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An Evaluation of Child Passenger Safety: The Effectiveness and Benefits of Safety Seats

Summary

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Principal findings and conclusions of a comprehensive evaluation of the benefits, effectiveness and usage of child passenger safety measures in the United States

16. Abstract

The purpose of child safety seats is to reduce the number of child passengers killed or injured in motor vehicle crashes. The seats function by absorbing and safely distributing crash impact loads over the child's body while holding the child in place and preventing contacts with vehicle interior components or ejection from the vehicle. Seats have to be convenient and easy to use. Federal Motor Vehicle Safety Standard 213 specifies performance and labeling requirements for child safety seats. The objectives of this agency staff evaluation are to measure the effectiveness, benefits and usage of safety seats and other safety measures for child passengers aged 0-4. The study is based on statistical analyses of National Accident Sampling System, Fatal Accident Reporting System and State accident data, analyses of sled test and compliance test results, and observational surveys of restraint system usage and misuse. It was estimated that:

- Child safety seats saved the lives of 158 children aged 0-4 during 1984. Lap belts saved an additional 34 lives. In all, 192 children were saved by child passenger safety measures in 1984.
- 46 percent of child passengers aged 0-4 were in a safety seat in 1984. An additional 14 percent used the lap belt only.
- 39 percent of safety seats were correctly used in 1984.
- A correctly used safety seat reduces fatality risk by 71 percent and serious injury risk by 67 percent. But misuse can partially or completely nullify this effect. In 1984, the average overall effectiveness of safety seats (correct users plus misusers) was 46 percent.

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Summary

Safety seats for infants and small children riding in motor vehicles are one of the most successful auto safety innovations of the 1960's. They are designed to hold children in place during a crash and prevent them from being thrown into the instrument panel or other parts of the vehicle or from being ejected from the passenger compartment. Moreover, they are specifically tailored to a child's anatomy and designed to restrain a child without applying dangerous forces to vulnerable body regions. By contrast, the lap and shoulder belts that come with the vehicle are designed for adults and are in several ways inappropriate for small children.

At first, the seats were purchased only by a minority consisting of the most safety-conscious parents. During the 1970's, a massive educational campaign by the medical community, consumer groups, safety seat manufacturers and insurance companies, among others, made a much wider public aware that children needed safety seats. Between 1978 and 1985 every State, beginning with Tennessee, passed laws requiring safety seats for young child passengers. The public has supported the laws and generally understands why they are needed. By 1984, close to half of the child passenger population aged 0-4 was riding in safety seats.

The National Highway Traffic Safety Administration has long had a critical role in child passenger safety. Federal Motor Vehicle Safety Standard 213, which took effect on April 1, 1971, required that any child seat marketed for use in a vehicle be designed to restrain and protect children in a crash: it had to be attachable within a car by the car's belt

system and it would have to distribute rather than concentrate crash forces over the child's torso. A new version of Standard 213 took effect on January 1, 1981, with a 30 mph dynamic test requirement. In the dynamic test, dummies' excursion beyond the confines of the seat had to be within specified limits. So did head and chest forces. The NHTSA standards helped eliminate nonsafety or inadequate seat designs from the market.

In addition to promulgating the standards, NHTSA held conferences and workshops on child passenger protection throughout the United States, provided information and resources to the State and local groups seeking to increase usage of safety seats and encouraged States to fund child passenger safety programs under Section 402 of the Highway Safety Act of 1966.

Executive Order 12291 (February 1981) requires agencies to evaluate their existing major programs, including any program whose annual effect on the economy is $100 million or more. The objectives of an evaluation are to determine the actual benefits--lives saved, injuries prevented, damage avoided--and costs of safety devices produced and sold in response to agency standards or programs and to assess cost-effectiveness.

This summary report contains the principal findings and conclusions of NHTSA's evaluation of what has been accomplished to enhance the safety of children aged 0-4 who are passengers in motor vehicles. The report provides estimates of the number of children actually being saved by safety seats each year. The growth in that number measures the success of the child passenger safety program. The most important parameter for calculating benefits is an estimate of the effectiveness of safety seats in actual use: the average reduction of casualty risk for children in safety seats (including correctly used and misused seats) relative to unrestrained children.

The exact effectiveness of safety seats (in actual use) is still not agreed upon by the safety community and a wide variety of estimates ranging as high as 90 percent is quoted in the literature. The evaluation's primary objective was to pin down an in-use effectiveness estimate, but in the process it was found that the goal is a moving target. Effectiveness is not constant, but has increased year by year as an ever greater percentage of the safety seats in use are being used correctly.

That brings up the second goal of the evaluation: a more complete understanding of the problem of improperly used seats. It is well known that an alarming percentage of safety seats (65 percent in one study) are not being used according to manufacturers' instructions; it is generally believed that misuse of seats is the major factor holding down effectiveness and benefits. But it has to be recognized that some types of misuse are far more detrimental than others. The evaluation identifies the more common use modes for each major type of safety seat and then groups them into three categories:

<u>Correct use</u> - exactly as recommended by the manufacturer or close enough that there would not be a significant loss of safety benefits.

<u>Partial misuse</u> - significantly lower effectiveness than correct use, but there should still be substantial benefits if the crash

is not too severe. Something is holding the child within the seat and something is anchoring the seat within the vehicle. But the child will experience more excursion or crash forces and/or the seat will be more likely to fail, because of the way it is misused (e.g., not using the required tether, misrouting the lap belt).

<u>Gross misuse</u> - situations where children would be thrown from the seats or the seats (with children in them) would become projectiles in a crash--basically like an unrestrained condition. (Also included in this category were children riding in feeder seats, infant carriers, or other devices intended for use in the home, not the car. By 1984, only 0.3 percent of child passengers were in such devices, although they were much more common in the 1970's. They could not be separated from grossly misused safety seats because the accident data, as well as many of the observational surveys, likewise do not identify them as a distinct category but merely include them among "safety seat users.")

The evaluation estimates the frequencies of the three categories, year-by-year, and the average effectiveness of each category. That makes it possible to estimate overall effectiveness (the weighted average of the three categories) and lives saved, year-by-year. The difference in benefits between 100 percent correct usage and the actual mix of correct use and misuse is the bottom-line effect of the problem of misused seats.

In addition, the evaluation tracks the overall usage of safety seats, year-by-year. It gives a preliminary comparison of the effectiveness of the major types of seats--when correctly used and, more importantly, when their frequency of misuse is taken into consideration. It estimates the effectiveness of two other child passenger safety measures that should be employed only when a certified safety seat is not available: restraining a child with an adult lap belt only or having the child ride unrestrained in the back seat. It also estimates the benefits of moving a restrained child from the front to the back seat.

The evaluation is based on analyses of accident data, observational surveys of restraint system usage and sled tests with restrained and unrestrained dummies.

Accident analyses have been performed in anticipation of this study since 1978. But the most recent data have been the most meaningful because they contain much larger samples of safety seat users. NHTSA's Fatal Accident Reporting System provided a good estimate of overall fatality reduction. The agency's in-depth accident data based on probability sampling--the National Accident Sampling System (NASS), National Crash Severity Study (NCSS) and Restraint Systems Evaluation Project (RSEP)--were combined to obtain an estimate of serious injury reduction. Pennsylvania data for 1981-83 were used for calculating injury-reducing effectiveness, overall and by injury type. State data from New York, Maryland, New Jersey and Idaho were analyzed for this evaluation, while published studies of Tennessee, Michigan and Washington data were reviewed. The accident data analyses, even though they are the basis for this study's overall effectiveness estimate, nevertheless have three shortcomings. They do not distinguish between correctly used and misused seats; the estimate derived from any data file is valid, at best, only for the year in which the data were collected--in later years, when a larger percentage of the seats would have been used correctly, effectiveness would have risen; the data are themselves biased because the investigators (police, NHTSA contractors) tended to report certain safety seat users, especially the gross misusers, as "unrestrained." A unique study performed in North Carolina during 1983-1984, however, compared police-reported safety seat use to actual use, by misuse mode (based on detailed interviews in which parents explained how they used each component of the safety seat)--thereby making it possible to correct for the biases in the other studies.

The comparison of correctly used and misused seats was based primarily on a sled test project conducted especially for this evaluation. The project differed from earlier sled test studies with child dummies in that:

- o The sled buck was the actual passenger compartment of a mid-sized car and the injury-producing contacts of the dummies were similar to those that would occur in real crashes.

- o Unrestrained dummies were included in the tests; the results for the restraint systems were always compared to the baseline, unrestrained case.

- o Tests were carried out with four distinct types of toddler seats, correctly used and in each common misuse mode, over a wide range of speeds, in frontal and oblique frontal impacts.

In combination with statistics on safety seat usage, the test results provided all information needed for an overall effectiveness estimate (in frontals). Side impact tests, however, could not be carried out nor was it possible to test infant seats or to include all of the less common types of toddler seats.

o Real world accident data (from NASS-NCSS-RSEP) were used to calibrate a relationship between the front-seat unrestrained dummies' Head Injury Criterion/torso deceleration and children's risk of serious head/torso injury in frontal crashes (through the mutual association of dummy results and injury risk with crash velocity). Thus, the sled tests results could be used to predict realistic injury rates.

The data from this special study were complemented by a statistical analysis of 1981-84 compliance test results for Standard 213--frontal sled tests of correctly used and partially misused safety seats. The compliance tests provided data on a variety of safety seat models which were not included in the special study. They employed a more severe deceleration pulse than the tests in the special study; as a result, the seat types which performed best in the compliance tests were not the same as the best performers in the special study--although, in both test series, all correctly used seats performed very well relative to misused seats or unrestrained dummies.

The sled test results were used to obtain effectiveness estimates for safety seats, correctly used and in each of the misuse modes that commonly occur in actual practice. Next, observational surveys of safety seat usage indicated the relative frequency of occurrence of each seat type/misuse mode combination. The effectiveness estimates were then averaged (weighted by frequency of occurrence) to obtain an overall estimate of serious injury reduction for the mix of correctly used and misused seats that was actually found in the traffic population. Since that mix changed from year to year, so did the overall estimate.

The most detailed observational survey of safety seat usage was conducted at Hardee's restaurants during 1984. The make/model of safety seat and the exact way in which it was used was recorded for over 1000 children; based on the taxonomy of this evaluation, the data were grouped to estimate the frequency of occurrence of each seat type/misuse mode in 1984. Five other observational surveys gave accurate estimates of overall usage during 1974-84 and (with some interpretation) a split between correct use/partial misuse, on the one hand, and gross misuse, on the other. The Hardee's data, sales trends for safety seats and three parking lot surveys of unoccupied seats made possible a further split between correct users vs. partial misusers. Thus, the frequency of correct users, partial misusers and gross misusers could be estimated year-by-year from 1979 to 1984 and employed for weighting the sled test results to obtain year-by-year estimates of overall effectiveness and benefits.

Finally, these year-by-year effectiveness estimates from the sled tests/usage surveys were compared to the police-reported accident data analyses (which were corrected for the usage reporting biases found in the

North Carolina study). The agreement was almost perfect: effectiveness (in actual practice) was just below 30 percent in the studies based on pre-1979 accident data and just over 45 percent by 1984. Moreover, the sled tests accurately estimated safety seat effectiveness in NASS (57 percent, since gross misusers are counted as "unrestrained") and the injury reductions in the various accident studies for lap belt only and for moving an unrestrained child to the back seat. The excellent correlation of the sled test predictions with the results of the accident analyses and the consistent trend among the accident studies themselves (after the year of the data collection and the source of the reporting biases are taken into account) provide an especially high degree of confidence in the overall effectiveness estimates of this evaluation and the year-to-year trend of rising effectiveness. Each of the data sources used in the evaluation had some shortcomings (documented in the text); nevertheless they fit together exceptionally well and the whole picture became clear after assembling the parts.

The sled test data analyzed in this evaluation showed that each of the major types of approved safety seats currently on the market is highly effective when correctly used. They do not support a conclusion that any particular type of seat (correctly used) is significantly more effective than the other types (correctly used) over the full range of frontal crash types that occur on the highway--although the tests did show that certain types of seats may excel in some specific crash situations.

Some topics were not addressed in this evaluation and remain to be resolved in follow-up studies: the effectiveness of correctly used and misused toddler seats in side impacts, by seat position--to be studied using sled tests supported by accident data; the effectiveness of correctly used vs. misused infant seats; booster seats vs. adult belts for children age 5 or older; the compatibility of safety seat designs with the various types of safety belt systems that are installed in passenger vehicles; a State-by-State analysis of safety seat usage vs. the type of buckle-up law, the level of enforcement, and the States' educational and promotional activities in child passenger safety--to identify the combinations of factors that best increase usage of safety seats.

The principal findings and conclusions of this evaluation are the following:

Principal Findings

BENEFITS

o The estimated number of child passengers, aged 0-4, in cars, light trucks and vans who were saved by a safety seat or by the vehicle's lap belt steadily increased from 38 in 1979 to 192 in 1984:

Lives Saved in:	1979	1980	1981	1982	1983	1984
By safety seats	30	47	60	88	135	158
By lap belts	8	9	10	15	24	34
TOTAL	38	56	70	103	159	192

o The actual number of child passenger fatalities dropped steadily from 694 in 1979 to 551 in 1984. If restraints had been unavailable for children, the number of fatalities would have remained almost constant:

	1979	1980	1981	1982	1983	1984
Actual fatalities	694	688	632	632	617	551
Lives saved by restraints	38	56	70	103	159	192
Fatalities if restraint usage had been zero	732	744	702	735	776	743

o In 1984, safety seats and lap belts saved 26 percent (192 out of 743) of the fatalities that would have occurred to child passengers aged 0-4.

o The injury saving benefits of safety seats and lap belts in 1984 were:

	Hospitalizations Prevented	Children Avoiding any Injury
By safety seats	1,020	17,000
By lap belts	330	4,000
TOTAL	1,350	21,000

USAGE

o The percentage of child passengers aged 0-4 who used a child seat or lap belt tripled between 1974 (20 percent) and 1984 (60 percent). Most of the increase came after 1981, with the widespread introduction of State buckle-up laws:

Percent of Children in	1974	....	1979	1980	1981	1982	1983	1984
Child seats	16		15	20	24	32	42	46
Lap belt only	4		3	4	4	6	9	14
Child seats or lap belts	20		18	24	28	38	51	60
Number of States with buckle-up laws in effect at the end of the year	0		1	2	3	13	31	46

o Among child seat users, the percentage of seats that were used correctly increased from 18 percent in 1979 to 39 percent in 1984. The percent of seats that were grossly misused or not intended for automotive use (such as feeder seats or infant carriers for home use) decreased from 50 percent in 1979 to 21 percent in 1984:

<table>
<tr><th>Percent of Child Seats in Use</th><th>1974</th><th>....</th><th>1979</th><th>1980</th><th>1981</th><th>1982</th><th>1983</th><th>1984</th></tr>
<tr><td>Correctly used</td><td rowspan="2">39</td><td></td><td>18</td><td>20</td><td>22</td><td>25</td><td>30</td><td>39</td></tr>
<tr><td>Partially misused</td><td></td><td>32</td><td>38</td><td>41</td><td>45</td><td>46</td><td>40</td></tr>
<tr><td>Grossly misused safety seats/home child carriers used as car seats</td><td>61</td><td></td><td>50</td><td>42</td><td>37</td><td>30</td><td>24</td><td>21</td></tr>
</table>

o Since overall usage of safety seats tripled (from 15 to 46 percent of all child passengers) while the proportion of seats used correctly doubled (from 18 to 39 percent of seats in use), the percent of all child passengers who were in a correctly used safety seat increased (from 3 to 18 percent) between 1979 and 1984:

Percent of All Child Passengers in	1979	1980	1981	1982	1983	1984
Correctly used safety seats	3	4	5	8	13	18
Partially misused seats	5	8	10	14	19	18
Grossly misused safety seats/ home child carriers used as car seats	7	8	9	10	10	10
(Not in a child seat)	85	80	76	68	58	54

o Safety seat usage drops off sharply as children get older. According to 1984 nationwide observational and accident data, 68 percent of infants under age 1 were in safety seats but only 17 percent of 4-year-olds. One likely factor is that most of the State buckle-up laws currently do not require safety seats to be used through age 4.

Age of Child	Percent Using Safety Seats	Number of States in 1985 Requiring Safety Seat at that Age
0	68	All 50
1	62	47
2	51	40
3	27	30
4	17	10

o While safety seat usage keeps dropping as children get older, lap belt usage first increases but then levels off beyond age 2 - as evidenced by 1983-84 North Carolina accident data. Thus, the proportion of children using either restraint system falls as age increases:

Restraint System Usage in North Carolina (%)

Age of Child	Safety Seats	Lap Belt Only	Safety Seat or Lap Belt
0	76	1	77
1	55	11	66
2	25	19	44
3	10	20	30

(The North Carolina buckle-up law applies to children under 2, requiring a safety seat for infants under 1 and a choice of seat or belt for 1 year olds.)

OVERALL EFFECTIVENESS

o In 1984, the overall average effectiveness of safety seats (based on the mix of correct users and misusers that actually occurred on the road) and other safety measures for child passengers aged 0-4 were:

Percentage Reduction of:	Fatalities	Hospitalizations	Nonserious Injuries
Safety seats	46	46	37
Lap belt only	33	50	30
Unrestrained: back seat vs. front seat	27	27	25
Safety seat users: back seat vs. front seat	20	20	20

o Before 1984, the overall average effectiveness of safety seats was lower because a larger percentage of the seats were misused. Effectiveness increased steadily from 27 percent in 1979 to 46 percent in 1984:

Reduction in Fatalities/Hospitalizations	1979	1980	1981	1982	1983	1984
Safety seats	27	32	35	38	42	46
Lap belt only (fatality reduction)	33	33	33	33	33	33
Unrestrained: back seat vs. front seat	27	27	27	27	27	27
Safety seat users: back seat vs. front seat	23	23	22	22	21	20

o The benefits of moving a restrained child from the front seat to the back seat were slightly higher before 1984 because a greater proportion of the seats were misused. When safety seats are used correctly, there is relatively less difference between the front and rear seat of a car, because the child is less likely to contact vehicle interior surfaces (which are more hazardous in the front seat than in the back seat).

o Lap belts are quite effective for small children at moderate speeds, but casualty reduction in frontal crashes dwindles beyond crash velocities (Delta V) of 30 mph.

o An unrestrained child (age 0-4) in the back seat has 55 percent lower risk of a hospitalizing head or torso injury in frontal crashes than an unrestrained child in the front seat. But unrestrained front and back seat passengers have about equal risk of serious injuries in nonfrontal crashes. They also have about equal risk of arm or leg injuries, even in frontal crashes.

EFFECTIVENESS - CORRECTLY USED VS. MISUSED SEATS

o Correctly used safety seats are estimated to reduce fatalities by 71 percent and hospitalizations by 67 percent. These are averages for all types of seats in correct use during 1984--but the estimates would have been about the same in other years.

o Partially misused seats are estimated to reduce fatalities by about 44 percent and hospitalizations by 48 percent. These are the averages for all the partial misuse modes of the various types of seats in use during 1984--the estimate would have been about the same in other years. Effectiveness of partially misused seats decreased rapidly after crash velocity (Delta V) exceeded 30 mph in frontal crashes.

o Grossly misused safety seats are of little or no value in preventing fatalities or serious injuries.

EFFECTIVENESS OF SAFETY SEATS - IN THE BACK SEAT VS. THE FRONT SEAT

o The serious injury reductions for safety seats, when used in the front seat of a car, were:

	Reduction (%) of Hospitalizations Relative to Front-Seat Unrestrained
Correctly used seat	69
Partially misused	49
Grossly misused	0
OVERALL (1984 mix of correct/misused)	48

o The serious injury reductions for safety seats, when used in the back seat of a car, were:

	Reduction (%) of Hospitalizations Relative to		
	Front-Seat Unrestrained	Back-Seat Unrestrained	Front-Seat Restrained*
Correctly used seat	73	63	11
Partially misused	59	45	20
Grossly misused	26	0	26
OVERALL (1984 mix of correct/misused)	58	43	20

*I.e., correctly used: back vs. front; partially misused: back vs. front; etc.

o A child in a correctly used safety seat in the back seat of a car is 73 percent less likely to be hospitalized than an unrestrained child in the front seat.

o In 1984, the overall effectiveness of safety seats (based on the mix of correct and incorrect usage) was 48 percent in the front seat and 43 percent in the back seat - relative to unrestrained children in the same seat position.

EFFECTIVENESS OF SAFETY SEATS - INFANTS VS. TODDLERS

o Safety seats are about equally effective in reducing the fatalities of infants and toddlers, as evidenced by statistics based on the 1980-84 mix of correctly used and misused seats:

	Fatality Reduction, 1980-84 (%)
Infants (age less than 1)	43
Toddlers (age 1-3)	44
Average of both groups	43

Each of these numbers would be about 3 percent higher for 1984, alone, since a larger proportion of the seats was used correctly than in 1980-83.

EFFECTIVENESS OF SAFETY SEATS - BY BODY REGION

o Safety seats are quite effective in preventing injuries to every body region, even when misuse of seats is taken into account:

Percent Reduction by Body Region	Pennsylvania 1981-83 Moderate Injuries* All Crashes	Sled Tests, 1984 Mix Hospitalizations Frontal Crashes
Head, face	48	41
Torso	44	44
Neck, back	25	
Arms	74	
Legs	87	

*Police-reported levels K, A or B.

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CORRECT USAGE AND MISUSE - BY TYPE OF SAFETY SEAT

o Ten types of safety seats were identified in this evaluation. Correct usage varied from 9 to 90 percent among the different types, gross misuse from zero to 33 percent. The tethered seat (belt through frame) was the least often correctly used and most often grossly misused type. Seats with full shields were least often misused. A partial shield (harness pad--not armrest) significantly reduced gross misuse of tetherless seats.

Type of Seat	Example of a Best-Selling Make/Model	Share of 1984 On-the-Road Mix	Correct Use	Partial Misuse	Gross Misuse
Tethered (belt thru frame)	Strolee Wee Care 597, 599	17	9	58	33
Tethered belt-around	GM/Century Child Love Seat	3	18	79	3
Tetherless belt-around	Bobby Mac Champion	9	12	74	14
Tetherless, harness only	Century 100	18	53	21	26
Tetherless, partial shield	Questor One-Step	20	56	29	15
Tetherless, full shield	Cosco/Peterson Safe-T-Shield	2	76	24	0
Shield-booster	Collier-Keyworth Co-Pilot	4	90	0	10
Booster (using car's shoulder belt or tether-harness)	Kolcraft Tot Rider XL	12	40	45	15
Infant belt-around	GM/Century Infant Love Seat	10	41	48	11
Infant (belt thru frame)	Most convertible seats, when used by infants	5	45	45	10
	TOTAL OR AVERAGE	100	39	40	21

EFFECTIVENESS - BY TYPE OF SAFETY SEAT - WHEN CORRECTLY USED

o The sled test studies that were conducted or reviewed for this evaluation showed that all types of approved toddler seats are highly effective when correctly used. They did not consistently support a conclusion that any one type is significantly more effective than the others. Therefore, the preliminary conclusion is that all types of correctly used seats reduce fatalities by close to 71 percent and hospitalizations by close to 67 percent. The detailed findings of the studies were:

o In the sled tests which used the passenger compartment of a mid-sized car, "soft" crash pulses, and 15-35 mph frontal and oblique-frontal impact speeds: dummies in boosters and seats with full shields had less severe head injury predictions than dummies in toddler seats with harnesses (tethered or tetherless-harness only types).

o But in 1981-84 NHTSA compliance tests, with substantially "harder" crash pulses at a 27.5 mph impact speed: booster, shield-booster, tetherless full-shield and tetherless belt-around seats had more severe head injury predictions than tetherless (harness only or partial shield) or tethered (belt-around or belt through frame) types.

o In both series of tests, there were no significant differences among chest injury predictions for the various types, although tetherless-full shield seats performed slightly worse than the other types.

o In the compliance tests, boosters (with tether-harness or shoulder belt), tethered belt-around and tethered (belt through frame) seats allowed significantly less excursion of the dummies' heads in frontal impacts than did the other types.

o Very limited side impact data suggested that the tethered belt-around seat allowed less head excursion than the other types. Little else is known about performance in side impacts, especially for seats with a full shield and no harness.

o Sled tests conducted to date do not offer predictions of neck or abdominal injuries for children in toddler seats and not even for head and chest injuries in infant seats.

o The data base on boosters and shield-boosters is still scanty. Specifically, researchers are concerned about the potential for abdominal injury when users of booster seats make direct contact with a car's lap belts or with the shield. For shield-booster seats, there are also unanswered questions about the kinematics of subjects that are larger or smaller than a 3-year-old dummy.

EFFECTIVENESS - BY TYPE OF SEAT - WHEN MISUSERS ARE INCLUDED

o In 1984, the overall average serious injury reduction for each type of safety seat (based on the mix of correct users and misusers that actually occurred on the road) was:

Type of Seat	Reduction (%) of Hospitalizations Based on Frontal Sled Tests
Tethered (belt thru frame)	34
Tethered belt-around	49
Tetherless belt-around	41
Tetherless, harness only	45
Tetherless, partial shield	51
Tetherless, full shield	62
Shield-booster	60
Booster (using shoulder belt or tether-harness)	54
Infant seats (both types)	43*

*Fatality reduction based on 1980-84 accident data

o Since all types of seats are estimated to reduce hospitalizations by 67 percent when correctly used, the differences between seat types in the preceding table are due only to the fact that some types are misused more often and/or more severely than others.

o All of the preceding estimates are preliminary and subject to change when more sled test or accident data become available (especially on side impacts).

THE MOST COMMON MISUSE MODES

o The most common forms of partial misuse of safety seats in 1984 were:

Misuse Mode	Percent of All Partial Misusers
Lap belt misrouted thru frame	23
Tether not used	21
Harness not used (lap belt correctly routed around child)	20
Booster seat--no shoulder belt/tether harness	13
Infant seat--facing wrong way	7
Bobby Mac--shield not used, else correct	5
Tether not used and belt misrouted	4

o The most common forms of gross misuse in 1984 were:

Misuse Mode	Percent of All Gross Misusers
Child not secured in seat	37
Child not secured and seat not anchored in car	33
Seat not anchored in car	27

MISUSE OF INDIVIDUAL HARDWARE ITEMS

o Tethers were more often not used than any other hardware item during 1984. Full shields and integral harness/partial shields were much less frequently misused than plain harnesses. Seats with lap belt routing around the child had no more lap belt non-use than seats with routing through the frame--and virtually no incorrect use.

Types of Seats	Individual Item Misused		Percent of Seats of those Types
All seats with tethers	Tether not used		85
Booster seats	Shoulder belt/tether harness not used		60
All seats with plain harness	Harness not used		36
Lap belt through frame	Lap belt routed too low	24	35
	Lap belt not used at all	11	
Infant seats	Seat facing wrong way		33
Lap belt around child	Lap belt not used		11
Seats with full shields	Shield not used		9
Seats with integral harness/ partial shield	Harness not used		8

NOTE: The identification of partial vs. gross misuse takes into account simultaneously the status of each of the seat's hardware items and the design of the seat. It cannot be derived from the percentages shown in the above table.

EFFECTIVENESS OF SPECIFIC PARTIAL MISUSE MODES

o The serious injury reductions in four specific partial misuse modes, as estimated in the frontal and oblique-frontal sled tests which used the passenger compartment of a mid-sized car, were:

Type of Seat	Partial Misuse Mode	Effectiveness (Percent)
Tethered	Tether not used-otherwise OK	49
Tethered	Tether not used and lap belt too low	44
Tetherless - harness only	Lap belt too low	46
Booster	No shoulder belt/tether harness	59*

*However, in the 1981-84 NHTSA compliance tests, which used a "harder" crash pulse, the booster seat with no shoulder belt/tether harness had significantly <u>more severe</u> head injury predictions than the tethered seat with the tether not used. (The other two misuse modes were not tested.)

POTENTIAL BENEFITS OF SAFETY SEATS

o In 1984, safety seats spared an estimated 158 lives. That number could have been as high as 527 if every child age 0-4 had been in a correctly used seat:

Overall Usage	Actual Effectiveness (1984 Correct/Misuse Mix)	Potential Effectiveness (All Seats Used Correctly)
1984 level	158	244
1984 level for infants (no dropoff for older children	233	360
100 percent usage	341	527

Conclusions

o All of the safety seats tested in this evaluation were highly effective in frontal crashes when they were correctly used. The study does not conclude that any specific type of safety seat is more effective than the others, when correctly used.

o Even partially misused safety seats are quite effective at the lower crash speeds. Thus, certain seat types which are rarely used correctly still have benefits because their misuse is, in most cases, just a partial misuse.

o Lap belts significantly reduce fatalities and injuries of children aged 1-4 who ride in passenger cars. Moving an unrestrained child aged 0-4 from the front seat to the back seat has similar benefits. But neither measure is nearly as effective as a correctly used safety seat.

o The fatality and injury risk for a safety seat user in the back seat of a car is significantly lower than in the front seat. Thus, the best protection is obtained by correctly using a safety seat in the back seat of a car.

o Overall usage and correct use of safety seats increased dramatically from 1979 to 1984. State buckle-up laws, more convenient safety seat designs and educational programs by the safety/medical community have all contributed significantly to this vital safety improvement.

o In general, the types of seats that intuitively seem more convenient are the ones that are most often used correctly. An exception is the seats that require the lap belt to be routed around the child each time the seat is used. Despite that apparent inconvenience, they had just as low a rate of belt nonuse as the seats with one-time belt-through-frame routing and they had virtually no problem of misrouted belts.

o Designs in which the harness is integral with a partial shield have greatly reduced failures by parents to buckle the harnesses. They have remedied the form of misuse responsible for the largest loss of benefits for safety seats.

o Nonuse of tethers and misrouting of lap belts through the frame are two other problems that occur frequently and significantly reduce the overall benefits of safety seats.

o Safety seat usage drops off rapidly after a child reaches age 2, resulting in a serious loss of potential benefits for the seats. Many of the current State buckle-up laws do not require a safety seat to be used beyond age 2 or 3.

o Safety seats are one of the most effective and beneficial auto safety devices currently in use, but there is still much room for increased benefits since fewer than half of child passengers are using the seats and fewer than half of the seats are being correctly used.