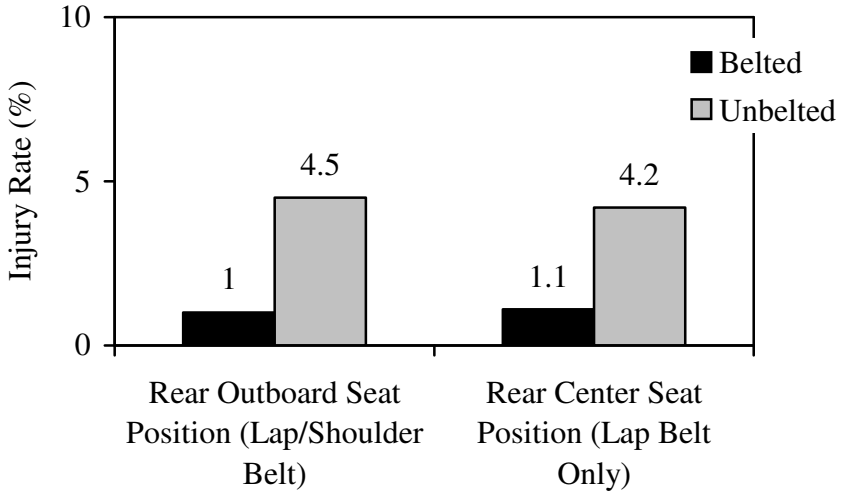
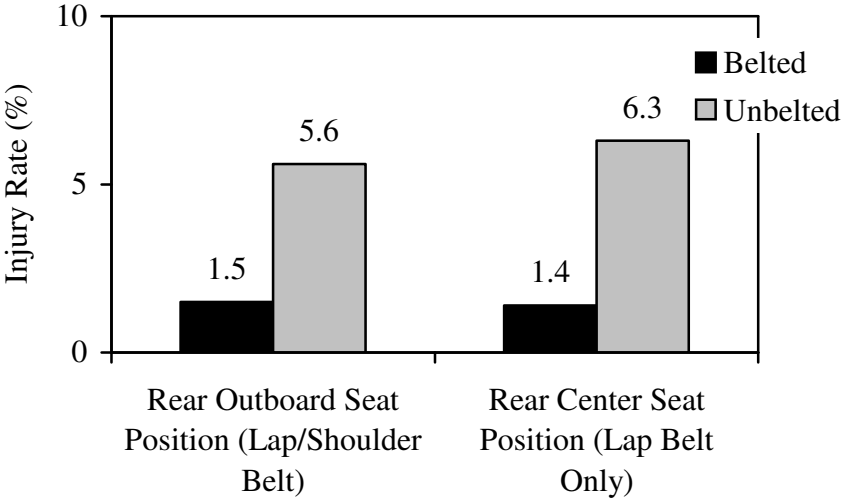


Figure 2. Serious (KA) Injury Risk for Children (2-14) in Side-Impact Crashes (State Data)



[2] "KABCO" is an observational scale used in police reporting of crash injuries where K = killed, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = no injury.

any rear seating position. Both belt types are shown to be highly effective in reducing serious injuries to children in frontal crashes.

Figure 2 presents corresponding data for children with fatal/serious injuries in side-impact crashes. The side-impact data, again, shows no difference in injury rates for rear outboard lap/shoulder belted (1.5%) and rear center lap belted (1.4%) children, and for an unbelted child in the rear seat, about 4 times greater likely of sustaining serious/fatal injuries compared to a belted child. The figure shows that both outboard lap/shoulder and center lap belts are highly effective in reducing serious injuries to children in side crashes.

BELT MISUSE — NASS/CDS data for 1992-2002[3] indicates that improper belt use rates have not declined over the years. Among rear seat children ages 0-8 who were not in child safety seats, approximately 10% were coded with "improper" belt use (shoulder belt worn behind the back, etc.) across this time period. For children 9-14, the improper belt use rate was approximately 3%. NASS/CDS was also examined for age-inappropriate use of adult seat belts, and the results show that 12% of children ages 0-3 and 77% of children ages 4-8 were using age-inappropriate restraints.

In addition, NASS/GES data (1992-2004) was examined to determine belt misuse rates for seriously injured children. The results show that, among seriously injured (KA) rear seat children, approximately 13% of 0-3 year olds and 60% of 4-8 year olds were using age-inappropriate restraints. This shows, again, a high percentage of seriously injured children under 8 are not in age-appropriate seat belts.

FARS data (1992-2004) reveals there were 35 fatalities involving rear center lap belted children (2-14), and 132 fatalities involving rear outboard lap/shoulder belted children, in frontal crashes. Of the 35 fatally injured rear center lap belted children, about 71% were in age-inappropriate seat belts, and of the 132 fatally injured rear outboard lap/shoulder belted children, about 61% were in age-inappropriate seat belts. For children under 8 years old, such "premature graduation" to adult belts (Winston and Durbin, 2000) could have led to higher risk of fatality.

DOUBLE PAIR RESULTS — Double pair comparison models were used to examine the factors influencing odds of fatality/serious injury to rear seat occupants in frontal and side-impact crashes.

FARS Model. As noted, there is limited data on fatalities to children in rear center seats in frontal and side-impact crashes. Hence, preliminary results for the FARS analysis resulted in wide

[3] NASS stopped coding proper/improper belt use in 2003.

confidence bounds when comparing effectiveness of rear outboard and rear center seat belts for occupants of all ages and for children. Consequently, these analyses have to be repeated upon availability of more data in the future.

State Models. The state accident data had sufficient number of observations for each crash configuration (front and front + side) and offered more robust models. Using the double pair comparison methods, overall model fit parameters and the statistical significance of each factor included were examined. The set of models was developed for two levels of injury: Serious/Fatal (KA) and Moderate/Serious/Fatal (KAB).

Table 2 presents the results for the sixteen statistical models developed comparing lap/shoulder belts and lap belts. Odds ratios closer to 1 mean their relative effectiveness is virtually the same. Odds ratios less than 1 indicate lap-belted occupants have greater likelihood of injury.

As the table shows, most of the odds ratio estimates are closer to 1 and, hence, none of the results presented can show statistically significant difference from 1 (as indicated by p-values). However, the narrower confidence bounds, around 1, presented in the table for most of the models indicate that there is no discernable difference between odds of injury for rear lap/shoulder belts and lap belts.

Table 2. Comparison of Injury Odds, Outboard Lap/Shoulder versus Center Lap, in Frontal and Front and Side-Impacts Passenger Car Crashes (State Models)

Age Group	Injury Severity	Odds Ratio Lap/Shldr vs. Lap (95% conf. bnds)	Number of Crashes	Injured Rear Seat Occupants
Frontal Impacts				
Ages 2+	Serious/Fatal	1.04 (0.80, 1.36) p=0.76	2,790	998
Ages 2-14	Serious/Fatal	0.94 (0.66, 1.33) p=0.71	1,380	337
Ages 15-54	Serious/Fatal	1.29 (0.83, 1.98) p=0.26	1,145	477
Ages 55+	Serious/Fatal	0.84 (0.21, 3.49) p=0.81	265	184
Ages 2+	Moderate/ Serious/Fatal	1.00 (0.88, 1.13) p=0.98	12,639	4,311
Ages 2-14	Moderate/ Serious/Fatal	0.99 (0.85, 1.16) p=0.89	6,629	1,826
Ages 15-54	Moderate/ Serious/Fatal	1.04 (0.84, 1.28) p=0.74	5,103	1,937
Ages 55+	Moderate/ Serious/Fatal	0.77 (0.41, 1.44) p=0.41	907	548

Table 2, continued

Front and Side Impacts				
Ages 2+	Serious/Fatal	1.12 (0.91, 1.39) p=0.28	4,458	1,789
Ages 2-14	Serious/Fatal	1.08 (0.82, 1.42) p=0.60	2,126	598
Ages 15-54	Serious/Fatal	1.18 (0.82, 1.68) p=0.37	1,822	831
Ages 55+	Serious/Fatal	1.51 (0.58, 3.96) p=0.40	510	360
Ages 2+	Moderate/ Serious/Fatal	1.04 (0.94, 1.15) p=0.42	18,298	7,112
Ages 2-14	Moderate/ Serious/Fatal	1.06 (0.93, 1.20) p=0.39	9,339	2,896
Ages 15-54	Moderate/ Serious/Fatal	1.01 (0.84, 1.21) p=0.92	7,442	3,222
Ages 55+	Moderate/ Serious/Fatal	1.06 (0.64, 1.75) p=0.82	1,517	994

NASS CASE REVIEWS — Detailed case reviews were also made focusing on frontal crashes. From the 1997-2004 NASS/CDS database, detailed case reviews for 15 cases involving seriously injured (MAIS 3-6/fatal) belted rear seated children in frontal crashes were made. Of these 15 cases, 5 involved a lap belted child in the rear center seat, 11 involved lap and shoulder belted children in rear outboard seats, and 1 case, double counted above, involved both (i.e., two children were seriously injured in the same vehicle, with one in center seat and one in outboard position). The cases are summarized in Table 3.

Of the 11 NASS/CDS cases with serious injuries to outboard lap/shoulder belted children, only 1 involved a fatality. There were no fatalities in NASS/CDS for children in the center seat. Of the 11 lap/shoulder belt cases for seriously injured children, 7 involved children less than 8 years old — and of the 4 cases with center lap belts, 3 involved children less than 8 years old — when booster seats or child safety seats would have been more appropriate. In addition, many of the injury patterns were similar between center lap belted and outboard lap and shoulder belted children. There was also evidence of improper belt use cited by NASS investigators.

LIMITATIONS

The statistical modeling included some confounding factors that are easily identified in state accident databases. However, the authors recognize that there are other confounding factors (impact speed, intrusion, restraint misuse) that were not controlled for since

Table 3. Summary of MAIS 3+ Injury Cases Involving Rear Center Lap and Outboard Lap/Shoulder Belted Children (2-12) in Frontal Impacts in Passenger Cars (NASS/CDS, 1997-2004)

Case No.	Delta -V	Position / Belt Type	Age	Injury	Details
Center					
1997-81-88K	19 mph	Center lap	11 yrs	MAIS 3 orbit and maxilla fracture	Head-on collision
1998-12-132K	14 mph	Center lap	8 yrs	MAIS 3 jejunum-ileum lacerat./perforation	Severe crash
2003-45-146J	31 mph	Center lap	7 yrs	MAIS 4, jejunum-ileum/colon lacerat.	Severe crash
2003-79-195K	29 mph	Center lap	5 yrs	MAIS 3 lung contusion	
Center and Rear Outboard					
2000-13-222J	25 mph	Center lap	7 yrs	MAIS 3 femur fracture	3rd child, RO seat: Improper belt use
		LO lap/shldr	4 yrs	MAIS 3 colon lacerat./perforation	
Rear Outboard					
1997-12-67J	19 mph	LO lap/shldr	6 yrs	MAIS 4 injury	
1998-12-84K	23 mph	LO lap/shldr	11 yrs	MAIS 4 cerebrum hematoma / hemorrhage and Vault skull fracture	
2000-11-18C	32 mph	RO lap/shldr	10 yrs	MAIS 3 lung contusion	
2000-12-157C	25 mph	RO lap/shldr	7 yrs	MAIS 3 femur fracture	Improper belt use
2002-43-127C	22 mph	LO lap/shldr	7 yrs	MAIS 3 orbit fracture	
2002-76-97A	41 mph	LO lap/shldr	11 yrs	MAIS 3 lumbar spine fracture	Head-on, severe
2004-48-94J	20 mph	RO lap/shldr	10 yrs	MAIS 3 lumbar spine fracture	
2004-50-77C	19 mph	RO lap/shldr	7 yrs	MAIS 3 jejunum-ileum lacerat./perforation	
2004-73-205B	24 mph	RO lap/shldr	6 yrs	**Fatality**; also serious head, blunt/ trauma abdominal, and cervical spine	Frontal impact w/ tree
2004-79-188B	20 mph	Outboard lap/shldr	7 yrs	MAIS 3 lung contusion	

data on such factors are not included in accident databases used. In addition, the study uses a police-reported injury severity scale (KABCO) which might not report injuries that have less obvious external signs. However, these state databases are widely used by NHTSA for regulatory and rulemaking activities, and there are no inherent biases in favor of or against specific vehicles/restraint systems or injuries.

The large volumes of data provide insight into the crash experience of rear-seated occupants in frontal and side impacts. The study looked at frontal crashes separately, but for side impacts, data was not sufficient to perform meaningful statistical analyses. Hence, side impacts and frontals were combined. Neither was there sufficient data to study near side/far side separately; of the rear outboard occupants included in the study data set, 56% were near side (struck side) and 44% were far side. Upon availability of more data, side impacts can be examined separately and in greater detail.

DISCUSSION

The field data shows that there is very little difference between injury odds for center lap and outboard lap/shoulder belts in the rear seat in frontal or side-impact, non-rollover crashes. As field data and the case reviews show, there is still some amount of belt misuse (belts worn improperly and/or use of age-inappropriate belts) that could be one of the reasons for the similar effectiveness seen for center lap and outboard lap/shoulder belts. NASS/CDS data does not indicate that improper belt use rates have declined over the years, although all indicators suggest use of seat belts has increased.

There are studies showing rear center lap/shoulder belts have less likelihood of serious injury than rear center lap belts. Arbogast et al. (2004) found that “belted children in the center rear of vehicles equipped with a lap shoulder belt are at an 81% reduction in risk of injury (odds ratio of 0.19)” compared with center rear lap-belted children. However, this finding was based on a fairly small unweighted sample (11 children in center seat lap/shoulder belt, and 42 in center lap, with an AIS 2+ injury in any crash involving a child in the rear center seat), resulting in wide confidence bounds (0.04, 0.92). The study presented here includes over several hundred injured rear seat child occupants (2-14), which provides narrower confidence bounds for odds ratio estimates.

As for the ability of the appropriate restraint to reduce or mitigate types of injury, a recent study of belt-positioning booster seats (Durbin et al., 2003: p. 1) seems to support this, finding that children 4-7 years old in such seats “had no injuries to the abdomen, neck/spine/back, or lower extremities.” This is an intriguing finding;

however, there is limited field data on booster seats and, hence, examination of nature of injuries to 4-7 year olds was beyond the scope of this study.

Likewise, due to a paucity of detailed crash data for rear seat occupants overall, it was not possible to filter out specific influences (such as effects of side airbags or intruding objects) on injury risk for frontal or side impacts for this study.

In summary, this study found that both belt types significantly reduce injuries and fatalities, and neither is a bad option. The authors of this study understand NHTSA's rulemaking to equip all center seats with lap/shoulder belts. While three-point (lap/shoulder) belts may offer better protection than two-point (lap) belts in some circumstances, the field data to date shows misuse and age-inappropriate belt use for children in rear seats that might account for the equal effectiveness observed for lap and lap/shoulder belts. We would like to recommend the public safety community focus on the issue of belt misuse and children not seated in safety and booster seats. It is to be hoped that, with children properly restrained in age- and size-appropriate devices (child safety seats, booster seats, or lap/shoulder belts or lap belts properly worn), injuries would be significantly reduced and safety improved in the rear seat environment.

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