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Effectiveness of Lap/Shoulder Belts in the Back Outboard Seating Positions

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16. Abstract

Most of the analyses are based on Fatality Analysis Reporting System (FARS) data from 1988 through the first six months of 1997. The primary analysis compares the fatality risk for back seat outboard belted occupants (lap or lap/shoulder belted) to the corresponding risk for unbelted occupants, as well as the fatality risk for lap/shoulder belted occupants to the risk for lap belted occupants. Fatality risk is the ratio of fatalities in the back seat to fatalities in the front seat (a control group). This procedure of comparing a subject group to a control group is called "double pair comparison." The principal conclusions are: back seat lap belts are 32 percent effective in reducing fatalities and lap/shoulder belts are 44 percent effective in reducing fatalities when compared to unrestrained back seat occupants in passenger cars. In passenger vans and Sport Utility Vehicles, lap belts are 63 percent effective and lap/shoulder belts are 73 percent effective. The change from lap to lap/shoulder belts has significantly enhanced occupant protection, especially in frontal crashes. In all crashes, lap/shoulder belts are 15 percent more effective than lap belts alone. In frontal crashes, lap/shoulder belts are 25 percent more effective than lap belts alone. Back seat lap belts reduce the risk of head injuries while increasing the risk of abdominal injuries in potentially fatal frontal crashes. Lap/shoulder belts reduce the risk of both head and abdominal injuries in potentially fatal frontal crashes relative to lap belts only: head injuries by 47 percent and abdominal injuries by 52 percent.

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* “Double pair comparison” method relative to front seat outboard occupants.

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EXECUTIVE SUMMARY

The objective of this report is to evaluate back seat outboard lap/shoulder belts. This report evaluates the effectiveness of lap/shoulder belts for back seat outboard occupants and whether they are more effective than lap belts for these occupants. A controversial study by the National Transportation Safety Board (NTSB) claimed that lap belts are ineffective and possibly dangerous and that only lap/shoulder belts could protect the occupants. Other studies, while not disputing that lap/shoulder belts would be superior, found benefits for lap belts. A second objective of this evaluation is to determine whether lap belts are effective, whether lap belts are harmful to back seat belt users, and whether lap/shoulder belts correct the problems found with lap belts.

Agencies are required to evaluate their existing programs and regulations by the Government Performance and Results Act of 1993 and Executive Order 12866 (October 1993). This report is an evaluation of the Federal Motor Vehicle Safety Standard (FMVSS) 208 (occupant crash protection), specifically the back seat lap/shoulder belt requirement. Back seat outboard lap/shoulder belts were first required in passenger cars after December 11, 1989 and in convertible passenger cars, light trucks, vans, and sport utility vehicles (SUVs) after September 1, 1991. Before this, passenger vehicles were required to have at least lap belts at all forward-facing rear outboard seating positions, although lap/shoulder belts would also have met this requirement. By model year 1990, all passenger cars, except convertibles, had lap/shoulder belts at the rear outboard seating positions. Similarly, many passenger vans and SUVs were equipped with lap/shoulder belts in the back outboard seating positions before the FMVSS 208 requirement.

Most of the analyses are based on Fatality Analysis Reporting System (FARS) data from 1988 through the first six months of 1997. FARS is a census of fatal crashes in the United States. Several different analytical methods are used to assess the effectiveness of back seat outboard lap and lap/shoulder belts. Our primary analysis compares the fatality risk for belted occupants (lap and lap/shoulder belted) to the corresponding fatality risk for unbelted occupants, as well as the fatality risk for lap/shoulder belted occupants to the fatality risk for lap belted occupants ("when-used" analysis). Fatality risk is the ratio of fatalities in the back seat to fatalities in the front seat (a control group). This procedure of comparing a subject group to a control group is called "double pair comparison."

The principal conclusions of the study are that lap belts and lap/shoulder belts are effective for back seat outboard occupants. The change from lap to lap/shoulders has significantly enhanced occupant protection, especially in frontal crashes. Back seat lap belts reduce the risk of head injuries while increasing the risk of abdominal injuries in frontal crashes. Lap/shoulder belts reduce the risk of both head and abdominal injuries in frontal crashes relative to lap belts only. Lap/shoulder belts reduce abdominal injuries by 52 percent relative to lap belts only. A passenger car fleet entirely equipped with lap/shoulder belts will have approximately 124 fewer fatalities per year than a fleet equipped only with lap belts. The principal findings and conclusions are the following:

BELT USE BY BACK SEAT OUTBOARD OCCUPANTS

- Back seat outboard belt use is substantially lower than front seat outboard belt use. Front seat belt use in 1997 was almost 70 percent whereas back seat belt use was 40 percent.

- Back seat outboard belt use is higher in cars equipped with lap/shoulder belts than cars with lap belts. Belt use is 7-10 percentage points higher in cars with lap/shoulder belts than cars with lap belts after controlling for vehicle age and calendar year.

FATALITY REDUCTION - BACK SEAT OUTBOARD BELTS - PASSENGER CARS

- **In all crashes, back seat lap belts are 32 percent effective in reducing fatalities when compared to unrestrained back seat occupants. The effectiveness estimate is statistically significant with confidence bounds: 23 to 40 percent.**

- **In all crashes, back seat lap/shoulder belts are 44 percent effective in reducing fatalities when compared to unrestrained back seat occupants. The effectiveness estimate is statistically significant with confidence bounds: 38 to 50 percent.**

- In all crashes, back seat lap/shoulder belts are 15 percent effective in reducing fatalities when compared to back seat lap belts. The effectiveness estimate is statistically significant with confidence bounds: 5 to 25 percent.

- **At current belt use rates in the back seat, a passenger car fleet equipped entirely with lap/shoulder belts will have approximately 124 fewer fatalities per year than a fleet equipped only with lap belts (confidence bounds: 63 to 180).**

- **If belt use in the back seat increased to 100 percent, lap/shoulder belts could save an additional 515 lives.**

FATALITY REDUCTION IN FRONTAL CRASHES - BACK SEAT OUTBOARD BELTS - PASSENGER CARS

- **In frontal crashes, lap belted back seat outboard occupants did not have a statistically significant benefit relative to unrestrained occupants. The effectiveness estimate is 1 percent.**

- **Lap/shoulder belts are 29 percent effective in reducing fatalities when compared to unrestrained occupants in frontal crashes. This estimate is statistically significant with confidence bounds: 15 to 42 percent.**

- In frontal crashes, the lap/shoulder belt is a great improvement over the lap belt. Lap/shoulder belts are 25 percent effective in reducing fatalities when compared to lap belted occupants in frontal crashes. This estimate is statistically significant with confidence bounds: 12 to 36 percent.

FATALITY REDUCTION IN NON-FRONTAL CRASHES - BACK SEAT OUTBOARD BELTS - PASSENGER CARS

- In all types of non-frontal crashes, including side impacts, rear impacts, rollovers, and others, lap/shoulder belts are perhaps slightly more effective in reducing fatalities than lap belts, but the increment is not statistically significant:

  (2) lap belted vs. unrestrained back seat outboard occupants: 48 percent.
  (3) lap/shoulder belted vs. unrestrained back seat outboard occupants: 53 percent.
  (4) lap/shoulder belted vs. lap belted back seat outboard occupants: 6 percent.

- In rollovers, lap and lap/shoulder belts when used are both highly effective in preventing a fatality: 76 and 77 percent, respectively. In rollovers, the lap/shoulder belt does not provide any significant additional protection over a lap belt.

- In side impact crashes, the lap/shoulder belt when used provides about the same protection against a fatality as a lap belt.

FATALITY REDUCTION BY AGE AND GENDER GROUPS - BACK SEAT OUTBOARD BELTS - PASSENGER CARS

- Children ages 5-14 appear to derive the greatest incremental benefit from using back seat lap/shoulder belts rather than just a lap belt. The incremental effectiveness of lap/shoulder belts is 26 percent for children.

- It is unclear if males age 15-54 benefit more from being lap/shoulder belted than just lap belted.

- Females age 15-54 appear to benefit slightly from lap/shoulder belts over lap belts.

- Seniors ages 55 and over benefit from using back seat lap/shoulder belts over lap belts, but neither lap nor lap/shoulder belts when used are as beneficial for seniors as they are for the other age/gender groups.

- In frontal crashes, both lap and lap/shoulder belts have consistently lower effectiveness estimates as occupants get older when compared to unbelted occupants. However, the relative incremental benefit of lap/shoulder belts over lap belts remains reasonably consistent, ranging from 25 to 41 percent.

- Gender also appears to affect the effectiveness estimates in frontal crashes. Females age 15-54 have lower effectiveness estimates than males age 15-54.

FATALITY REDUCTION - BACK SEAT OUTBOARD BELTS - PASSENGER VANS AND SUVS

- **Back seat outboard belts are highly effective is reducing fatalities when compared to unrestrained occupants in passenger vans and SUVs. Lap belts are 63 percent effective and lap/shoulder belts are 73 percent effective. Belts are so effective in these vehicles because they eliminate the risk of ejection, a big problem for unrestrained occupants in these vehicles.**

- The effectiveness of the lap/shoulder belt relative to the lap belt in passenger vans and SUVs is 20 percent. This estimate is not statistically significant, but it is close to the corresponding estimate for passenger cars.

- In frontal crashes, both the lap and lap/shoulder belts are highly effective in passenger vans and SUVs. Ejection is also a big problem in frontal crashes for these vehicles, so even the lap belt is effective in frontal crashes. But the lap/shoulder belt is not significantly safer than the lap belt in frontal crashes for these vehicles.

FATAL INJURY RATE BY BODY REGION IN FRONTAL CRASHES

By combining the FARS and the Multiple Cause of Death (MCOD) files, we found the causes of death listed on the death certificate of fatal crash victims. We analyzed this file and found the following regarding causes of death by body region injured:

- Lap belt use in frontal crashes increases the risk of abdominal injuries even while reducing the risk of head injuries relative to unrestrained occupants.

- Lap/shoulder belts reduce abdominal injuries by 52 percent relative to lap belts only.

- Lap/shoulder belts reduce head injuries by 47 percent relative to lap belts only.

- The shoulder belt does not appear to increase the risk of chest injuries. The fatality rate due to chest injuries for lap/shoulder belted occupants is only slightly higher than the rate for lap belts, which is slightly higher than unrestrained occupants.

- Belted children, ages 5-14, do not have an increased risk of abdominal injuries. Lap belted and lap/shoulder belted children have abdominal injury rates slightly higher than unrestrained children in frontal crashes, but at or below the injury rate of all lap belted and lap/shoulder belted occupants in frontal crashes.

- Lap belted seniors (aged 55 and older), males (ages 15-54), and females (ages 15-54) have an increased risk of abdominal injuries in frontal crashes. However, the risk of abdominal injuries for lap belted females is lower than the risk for males and seniors.

CHAPTER 1

INTRODUCTION AND BACKGROUND

Agencies are required to evaluate their existing programs and regulations by the Government Performance and Results Act of 1993[1] and Executive Order 12866 (October 1993).[2] This report is an evaluation of the Federal Motor Vehicle Safety Standard (FMVSS) 208 (occupant crash protection),[3] specifically the back seat lap/shoulder belt requirement. This evaluation will also show if lap belts are effective, if lap belts are harmful to back seat belt users, and if lap/shoulder belts correct the problems found with lap belts.

Back seat outboard lap/shoulder belts were first required in passenger cars, except convertibles, manufactured on or after December 11, 1989. Before this, passenger cars were required to have at least lap belts at all forward-facing rear outboard seating positions, although lap/shoulder belts would also have met this requirement. The latest regulation affecting back seat outboard seating positions requires integral lap/shoulder belts in passenger cars manufactured on or after September 1, 1990. Integral lap/shoulder belts are belts where the lap belt can not be detached from the shoulder belt.

Convertible passenger cars and light trucks, vans, and sport utility vehicles (SUVs) manufactured on or after September 1, 1991 are also required to have integral lap/shoulder belts at all forward-facing rear outboard seating positions. The forward-facing rear outboard seating positions adjacent to a walkway located between the seat and the side of the light trucks, vans, and SUVs are exempt from this requirement, when the walkway allows access to more rearward seating positions. Prior to September 1, 1991, lap belts were required in the rear seats of these vehicles but lap/shoulder belts would have also met this requirement.

In July 1986, a National Transportation Safety Board (NTSB) study[4] was published claiming that lap belts are ineffective and may even be harmful to belt wearers. The study was widely criticized because it was not a statistical study and the conclusion were based on a small number of cases. But it may have been the catalyst behind the Los Angeles Area Child Passenger Safety Association petitioning the agency to require back seat lap/shoulder belts. In August 1986, the

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[1] *Government Performance and Results Act of 1993*, Public Law 103-62, August 3, 1993.

[2] *Federal Register* 58 (4 October 1993), 51735.

[3] *Code of Federal Regulations*, Title 49, Government Printing Office, Washington, DC, 1997, Part 571.208.

[4] *Performance of Lap Belts in 26 Frontal Crashes*, National Transportation Safety Board, Report No. PB86-917006, 1986.

agency decided to grant the petition and re-examine the issue of requiring the installation of back seat outboard lap/shoulder belts because of the widespread adoption of state safety belt use laws.

At that time, there were not any studies on the effectiveness of back seat lap/shoulder belts. There were several studies on the effectiveness of back seat lap belts. Most of the studies disagreed with the NTSB study and concluded that lap belts are effective in the rear seat. There were also many studies on the effectiveness of front seat lap/shoulder belts, showing that front seat lap/shoulder belts are more effective in reducing injuries and fatalities than lap only belts.

In the Final Regulatory Evaluation,[5] the National Highway Traffic Safety Administration (NHTSA) argued that since lap/shoulder belts are more effective than lap belts in front seat, they would also be more effective than lap belts in the back seat. The agency also argued that lap/shoulder belts would be less effective in the back seat than in the front seat because the "primary benefit of shoulder belts is in frontal accidents and that a larger proportion of front seat occupant injuries occur in frontals than do rear seat occupant injuries." Therefore, using this logic, NHTSA estimated that back seat outboard lap/shoulder belt would be 41 percent effective in reducing the risk of death, given that "rear seat lap belts are 32 percent effective in reducing the risk of death" and front seat lap/shoulder belts are 40-50 percent effective in preventing fatalities.

Before the final rule was announced, the major domestic manufacturers and about twenty-four foreign manufacturers were installing or planned to install lap/shoulder belts in the rear seat of some or all of their passenger cars. By model year 1990, all passenger cars, expect convertibles, had lap/shoulder belts at the rear outboard seating positions. Similarly, many passenger vans and SUVs were equipped with lap/shoulder belts in the back outboard seating positions before the FMVSS 208 requirement. Most manufacturers of passenger vans and SUVs also chose to equip the outboard seats adjacent to walkway with lap/shoulder belts, even though these seats were allowed to have lap or lap/shoulder belts.

This evaluation is limited to the effectiveness of lap and lap/shoulder belts in the rear outboard seating positions. At this time, only a few cars have lap/shoulder belts in the rear center position. If such installation were to increase substantially in the future, NHTSA would evaluate their effectiveness.

1.1 RESULTS OF EARLIER EFFECTIVENESS STUDIES

After reviewing effectiveness studies, we found that the effectiveness of lap/shoulder belts in the back seat is unresolved. Very few studies have been done on back seat lap/shoulder belts. The effectiveness of lap/shoulder belts in the front seat is determined. The studies agree that front seat

[5] *Final Regulatory Evaluation - Rear Seat Lap/Shoulder Belts in Passenger Vehicles Under 10,001 LBS. GVWR*, NHTSA, Washington, DC, 1989.

lap/shoulder belts are 40-50 percent effective in reducing fatalities. And the effectiveness of lap belts in the back seat is unsettled. A NTSB case study[6] claims lap belts are ineffective and possibly harmful, but other statistical studies disagree with NTSB's claim and show that lap belts are effective in the back seat.

A 1992 paper[7] found the injury (fatal, major and minor injuries) effectiveness of back seat outboard lap/shoulder belts is 35 - 62 percent and the injury effectiveness of back seat outboard lap belts is 48 - 58 percent. This study concluded that both the lap and lap/shoulder belts significantly reduce injuries to back seat outboard occupants, but "there is no measurable difference between lap belt and lap/shoulder belt performance in the rear-seat environment." These conclusions may be inaccurate because they are based on a small amount of data, before lap/shoulder belts were universally installed in the back seat of passenger cars.

Most of the effectiveness studies done on lap/shoulder belts have been for front seat outboard occupants. A widely accepted fatality effectiveness of lap/shoulder belts in the front seat is 40-50 percent. A 1986 study by Evans[8] estimates the fatality effectiveness of lap/shoulder belts for front seat outboard occupants is (41.4 ± 3.8) percent. The agency's official effectiveness estimate is 40 - 50 percent for front seat outboard occupants.[9]

There have been many studies on the effectiveness of lap belts, but the results are not consistent. All of the statistical studies show that lap belts are effective in the back seat, but an NTSB case study[10] claims otherwise. The later statistical studies show higher effectiveness estimates than the earlier ones, making it unclear just how effective lap belts are in the back seat. The NTSB study also claims that lap belts may be harmful to belt users and there is some evidence that supports this claim. We discuss the details of these studies below.

NTSB did in-depth investigations of lap belts in 26 frontal crashes. The Safety Board concluded that:

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[6]NTSB (1986).

[7]Padmanaban, J., & Ray, R., "Safety Performance of Rear Seat Occupant Restraint Systems," *36th STAPP Car Crash Conference Proceedings*, SAE Publication No. P-261, Warrendale, PA, 1992.

[8]Evans, L., Traffic Safety and the Driver, Van Nostrand Reinhold, New York, 1991, pp. 228-229.

[9]*Final Regulatory Impact Analysis, Amendment to Federal Motor Vehicle Safety standard 208, Passenger Car Front Seat Protection*, NHTSA Report No. DOT HS 806 572, Washington, DC, 1984, p. IV-2.

[10]NTSB (1986).

> "the crash performance of the lap belts in these cases was very poor. Among the 50 persons using a lap-only belt, the Board determined that at least 32 of them would have fared substantially better if they had been wearing a lap/shoulder belt. In many cases, the lap belts induced severe to fatal injuries that probably would not have occurred if the lap belts had not been worn."

The Safety Board also concluded that lap belts induce head, spine, and abdomen injuries from minor to fatal in severity. Both males and females were injured by the lap belt and more than half of the injured persons were younger than 15 years. This study was criticized because it was not a statistical study and the conclusions were based on very few cases.

Several statistical studies refuted NTSB's claims that lap belts are ineffective. A study by Kahane[11] showed that rear seat outboard lap belts are effective in reducing injuries and fatalities to back seat occupants. Using a "double pair comparison" method, the author concluded that "Lap belts significantly reduce the risk of fatalities by 17-25 percent, serious injuries by 37 percent, moderate to serious injuries by 33 percent and injuries of any severity by 11 percent, relative to the unrestrained back seat occupant."

At the same time, an analysis by Evans[12] using the same method also found that lap belts are effective in preventing fatalities to back seat outboard occupants. This analysis estimates that lap belts are (18 ± 9) percent effective, less than the effectiveness estimates for front seat lap/shoulder belts and similar to Kahane's results. In the 1989 Regulatory Evaluation of lap/shoulder belts,[13] the agency estimates lap belts are 32 percent effective in reducing fatalities to back seat outboard occupants. Evans', Kahane's, and the Regulatory Evaluation analyses are based on double-pair comparison of Fatality Analysis Reporting system (FARS) data. The later the study, and the more recent the FARS data, the higher the effectiveness estimate.

A 1992 study[14] based on State data shows the injury effectiveness of back seat outboard lap belts is 48 - 58 percent. This later study shows higher injury effectiveness estimates than Kahane's study found using a similar method and fewer years of data.

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[11]Kahane, C., "Fatality Injury Reducing Effectiveness of Lap Belts for Back Seat Occupants," *Restraint Technologies: Rear Seat Occupant Protection*, SAE Publication No. SP-691, Warrendale, PA, 1987.

[12]Evans (1991), pp. 237-238.

[13]NHTSA (1989).

[14]Padmanaban (1992).

NTSB's[15] claim that lap belts may be harmful to occupants has been somewhat substantiated by other analyses. Kahane's study[16] found in frontal crashes that lap belted back seat occupants have a higher torso injury risk than unrestrained occupants, like the NTSB study. But unlike the NTSB study, this study shows that lap belted back seat occupants have a lower head injury risk than unrestrained occupants in frontal crashes. A later study[17] by Cooper and others concluded that back seat lap belts induce abdominal injuries in all crashes, not just frontal crashes. Using regional trauma registry data, this study finds that rear seat lap belted occupants are at increased risk of abdominal injuries of AIS levels 2 and 3 when compared to unbelted rear seat occupants.

1.2 BELT USE

Before we can evaluate the effectiveness of safety belts, we must consider their use. We will assess overall belt use first. We will assess back seat outboard belt use and see if it is different than front seat belt use. Secondly, we will assess if belt use changed when the restraint type switched from lap to lap/shoulder belts in the back seat outboard seating positions. Finally, we need to assess the accuracy of reported belt use by back seat outboard occupants in our crash data, because it strongly influences what types of effectiveness analysis should be performed with these data.

The National Occupant Protection Use Survey (NOPUS) is the only recent observational national survey of belt use. NHTSA conducts the survey every two years to assess safety belt usage. NOPUS is composed of three separate studies: the **moving traffic study,** which provides information on overall shoulder belt use; the **controlled intersection study**, which provides more detailed information about shoulder belt use by type of vehicle and person characteristics; and the **shopping center study**, which provides information on back seat belt use. Unlike the other NOPUS studies, the Shopping Center data cannot be weighted to produce national estimates of belt use because the data were not collected at statistically selected sites due to the difficulty of obtaining these data. But the Shopping Center Study (SCS) is the only study that provides valuable observational back seat belt use information.

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[15]NTSB (1986).

[16]Kahane (1987).

[17]Cooper, K., Proctor, S., Ragland, D., & Barkan, H., "Seat Belt Syndrome: An Examination of Patterns of Injury Associated with Seat Belt Use," *Association for the Advancement of Automotive Medicine, 38th Annual Proceedings,* Des Plaines, IL, 1994.

1.2.1 Observed Belt Use

For the SCS, the data collectors chose two or three shopping centers in each of the 50 geographical selected sites. The shopping center chosen had to represent diverse socioeconomic clientele and had a separate, one lane exit with curbs on both sides and traffic controlled by a stop light or stop sign. Most frequently these conditions were found in strip malls or neighborhood shopping centers with a grocery or convenience store. In the 1994 SCS, two person data collection teams observed belt use for one hour at each of 143 shopping centers. They collected:

- Driver and Right Front (RF) passenger shoulder belt use, lap belt use, and shoulder belt misuse;
- Back outboard passengers shoulder belt use, lap belt use, and shoulder belt misuse; and
- License plate number, state, and model of all eligible vehicles.

Belt use was not collected for passengers in the middle position of the seat.

At the completion of the survey, NHTSA sent the license plate numbers of the observed vehicles to the state and asked the state to supply the Vehicle Identification Number (VIN) for these vehicles. The data received from the states varied by state. Beside the licence plate number and VIN, most states sent the vehicle make, the vehicle model, the model year, and a state specified body type.

We merged the VIN and some of the other state supplied data to the SCS data by matching on the state and license plate number. Only 53 percent of the vehicles in the SCS data matched to vehicles in state supplied data. Errors recording the state and/or license plate number, errors automating the state and/or license plate number, and time delays between observing the vehicles and requesting the VINs are just a few of the reasons for unmatched vehicles.

We analyzed model year 1985-1995 VIN's in this merged data set to determine the specific vehicle make and model, so we could determine the specific restraint type available in these vehicles in both the front and back outboard seating positions. Most of the vehicles analyzed were passenger cars, only a few were light trucks, vans, or SUVs.

The data collectors observed belt use for over 8,000 outboard occupants. Table 1-1 shows the percent of belt use for the front and back seat outboard occupants in the 1994 SCS. Thirty-nine percent of the front seat occupants were unrestrained and 61 percent of them were belted (lap belted, shoulder belted, or lap/shoulder belted). But only 38 percent of the back seat occupants were belted. So the SCS shows that belt use was much lower for back seat occupants than for front seat occupants in 1994.

TABLE 1-1 NOPUS 1994 SHOPPING CENTER SURVEY PERCENT OF BELT USE BY FRONT AND BACK SEAT OUTBOARD OCCUPANTS				
	Front Seat		Back Seat	
	Number	Percent	Number	Percent
Unrestrained	2,874	39%	398	61%
Lap belted	198	3%	48	7%
Shoulder Belted	78	1%	**	**
Lap/shoulder belted	4,274	58%	204	31%
Total	7,424		650	

* Percents may not add to 100 percent due to rounding.
** Not applicable.

Using the merged data, we calculated the belt use by belt type: lap/shoulder belt equipped or lap belt equipped. There were 181 back seat outboard occupants observed in vehicles equipped with back seat outboard lap/shoulder belts and 44 percent of these occupants were wearing the lap/shoulder belt. There were 98 occupants observed in vehicles equipped with back seat outboard lap belts and only 37 percent of these occupants were wearing the lap belt. This is shown in Table 1-2. Therefore, observed belt use is higher for back seat outboard occupants in vehicles equipped with lap/shoulder belts than vehicles equipped with lap only belts.

TABLE 1-2 NOPUS 1994 SHOPPING CENTER SURVEY PERCENT OF BELT USE FOR BACK SEAT OUTBOARD OCCUPANTS BY BELT TYPE				
	Used	Not Used	Total	Percent of Belts Used
Lap belt equipped	36	62	98	37%
Lap/shoulder belt equipped	79	102	181	44%

It would be advantageous to use FARS back seat outboard survivors as a surrogate for the observational data because they are far more numerous than observational data. Table 1-3 shows the analogous data for back seat outboard **survivors** in FARS 1994. Fatality cases are not included: if belts are beneficial, we would expect a lower percentage of belt use among the fatalities than among the population in general. The survivors' belt use had to be known and the survivors had to be older than 4 years to be included in the table (many occupants younger than 4 years are in child restraints). The FARS survivor data shows that belt use is higher by back seat outboard occupants wearing lap/shoulder belts than these occupants wearing lap belts -- 48 percent vs. 34 percent.

TABLE 1-3
FARS 1994
PERCENT OF BELT USE FOR BACK SEAT OUTBOARD SURVIVORS IN PASSENGER CARS BY BELT TYPE

	Used	Not Used	Total	Percent of Belts Used
Lap belt equipped	359	682	1,041	34%
Lap/shoulder belt equipped	722	788	1,510	48%

The NOPUS (Table 1-2) and the FARS survivors (Table 1-3) have relatively consistent results, although the percent of belt use by belt type is slightly different in the two data sets. To see if these differences are significant, we calculated the difference between two uncorrelated proportions (z test). The z test value is 1.018 for lap/shoulder belt equipped cars, comparing 44 percent belt use in NOPUS to 48 percent belt use in FARS. The z test value is 0.598 for lap belt equipped cars. Neither z test value is statistically significant, so we may accept the null hypothesis and presume that the percent of belt use in NOPUS and FARS survivors is essentially the same.

Importantly, the belt use by back seat outboard occupants in FARS is not grossly overreported. The preceding data showed that belt use reported for survivors in FARS is about the same as the belt use in NOPUS. There is little reason to expect inaccurate belt use for fatally injured occupants. Reliable belt use is important for our effectiveness analysis. With reliable belt use, our effectiveness analysis can directly compare statistics for people reported as belted to people reported as unbelted ("when-used" analysis).

By contrast, our injury analysis of state data will be limited because the reported belt use is clearly overreported. Belt use is reported to be over 70 percent for back seat outboard survivors in Pennsylvania and Florida. We will only be able to compare the overall injury rate in cars equipped with lap/shoulder belts to the rate in cars equipped with lap belts ("as-used" analysis).

1.2.2 Back Seat Belt Use

We can use FARS survivors data to assess trends in belt use by back seat outboard occupants. (Most observational surveys only report front seat belt use.) In this section, we will present back seat belt use and show if it is different from the front seat. We shall also investigate if back seat belt use has changed with the installation of lap/shoulder belts in the back seat.

Back seat belt use remains substantially lower than front seat belt use. In the back seat, belt use is around 40 percent, but in the front seat it is almost 70 percent. Table 1-4 show the percent of belt use by outboard occupants in the front and back seat during 1994 - 97. The back seat belt use is survivors' belt use in FARS. The front seat belt use is the combined front seat belt use found in observational belt use surveys conducted in each state.

TABLE 1-4
PERCENT OF BELT USE IN PASSENGER CARS BY CALENDAR YEAR

Calendar Year	FARS Back Seat Outboard Survivors	State Surveys Front Seat Outboard Occupants
1994	42%	67%
1995	44%	68%
1996	43%	68%
1997	40%	69%

Back seat belt use was stagnant in 1994 - 97. At the same time, front seat belt use inched upwards. The historical gap between back and front seat belt use may be getting wider.

Did back seat outboard belt use change with the installation of lap/shoulder belts in these seating positions? If so, how much? Answers to these questions are important in our analysis. If back seat belt use in vehicles with lap/shoulder belts is higher than belt use in vehicles with lap belts, then the regulation that required lap/shoulder belts could have a double benefit: higher use as well as higher effectiveness.

Table 1-5 shows the percent of belt use for back seat outboard survivors in passenger cars equipped with lap belt and cars equipped with lap/shoulder belts. This table includes FARS data from 1988 through the first 6 months of 1997. Here too, belt use is higher in cars with lap/shoulder belts than cars with lap only belts.

Nevertheless, vehicle age and calendar year could account for the difference in belt use between the lap and lap/shoulder belt equipped vehicles. Studies have shown that belt use (at least, in the front seat) is less in older cars than newer cars: the vehicle age effect.[18] In our data, back seat

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[18]Datta, T. P., and Guzek, P., *Restraint System Use in 19 U.S. Cities: 1989 Annual Report*, NHTSA Report No. DOT HS 807 595, Washington, DC, 1990, p. 23.

outboard lap/shoulder belts are primarily in newer model year vehicles and lap belts are in older model year vehicles. Studies have also shown that belt use (at least, in the front seat) is increasing over time: the calendar year effect.[19] (Although not true for back seat outboard occupant belt use in recent years.)

TABLE 1-5
FARS 1988- FIRST 6 MONTHS OF 1997
PERCENT OF BELT USE FOR BACK SEAT OUTBOARD SURVIVORS
IN PASSENGER CARS BY BELT TYPE

	Used	Not Used	Total	Percent of Belts Used
Lap belt equipped	3,321	6,897	10,218	33%
Lap/shoulder belt equipped	4,900	5,722	10,622	46%

To control for these possible effects in FARS, we analyzed the belt use in a limited set of passenger cars. We calculated the belt use for back seat outboard survivors in matching make/models, passenger cars produced 3 model years before and after the transition from lap to lap/shoulder belts. Section 2.4 explains in detail the criteria used to limit the passenger cars and Appendix A contains a complete list of cars and model years ranges included in the "matching make/models." Table 1-6 shows the percent of belt use for back seat outboard occupants by belt type in the "matching make/models".

TABLE 1-6
FARS 1988- FIRST 6 MONTHS OF 1997
PERCENT OF BELT USE FOR BACK SEAT OUTBOARD SURVIVORS
IN "MATCHING MAKE/MODELS" BY BELT TYPE

	Used	Not Used	Total	Percent of Belts Used
Lap belt equipped	1,595	2,988	4,583	35%
Lap/shoulder belt equipped	1,676	2,316	3,992	42%

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[19]Kahane, C. J., *Fatality Reduction by Air Bags: Analyses of Accident Data Through Early 1996*, NHTSA Technical Report No. DOT HS 808 470, Washington, DC, 1996, Appendix D.

Again, belt use is higher by back seat outboard occupants in cars equipped with lap/shoulder belts than in cars equipped with lap only belts. Thirty-seven percent of the back seat outboard survivors were belted in cars with back seat lap/shoulder belts and only 31 percent of the back outboard seat survivors were belted in cars with back seat lap belts. This is a difference of 7 percent. It is a smaller difference than in Table 1-5, but it still suggests higher use of lap/shoulder belts.

Another way to control for the possible vehicle age and calendar year effects is a regression analysis. Table 1-7 shows the results from this regression analysis. The independent variables describe the back seat outboard survivors' restraint type, the vehicle's age, and the calendar year. This procedure splits the data in Table 1-5 into cells by restraint type, calendar year, and model year (total of 142 cells). (In each cell, VEHAGE = CY - MY.) The belt use is computed in each cell and is the dependent variable. The regression is weighted by N, the number of observed back seat outboard survivors in each cell. A weighted linear regression is performed by the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS).[20] The R^2 value for this analysis is 0.658.

TABLE 1-7
FARS 1988-FIRST 6 MONTHS OF 1997
LINEAR REGRESSION OF BELT USE FOR BACK SEAT OUTBOARD SURVIVORS BY RESTRAINT TYPE, VEHICLE AGE, AND CALENDAR YEAR IN PASSENGER VEHICLES

Dependent Variable: USERATE (Belt use rate)

N of Observations: 142

Weighting Factor: N (Number of back seat outboard survivors)

REGRESSION COEFFICIENTS

Independent Variable	Regression Coefficient	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-0.6273713916	-3.01	0.0031	0.20820606
BKLS	0.1025275132	7.98	0.0001	0.01285535
VEHAGE	-0.0064960568	-2.81	0.0057	0.00231360
CY	0.0096201402	3.93	0.0001	0.00244629

[20] *SAS/STAT User's Guide: Volume 2, GLM-VARCOMP*, Version 6, Fourth Edition, SAS Institute Inc., Cary, NC, 1990.

The regression coefficient of 0.102 for BKLS means that back seat outboard survivors belt use increased 10 percent in passenger cars equipped with lap/shoulder belts over cars equipped with lap belts. The regression coefficient for VEHAGE shows that back seat outboard survivor's belt use decreases as cars get older. Belt use decreases 1 percent for every year a car gets older. The CY coefficient shows belt use is increasing over time, about 1 percent each year.   The t test values for these coefficients are all statistically significant. Therefore, belt use is significantly higher in cars with lap/shoulder belts than cars with lap only belts after controlling for vehicle age and calendar year effects.

We are unsure why belt use is higher in cars equipped with lap/shoulder belts even after controlling for vehicle age and calendar year effects. It may be because lap/shoulder belts are more visible and/or easier to use than lap belts. The shoulder belt rests on the seat back cushion when not in use, making the lap/shoulder belts clearly visible. Non-retractable, self adjusting, lap belts can become hidden between the seat back and seat bottom cushion when not in use, making them not visible and difficult to retrieve. Retractable lap belts are easy to use, but retracted out of sight when not in use. For whatever the reason, this means lap/shoulder belts have more benefits than lap belts simply because they are used more than lap belts.

CHAPTER 2

FATALITY REDUCTION BY BACK SEAT BELTS, WHEN USED, IN PASSENGER CARS

The first goal of this evaluation is to estimate the fatality reducing effectiveness of lap/shoulder belts "when used": the percentage reduction in the fatality risk of a lap/shoulder belted back seat outboard occupant relative to an unrestrained back seat outboard occupant. We will likewise estimate the effectiveness of the lap belt alone for the back seat occupant, relative to the unrestrained occupant. We will also compare the fatality risk of the lap/shoulder belted to the lap belted occupant, to see if the change from lap to lap/shoulder belts significantly reduced fatality risk for back seat occupants who use belts.

This chapter presents several different analysis methods for estimating the effectiveness of belts when used. When different methods produce consistent effectiveness estimates, our confidence in the results should be higher than if only one estimate had been presented. Although the analyses in this chapter do not agree perfectly, their central tendency strongly supports the following conclusions: (1) lap/shoulder belts are effective for back seat occupants, in all crashes and in frontal crashes; (2) the lap belt alone is effective in non-frontal crashes, but not in frontal crashes; (3) the change from lap to lap/shoulder belts has significantly enhanced occupant protection in frontal crashes.

2.1 DATA PREPARATION

Most of the analyses in this chapter rely on the "double pair comparison" procedure[21]. The fatality risk of a back seat outboard occupant (unrestrained, lap-belted, or lap/shoulder belted) is measured relative to a control group of occupants in some other seat position. In the first set of analyses of this chapter (Sections 2.1-2.9), that control group consists of front-seat outboard occupants. In order to run double-pair comparison analyses, it is first necessary to generate a file of "paired-occupant records," each record containing data on a back seat outboard occupant and a front-seat outboard occupant who had been riding in the same crash-involved vehicle.

2.1.1 Vehicle-level File

The analyses were based on Fatality Analysis Reporting System (FARS) data from calendar years 1988 through the first six months of 1997. The FARS vehicle and person data files were used to create a vehicle-level file. Each record contained information on the vehicle and on the occupants

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[21]Evans, L., "Double Pair Comparison - A New Method to Determine How Occupant Characteristics Affect Fatality Risk in Traffic Crashes," *Accident Analysis and Prevention* 18, 1986.

in the driver seat, the front right (FR) passenger seat, the back left (BL) passenger seat, and the back right (BR) passenger seat. These four seat positions are coded 11, 13, 21, and 23, respectively, on FARS.

First, the Vehicle Identification Numbers (VINs) of passenger cars, model year 1985-1996, were analyzed to determine the specific vehicle make and model, so the specific restraint type available in these cars at both the front and back outboard seating positions could be determined. Although lap/shoulder belts were not required in back outboard positions in passenger cars until model year 1990, many passenger cars were equipped with these belts prior to this requirement. Two-seaters, convertibles, and a few other passenger car records where restraint type available for back outboard seats was unknown or optional equipment were excluded. Appendix A lists the installation dates by make/model for the cars included in the analysis and the make/models for the cars excluded from the analysis.

Then, the occupant information for all the back seat outboard occupants, age 5 or more in seating positions 21 (BL) and 23 (BR) only, was extracted from FARS. Next, the vehicle information and occupant information were combined to create a vehicle-level file which had one record for each passenger car that had a back seat outboard occupant.

Finally, the information for front seat outboard occupants, drivers (age 14 or more and seating position 11) and front right passengers (age 5 or more and seating position 13) were appended to the vehicle-level back seat outboard occupant records. This permits the comparison of the front and back outboard seat restraint use, restraint type available, and injury severity. (In those infrequent situations where FARS shows two or more occupants in the same seat position, only the first occupant, i.e., the one with the lowest PER_NO, was included in the analysis.)

Although not explicitly stated, back seat fatalities and front seat fatalities throughout Sections 2.1-2.10 refer to only the outboard positions in these seats.

2.1.2 Paired-occupant File

Up to four paired-occupant records where at least one of the occupants died could be generated from one vehicle record:

Driver and BL Passenger
Driver and BR Passenger
FR Passenger and BL Passenger
FR Passenger and BR Passenger.

This method may involve "double counting" in the sense that the same occupant may appear on two paired-occupant records. For example, a vehicle with four outboard occupants and only one fatality, a driver, will generate two paired-occupant records: one as a front seat fatality with the

BL passenger and one as a front seat fatality with the BR passenger. The paired-occupant records and their number of front and back seat fatalities for this example are such:

	Back seat fatalities	Front seat fatalities
Driver and BL Passenger	0	1
Driver and BR Passenger	0	1
FR Passenger and BL Passenger	no record generated, since both survived	
FR Passenger and BR Passenger	no record generated, since both survived	
Total contributed to the analysis	0	2

The "double counting" does not grow to "triple counting" even when there are two or more fatalities in the same vehicle. The number of generated paired-occupant records, given a driver and BL passenger fatality, for example, are such:

	Back seat fatalities	Front seat fatalities
Driver and BL Passenger	1	1
Driver and BR Passenger	0	1
FR Passenger and BL Passenger	1	0
FR Passenger and BR Passenger	no record generated, since both survived	
Total contributed to the analysis	2	2

In this example, the driver is counted twice in the front seat fatalities and the BL passenger is counted twice in the back seat fatalities. In these two examples, each fatality is counted equally (twice), so this does not bias the results or double the effectiveness. Proof 1 in Appendix C shows this.

But there are situations where each fatality is not counted twice. For example, if the car has only one front seat occupant (the driver) and only one back seat occupant, only one record will be produced and each fatality will be counted once. Even worse, if there is a driver, a FR passenger and one back seat passenger, and only one of these three occupants is a fatality -- the method will generate only one record if the fatality is the driver or FR passenger, but two records will be generated if the fatality is the back seat occupant. In this case, the fatal will be counted once if the driver or FR occupant is fatally injured and twice if the back seat occupant is fatally injured. Appendix C also shows that even this last situation does not create a bias for or against the back seat occupant.

One bias the process does create is that it generates fewer records when there is only a driver and no FR passenger than when there is a driver and FR passenger. Thus, vehicles with no FR passengers are underrepresented in the paired-occupant analysis file. However, this bias is unimportant because more than 90% of the cars on FARS with a back seat occupant also have a FR occupant.

Although this method produces essentially **unbiased point-estimates** of effectiveness, it will **understate** the width of the **confidence bounds** if the numbers in the tables are taken literally as independent observations, since they are not. A procedure for computing confidence bounds is developed in Section 2.4.1.

2.1.3 Restraint Type and Restraint Use Categories

Front seat outboard restraint use and restraint type available were combined and reported in 5 categories:

- Unrestrained - The car was not equipped with an air bag at that seat position (as inferred by analysis of the VIN); the occupant was not using belts (as evidenced by MAN_REST or REST_USE = 0)

- Lap/shoulder belted - The car was not equipped with an air bag at that seat position but it was equipped with manual or automatic lap/shoulder belts (as inferred by analysis of the VIN); the occupant was belted (as evidenced by MAN_REST or REST_USE = 1, 2, 3, 8, or AUT_REST = 1 in calendar year 1988-89)

- 2-point belted - The car was not equipped with an air bag at that seat position but it was equipped with automatic shoulder (2-point) belts plus, in most cases, manual lap belts (as inferred by analysis of the VIN); the occupant wore some kind of belt(s) (as evidenced by MAN_REST or REST_USE = 1, 2, 3, 8, or AUT_REST = 1 in calendar year 1988-89). Since FARS will not reliably indicate if the occupant wore just the automatic shoulder belt, just the manual lap belt, or both, all belted occupants of these vehicles are classified as “2-point belted” regardless of whether they used just one belt or both.

- Air bag alone - The car was equipped with an air bag at that seat position (as inferred by analysis of the VIN); the occupant was not using belts (as evidenced by MAN_REST or REST_USE = 0). Since FARS will not reliably indicate if the air bag deployed, all unbelted occupants of these vehicles are classified as “air bag alone” regardless of whether or not the air bag deployed.

- Air bag plus lap/shoulder belted - The car was equipped with an air bag at that seat position and it was equipped with manual or automatic lap/shoulder belts (as inferred by analysis of the VIN); the occupant was belted (as evidenced by MAN_REST or REST_USE = 1, 2, 3, 8, or AUT_REST = 1 in calendar year 1988-89). Again, since FARS will not reliably indicate if the air bag deployed, all belted occupants of these vehicles are classified as “air bag plus lap/shoulder belted” regardless of whether or not the air bag deployed.

For the back seat occupants, restraint use and restraint type available were reported in 3 categories:

- Unrestrained - The occupant was not using belts (as evidenced by MAN_REST or REST_USE = 0)

- Lap belted - The car was equipped with a lap belt at that seat position (as inferred by analysis of the VIN); the occupant was belted (as evidenced by MAN_REST or REST_USE = 1, 2, 3, or 8)

- Lap/shoulder belted - The car was equipped with a lap/shoulder belt at that seat position (as inferred by analysis of the VIN); the occupant was belted (as evidenced by MAN_REST or REST_USE = 1, 2, 3, or 8)

Other FARS restraint use codes such as “unknown” were excluded from the analysis, i.e., “unknown” restraint use by at least one of the occupants in the paired-occupant record causes the paired-occupant record to be excluded.

2.2 ANALYSIS USING THE ENTIRE DATA SET

Individual comparisons can be summarized in tabular form, as in the following example of 4,410 paired-occupant records where the front seat occupant was lap/shoulder belted, the back seat occupant was unrestrained, and at least one of them was killed:

	N of FARS Cases
Front seat occupant died, back seat occupant survived	1,382
Back seat occupant died, front seat occupant survived	2,312
Both died	716

Thus, there was a total of 2,312 + 716 = 3,028 unrestrained back seat occupants who died in those cases and 1,382 + 716 = 2,098 lap/shoulder belted front seat occupants who died. The risk factor for unrestrained back seat occupants (relative to lap/shoulder belted front seat occupants) is 3,028 / 2,098 = 1.443.

For lap belted back seat occupants accompanied by lap/shoulder belted front seat occupants, the comparable tabulation is:

	N of FARS Cases
Front seat occupant died, back seat occupant survived	804
Back seat occupant died, front seat occupant survived	860
Both died	275

Here, there were 860 + 275 = 1,135 fatally injured back seat occupants and 804 + 275 = 1,079 fatally injured front seat occupants. The risk factor for lap belted back seat occupants (again, relative to the control group of lap/shoulder belted front seat occupants) is 1,135 / 1,079 = 1.052. With the plausible assumption that the two control groups of lap/shoulder belted front seat occupants are subject to about equal risk, the probability of fatality is 1 - (1.052 / 1.443) = 27 percent lower for lap belted back seat occupants than unrestrained back seat occupants.

The preceding can be repeated for lap/shoulder belted back seat occupants accompanied by lap/shoulder belted front seat occupants.

	N of FARS Cases
Front seat occupant died, back seat occupant survived	674
Back seat occupant died, front seat occupant survived	601
Both died	206
Relative Risk	807 / 880 = 0.917

The same assumption that the two control groups of lap/shoulder belted front seat occupants are equal still applies, so the probability of fatality is 1 - (0.917 / 1.443) = 36 percent lower for lap/shoulder belted back seat occupants than unrestrained back seat occupants. In other words, the lap/shoulder belt shows a higher effectiveness (36 percent) than the lap belt alone (27 percent).

Table 2-1 includes the preceding calculations and carries out four more: for “unrestrained,” “2-point belted,” “air bag alone,” and “air bag plus lap/shoulder belted” front seat outboard occupants as control groups. However, none of these four groups includes anywhere near as many cases of belted back seat occupants as the preceding group.

We found a similar distribution of crash modes between lap and lap/shoulder belts. The percentage of front seat fatalities by crash mode is consistent across lap and lap/shoulder belts. If the distribution of crash modes across lap and lap/shoulder belts was inconsistent then the effectiveness estimate for lap belts and lap/shoulder belts would not be comparable.

TABLE 2-1 FARS 1988- FIRST 6 MONTHS OF 1997 EFFECTIVENESS OF ALL BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS RELATIVE TO BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE AND RESTRAINT TYPE					
Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities	Risk Factor	Fatality Reduction
Unrestrained	3,028	Lap/shoulder belted	2,098	1.443	
Lap belted	1,135		1,079	1.052	27%
Lap/shoulder belted	807		880	0.917	36%
Unrestrained	4,953	Unrestrained	7,248	0.683	
Lap belted	161		471	0.342	50%
Lap/shoulder belted	119		344	0.346	49%
Unrestrained	1,016	2 pt. belted	818	1.242	
Lap belted	89		133	0.669	46%
Lap/shoulder belted	403		603	0.668	46%
Unrestrained	650	Air bag alone	820	0.793	
Lap belted	0		1		
Lap/shoulder belted	49		148	0.331	58%
Unrestrained	670	Air bag plus lap/shoulder belted	371	1.806	
Lap belted	3		2		
Lap/shoulder belted	431		490	0.880	51%
Weighted average for lap belted vs. unrestrained back seat outboard occupants:					32%
Weighted average for lap/shoulder belted vs. unrestrained back seat outboard occupants:					44%

* "Double pair comparison" method relative to front seat outboard occupants.

When unrestrained front seat occupants are the control group, lap belted back seat occupants have 50 percent lower fatality risk than the unrestrained back seat occupants and lap/shoulder belted back seat occupants have 49 percent lower fatality risk than unrestrained back seat occupants. When 2-point belted front seat occupants are the control group, lap belted and lap/shoulder belted back seat occupants each have 46 percent lower fatality risk than unrestrained back seat occupants. The fatality reductions for lap belted back seat occupants for air bag alone and air bag plus lap/shoulder belted control groups are not calculated because the cell sizes are very small. This is expected, since most passenger cars that are equipped with air bags are model year 1990 or later and therefore are also equipped with lap/shoulder belts in the back outboard seating positions. The resulting fatality reduction estimates in the air bag alone and air bag plus lap/shoulder belted control groups are 58 percent and 51 percent, respectively, for lap/shoulder belted relative to unrestrained back seat occupants.

2.3 OVERALL EFFECTIVENESS

The overall effectiveness of lap/shoulder belts in back outboard seats is calculated using a weighted average of the five fatality reduction estimates. This allows the estimates based on larger number of belted back seat occupant fatalities to be given proportionately greater weight. The numerator is the actual number of back seat lap/shoulder belt fatalities. The denominator is the number that would have occurred if these occupants had been unrestrained, based on the risk factors in Table 2-1. The overall effectiveness for lap/shoulder belts in back outboard seats is

$$1 - \left[\frac{807 + 119 + 403 + 49 + 431}{807(1.443/.917) + 119(.683/.346) + 403(1.242/.668) + 49(.793/.331) + 431(1.806/.880)} \right] = 44\%$$

Forty-four percent is within the 36 to 58 percent range of the five individual estimates, and it is closer to the 36 percent because the largest sample of 807 back seat occupant fatalities is used to calculate the fatality reduction in the lap/shoulder belted control group.

The weighted average of the three fatality reduction estimates for lap belts in back outboard seats (excluding the air bag ones because of small sample size) is

$$1 - \left[\frac{1{,}135 + 161 + 89}{1{,}135(1.443/1.052) + 161(.683/.342) + 89(1.242/.669)} \right] = 32\%$$

Again, within the 27 to 50 percent range and closer to the low end because the largest sample yielded the lowest fatality reduction estimate.

Another important finding in Table 2-1 is that the back seat is substantially safer than the front seat. The second section of Table 2-1 shows that there were only 4,953 back seat fatalities and 7,248 front seat fatalities where both the front and the back seat occupants were unrestrained. In other words, an unrestrained back seat occupant has 32 percent (1 - .683) lower fatality risk than an unrestrained front seat occupant (without controlling for the age, sex, etc. of these occupants). Line 10 of Table 2-1 shows that an unbelted back seat occupant is safer than an unbelted front seat occupant even when the front seat occupant was protected by an air bag and the back seat occupant was not. Here there were 650 back seat occupant fatalities and 820 front seat occupant fatalities.

Table 2-1 also shows that a lap belted back seat occupant, although much safer than an unrestrained or 2-point belted front seat occupant, is nevertheless slightly less safe than a lap/shoulder belted front seat occupant. Line 2 shows that there were 1,135 back seat fatalities and 1,079 front seat fatalities. Thus, in a car equipped with 3-point belts in the front seat but only lap belts in the back, the belt user's choice of whether to sit in the front or the back seat is nearly a toss-up, with perhaps a slight safety advantage for the front seat.

A lap/shoulder belted back seat occupant, on the other hand, is more safe than any front seat occupant no matter what restraint type was available and used. The lap/shoulder belted back seat occupant is much safer than an unrestrained, "air bag alone," or 2-point belted front seat occupant. They are also safer than a lap/shoulder belted front seat occupant. Line 3 shows that there were 807 lap/shoulder belted back seat fatalities and 880 lap/shoulder belted front seat fatalities. This means if a car is equipped with lap/shoulder belts in the back seat, the safety-conscious belt user should choose to ride in a back outboard seat over the front seat.

This is even true for cars equipped with air bags. There were 431 lap/shoulder belted back seat fatalities and 490 lap/shoulder belted front seat fatalities even when the front seat occupant was also protected by an air bag. A lap/shoulder belted back seat occupant has a 12 percent (1 - .880) lower fatality risk than a lap/shoulder belted front seat occupant also protected by an air bag. Therefore, in cars equipped with front seat air bags and back seat lap/shoulder belts, belt users maximize their safety by sitting in the back outboard seats rather then the front outboard seats.

2.4 ANALYSIS LIMITED TO "MATCHING" MAKE-MODELS

One important caveat with the preceding analysis is that cars equipped with back seat lap/shoulder belts are primarily newer vehicles (model year 1990 or later) whereas cars with lap belts only are older vehicles. The vehicle age difference could potentially bias the analysis for reasons such as:

- The older cars are not the same make/models as the newer cars
- The older cars are involved in different types of crashes than the newer ones
- The older cars may have younger drivers than the newer ones
- The newer cars may include equipment such as Antilock Brake Systems (ABS) not available on older cars.

It is not clear that any of these factors would be likely to bias the results either in favor or against lap/shoulder belts, especially in view of the fact that double-pair comparison is sort of a "self-controlling" analysis (since many potential biases would apply equally to the population at interest and the control group). Nevertheless, a potential for unknown biases still exists. In order to control for possible vehicle age effects, the analysis was limited to a set of matching make/models produced 3 model years before and after the transition from lap to lap/shoulder belts. Specifically

- Make/models that did not exist before model year 1990, or were discontinued before switching to lap/shoulder belts were excluded.

- The transition to lap/shoulder belts took place in model year 1987, 1988, 1989, or 1990.

- Lap/shoulder belts were not available as an option in the model years before they became standard.

- The make/model did not get ABS at the same time it got lap/shoulder belts.

- The analysis includes at most 3 model years before and after the transition to back seat lap/shoulder belts and in some cases limited it to ± 2 model years or only ± 1 model year depending when the make/model was redesigned or was equipped with ABS.

A redesigned car is a car whose wheelbase changed from one production year to the next. A redesigned car usually also receives a major body restyling, changes to the engine, suspension, interior, and/or the latest safety equipment. Minor body restyling or new equipment options are not counted as "redesigns."

Studies have shown that ABS can have either a positive or a negative effect on fatal crashes depending on the crash type[22]. Make/models that changed ABS status near the transition year the make/model received back seat lap/shoulder belts were excluded to eliminate any effect ABS had on fatal crashes involving these cars. For a complete list of cars and model year ranges included in the "matching" analysis, see Appendix A.

Table 2-2 shows the fatality risk for back seat outboard occupants by restraint usage and type for "matching" make/models. Table 2-2 shows the same general findings that Table 2-1 showed:

- an unrestrained back seat occupant is much safer than an unrestrained front seat occupant;

- an unrestrained back seat occupant is safer than an "air bag alone" restrained front seat occupant;

- a lap belted back seat occupant is slightly less safe than a lap/shoulder belted front seat occupant; and,

- a lap/shoulder belted back seat occupant is more safe than any front seat occupant no matter what restraint type available and used. A lap/shoulder belted back seat occupant is even slightly safer than an air bag plus lap/shoulder belted front seat occupant.

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[22]Kahane, C., *Preliminary Evaluation of the Effectiveness of Antilock Brake Systems for Passenger Cars*, NHTSA Technical Report No. DOT HS 808 206, Washington, DC, 1994.

TABLE 2-2 FARS 1988-FIRST 6 MONTHS OF 1997 EFFECTIVENESS OF "MATCHING MAKE/MODELS" BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE AND RESTRAINT TYPE					
Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities	Risk Factor	Fatality Reduction
Unrestrained	1,710	Lap/shoulder belted	1,173	1.458	
Lap belted	661		600	1.102	24%
Lap/shoulder belted	395		400	0.988	32%
Unrestrained	2,843	Unrestrained	4,142	0.686	
Lap belted	96		289	0.332	52%
Lap/shoulder belted	65		174	0.374	46%
Unrestrained	593	2 pt. belted	468	1.267	
Lap belted	89		132	0.674	47%
Lap/shoulder belted	195		288	0.677	47%
Unrestrained	79	Air bag alone	121	0.653	
Lap belted	0		1		
Lap/shoulder belted	5		10	0.500	23%
Unrestrained	61	Air bag plus lap/shoulder belted	39	1.564	
Lap belted	3		2		
Lap/shoulder belted	33		35	0.943	40%
Weighted average for lap belted vs. unrestrained back seat outboard occupants:					32%
Weighted average for lap/shoulder belted vs. unrestrained back seat outboard occupants:					39%

* "Double pair comparison" method relative to front seat outboard occupants.

Table 2-3 shows the fatality reduction estimates for the "all make/models" and the "matching make/models" analyses by restraint usage and restraint type. The estimates for the "all make/models" analysis are copied from Table 2-1.

TABLE 2-3
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND
LAP/SHOULDER BELTS RELATIVE TO
UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS *
BY RESTRAINT USAGE, RESTRAINT TYPE, AND ANALYSIS TYPE

Back Seat Restraint Use	Front Seat Restraint Use	Fatality Reduction "All make/models"	Fatality Reduction "Matching make/models"
Lap belted	Lap/shoulder belted	27%	24%
Lap/shoulder belted		36%	32%
Lap belted	Unrestrained	50%	52%
Lap/shoulder belted		49%	46%
Lap belted	2 pt. belted	46%	47%
Lap/shoulder belted		46%	47%
Lap/shoulder belted	Air bag alone	58%	23%
Lap/shoulder belted	Air bag plus lap/shoulder belted	51%	40%
Weighted average for lap belted vs. unrestrained back seat outboard occupants:		**32%**	**32%**
Weighted average for lap/shoulder belted vs. unrestrained back seat outboard occupants:		**44%**	**39%**

* "Double pair comparison" method relative to front seat outboard occupants.

The fatality reduction estimates in the "matching" and "all make/models" analyses are similar in the first three front seat occupant control groups. In the lap/shoulder belted, unrestrained, and 2-point belted front seat occupant control groups, the fatality reduction difference between the "matching make/models" and "all make/models" analyses is less than 5 percentage points. This is true for both the lap belted fatality reduction estimates and the lap/shoulder belted fatality reduction estimates. The other major similarity between the two analyses is the overall effectiveness for lap belted back seat occupants is 32 percent in both the "matching make/models" and "all make/models" analyses.

The most notable difference between the two analyses is the average effectiveness for lap/shoulder belted back seat occupants. In the "all make/models" analysis, the effectiveness is 44 percent, but the effectiveness drops to 39 percent in the "matching make/models" analysis.

Another difference between the two analyses is the consistently lower lap/shoulder belt effectiveness estimates and higher risk factors in the "matching make/models" analysis compared to the "all make/models" analysis results. Only the 2-point belted control group in the "matching make/models" analysis produces a fatality reduction estimate equal to or greater than the "all make/models" analysis estimates. In the unrestrained and lap/shoulder belted control groups, the "matching make/models" fatality reduction estimates are only a few percentage points lower than the "all make/models" estimates. But in the air bag alone and air bag plus lap/shoulder belted groups, the estimates are considerable lower (although the sample size for these analyses is quite small in the "matching" make/models).

2.4.1 Confidence Bounds

A jackknife procedure is used to obtain confidence intervals for the estimates of effectiveness and to test hypotheses. The procedure is described step-by-step in this section. This relatively complicated procedure was used because simpler formulas based on p * q / n will not work -- partly because the numbers in Table 2-1 and 2-2 are not counts of independent observations (since the cases were double-counted), and partly because the effectiveness estimator is a weighted average of ratios, not a simple rate.

Even so, a still relatively simple procedure might have estimated the variance as follows: order all the FARS cases by calendar year and case number (ST_CASE), split the FARS sample into 10 groups according to the last digit of the case number (ST_CASE), and estimate the effectiveness separately within each of the 10 subsamples. This gives 10 independent estimates of effectiveness, $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_{10}$, each based on a tenth of the FARS cases. Let

$$\bar{e} = \frac{\sum_{1}^{10} e_i}{10} \qquad\qquad s^2 = \frac{\sum_{1}^{10} \left(\bar{e} - e_i\right)^2}{9}$$

Then s^2 is an estimate of the variance of effectiveness based on a tenth of the FARS cases. The variance of the effectiveness using all of FARS is $s^2 / 10$.

Unfortunately, this approach is not advisable. It requires estimating effectiveness separately for each tenth of the FARS cases. A tenth of the FARS cases is so sparse a sample that it might result in some of the cells of Table 2-1 or 2-2 having zero cases, making it impossible to apply the effectiveness estimator developed in the preceding section.

The jackknife procedure circumvents that problem. Instead of effectiveness being calculated for one tenth of the FARS cases, it is computed for the nine tenths of the FARS cases that remain after removing a tenth of the file. Nine tenths of FARS does contain enough cases to apply the effectiveness estimator developed above. Let $\varepsilon_{(1)}, \varepsilon_{(2)}, \ldots, \varepsilon_{(10)}$ be the estimates of effectiveness, each based on 9/10 of FARS, i.e., all of FARS except the 1st, 2nd, . . ., 10th subsample, respectively. Let ε = 32 % be the effectiveness estimate based on all FARS (i.e., the effectiveness of lap belts in back outboard seats in the "all make/models" analysis, calculated in Section 2.3). Let

$$e_{*i} = 10e - 9e_{(i)}$$

Then ε_{*I} is a surrogate for ε_i, the effectiveness within the removed tenth of FARS: ε_{*I} is called a pseudoestimate of ε_i.

Let $$\overline{e_*} = \frac{\sum_1^{10} e_{*i}}{10} \qquad s^2 = \frac{\sum_1^{10} \left(e_{*i} - \overline{e_*}\right)^2}{9}$$

Then s^2 / 10 is an approximation to the variance of the effectiveness using all of FARS. It is called a **jackknife estimate of variance.**

A slightly different jackknife procedure will be used here. Recall the effectiveness, ε, is a ratio of ratios. It has some undesirable properties: above all, it has a skewed sampling distribution. The literature suggests that, rather than jackknifing the ratio directly, it is better to separately jackknife the numerators and denominators of ε[23].

The effectiveness estimate calculated in Section 2.3 was based on two quantities x and y, viz.,

$$e = 1 - \frac{y}{x} = 1 - \frac{1{,}135 + 161 + 89}{1{,}135\left(\frac{1.443}{1.052}\right) + 161\left(\frac{0.683}{0.342}\right) + 89\left(\frac{1.242}{0.669}\right)} = 1 - \frac{1{,}385}{2{,}044.4} = 32\%$$

(2,044.4 is the exact number. Calculating x in the above equation will not produce 2,044.4 because the risk factors were rounded to the nearest 1/1,000.)

y is the number of lap belted back seat outboard fatalities in FARS and x is the number of back seat outboard fatalities that would have occurred if these occupants had been unrestrained.

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[23]Mosteller, F., & Tukey, J. W., Data Analysis and Regression: A Second Course in Statistics, Addison-Wesley, Reading, MA, 1977.

The analogous quantities $x_{(I)}$ and $y_{(I)}$ can be estimated from the various nine-tenths of the FARS cases. The estimates are shown in the 2nd and 3rd columns of Table 2-4. They were obtained as follows: The FARS cases that had paired-occupant records where at least one of the occupants died were numbered consecutively in the order they appeared on the original FARS file. The cases whose identification number (ST_CASE) ends with the digit I were removed, where I is an integer between 0 and 9.

It is important to note that case numbering was done at the **crash level** (by ST_CASE), not at the vehicle or occupant level. In other words, all of the paired-occupant records generated from a single crash case were either included or were excluded from the one-tenth subset removed. This ensures that two or more paired-occupant records generated from a single crash case (e.g. due to double counting) are not separated from one another. The crash level numbering guarantees the removed one-tenth subsets are independent from one another.

TABLE 2-4
ESTIMATES AND PSEUDOESTIMATES OF THE NUMBER
OF BACK SEAT FATALITIES IN "ALL MAKE/MODELS" FOR JACKKNIFE
PROCEDURE IN WHICH TENTHS OF FARS CASES ARE REMOVED

All FARS cases except those with Case ID ending in	Observed number of lap belted back seat fatalities $y_{(I)}$	Expected number of unrestrained back seat fatalities $x_{(I)}$	Only those FARS cases with Case Id ending in	Pseudo estimate of number of fatalities	
				$y_{*I} = 1385 - y_{(I)}$	$x_{*I} = 2044.4 - x_{(I)}$
1	1,234	1903.6	1	151	140.8
2	1,252	1823.7	2	133	220.7
3	1,256	1816.6	3	130	227.8
4	1,238	1872.8	4	147	171.6
5	1,219	1895.9	5	166	148.5
6	1,251	1788.9	6	135	255.5
7	1,241	1836.5	7	144	207.9
8	1,262	1831.3	8	123	213.1
9	1,257	1794.1	9	128	250.3
0	1,255	1840.4	0	131	204.0
All FARS cases	1,385	2044.4			

The remaining cases, which constitute 9/10 of the FARS cases considered for the "all make/models" analysis, were cross-classified by back seat and front seat restraint usage and outboard fatalities, precisely as the data in Table 2-1. The total number of lap belted back seat outboard fatalities was summed across all the front seat restraint usage groups to yield $y_{(I)}$, the observed number of lap belted back seat fatalities. The $x_{(I),}$ the expected number of back seat fatalities if the back seat occupants were unrestrained, was calculated.

The next task is to obtain the pseudo estimates x_{*I} and y_{*I} by subtracting the respective estimates for 9/10 of the sample from the estimates from the full sample. These pseudo estimates are surrogates for the results that would have been obtained if only the removed tenth of the sampled had been used for the calculations.

$$x_{*i} = x - x_i = 2044.4 - x_{(i)}$$
$$y_{*i} = y - y_i = 1385 - y_{(i)}$$

The 10 values of x_{*I} and y_{*I} are shown in the 5th and 6th columns of Table 2-4. In 8 out of 10 cases, x_{*I} is larger than y_{*I} (often much larger) – suggesting that lap belts save lives. These values are used to calculate:

$$x_* = \sum_1^{10} x_{*i} = 2040.1 \qquad y_* = \sum_1^{10} y_i = 1385$$

$$s_x = \left(\frac{10\sum_1^{10} x_{*i}^2 - x_*^2}{9} \right)^{1/2} = 124.11 \qquad s_y = \left(\frac{10\sum_1^{10} y_{*i}^2 - y_*^2}{9} \right)^{1/2} = 41.88$$

Let Y be the variate corresponding to the numbers of lap belted back seat outboard fatalities that would have occurred among conceptual replications of the full FARS sample used for this analysis. The theory behind the jackknife procedure postulates that $(Y - y_*) / s_y$ is well approximated by a t distribution with 9 degrees of freedom (df).

Similarly, let the variate X be the numbers of back seat outboard fatalities that would have occurred if the back seat outboard occupants had been unrestrained among conceptual replications of our full sample. $(X - x_*) / s_x$ is approximately t distributed with 9 df.

The effectiveness $E = \left(1 - \frac{Y}{X}\right)\%$ is the ratio of 2 t distributions with 9 df each, several times multiplied by and subtracted from a constant.

The 90 percent confidence bounds for E (i.e., with á = .05 on each side) are obtained by solving the following quadratic equation for è:

$$1.833 = \frac{y_* - x_* q}{\sqrt{\left(s_y^2 + (s_x q)^2\right)}} .$$

The quadratic equation has two roots, è$_1$ = 0.7729 and è$_2$ = 0.6019. Using these two roots of è to solve for $E = (1 - q)\%$ gives the upper and lower confidence bounds for E.

With è$_1$ = 0.7729, the lower confidence bound for the effectiveness of back seat outboard lap belts is 23 percent. And with è$_2$ = 0.6019 the upper confidence bound is 40 percent.

The use of 90 percent confidence bounds (á = .05 on each side) is customary in NHTSA's evaluations of safety standards. The formula for the confidence bounds is derived from[24], pp. 125-6.

The null hypothesis that the effectiveness is zero can be tested by computing

$$\frac{y_* - x_*}{\sqrt{s_y^2 + s_x^2}} = -5.00$$

If the null hypothesis were true, the above quantity would be an observation from a t distribution with 9 df. Since the observed value of -5.00 is in the critical region of that distribution (á = .05), the null hypothesis is rejected. Effectiveness is significantly greater than zero.

Table 2-5 shows the confidence bounds, effectiveness estimates, and t test values for lap belt effectiveness in the "all make/models" and the "matching make/models" analyses.

TABLE 2-5
EFFECTIVENESS, CONFIDENCE BOUNDS AND T TEST VALUES OF BACK SEAT LAP BELTS RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS * BY ANALYSIS TYPE

	Lower Bound	Estimate	Upper Bound	t Test
"All make/models"	**23%**	**32%**	**40%**	**- 5.00**
"Matching make/models"	**20%**	**32%**	**42%**	**- 4.35**

* "Double pair comparison" method relative to front seat outboard occupants.

The analyses yield identical point estimates. Back seat lap belts are 32 percent effective in reducing fatalities when compared to unrestrained back seat occupants. Both estimates are statistically significant, as evidenced by the strong t test values.

[24]Kendall, M.G., & Stewart, A., The Advanced Theory of Statistics, 2nd ed., Vol. 2, Charles Griffin, London, 1967, pp. 125-6.

A similar jackknife procedure is used to derive confidence bounds for the effectiveness of lap/shoulder belts. Table 2-6 shows the confidence bounds, effectiveness estimates, and t test values for lap/shoulder belted occupants vs. unrestrained back seat occupants.

Lap/shoulder belt effectiveness is significantly greater than zero in both the "all make/models" and the "matching make/models" since the t test results are -8.56 and -7.29, respectively. The difference between the "all make/models" and the "matching make/models" point estimates, 44 vs. 39 percent, is well within the "noise range" as indicated by the confidence bounds for either estimate.

TABLE 2-6
EFFECTIVENESS, CONFIDENCE BOUNDS AND T TEST VALUES OF BACK SEAT LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED BACK SEAT OCCUPANTS * BY ANALYSIS TYPE

	Lower Bound	Estimate	Upper Bound	t Test
"All make/models"	**38%**	**44%**	**50%**	**-8.56**
"Matching make/models"	**30%**	**39%**	**46%**	**-7.29**

* "Double pair comparison" method relative to front seat outboard occupants.

2.5 LAP/SHOULDER BELT EFFECTIVENESS VS. LAP BELT ONLY

The preceding analyses provide strong evidence that both lap belts and lap/shoulder belts are significantly safer than being unrestrained. Since we are evaluating a regulation that replaced lap belts with lap/shoulder belts, the ultimate analytic goal is to compare lap/shoulder belts and lap belts directly, not to compare both of them to being unrestrained. Are back seat lap/shoulder belts significantly safer than lap belts? We have seen that back seat lap belts are 32 percent effective in reducing fatalities relative to unrestrained back seat occupants. Back seat lap/shoulder belts are 39 - 44 percent effective in reducing fatalities relative to unrestrained back seat occupants. This hints that back seat lap/shoulder belts may be safer than lap belts. But it does not answer the direct questions: How much safer are lap/shoulder belts than lap belts? Is that difference significant?

The calculation of lap/shoulder belt effectiveness relative to lap belts ought to be similar to the calculation of lap/shoulder belt effectiveness relative to unrestrained occupants. The same equations would be used. The only difference would be that lap belted fatalities are substituted in the equations for unrestrained fatalities. The fatality reduction for lap/shoulder belted back seat occupants relative to lap belted back seat occupants is

1 - (risk of lap/shoulder belted fatalities / risk of lap belted fatalities).

Ideally, one should calculate the fatality reduction for back seat lap/shoulder belts relative to lap belts for each of the five control groups of front seat occupants, using the data in Table 2-1: lap/shoulder belted, unrestrained, 2-point belted, air bag alone, and air bag plus lap/shoulder belted. But Table 2-1 shows that the cell size of lap belted fatalities is very small in air bag alone and air bag plus lap shoulder belted control groups. Newer model year cars that are equipped with air bags are usually equipped with back seat outboard lap/shoulder belts, not lap belts. In fact, in the air bag alone control group, the risk factor for lap belted back seat occupants would come out zero because there are zero lap belted back seat fatalities. It would be unwise to directly use the data for all five control groups in Table 2-1.

Another approach would be to calculate the effectiveness of lap/shoulder belts vs. lap belts using only three control groups that had an adequate sample size: lap/shoulder belted, unrestrained, and 2-point belted front seat occupants. But eliminating the air bag control groups from the lap/shoulder belt effectiveness estimates vs. lap belts would be throwing away a substantial portion of the data on lap/shoulder belted back seat occupants. It could also bias the results, because the effectiveness of lap/shoulder belts may be different in cars equipped with air bags (newer model year cars) from cars without air bags (older model year cars). Thus, eliminating the air bag control groups in this analysis would eliminate the newer model year cars, and could bias our results.

To produce unbiased results and avoid throwing away data, we included the cases where an air bag protected the front seat occupant by "transforming" them into non-air bag fatality counts and adding them to the non-air bag control groups. To do this, we used results from NHTSA's *Fatality Reduction by Air Bags*[25] report. The report concludes for passenger cars:

- air bags are about 13 percent effective in reducing fatalities for unbelted drivers and FR passengers in all crashes, and

- air bags are about 9 percent effective in reducing fatalities for belted drivers and FR passengers in all crashes.

In other words, each unbelted front seat fatality with an air bag corresponds to 1/(1 - 13%) unbelted fatalities without air bags. And each belted front seat fatality with an air bag corresponds to 1/(1 - 9%) belted fatalities without air bags.

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[25]Kahane, C., *Fatality Reduction by Air Bags*, NHTSA Technical Report No. DOT HS 808 470, Washington, DC, 1996.

Below are line 6 and line 12 from Table 2-1:

Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities
Lap/shoulder belted	119	Unrestrained	344
Lap/shoulder belted	49	Air bag alone	148

There were 148 front seat fatalities when the front seat occupant had an air bag but was unbelted and the back seat occupant was lap/shoulder belted. There would have been 148 * 1/(1 - 13%) = 170.1 unbelted front seat fatalities if those unbelted front seat outboard occupants had not been protected by air bags. Therefore, there would have been 344 + 170.1 = 514.1 total unrestrained front seat fatalities, when the back seat occupant was lap/shoulder belted, if air bags did not exist.

Since front seat air bags do not protect back seat occupants, the number of back seat fatalities would have remained the same if the air bag had not been available. Therefore, there are 119 + 49 = 168 lap/shoulder belted back seat fatalities regardless of whether the front seat occupant is unrestrained or “air bag alone” restrained. The risk factor for lap/shoulder belted back seat occupants (relative to unrestrained front seat occupants) is 168 / 514.1 = 0.327.

Below are line 3 and line 15 from Table 2-1:

Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities
Lap/shoulder belted	807	Lap/shoulder belted	880
Lap/shoulder belted	431	Air bag plus lap/shoulder belted	490

There are 490 lap/shoulder belted front seat fatalities when an air bag was present and the back seat occupant was lap/shoulder belted. This number would have increased to 490 * 1/(1 - 9%) = 538.5 lap/shoulder belted front seat fatalities if air bags had not been available. Since there are 880 actual lap/shoulder belted front seat fatalities when the back seat occupant is lap/shoulder belted, there would have been 880 + 538.5 = 1,418.5 total lap/shoulder belted front seat fatalities when the back seat occupant is lap/shoulder belted, if air bags did not exist.

There are 807 + 431 = 1,238 lap/shoulder belted back seat fatalities, regardless of whether the front seat occupant was protected by an air bag, since front seat air bags do not protect back seat occupants. The risk factor for lap/shoulder belted back seat occupants (relative to lap/shoulder belted front seat occupants) is 1,238 / 1,418.5 = 0.873.

Table 2-7 includes the preceding calculations and carries out similar ones when the back seat occupant is lap belted. Columns 1, 2, 4, and 5 of Table 2-7 are copied from Table 2-1. Column 3 is the adjusted number of back seat fatalities regardless of whether the front seat had an air bag or not. Column 6 shows the number of front seat fatalities if the air bag was not available in the air bag control groups and column 7 shows the adjusted number of front seat fatalities. The number of front and back seat fatalities when the front seat occupant is 2-point belted remains the same since this control group does not include any cars equipped with air bags.

Column 9 shows the fatality reduction in the three control groups and the overall effectiveness of lap/shoulder belts vs. lap belts. Assuming the two control groups of lap/shoulder belted front seat occupants are subject to about equal risk, the probability of fatality is 1 - (0.873 / 1.053) = 17 percent lower for lap/shoulder belted back seat occupants than lap belted back seat occupants. When a similar calculation is done for the unrestrained front seat control group, the fatality reduction for lap/shoulder belted occupant vs. lap belted is 4 percent. But in the 2-point belted group, there does not appear to be any fatality reduction for lap/shoulder belted vs. lap/belted back seat occupants.

TABLE 2-7
FARS 1988- FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS RELATIVE TO
LAP BELTED BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE
AND RESTRAINT TYPE FOR "ALL MAKE/MODELS"

Back Seat Restraint Use	Actual Back Seat Fatalities	Adjusted Back Seat Fatalities	Front Seat Restraint Use	Actual Front Seat Fatalities	Air Bag Adjustment FS Fatalities	Adjusted Front Seat Fatalities	Risk Factor	Fatality Reduction
Lap belted	1,135	1,138	Lap/shoulder belted	1,079		1,081.2	1.053	17%
Lap/shoulder belted	807	1,238		880		1,418.5	0.873	
Lap belted	161	161	Unrestrained	471		472.1	0.341	4%
Lap/shoulder belted	119	168		344		514.1	0.327	
Lap belted	89	89	2 pt. belted	133		133	0.669	0%
Lap/shoulder belted	403	403		603		603	0.668	
Lap belted	0		Air bag alone	1	1.1			
Lap/shoulder belted	49			148	170.1			
Lap belted	3		Air bag plus lap/shoulder belted	2	2.2			
Lap/shoulder belted	431			490	538.5			
Weighted average for lap/shoulder belted vs. lap belted back seat outboard occupants:								**15%**

* "Double pair comparison" method relative to front seat outboard occupants.

Using the weighted average of the three fatality reduction estimates, the overall effectiveness of lap/shoulder belts vs. lap belts in back outboard seats is

$$1 - \left[\frac{1{,}138(0.873/1.053) + 161(0.327/0.341) + 89(0.668/0.669)}{1{,}138 + 161 + 89} \right] = 15\%.$$

Using the same jackknife procedure as Section 2.4.1, we calculated the lower and upper bounds for the effectiveness of back seat lap/shoulder belts vs. lap belts and tested the null hypothesis. Table 2-8 shows the results. Back seat lap/shoulder belts are between 5 and 25 percent effective in reducing fatalities when compared to back seat lap belts. T test results are 2.72. This is statistically significant. So we reject the null hypothesis and conclude that lap/shoulder belts are significantly more beneficial than lap belts alone.

TABLE 2-8
EFFECTIVENESS, CONFIDENCE BOUNDS, AND T TEST VALUE OF BACK SEAT LAP/SHOULDER BELTS RELATIVE TO LAP BELTED BACK SEAT OUTBOARD OCCUPANTS *
FOR "ALL MAKE/MODELS"

	Lower Bound	Estimate	Upper Bound	t Test
Effectiveness	**5%**	**15%**	**25%**	**2.72**

* "Double pair comparison" method relative to front seat outboard occupants.

2.6 LIVES SAVED PER YEAR

The shift from lap belts to lap/shoulder belts saves lives because:

- Lap/shoulder belts are more effective than lap belts (44 vs. 32 percent), and
- Lap/shoulder belts have 7 to 10 percent higher use than lap belts, even after controlling for vehicle age.

During the "baseline" year 1996, there were 1,568 actual fatalities of back seat outboard occupants age 5 years or older, in passenger cars (call this N0). Some of those cars were equipped with lap belts, others with lap/shoulder belts. Some occupants were belted, others unrestrained. We are going to estimate the number of fatalities that would have occurred if:

- All occupants had been unrestrained (N1). N1 > N0.
- All cars had been equipped with lap belts only, at current lap belt use rates (N2). N1 > N2 > N0.

- All cars had been equipped with lap/shoulder belts, at current lap/shoulder belt use rates (N3). N1 > N2 > N0 > N3.

- The lives saved by the shift from lap belts to lap/shoulder belts: N2 - N3.

- Confidence bounds for these life-savings.

Given that lap belts in passenger cars reduce fatalities by 32 percent (Table 2-1), it is possible to infer, from the number of back seat outboard fatalities that have actually occurred in cars equipped with back seat lap belts, the number of fatalities that would have occurred if all back seat outboard occupants had been unrestrained. We can also calculate the number of back seat outboard fatalities than would have occurred if all back seat outboard occupant had been unrestrained in cars equipped with lap/shoulder belts. The combination of these two numbers gives fatalities in Potentially Fatal Crashes (PFC's).

In FARS 1996, there were N0 = 1,568 back seat outboard fatalities in passenger cars (occupants younger than 5 years are excluded). After distributing the unknowns, the number of fatalities by restraint use and restraint type is as follows:

	Lap belt equipped cars	Lap/shoulder belt equipped cars
Unrestrained	544.5	685
Belted	112.5	226
Total	657	911

Given that lap belts in passenger cars reduce fatalities by 32 percent (Table 2-1), the number of fatalities that would have occurred if all lap belted occupants had been unrestrained is 112.5/(1-.32) = 165.4. Thus, there would have been 544.5 + 165.4 = 710 back seat outboard fatalities in cars equipped with lap belts if all occupants had been unrestrained.

Similarly, we can calculate the number of fatalities in cars equipped with lap/shoulder belts if all occupants had been unrestrained. Since lap/shoulder belts reduce fatalities by 44 percent (Table 2-1) in passenger cars, the number of fatalities that would have occurred is 226/(1-.44) = 404 if all the lap/shoulder belted occupants had been unrestrained. There would have been 685 + 404 = 1,089 fatalities in cars equipped with lap/shoulder belts if all back seat outboard occupants had been unrestrained. Therefore, N1 = 710 + 1,089 = 1,799 fatalities if every person had been unrestrained (PFC's).

To calculate lives saved, we must first calculate back seat outboard belt use if all passenger cars were equipped with lap belts and back seat outboard belt use if all cars were equipped with lap/shoulder belts. These use rates are not the same as the actual belt use in the 1996 FARS because belt use rates are affected by vehicle age and the actual fleet is a combination of newer model year, lap/shoulder belt equipped cars and older model year, lap belt equipped cars.

Let u_1 equal the belt use by back seat outboard occupants in cars equipped with lap belts and u_2 equal the belt use by back seat outboard occupants in cars equipped with lap/shoulder belts. From Section 1.2.2, we know that belt use by back seat occupants is 8.5 percent higher (the midpoint of the two estimates, 7 and 10 percent) in cars equipped with lap/shoulder belts than those equipped with lap belts after controlling for vehicle age and calendar year ($u_2 = u_1 + .085$). We also know that the weighted average of u_1 and u_2 is equal to the belt use in PFC's $\left(\frac{710u_1 + 1{,}089u_2}{710 + 1{,}089} = \frac{404 + 165.4}{710 + 1{,}089}\right)$. The solution to these equations is u_1 =.265 and u_2 =.35. So 26.5 percent of the back seat occupants in PFC's would have been belted in cars if all cars had been equipped with lap belts and 35 percent of the occupants would have been belted if all cars were equipped with lap/shoulder belts.

Next, we calculate N2, the number of back seat fatalities that would have occurred in a fleet of cars equipped with lap belts. Using u_1 = .265, there would have been 1,799 * .265 * (1-.32) = 324 back seat outboard fatalities when the occupants had been lap belted in a fleet of cars equipped with lap belts. There would have also been 1,799 * (1-.265) = 1,322 back seat outboard fatalities when the occupants had been unrestrained. Therefore, there would have been N2 = 324 + 1,322 = 1,646 fatalities in a fleet of passenger cars equipped with lap belts.

To calculate N3, the number of back seat fatalities that would have occurred in a fleet of cars equipped with lap/shoulder belts, we use u_2 = .35 and the effectiveness estimate for lap/shoulder belts. There would have been 1,799 * .35 * (1-.44) = 353 back seat outboard fatalities when the occupants had been lap/shoulder belted and 1,799 * (1-.35) = 1,169 fatalities when the occupants had been unrestrained. Therefore, there would have been N3 = 353 + 1,169 = 1,522 fatalities in a fleet of passenger cars equipped with lap/shoulder belts.

Finally, we calculate the lives saved by switching from a fleet of cars equipped with lap belts to a fleet of cars with lap/shoulder belts. The difference is N2 - N3 = 1,646 - 1,522 = 124 lives saved per year at 1996 belt use rates by switching to back seat lap/shoulder belts. This benefit is partly due to the higher use of lap/shoulder belts, partly because they are more effective when used.

Even if lap/shoulder belt equipped cars had the same belt use as lap belt equipped cars and their only advantage was higher effectiveness, then a fleet of passenger cars equipped with back seat lap/shoulder belts would still save more lives than a fleet equipped with lap belts. To calculate this, we assume $u_2 = u_1$ and solve the weight average belt use equation. The result is $u_2 = u_1$ = 32 percent.

Since lap belts are 32 percent effective in reducing fatalities and u_1 = 32 percent, then there would have been 1,799 * .32 * (1-.32) = 391 lap belted fatalities and 1,799 * (1-.32) = 1,223 unrestrained fatalities in a fleet of cars equipped with lap belts. There would have been 391 + 1,223 = 1,614 total fatalities in cars equipped with lap belts if back seat belt use is 32 percent. Since lap/shoulder belts are 44 percent effective and u_2 = 32 percent, there would only be

1,799[.32(1-.44) + (1-.32)] = 1,546 fatalities in a fleet of cars equipped with lap/shoulder belts. Therefore, if back seat belt use is the same in both lap and lap/shoulder belt equipped cars, then 1,614 - 1,546 = 68 fewer back seat fatalities occur in a fleet of passenger cars equipped with lap/shoulder belts than a fleet with lap belts.

Let us also calculate the potential life-savings if back seat belt use is 100 percent in cars equipped with lap/shoulder belts. Then the number of back seat fatalities in cars equipped with lap/shoulder belts would be 1,799 * (1-.44) = 1,007. This would save approximately 1,799-1,007 = 792 lives a year in PFC's. Or an additional 1,522-1,007 = 515 lives would be saved every year if back seat belt use increased from 35 percent (the estimated back seat outboard belt use in 1996) to 100 percent.

To calculate the confidence bounds around our estimate of 124 lives saved by the shift from lap to lap/shoulder belts, we must use the following:

- back seat fatalities in PFC's
- belt use in cars equipped with lap belts,
- the effectiveness of lap belts relative to unrestrained occupants,
- the effectiveness of lap/shoulder belts relative to lap belted occupants, and
- the effectiveness of lap/shoulder belts relative to unrestrained occupants.

For the lower bound, we assumed the smallest difference in belt use between lap/shoulder and lap belt equipped cars and the smallest lap/shoulder belt effectiveness estimate, but the highest lap belt effectiveness estimate. For the upper bound, we assumed the opposite; the largest difference in belt use and the largest lap/shoulder belt effectiveness estimate, but the smallest lap belt effectiveness estimate. The switch from a fleet of cars equipped with lap belts to a fleet of cars with lap/shoulder belts would have saved at least 63 lives using the lower bound assumptions and at most 180 lives using the upper bound assumptions. Therefore, a passenger car fleet entirely equipped with lap/shoulder belts will have approximately 124 fewer fatalities per year than a fleet equipped only with lap belts (confidence bounds: 63 to 180).

2.7 BELT EFFECTIVENESS BY TYPE OF CRASH

Studies have shown that the principal shortcoming of a lap belt, and the greatest potential benefit of switching to a lap/shoulder belt is in frontal collisions rather than in side or rear collisions. This makes sense intuitively. The primary effect of shoulder belts is the restriction of forward upper body movement. This type of motion is most likely to result from a frontal impact. In frontal crashes, the National Transportation Safety Board (NTSB) report[26] and Kahane's 1987[27] paper suggests that lap belts may offer little or no improvement over being unrestrained in the back seat.

The FARS variables, Most Harmful Event and Principal Point of Impact for the vehicle, were used to classify crashes into the following crash types:

- Rollover - Most harmful event for vehicle is overturn or principal point of impact is top.
- Frontal - Principal point of impact is clock points 11,12, and 1.
- Side - Principal point of impact is clock points 2, 3, 4, 8, 9, and 10.
- Rear - Principal point of impact is clock points 5, 6, and 7.
- Other - Most harmful event for vehicle is non-collision or principal point of impact is "other" or unknown.

Rollover, side, rear, and other categories were sometimes combined to create a single "non-frontal" crash type. Each crash type was separately analyzed using the "double pair comparison" method to estimate the effectiveness of lap/shoulder and lap belts relative to an unrestrained occupant and to see if lap/shoulder belts provide additional benefits over lap belts for rear seat outboard occupants.

Table 2-9 shows the fatality risk for back seat occupants in frontal crashes in all make/models and Table 2-10 shows it in the "matching" analysis. Table 2-11 shows the combined results found in Tables 2-9 and 2-10.

Table 2-11 shows a negative effect for lap belts in frontal crashes in the analysis with the most crash cases - when lap/shoulder belted front seat occupants are the control group. The lap belted back seat occupant has a 5 percent higher fatality risk than the unrestrained back seat occupant in the "all make/models" analysis and 4 percent higher in the "matching" analysis. These negative effects are more or less offset by positive results in the analysis with the other control groups. The overall effectiveness of back seat lap belt in frontal crashes is 1 percent in the "all make/models" analysis and 4 percent in "matching" make/models. Therefore, lap belted back seat outboard occupants are not necessarily safer than unrestrained back outboard occupants in frontal crashes.

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[26]NTSB (1986).

[27]Kahane (1987).

TABLE 2-9 FRONTAL CRASHES: FARS 1988-FIRST 6 MONTHS OF 1997 EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE AND RESTRAINT TYPE FOR ALL MAKE/MODELS					
Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities	Risk Factor	Fatality Reduction
Unrestrained	1,038	Lap/shoulder belted	1,016	1.022	
Lap belted	480		447	1.074	-5%
Lap/shoulder belted	277		352	0.787	23%
Unrestrained	1,779	Unrestrained	3,432	0.518	
Lap belted	69		160	0.431	17%
Lap/shoulder belted	40		132	0.303	42%
Unrestrained	280	2 pt. belted	436	0.642	
Lap belted	28		68	0.412	36%
Lap/shoulder belted	141		301	0.468	27%
Unrestrained	205	Air bag alone	263	0.779	
Lap/shoulder belted	14		47	0.298	62%
Unrestrained	217	Air bag plus lap/shoulder belted	145	1.497	
Lap belted	2		2	1.000	
Lap/shoulder belted	169		167	1.012	32%
Weighted average of lap belted vs. unrestrained back seat outboard occupants in frontal crashes					1%
Weighted average of lap/shoulder belted vs. unrestrained back seat outboard occupants in frontal crashes					29%

* “Double pair comparison” method relative to front seat outboard occupants.

TABLE 2-10
FRONTAL CRASHES: FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS
RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS *
BY RESTRAINT USAGE AND RESTRAINT TYPE
FOR "MATCHING" MAKE/MODELS WITH SPECIFIC MODEL YEARS

Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities	Risk Factor	Fatality Reduction
Unrestrained	576	Lap/shoulder belted	564	1.021	
Lap belted	276		259	1.066	-4%
Lap/shoulder belted	144		166	0.867	15%
Unrestrained	1,023	Unrestrained	1,960	0.522	
Lap belted	39		94	0.415	21%
Lap/shoulder belted	24		62	0.387	26%
Unrestrained	149	2 pt. belted	240	0.621	
Lap belted	28		68	0.412	34%
Lap/shoulder belted	66		141	0.468	25%
Unrestrained	32	Air bag alone	29	1.103	
Lap/shoulder belted	2		1	2.000	-81%
Unrestrained	23	Air bag plus lap/shoulder belted	11	2.091	
Lap belted	2		2	1.000	
Lap/shoulder belted	17		16	1.063	49%
Weighted average of lap belted vs. unrestrained back seat outboard occupants in frontal crashes					4%
Weighted average of lap/shoulder belted vs. unrestrained back seat outboard occupants in frontal crashes					22%

* "Double pair comparison" method relative to front seat outboard occupants.

TABLE 2-11
FRONTAL CRASHES: FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS
RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS *
BY RESTRAINT USAGE, RESTRAINT TYPE, AND ANALYSIS TYPE

Back Seat Restraint Use	Front Seat Restraint Use	Fatality Reduction	
		"All make/models"	"Matching make/models"
Lap belted	Lap/shoulder belted	-5%	-4%
Lap/shoulder belted		23%	15%
Lap belted	Unrestrained	17%	21%
Lap/shoulder belted		42%	26%
Lap belted	2 pt. belted	36%	34%
Lap/shoulder belted		27%	25%
Lap/shoulder belted	Air bag alone	62%	-81%
Lap/shoulder belted	Air bag plus lap/shoulder belted	32%	49%
Weighted average of lap belted vs. unrestrained back seat outboard occupants in frontal crashes		**1%**	**4%**
Weighted average of lap/shoulder belted vs. unrestrained back seat outboard occupants in frontal crashes		**29%**	**22%**

* "Double pair comparison" method relative to front seat outboard occupants.

The average effectiveness of lap/shoulder belted back seat occupants vs. unrestrained back seat occupants in frontal crashes is 29 percent in the "all make/model" analysis. In each control group analysis, lap/shoulder belted back seat occupants vs. unrestrained back seat occupants show a positive fatality reduction in "all make/models" ranging from 23 percent in the lap/shoulder belted front seat occupant control group to 62 percent in the 2-point belted front seat occupant control group. In the "matching make/models," all except the air bag alone control group (which has a very small sample size) show a positive fatality reduction. In most cases, the fatality reduction is smaller in the "matching make/model" analysis than the "all make/models" analysis leading to a smaller average effectiveness of 22 percent for lap/shoulder belted back seat occupants in the "matching make/model" analysis.

The potential additional benefits of belts in the back seat is limited because the back seat is much safer for an unrestrained occupant than the front seat in frontal crashes. At first glance, back seat lap/shoulder belted fatality reductions of 22-29 percent do not look spectacular, at least in comparison to the effectiveness of lap/shoulder belts in all crashes or in comparison to belt effectiveness for front seat occupants in frontal crashes.

Unrestrained back seat occupants are safer than unrestrained, 2-point belted, and air bag restrained front seat occupants in frontal crashes. Their risk factors are 0.518, 0.642, and 0.779, respectively. Since all their risk factors are less than one, it shows that the back seat is safer than the front seat in frontal crashes.

Even an unrestrained back seat occupant is only slightly less safe than lap/shoulder belted front seat occupant in frontal crashes. The same is true for lap/shoulder belted back seat occupants when compared to front seat lap/shoulder belted occupants also protected by an air bag. Their risk factors are 1.022 and 1.012, respectively, slightly greater than one.

TABLE 2-12
EFFECTIVENESS, CONFIDENCE BOUNDS, AND T TEST VALUE OF BACK SEAT LAP AND LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS * IN FRONTAL CRASHES

		Lower Bound	Estimate	Upper Bound	t Test
Lap belted vs. unrestrained back seat outboard occupants					
	"All make/models"	**- 13%**	**1%**	**14%**	**- 0.14**
	"Matching make/models"	**- 14%**	**4%**	**19%**	**- 0.43**
Lap/shoulder belted vs. unrestrained back seat outboard occupants					
	"All make/models"	**15%**	**29%**	**42%**	**- 3.51**
	"Matching make/models"	**- 5%**	**22%**	**42%**	**- 1.51**

* "Double pair comparison" method relative to front seat outboard occupants.

More importantly, the lap/shoulder belt is a great improvement over the lap belt, which has essentially zero benefit in frontal crashes. Back seat lap/shoulder belts effectiveness, 29 percent, is significantly greater than zero in the "all make/models" analysis for frontal crashes. Lap/shoulder belt effectiveness is not statistically different from zero in the "matching make/models" analysis for frontal crashes. Lap belts effectiveness estimates are also not statistically different from zero in both the "all" and "matching" analyses for frontal crashes.

Table 2-12 presents the confidence bounds and t test results for lap and lap/shoulder belts in both the "all make/model" and "matching make/model" analyses using the jackknife procedure explained in Section 2.4.1.

2.7.1 Lap/shoulder Belt Effectiveness Vs. Lap Belt in Frontal Crashes

We calculated the effectiveness of lap/shoulder belts vs lap belts in frontal crashes to see how much an improvement the back seat lap/shoulder belt is over the lap belt. We used the same method described in Section 2.5. To calculate the air bag adjustment for front seat fatalities, we used the following:

- air bag effectiveness is 29 percent for unbelted front seat outboard occupants in frontal crashes and
- air bag effectiveness is 19 percent for lap/shoulder belted front seat outboard occupants in frontal crashes.

We calculated these air bag effectiveness estimates in frontal crashes (11:00-1:00 impacts excluding most harmful event rollovers) similar to the method in[28], using the most recent 1986-1997 FARS data.

Lap/shoulder belts provide added protection over the lap belt in frontal crashes. Lap/shoulder belts have a statistically significant benefit relative to lap belts in frontal crashes in the "all make/model" analysis. Table 2-13 shows that back seat lap/shoulder belts are 25 percent effective in reducing fatalities in the "all make/model" analysis. Their effectiveness ranges from 12 percent to 36 percent and is significantly greater than zero.

The results are not as good in the "matching make/model" analysis. In frontal crashes, lap/shoulder belts effectiveness is 14 percent. It is not significantly different from zero. Confidence bounds range from -10 percent to 36 percent. The cell size in this analysis is substantially smaller than in the "all make/models" analysis.

[28]Kahane (1996).

TABLE 2-13 FARS 1988-FIRST 6 MONTHS OF 1997 EFFECTIVENESS, CONFIDENCE BOUNDS, AND T TEST VALUES OF BACK SEAT LAP/SHOULDER BELTS RELATIVE TO LAP BELTED BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE, RESTRAINT TYPE, AND ANALYSIS TYPE IN FRONTAL CRASHES			
		Fatality Reduction	
Back Seat Restraint Use	Front Seat Restraint Use	"All make/models"	"Matching make/models"
Lap/shoulder belted	Lap/shoulder belted	25%	18%
Lap/shoulder belted	Unrestrained	37%	1%
Lap/shoulder belted	2 pt. belted	-14%	-14%
Weighted average of lap/shoulder belted vs. lap belted back seat outboard occupants		**25%**	**14%**
Confidence bounds		**12 to 36%**	**-10 to 35%**
t test		**3.36**	**1.12**

* "Double pair comparison" method relative to front seat outboard occupants.

2.7.2 Belt Effectiveness in Non-frontal, Rollover and Side Impact Crashes

Table 2-14 shows the overall effectiveness of back seat lap and lap/shoulder belted occupants in all non-frontal and in rollover and side impact crashes. Lap/shoulder belt effectiveness vs. lap belts is also in Table 2-14. We calculated lap/shoulder belt effectiveness vs. lap belt similarly to Section 2.5. We assumed air bags effectiveness was zero in non-frontal, rollover, and side impact crashes. (The "rear" and "other" impact categories do not contain enough data for statistically meaningful separate estimates.)

In non-frontal crashes, both lap belted and lap/shoulder belted back seat occupants have lower fatality risks than unrestrained back seat occupants. Lap belted back seat occupants in non-frontal crashes have an overall effectiveness of 48 percent in "all make/models" and 45 percent in "matching make/models." Lap/shoulder belted back seat occupants in non-frontal crashes have a 53 percent effectiveness in "all make/models" and 48 percent in "matching make/models."

TABLE 2-14
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED AND LAP BELTED BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE, RESTRAINT TYPE, AND CRASH TYPE

		Fatality Reduction	
All non-frontal crashes		"All make/models"	"Matching make/models"
	Lap belted vs. unrestrained back seat occupants	48%	45%
	Lap/shoulder belted vs. unrestrained back seat occupants	53%	48%
	Lap/shoulder belted vs. lap belted back seat occupants	6%	3%
Rollover crashes			
	Lap belted vs. unrestrained back seat occupants	76%	78%
	Lap/shoulder belted vs. unrestrained back seat occupants	77%	76%
	Lap/shoulder belted vs. lap belted back seat occupants	-2%	-10%
Side impact crashes			
	Lap belted vs. unrestrained back seat occupants	39%	35%
	Lap/shoulder belted vs. unrestrained back seat	42%	37%
	Lap/shoulder belted vs. lap belted back seat occupants	1%	-5%

* "Double pair comparison" method relative to front seat outboard occupants.

Lap/shoulder belted back seat occupant also have a slightly lower fatality risk than lap belted back seat occupants. Lap/shoulder belt effectiveness is 6 percent in the "all make/model" and 3 percent in the "matching make/models." Therefore, lap/shoulder belts are perhaps slightly more effective in reducing fatalities than back seat lap belts in non-frontal crashes. However, this increment is not statistically significant, it is well within the "noise" range of these estimates. It is evident that the primary advantage of lap/shoulder belts over lap belts is in frontal crashes.

In rollover crashes, Table 2-14 shows a 76 - 78 percent effectiveness for lap belted and lap/shoulder belted back seat outboard occupants when compared to unrestrained back seat occupants. Lap/shoulder belt effectiveness vs. lap belt is negative in both the "all make/model" and "matching make/model" analyses. Hence, a lap/shoulder belt when used does not provide any significant additional protection over a lap belt in rollover crashes.

In side impact crashes, the overall effectiveness of lap belted back seat occupants vs. unrestrained back seat occupants is 39 percent and lap/shoulder belted back seat occupants is 42 percent in "all make/models." When limited to the "matching make/models," the effectiveness drops to 35 percent for lap belted and 37 percent for lap/shoulder belted back seat occupants. Lap/shoulder belt effectiveness relative to lap belted back seat occupants is 1 percent in the "all make/model" and -5 percent in the "matching make/model" analyses. In side impacts, the lap belt when used provides protection against a fatality and the lap/shoulder belt when used provides about the same protection against a fatality as a back seat outboard lap belt.

Lap and lap/shoulder belts are effective in reducing fatalities even in near-side and far-side impact crashes. In near-side impact crashes, the effectiveness of lap belts is 35 percent and the effectiveness of lap/shoulder belts is 40 percent in the "all make/models" analysis when compared to unrestrained back seat occupants. In far-side impact crashes, the effectiveness estimates are even higher, 49 percent for lap belts and 47 percent for lap/shoulder belts. Belts in side impact crashes reduce the risk of ejection for back seat occupants which may account for their relatively high effectiveness estimates when compared to the effectiveness estimates found in frontal crashes (Section 2.7).

2.8 BELT EFFECTIVENESS BY OCCUPANT AGE AND SEX

Weight, height, ability to survive trauma, and other occupant age/sex characteristics could influence belt effectiveness. Children are shorter, lighter, more flexible, and heal quickly when compared to adults. Adult males are taller, heavier and generally stronger than their female peers. Seniors, whose height and weight are similar to other adults, have brittle bones and other health problems which make them more susceptible to fatalities in crashes. Belt effectiveness may be influenced by these varying occupant age/sex characteristics.

The back seat lap and lap/shoulder belt effectiveness varies considerably by occupant age and sex. Table 2-15 shows the effectiveness of lap belted vs. unrestrained, lap/shoulder belted vs. unrestrained, and lap/shoulder belted vs. lap belted back seat occupants. For children, the back seat lap/shoulder belt is 52 percent effective in reducing fatalities in "all make/models" when compared to unrestrained back seat occupants and 60 percent in "matching make/models." The back seat lap belt for children is 38 percent effective in "all make/models" and 36 percent effective in "matching make/models."

Children ages 5-14 appear to derive the greatest incremental benefit from using back seat lap/shoulder belts rather than just a lap belt. The effectiveness of lap/shoulder belts vs. lap belted back seat occupants is 26 percent for children in "all make/models." Children have the highest effectiveness of lap/shoulder belted vs. lap belted when compared to the other age and sex groups.

For males age 15-54, lap belt effectiveness is consistent at 45 percent for "all make/models" and "matching make/models." Lap/shoulder belts for males when used are 53 percent effective in reducing fatalities in "all make/models." Effectiveness drops to 45 percent in the "matching make/models." Effectiveness of lap/shoulder belts vs. lap belts is 15 percent in the "all make/models" analysis and negative 1 percent in the "matching" analysis. Although, in these detailed analyses, we should rely primarily on the "all make/models" method that has a larger sample size, the "matching" result makes it hard to conclude unequivocally that males are benefitting more from being lap/shoulder belted than just lap belted.

TABLE 2-15
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED AND LAP BELTED BACK SEAT OUTBOARD OCCUPANTS *
BY RESTRAINT USAGE, RESTRAINT TYPE, AGE, AND SEX

		Fatality Reduction	
Children ages 5-14		"All make/models"	"Matching make/models"
	Lap belted vs. unrestrained back seat occupants	38%	36%
	Lap/shoulder belted vs. unrestrained back seat	52%	60%
	Lap/shoulder belted vs. lap belted back seat	26%	34%
Males ages 15-54			
	Lap belted vs. unrestrained back seat occupants	45%	45%
	Lap/shoulder belted vs. unrestrained back seat	53%	45%
	Lap/shoulder belted vs. lap belted back seat	15%	-1%
Females ages 15-54			
	Lap belted vs. unrestrained back seat occupants	35%	40%
	Lap/shoulder belted vs. unrestrained back seat	45%	42%
	Lap/shoulder belted vs. lap belted back seat	9%	8%
Seniors ages 55 +			
	Lap belted vs. unrestrained back seat occupants	10%	-2%
	Lap/shoulder belted vs. unrestrained back seat	28%	8%
	Lap/shoulder belted vs. lap belted back seat	12%	5%

* "Double pair comparison" method relative to front seat outboard occupants.

Females age 15-54 appear to benefit slightly from lap/shoulder belts over lap belts only. Effectiveness of lap/shoulder belts vs. lap belts is 8 - 9 percent. Lap belt effectiveness vs. unrestrained back se at occupants is 35 percent for “all make/models” and 40 percent for “matching make/models.” But lap/shoulder belt effectiveness increases to 45 percent for “all make/models” and increases slightly to 42 percent for “matching make/models.”

Seniors benefit from using back seat lap/shoulder belts over lap belts. In both the “matching” and “all make/models” analyses, lap/shoulder belt effectiveness vs. lap belt is 5 percent and 12 percent, respectively. But neither lap nor lap/shoulder belts when used are as beneficial for seniors as they are for the other age/sex groups. In fact, the “matching” analysis raises doubts about whether lap belts have any overall net benefit for seniors.

In frontal crashes, Table 2-16 shows consistently lower effectiveness estimates for both types of belts as occupants get older. Back seat outboard lap belt effectiveness for children in frontal crashes is almost 30 percent. The effectiveness drops to below 5 percent for both males and females aged 15-54. And, for occupants aged 55 or older, it is a **negative** 46 percent. The effectiveness estimates of back seat lap/shoulder belts also decline as occupants get older in frontal crashes. For children, the effectiveness is 49 percent and it drops to 11 percent for seniors. However, the relative incremental benefit of lap/shoulder belts over lap belts only remains reasonably consistent, ranging from 25 to 41 percent.

Gender also appears to affect the effectiveness estimates in frontal crashes. Females age 15-54 have lower effectiveness estimates than their male counterparts. Lap belts effectiveness is 4 percent for males and only 1 percent for females. But female lap/shoulder belt effectiveness vs. unrestrained and vs. lap belted back seat occupant estimates are about 20 percentage points lower than the male lap/shoulder belt effectiveness estimates.

Children benefit the most from back seat belt use in frontal crashes. They have the highest lap/shoulder belt effectiveness vs. unrestrained back seat occupants in Table 2-16, almost 50 percent. Children age 5-14 also have the highest lap belt effectiveness, around 25 percent. This implies that even lap belts protect children in frontal crashes, but lap/shoulder belts do a much better job. The incremental effectiveness of lap/shoulder belts over lap belts for children in frontal crashes is 31 percent.

Males age 15-54 have the most obvious benefit in frontal crashes from lap/shoulder belts over lap belts. Lap belt effectiveness for males is 4 percent. Lap/shoulder belt effectiveness jumps to 46 percent. The incremental effectiveness of lap/shoulder belts over lap belts is 41 percent for males. It is the highest incremental shoulder belt effectiveness estimates across all age and sex groups.

TABLE 2-16
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND
LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED AND
LAP BELTED BACK SEAT OUTBOARD OCCUPANTS *
BY RESTRAINT USAGE, RESTRAINT TYPE, AGE, AND SEX
FOR "ALL MAKE/MODELS" IN FRONTAL CRASHES

Children ages 5-14		Fatality Reduction
	Lap belted vs. unrestrained back seat occupants	29%
	Lap/shoulder belted vs. unrestrained back seat occupants	49%
	Lap/shoulder belted vs. lap belted back seat occupants	31%
Males ages 15-54		
	Lap belted vs. unrestrained back seat occupants	4%
	Lap/shoulder belted vs. unrestrained back seat occupants	46%
	Lap/shoulder belted vs. lap belted back seat occupants	41%
Females ages 15-54		
	Lap belted vs. unrestrained back seat occupants	1%
	Lap/shoulder belted vs. unrestrained back seat occupants	26%
	Lap/shoulder belted vs. lap belted back seat occupants	25%
Seniors ages 55 +		
	Lap belted vs. unrestrained back seat occupants	-46%
	Lap/shoulder belted vs. unrestrained back seat occupants	11%
	Lap/shoulder belted vs. lap belted back seat occupants	34%

* "Double pair comparison" method relative to front seat outboard occupants.

Females appear to benefit from rear seat lap/shoulder belts. Females in frontal crashes have an incremental shoulder belt effectiveness of 25 percent. Lap belted back seat females vs. unrestrained occupants have a 1 percent effectiveness while lap/shoulder belted, back seat females vs. unrestrained occupants have a 26 percent effectiveness.

Seniors in the back outboard seats involved in frontal crashes may benefit from lap/shoulder belt use, but they do not benefit from lap belt use. Table 2-16 shows a **negative** 46 percent effectiveness for seniors in lap belts. In other words, seniors are 46 percent more likely to be killed in frontal crashes when using a lap belt than being unrestrained. Using the jackknife procedure to calculate confidence bounds and test for statistical significance, **negative** 46 percent effectiveness is significantly less than zero. (t test results are 2.51.) The problem is only partially remedied by lap/shoulder belts. Thirty-four percent incremental effectiveness for lap/shoulder belts over lap belts is promising for seniors in frontal crashes. But lap/shoulder belted back seat seniors in frontal crashes have a only relatively low 11 percent effectiveness vs. unrestrained occupants. The 11 percent effectiveness is not statistically different from zero. (t test results are -0.55).

2.9 CAVEATS FOR EFFECTIVENESS ANALYSIS

Belt effectiveness estimates using the "double pair comparison" method may be overstated. Specifically, "double pair comparison" analysis of front seat belt effectiveness on more recent years of FARS data have resulted in overstated effectiveness estimates. Since the lap and lap/shoulder belt effectiveness estimates are calculated in this chapter by using the "double pair comparison" method on recent FARS data, they could theoretically have the same problem.

Front seat belt effectiveness estimates are higher in more recent years of FARS data than previous years using the "double pair comparison" method. A 1986 study[29] using the "double pair comparison" method on the 1975-1983 FARS data shows front seat outboard lap/shoulder belts are 41 percent effective in passenger cars. A later study[30] using the same method but on 1982-1987 FARS data finds that front seat outboard lap/shoulder belts have 55 percent effectiveness in passenger cars. The later study also computes the effectiveness estimates by calendar year showing that the effectiveness estimates tend to be higher in 1985 through 1987 FARS data than in 1982 through 1984 FARS data. Since NHTSA believes, taking all analyses and data sources into consideration, that front seat belts reduce fatality risk by 40 - 50 percent,[31] the 1975-83 result is about right, and the 1982-87 result appears to be overstated.

The overstating of front seat belt effectiveness is probably due to people inaccurately reporting belt use in the more recent years of FARS. Between 1984 and 1987, most states adopted belt use laws that made it unlawful for front seat occupants to be unbelted. So to escape violation of belt use laws, some front seat occupants may claim to be belted even though they were not. We believe that the inaccurate reporting of belt use is more common among uninjured or slightly

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[29]Evans (1986), pp. 228-229.

[30]Partyka, S., "Belt Effectiveness in Pickup Trucks and Passenger Cars by Crash Direction and Accident Year," *Papers on Adult Seat Belts -- Effectiveness and Use*, NHTSA Technical Report No. DOT HS 807 285, Washington, DC, 1988.

[31]NHTSA (1984), p. IV-2.

injured occupants than severely injured or fatally injured occupants. If some of the surviving occupants have miscoded belt use, then the fatality risk of belted occupants is lower than it should be, the fatality risk of unbelted occupant is higher than it should be, and the ratio of the two is less than it should be. Therefore, the effectiveness estimate of belts is overstated.

We think inaccurate reporting of belt use is less of a problem with back seat occupants. Most importantly, belt use laws generally do not apply to back seat occupants (except some children). That takes away the principal motive for inaccurate reporting at least among those who are aware the law does not apply to the back seat. Secondly, we have already seen in Section 1.2 that belt use of back seat outboard survivors in FARS is not significantly different from observed belt use. And finally, the Multiple Cause of Death (MCOD) analysis presented in Chapter 5 shows such clearly different injury patterns for people reported as unrestrained, lap belted, and lap shoulder belted that there could hardly be vast amounts of inaccurate reporting. If a large percent of those reported as belted were really unrestrained, how could they have such a high ratio of torso to head injuries?

Even if back seat belt use is inaccurate in FARS, our effectiveness estimates for lap/shoulder belts versus lap belts would not be overstated. The effectiveness estimates for back seat lap and lap/shoulder belts versus unrestrained occupants would each be slightly overstated, but they would tend to be overstated by similar amounts. The effectiveness estimates for lap/shoulder belts versus lap belts would be correct, because the fatality risk of lap belted and fatality risk of lap/shoulder belted occupants would change by the same amount, not affecting the ratio of the two fatality risks or the effectiveness estimates. The “as-used” results in Chapter 3 also help to confirm that our lap/shoulder belt versus lap belt effectiveness estimates are correct.

2.10 LAP/SHOULDER BELT EFFECTIVENESS IN FRONTAL CRASHES, USING NON-FRONTALS AS A CONTROL GROUP

Earlier in this report, we found:

- lap belts are not effective in reducing fatalities in frontal impacts (Table 2-12),
- lap/shoulder belt are about 30 percent effective in reducing fatalities in frontal impacts (Table 2-12), and
- back seat lap belts and lap/shoulder belts are both about equally effective in reducing fatalities in non-frontal crashes. Lap/shoulder belts are perhaps at best a non-significant 3 to 6 percent more effective in reducing fatalities than back seat lap belts in non-frontal crashes (Table 2-14).

One can use another method for estimating the incremental benefit of adding the shoulder belt. Since the addition of the shoulder belt has little or no effect on fatality risk in non-frontal crashes and it appears to have an effect in frontal crashes, the ratio of frontal to non-frontal back seat outboard fatalities of lap/shoulder belted occupants ought to be lower than the corresponding ratio of back seat outboard occupants wearing only the lap belt. The incremental effectiveness of shoulder belts in frontal crashes is estimated by the relative difference in the ratios. The calculated effectiveness, in this analysis, is the incremental effectiveness of shoulder belts in frontal crashes relative to non-frontal crashes. NHTSA's *Fatality Reduction by Air Bags*[32] report uses the same method to calculate the incremental benefit of a driver air bag in frontal crashes i.e., it uses non-frontal crashes as a control group and assumes air bags have essentially no effect here.

The advantage of using this method is its simplicity and excellent prospects for statistical significance. The disadvantage is its assumption that the shoulder belt has no incremental benefit in non-frontal crashes. To the extent that we cannot rule out at least some small benefit in non-frontal crashes, this assumption will result in conservative estimates of benefits in frontal crashes.

Table 2-17 presents the data needed to calculate the fatality reduction of back seat outboard lap/shoulder belts in frontal crashes for "all make/models." There were 579 back seat outboard fatalities in frontal crashes and 809 back seat outboard fatalities in non-frontal crashes when the back seat occupant was lap belted. But if the back seat outboard occupant was lap/shoulder belted, there were only 641 frontal fatalities as opposed to 1,168 non-frontal fatalities. The relative reduction of fatalities for back seat outboard lap/shoulder belted occupants in frontal crashes is

$$1-[(641/1{,}168) / (579/809)] = 23 \text{ percent.}$$

TABLE 2-17
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD
LAP/SHOULDER BELTS BASED ON REDUCTION
OF FRONTAL FATALITIES
RELATIVE TO NON-FRONTAL FATALITIES
FOR "ALL MAKE/MODELS"

	Back Seat Outboard Fatalities		
	Lap belted	Lap/shoulder belted	Fatality Reduction
Non-frontal	809	1,168	
Frontal	579	641	23%

[32]Kahane (1996).

It is statistically significant at the .05 level ($\div^2$ = 13.13; if shoulder belts had no incremental protection over lap belts, we would hypothesize the same distribution of back seat outboard fatalities, by impact location, in the lap and lap/shoulder belted occupants; the $\div^2$ test of the 2 x 2 table of back seat fatalities by type of occupant protection and impact location tests this null hypothesis.).

In the "matching make/model" analysis, the incremental fatality reduction for the shoulder belt in frontal crashes is 16 percent. This is not statistically significant at the .05 level ($\div^2$ = 2.74).

TABLE 2-18
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD
LAP/SHOULDER BELTS BASED ON REDUCTION
OF FRONTAL FATALITIES
RELATIVE TO NON-FRONTAL FATALITIES
FOR "MATCHING MAKE/MODELS"

	Back Seat Outboard Fatalities		
	Lap belted	Lap/shoulder belted	Fatality Reduction
Non-frontal	504	440	
Frontal	345	253	16%

2.10.1 Lap/shoulder Belt Effectiveness in Frontal Crashes by Occupant Age and Sex

One can estimate the additional protection the shoulder belt provides over a lap belt in frontal crashes by occupant age and sex using the same method discussed in Section 2.10. We compared the ratio of frontal and non-frontal back seat outboard fatalities of lap/shoulder belted occupants to the corresponding ratio of back seat outboard occupants wearing only the lap belt by occupant age and sex groups.

Table 2-19 shows the additional benefit provided to occupant age and sex groups by shoulder belt use. Occupants aged 15-54 benefit the most from using the added shoulder belt in frontal crashes, with lap/shoulder belts slightly more effective for females than males in this age group. Females have a 45 percent and males have a 41 percent fatality reduction. On the other hand, seniors, occupants aged 55 and above, appear to benefit the least from shoulder belt usage when compared to the other occupant age and sex groups in frontal crashes. Lap/shoulder belts are only 8 percent effective in reducing fatalities in frontal crashes for seniors. Lap/shoulder belt effectiveness in frontal crashes for children aged 5-14 is between the two extremes: 18 percent.

TABLE 2-19
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF FRONTAL FATALITIES RELATIVE TO NON-FRONTAL FATALITIES BY AGE AND SEX

		Back Seat Outboard Fatalities		Fatality Reduction
		Lap belted	Lap/shoulder belted	
Children ages 5-14				
	Non-frontal	271	268	
	Frontal	133	108	18%
Males ages 15-54				
	Non-frontal	143	271	
	Frontal	101	112	41%
Females ages 15-54				
	Non-frontal	136	270	
	Frontal	112	123	45%
Seniors ages 55 +				
	Non-frontal	258	357	
	Frontal	233	298	8%

All age and sex groups appear to benefit from using the lap/shoulder belts over lap belts in frontal crashes. This is consistent with our earlier results found in Section 2.8. Also consistent with our earlier results is that lap/shoulder belt effectiveness varies by age and sex groups in frontal crashes. In other words, the level of benefit provided by the shoulder belt usage in frontal crashes is different by occupant age and sex groups. But our results are not consistent enough to tell us which age and sex groups benefit the most or the least by using lap/shoulder belts over lap belts. Earlier, Table 2-16 showed the incremental benefit of lap/shoulder belts over lap belts is relatively consistent across age and sex groups. But Table 2-19 shows that adult males and females benefit much more than children and seniors by using the lap/shoulder belts in frontal crashes.

Are the effectiveness significantly different by age and sex groups? CATMOD analysis of the 2 x 4 x 2 tabulations of fatalities in Table 2-19 shows that effectiveness varies significantly by age and sex groups. The interaction term between belt type by age and sex group is statistically significant at the .05 level ($\div^2 = 8.77$ with df = 3).

2.11 ANALYSES USING BACK CENTER SEAT OCCUPANTS AS THE CONTROL GROUP

The back center seat occupants can also be used in the “double pair comparison” procedure as a control group. In this analysis, the fatality risk of back seat outboard occupants are compared relative to the back center seat occupants. The advantage of using the back center seat occupant is that the crash conditions experienced by back outboard and back center seat occupants tend to be similar while the crashes conditions experienced by back seat outboard occupants and front seat outboard occupants tend to be different. Especially, in a frontal crash, the back outboard and center occupants are in about the same, relatively benign environment while front seat occupant experience a harsher environment. So one would expect back seat outboard occupants to have relatively the same risk, to a point, as back center seat occupants.

This argument is less true for side impact crashes. The risk of injury in side impact crashes to back outboard occupants differs from the risk to the back center occupants. The back outboard occupants will either initially or subsequently impact the relatively hard surfaces available in the back seat (e.g., the side door, side window, and/or door frame). But the back center occupants will impact with relatively soft surfaces (e.g., the back seat or other back seat occupants). Nevertheless, since frontal crashes are of greatest interest in this evaluation, the back center occupants should be useful as a control group.

A vehicle-level file was prepared similar to the front seat control group analysis. The VINs of passenger cars, model year 1985-1996, were analyzed to determined the specific vehicle make and model, so the specific restraint type available in these cars at the back outboard seating positions could be determined. Then the occupant information for all the back seat outboard occupants, age 5 or more in seating positions 21 and 23 only, was extracted from FARS. Next, the vehicle information and occupant information were combined to create a vehicle-level file which had one record for each passenger car that had a back seat outboard occupant. Finally, the information for back center seat (BC) occupants (age 5 or more and seating position 22) were appended to the vehicle-level back seat outboard occupant records.

Again, a paired-occupant file was created. Only this time a maximum of two paired-occupant records where at least one of the occupants died could be generated from one vehicle record, instead of four. The possible records generated are:

BC Passenger and BL Passenger
BC Passenger and BR Passenger

This method involves “double counting” when a BC passenger is a fatality. For example, if a vehicle has three back seat occupants and a back center passenger fatality, two paired-occupant records will be generated: one as BC fatality with the BL passenger and one as a BC fatality with the BR passenger. The paired-occupant records and their number of back center and back seat outboard fatalities for this example are such:

	Back outboard seat fatalities	Back center seat fatalities
BC Passenger and BL Passenger	0	1
BC Passenger and BR Passenger	0	1
Total contributed to the analysis	0	2

But not all fatalities are counted twice as is with a back outboard fatality. A back outboard fatality is only counted once.

These inconsistencies in counting appear to create a bias by "double counting" only back center seat fatalities and not the back seat outboard fatalities. But as we discussed in Section 2.1.2 and proved in Proof 2 of Appendix C, the "double counting" does not create a bias for or against the back seat outboard occupants when fatalities are counted inconsistently. The proof that the "double counting" when BC seat occupants are the control group is not presented in the report, but it is similar to Proof 2 in Appendix C. So the "double counting" of the BC seat fatalities does not bias the results for or against the back seat outboard occupants.

A potential problem with using the back center seat occupants for control groups, instead of the front outboard occupants, is that few cars have back center seat occupants. In fact, only 15 percent of the cars on FARS which have a least one back seat outboard occupant also have a back center seat occupant. The other 85 percent will be excluded from the analysis. When the front seat outboard occupant was the control group, this problem did not exist. Since all cars have at least one front seat outboard occupant, the driver, paired-occupants records were generated when the car had at least one back seat outboard occupant and a fatality in the paired record.

Excluding records which do not have back center seat occupants causes small sample sizes and may bias the analysis. Our analysis will be biased if the cars with back center seat occupants are different from cars without, or are driven differently. Cars will have a back center seat occupant typically when all the other outboard seats in the car also have occupants e.g. a family with three children in the back seat or a group of five teenagers. The way these cars are driven will differ depending on the occupants. The family car will be driven much safer than the car with teenagers. So the analysis will include both high and low risk drivers, thus no bias here. But age of the back seat occupant could bias this analysis.

We can expect slightly higher belt effectiveness estimates in this analysis. The average age of back seat outboard occupants in cars when a BC occupant is present is 5 years younger than the average age in all cars. The data in Section 2.8 suggests that younger occupants have higher belt effectiveness estimates than older occupants.

Vehicle age could also potentially bias this analysis similar to the reasons stated earlier in this report. It is not clear that vehicle age does bias the analysis but it is possible. In this analysis, the vehicle age effect could not be eliminated by analyzing the “matching” make/models because this would have reduced the sample size even further.

Another bias this method does create is that it generates fewer records when there is a center rear passenger and one back seat outboard passenger. In this situation, one record will be produced and each fatality will be counted once. Thus, vehicles with only one back seat outboard occupant are underrepresented in the paired-occupant analysis file. However, there are less than 5 percent of the cars on FARS with one back seat outboard occupant and a back center seat occupant so this bias is insignificant.

For the back center seat occupants, restraint use and restraint type available are reported in 2 categories: unrestrained and lap belted. Table 2-20 shows lap belted back seat outboard occupants have a 5 percent lower fatality risk than unrestrained back seat outboard occupants when unrestrained back center seat occupants are the control group. In the same control group, lap/shoulder belted back seat outboard occupants have 55 percent lower fatality risk than unrestrained back seat outboard occupants. When lap belted back center seat occupants are the control group, lap belted back seat outboard occupants have 57 percent lower fatality risk than unrestrained back seat outboard occupants and lap/shoulder belted back seat outboard occupants have 65 percent lower fatality risk.

TABLE 2-20
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS
RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS *
BY RESTRAINT USAGE AND RESTRAINT TYPE

Back Seat Outboard Restraint use	BSO Fatalities	Back Center Seat Restraint Use	BC Seat Fatalities	Risk Factor	Fatality Reduction
Unrestrained	899	Unrestrained	756	1.189	
Lap belted	25		22	1.136	5%
Lap\shoulder belted	25		47	0.532	55%
Unrestrained	45	Lap belted	16	2.813	
Lap belted	52		43	1.209	57%
Lap\shoulder belted	69		71	0.972	65%
Weighted average for lap belted vs. unrestrained back seat outboard occupants:					48%
Weighted average for lap/shoulder belted vs. unrestrained back seat outboard occupants:					63%

* “Double pair comparison” method relative to back center seat occupants.

The overall effectiveness is calculated the same way as in Section 2.3, using the weighted average of the two fatality reduction estimates. The overall effectiveness for lap belts in back outboard seats is

$$1 - \left[\frac{25 + 52}{25(1.189/1.136) + 52(2.813/1.209)} \right] = 48\%$$

The effectiveness for lap/shoulder belts in back outboard seats is 63 percent.

These effectiveness estimates are substantially higher than the corresponding estimates with front seat occupants as the control group (Table 2-1). However, they are based on 1/20 as many data. The analyses in Table 2-1 include 1,388 records of lap belted back seat occupant fatalities and 1,809 lap/shoulder belted. The calculations here involve only 77 lap belted and 94 lap/shoulder belted fatalities. The results of this analysis should be given far less weight than the preceding ones, because of the much smaller sample, as well as, the possible bias that may exist. The average young age of these occupants does not explain the much higher effectiveness estimates found in this analysis.

As expected, Table 2-20 shows the back center seat is safest seat in cars. Unrestrained back center passengers are safer than unrestrained back seat outboard passengers. Unbelted back center seat occupants are about as safe as, or perhaps slightly more safe than, lap belted back seat outboard occupants. This is not the case with lap/shoulder belts. Lap/shoulder belted back outboard occupants are much safer than unrestrained back center seat occupants by almost 50 percent. There are only 25 lap/shoulder belted back seat outboard fatalities. But there are 47 unbelted back center seat fatalities in Table 2-20.

Lap belted back center seat passengers are safer than unrestrained and lap belted back seat outboard passengers. But lap belted back center seat occupants are perhaps slightly less safe than lap/shoulder belted back seat outboard occupants. Table 2-20 shows that there are 71 lap belted back center seat occupant fatalities vs. 69 lap/shoulder belted back outboard occupant fatalities.

To summarize, if a car is equipped with lap belts only in the back seat, then the back center seat is safer than the back outboard seats. If a car is equipped with back seat outboard lap/shoulder belts, but only lap belts in the center seat then belt users are probably as safe or safer in the back outboard seats with lap/shoulder belts.

2.11.1 Fatality Reduction for Back Seat Outboard Lap/shoulder Belts Relative to Lap Belts

A simpler way of calculating the effectiveness of back seat outboard lap/shoulder belts is to use a variation of the "double pair comparison" method. In this analysis, the ratio of back seat outboard to back center seat fatalities in cars where the back outboard occupant was lap/shoulder belted is compared to the corresponding ratio where the back outboard occupant was lap belted.

The effectiveness of lap/shoulder belts is estimated by the relative difference in the ratios. In this method, the lap/shoulder belt effectiveness is calculated relative to lap belts. In the previous analysis, the effectiveness of lap belts and lap/shoulder belts was calculated relative to unrestrained occupants. Additionally, all back center occupants are placed in a single control group, regardless of whether they were belted. This helps avoid the very small cells that occurred in the previous analysis, when the back center occupants were split into two control groups. Nonetheless, it has the same disadvantage as the previous analysis. The analysis has to be limited to cars where both the back outboard and back center seats are occupied. The analysis could be biased, mainly by young back seat occupants.

Table 2-21 shows the fatality reduction for back seat outboard lap/shoulder belts vs. lap belts. The risk ratio is 77/65 = 1.185 for lap belted back seat outboard occupants. But, the risk factor is 0.797 for lap/shoulder belted back seat outboard occupants. Thus, a lap belted back seat outboard occupant is slightly more at risk than a back center seat occupant (belted or unbelted) and a lap/shoulder belted back seat outboard occupant is less at risk than a back center seat occupant. The probability of a fatality is 1 - (1.185 / 0.797) = 33 percent lower for lap/shoulder belted back seat outboard occupants than lap belted back seat outboard occupants.

Chi-square($\div^2$) for the 2 x 2 table is 3.32, not statistically significant at the .05 level. $\div^2$ has to be at least 3.84 for significance at the .05 level. Since the $\div^2$ is not greater than 3.84, we are unable to conclude that a lap/shoulder belt provide significant additional benefits over a lap belt in all crash modes.

TABLE 2-21
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD
LAP/SHOULDER BELTS BASED ON REDUCTION OF
BACK SEAT OUTBOARD FATALITIES
RELATIVE TO BACK CENTER SEAT FATALITIES

Back Seat Outboard Restraint Use	BSO Fatalities	BC Seat Fatalities	Risk Factor	Fatality Reduction
Lap belted	77	65	1.185	
Lap\shoulder belted	94	118	0.797	33%

2.11.2 <u>Fatality Reduction for Back Seat Outboard Lap/shoulder Belts in Frontal Crashes</u>

By using the same variation of the "double paired comparison" method as the above analysis, the effectiveness of lap/shoulder belts in frontal crashes can be calculated relative to lap belts.

In Table 2-22, there are about an equal number of back center fatalities (regardless of belted usage) and back outboard fatalities in frontal crashes when the back outboard occupant was lap belted. So lap belted back outboard occupants have about the same fatality risk as back center occupants in frontal crashes. But there are 48 back center fatalities (regardless of belt usage) and only 21 back outboard fatalities when the back outboard occupant was lap/shoulder belted. So there are fewer than half as many lap/shoulder belted back outboard fatalities than back center fatalities. Therefore, lap/shoulder belted back seat outboard occupants have a fatality reduction of 59 percent in frontal crashes. That is for every 100 lap belted back seat outboard occupants killed in frontal crashes, there would only be 41 fatalities if the lap belted occupants were lap/shoulder belted. The fatality reduction is statistically significant at the .05 level ($\div^2 = 5.72$).

TABLE 2-22
FARS 1988-FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD
LAP/SHOULDER BELTS BASED ON REDUCTION OF
BACK SEAT OUTBOARD FATALITIES RELATIVE TO BACK
CENTER SEAT FATALITIES IN FRONTAL CRASHES

Back Seat Outboard Restraint use	BSO Fatalities	BC Seat Fatalities	Risk Factor	Fatality Reduction
Lap belted	27	25	1.080	
Lap\shoulder belted	21	48	0.438	59%

Again, these results are substantially higher than comparable findings in Section 2.7.1. However, since these results are based on much smaller samples, slightly biased towards younger occupants, they cannot be given the same credence as the earlier results.

CHAPTER 3

FATALITY AND INJURY REDUCTION BY BELTS, AS USED, IN PASSENGER CARS

If lap/shoulder belts are more effective than lap belts alone for back seat occupants, and if the use rates for both types of belts are about the same, cars equipped with lap/shoulder belts ought to have a lower overall fatality risk for back seat occupants than the cars equipped only with lap belts, **even when the unrestrained occupants are included in the calculations**. Although the unrestrained occupants will be unaffected by the change in the belt system, the benefit for the belt users should be enough to lower the overall fatality risk for the entire occupant population. This approach of comparing overall fatality risk of two groups of cars with different safety equipment, including both the users and the nonusers of the equipment in the calculations, is called "as used" effectiveness estimation. It is often employed by NHTSA - e.g., the evaluation of Antilock Brake Systems (ABS) took into account all crash-involved drivers, regardless of whether they applied brakes or triggered ABS prior to the crash.

Although "as used" effectiveness is certainly a cruder measure than the "when-used" approach of Chapter 2 (because the large numbers of unrestrained people water down the effectiveness) there are three good reasons for measuring it: (1) It can provide additional confirmation and corroboration of the "when-used" results. (2) It comes closest to measuring the societal benefit of a regulation (e.g., if few people use the new safety equipment, the benefits to society will be minimal). (3) This method does not rely on the belt use reported in crash data files, only on the type of belts equipped (derived directly from the VIN); since there have been some questions about the accuracy of the belt use reporting of survivors in Fatality Analysis Reporting System (FARS), and clear instances of inaccurate belt use reporting of all occupants in State files, the "as used" approach is safe for FARS and it is the only method that can readily be defended for State data analyses.

The "as used" analysis enjoys a much larger sample size than the "when used" analysis. All crash cases are included in the "as used" analysis, regardless of the back seat outboard occupant's belt usage. Specifically, cases where the back seat outboard occupant restraint usage was reported as "unknown" or "missing" are included.

3.1 LAP/SHOULDER BELT FATALITY REDUCTION IN FRONTAL CRASHES, USING NON-FRONTAL CRASHES AS A CONTROL GROUP

The simplest method in Chapter 2 for calculating the effectiveness of lap/shoulder belt in frontal crashes was described in Section 2.10. It assumed shoulder belts had no incremental benefit over lap belt in non-frontal crashes but they had an effect in frontal crashes. Therefore, we used non-frontal crashes as a control group. In Section 2.10, the back seat outboard fatalities were classified as lap/shoulder belted and lap belted. Here, the back seat outboard fatalities are classified by how their cars were equipped: with back seat outboard lap belts or with lap/shoulder belts.

Table 3-1 presents the "as used" data needed to calculate the frontal fatality reduction for back seat outboard lap/shoulder belts for "all make/models." In cars equipped with lap belts, there were 4,383 non-frontal fatalities and 2,554 frontal fatalities. In cars equipped with lap/shoulder belts, there were 4,929 non-frontal fatalities. If lap/shoulder belts had no advantage over lap belts, we would have expected 4,924 * (2,554/4,383) = 2,872 frontal fatalities. In fact, there were only 2,452.

TABLE 3-1
FARS 1988-FIRST 6 MONTHS OF 1997
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD
LAP/SHOULDER BELTS BASED ON REDUCTION
OF FRONTAL FATALITIES RELATIVE TO
NON-FRONTAL FATALITIES FOR "ALL MAKE/MODELS"

	Back Seat Outboard Fatalities		
	Lap belt equipped	Lap/shoulder belt equipped	Fatality Reduction
Non-frontal	4,383	4,929	
Frontal	2,554	2,452	15%

This relative reduction of frontal fatalities for back seat outboard lap/shoulder belts is 15 percent in the "all make/model" analysis. It is statistically significant at the .01 level ($\div^2$ = 20.34). In the corresponding analysis for the "matching make/model" data described in Section 2.4, the incremental fatality reduction for the shoulder belt in frontal crashes is 10 percent, as shown in Table 3-2. Although this is a lower point estimate based on a smaller number of crash cases, it is nevertheless statistically significant at the .05 level ($\div^2$ = 4.18).

TABLE 3-2
FARS 1988-FIRST 6 MONTHS OF 1997
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD
LAP/SHOULDER BELTS BASED ON REDUCTION
OF FRONTAL FATALITIES RELATIVE TO NON-FRONTAL
FATALITIES FOR "MATCHING MAKE/MODELS"

	Back Seat Outboard Fatalities		
	Lap belt equipped	Lap/shoulder belt equipped	Fatality Reduction
Non-frontal	2,753	1,940	
Frontal	1,554	988	10%

The “as used” lap/shoulder belt effectiveness estimates should always be proportionately lower then the “when used” estimates because we included the unrestrained occupants who get zero benefit from belts. If one-third of the back seat occupants are belted then the “as used” lap/shoulder belt effectiveness estimate should be one-third as large as the “when used” effectiveness estimate for lap/shoulder belts relative to lap belts. In that case, our “as used” effectiveness of 10-15 percent is equivalent to 30 - 45 percent “when used” effectiveness in frontal crashes. If 40 percent of the back seat occupants are belted, then our 10-15 percent “as used” effectiveness estimate is equivalent to 25 - 37.5 percent “when used” effectiveness estimate. Thus, our “as used” lap/shoulder belt effectiveness estimate corresponds to an appreciable “when used” effect in frontal crashes, in fact, one that is higher than the 14 to 25 percent range seen in Sections 2.7.1.

3.2 FATALITY REDUCTION, USING FRONT SEAT OUTBOARD OCCUPANTS AS THE CONTROL GROUP

The double-pair comparison method found in Section 2.5 can be adapted to calculate the “as used” lap/shoulder belt effectiveness estimates relative to cars equipped with lap belts. In this analysis, the back seat outboard occupant fatalities are classified into two categories: lap belt equipped and lap/shoulder belt equipped. The front seat outboard occupant fatalities are still classified into five control groups: lap/shoulder belted, unrestrained, 2-point belted, air bag alone, and air bag plus lap/shoulder belted.

Table 3-3 shows the fatalities, adjusted fatalities, and effectiveness of lap/shoulder belts vs. lap belts for “all make/models.” Notice the number of fatalities in both the back and front seats are larger than the ones in Table 2-7. We derived the adjusted fatalities using the same adjustment factor found in Section 2.5. The effectiveness of “as used” lap/shoulder belts vs. lap belts is close to zero. In other words, back seat outboard occupants in cars equipped with lap/shoulder belts in these seating position have the same fatality risk as occupants in cars equipped with lap belts at these positions.

Table 3-4 shows the overall effectiveness estimate shown in Table 3-3 and adds the overall effectiveness estimates for the “matching make/models” analysis. Also shown in Table 3-4 are the overall effectiveness estimates of lap/shoulder belts vs. lap belts by crash type and analysis type. The effectiveness of “as used” lap/shoulder belts is -3 to -4 percent in frontal crashes. In non-frontal crashes, the effectiveness is 3 to 4 percent. In rollover crashes, the effectiveness is -3 to -7 percent and in side impact crashes the effectiveness is 3 to 7 percent.

TABLE 3-3
FARS 1988- FIRST 6 MONTHS OF 1997
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS
RELATIVE TO BACK SEAT OUTBOARD OCCUPANTS * IN CARS EQUIPPED WITH LAP BELTS
BY RESTRAINT USAGE AND RESTRAINT TYPE FOR "ALL MAKE/MODELS"

Back Seat Restraint Type	Back Seat Fatalities	Adjusted Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities	Air Bag Adjustment FS Fatalities	Adjusted Front Seat Fatalities	Risk Factor	Fatality Reduction
Lap belt	3,235	3,243	Lap/shoulder belted	2,578		2,586.8	1.254	5%
Lap/shoulder belt	2,197	3,388		1,857		2,855.9	1.186	
Lap belt	3,352	3,357	Unrestrained	5,372		5,376.6	0.624	-5%
Lap/shoulder belt	1,969	2,680		2,946		4,097.7	0.654	
Lap belt	337	337	2 pt. belted	364		364.0	0.926	-5%
Lap/shoulder belt	1,313	1,313		1,351		1,351.0	0.972	
Lap belt	5		Air bag alone	4	4.6			
Lap/shoulder belt	711			1,002	1,151.7			
Lap belt	8		Air bag plus lap/shoulder belted	8	8.8			
Lap/shoulder belt	1,191			909	998.9			
Weighted average for lap/shoulder belt vs. lap belt:								none

* "Double pair comparison" method relative to front seat outboard occupants.

TABLE 3-4 FARS 1988- FIRST 6 MONTHS OF 1997 "AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS RELATIVE TO BACK SEAT OUTBOARD OCCUPANTS IN CARS EQUIPPED WITH LAP BELTS BY TYPE OF CRASH		
	"All make/models"	"Matching make/models"
All crashes	none	-1%
Frontal crashes	-3%	-4%
All non-frontal crashes	4%	3%
Rollover crashes	-7%	-3%
Side impact crashes	7%	3%

* "Double pair comparison" method relative to front seat outboard occupants.

These results are the only exception to the otherwise uniformly positive findings for lap/shoulder belts relative to lap belts, both "when used" and "as used" in frontal crashes. It is unknown why this particular analysis does not yield a favorable result.

One problem with this method is that belt use in the rear seat differs greatly as a function of belt use in the front seat. It is much higher when the front seat occupants are also belted. Thus, in Table 3-3, most rear seat belt users and most potential benefits of lap/shoulder belts occur with lap/shoulder belted front seat occupants. It is not surprising that the rear seat belts are not effective for those with an unbelted front seat occupant, since this usually means that the rear seat belt was not in use. We believe, but are not absolutely sure, that the weighted average at the bottom of Table 3-3 is an unbiased estimate of the overall effect.

3.3 FATALITY REDUCTION, USING BACK CENTER SEAT OCCUPANTS AS THE CONTROL GROUP

The "as used" effectiveness of lap/shoulder belts relative to lap belts for back seat outboard occupants, using back center seat occupants as the control group, is calculated in Table 3-5. In this analysis, the back seat outboard occupants are classified by restraint type available: lap belt equipped and lap/shoulder belt equipped. The fatality reduction of lap/shoulder belt equipped cars is calculated for two back center seat occupant control groups: unrestrained and lap belted. The "as used" effectiveness of lap/shoulder belts by this method is 9 percent in all crash modes. As explained above that corresponds to a substantially higher "when used" effectiveness.

TABLE 3-5 FARS 1988- FIRST 6 MONTHS OF 1997 "AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS RELATIVE TO BACK SEAT OUTBOARD OCCUPANTS * IN CARS EQUIPPED WITH LAP BELTS BY RESTRAINT USAGE AND RESTRAINT TYPE FOR "ALL MAKE/MODELS"					
Back Seat Outboard Restraint Type	Back Seat Outboard Fatalities	Back Center Seat Restraint Use	Back Center Seat Fatalities	Risk Factor	Fatality Reduction
Lap belt	502	Unrestrained	415	1.210	9%
Lap/shoulder belt	466		425	1.096	
Lap belt	74	Lap belted	53	1.396	10%
Lap/shoulder belt	100		80	1.250	
Weighted average for lap/shoulder belt vs. lap belt:					9%

* "Double pair comparison" method relative to front seat outboard occupants.

In Table 3-6, the analysis is simplified by combining all back center seat occupants into a single control group, regardless of their belt use. The "as used" effectiveness of outboard lap/shoulder belts using this variation is also 9 percent, the same value found in Table 3-5 using the more complicated "double pair comparison" method.

TABLE 3-6 FARS 1988-FIRST 6 MONTHS OF 1997 "AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF BACK SEAT OUTBOARD FATALITIES RELATIVE TO BACK CENTER SEAT FATALITIES				
Back Seat Outboard Restraint Type	Back Seat Outboard Fatalities	Back Center Seat Fatalities	Risk Factor	Fatality Reduction
Lap belt	576	468	1.231	
Lap\shoulder belt	566	505	1.121	9%

Table 3-7 shows the effectiveness of lap/shoulder belt equipped cars in **frontal** crashes relative to lap belt equipped cars also using the method of Table 3-6. Lap/shoulder belt equipped cars have a fatality reduction of 6 percent in frontal crashes. This would be a 15 - 20 percent "when used" effectiveness estimate in frontal crashes if 30 to 40 percent of back seat occupants are belted, and this corresponds closely to the results of Section 2.7.1.

TABLE 3-7
FARS 1988-FIRST 6 MONTHS OF 1997
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF BACK SEAT OUTBOARD FATALITIES RELATIVE TO BACK CENTER SEAT FATALITIES IN FRONTAL CRASHES

Back Seat Outboard Restraint Type	Back Seat Outboard Fatalities	Back Center Seat Fatalities	Risk Factor	Fatality Reduction
Lap belt	178	174	1.023	
Lap\shoulder belt	155	162	0.957	6%

3.4 "AS USED" FATALITY RATES PER 100,000 REGISTERED VEHICLE YEARS, BASED ON "MATCHING MAKE/MODEL" CARS

It might seem that the simplest way to see if lap/shoulder belts are more effective than lap belts is to look at the fatality rate per 100,000 registered vehicle years. R. L. Polk's *National Vehicle Population Profile* is a census of cars registered in the United States, classified by make/model, model year, and some other vehicle parameters[33]. In combination with fatality data, it is possible to compute fatality rates by make/model and other vehicle parameters. But the Polk data provide no information about the belt use of the vehicle occupants. They do not tell use how many vehicle years were "belted" and how many were "unbelted." So only an "as used" analysis of fatality rate per registered car is possible.

If the use rate for both types of belts are the same then the fatality rate of back seat outboard occupants in cars equipped with lap/shoulder belts should be lower than the fatality rate of occupants in cars with lap belts. But the use rates for both types of vehicles are not the same. The cars equipped with lap belts are, on the average, older than the cars equipped with lap/shoulder belts, and Chapter 1 shows that older cars have lower belt use. Moreover, the basic overall fatality rate per 100,000 vehicle years also varies with vehicle age. In particular, newer vehicles are driven more and have higher fatality rates than older vehicles. So analysis of the simple fatality rate per registered vehicles has some inherent problems. The simple fatality rate analysis and a regression analysis controlling for vehicle age are presented in this section. These

[33]Kahane, C., *Relationships between Vehicle Size and Fatality Risk in Model Year 1985-93 Passenger Cars and Light Trucks*, NHTSA Technical Report No. DOT HS 808 570, Washington, DC, 1997.

analyses assume that the rear seat occupancy is the same for different types of seat belts and could be biased if it is not.

Both analyses in this section are based on the FARS Vehicle-Level file described in Section 2.1.1 and on the R. L. Polk's *National Vehicle Population Profile*. The Polk registration files has the number of vehicles registered on July 1st of every year by make/model, model year, body style, and calendar year.

To calculate meaningful fatality rates per registered vehicles, there has to be exact correspondence between the FARS and Polk files. Vehicles excluded on the fatality data have to be excluded on the registration data. And vice visa, vehicles excluded on the Polk file have to be excluded on the FARS file. The Polk make/model, model year, and body style codes were translated into make/model and body style codes that match codes produced by decoding the VIN in the fatality data. This translation process is described in detail on pages 63-64 of the Relationships between Vehicle Size and Fatality Risk report[34].

The next step is to limit the range of model years and vehicle age on both files, so the vehicles remain matched. The Polk data were limited to the same calendar years as the FARS data, 1988-1996. Both Polk and FARS data were limited to the "matching make/model" cars discussed in Section 2.4 and listed in Appendix A. Brand new cars, cars with model year equal to or greater than the calendar year, were excluded from both data sets. In any year, new vehicles registered after July 1 are not included in the Polk data because the Polk data is compiled as of July 1. Since the FARS data do not specify on what day of the year the car was registered, new vehicles have to be excluded, because there is no way to tell if this FARS vehicle is on the Polk file or not.

Some calendar years of data were also excluded on both data sets so there is an equal number of model years in the lap/shoulder belt equipped cars and lap belt equipped cars. Otherwise, older model year cars, cars equipped with lap belts, will have more model years included than newer model year cars since they are bought and registered earlier than new model year cars. For example, the Chrysler 5th Avenue switched to lap/shoulder belts in model year 1990, so three model years before and after 1990 means model year 1987-1992 are included. The following table shows the total number of years available in the registration data and the included number of years by model year.

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[34]Kahane (1997).

Model Year	Total Available		Included in the Analysis	
	Registered Calendar Years	Registered Vehicle Years	Registered Calendar Years	Registered Vehicle Years
1987	1988-1996	9	1993-1996	4
1988	1989-1996	8	1992-1996	5
1989	1990-1996	7	1991-1996	6
1990	1991-1996	6	1991-1996	6
1991	1992-1996	5	1992-1996	5
1992	1993-1996	4	1993-1996	4

If calendar years were not excluded on the lap belt equipped cars then there would have been 9 + 8 + 7 = 24 total model years for lap belt equipped cars and only 6 + 5 + 4 = 15 years for lap/shoulder belt equipped cars. So by excluding certain calendar years of data depending on the model year and transition year we have equal number of model years with lap/shoulder belts and with lap belts.

We calculated the fatality rate per 100,000 registered car for one, two, and three model years before and after the transition to lap/shoulder belts to limit the vehicle age effect. There are 404 back seat occupant fatalities in ± 1 model year of lap belt equipped cars in non-frontal crashes and there are 50,062,363 corresponding registered cars. So the lap belt fatality rate per 100,000 registered cars in non-frontal crashes is 404 / 50,062,363 * 100,000 = .81. There are 432 back seat occupant fatalities in ± 1 model year of lap/shoulder belt equipped cars in non-frontal crashes and there are 51,769,865 corresponding registered cars, so the lap/shoulder belt fatality rate is .83. The percent change in fatality rates in non-frontal crashes is (.81 - .83) / .81 = -3 percent. This is a 3 percent increase in the fatality rate for lap/shoulder belts in non-frontal crashes. Table 3-8 shows these fatality rates and adds the ones for frontal crashes. Table 3-8 also includes the fatality rates for two and three model years before and after the transition to lap/shoulder belts.

In non-frontal crashes, we see an increase in the percent change in fatality rate as we add more model years before and after the transition year. In ± 1 year, there is a 3 percent change and in ± 3 years, there is a 14 percent change. This clearly illustrates that the vehicle age bias is affecting this analysis. In frontal crashes, this trend is not as apparent.

TABLE 3-8 "AS USED" FATALITY RATE AND PERCENTAGE INCREASE IN FATALITY RATE BY YEARS BEFORE AND AFTER THE TRANSITION TO LAP/SHOULDER BELTS AND CRASH MODE FOR "MATCHING MAKE/MODEL" CARS						
Crash Mode		Back Seat Outboard Restraint Type	Back Seat Outboard Fatalities	Number of Registered Cars	Fatality Rate per 100,000 Registered Cars	Percentage Increase in Fatality Rate
± 1 year						
	Non-frontal	Lap belt	404	50,062,363	0.81	
		Lap/shoulder belt	432	51,769,865	0.83	-3%
	Frontal	Lap belt	257	50,062,363	0.51	
		Lap/shoulder belt	303	51,769,865	0.59	-14%
± 2 years						
	Non-frontal	Lap belt	702	90,327,497	0.78	
		Lap/shoulder belt	711	85,254,203	0.83	-7%
	Frontal	Lap belt	461	90,327,497	0.51	
		Lap/shoulder belt	471	85,254,203	0.55	-8%
± 3 years						
	Non-frontal	Lap belt	903	117,075,792	0.77	
		Lap/shoulder belt	952	107,926,329	0.88	-14%
	Frontal	Lap belt	600	117,075,792	0.51	
		Lap/shoulder belt	604	107,926,329	0.56	-9%

To measure statistically significance of the difference between the rates for these two populations, lap belt equipped cars and lap/shoulder belt equipped cars, we calculate the standard deviation of both populations. Let r_1 be the fatality rate per 100,000 registered lap belt equipped cars and r_2 be the fatality rate for lap/shoulder belt equipped cars. For ± 3 years in non-frontal crashes, r_1 = .77127 and r_2 = .88205, as seen in Table 3-8. The fatality rate per 100,000 registered vehicles is a Poisson distribution divided by a constant, so the standard deviation is the square root of the number of fatalities divided by a constant, the number of 100,000 registered cars. For ± 3 years in non-frontal crashes, the standard deviations are

$$s_1 = \sqrt{903}\big/1170.8 = 0.025666 \qquad \text{and} \qquad s_2 = \sqrt{952}\big/1079.3 = 0.028589$$

in our two populations. The standard deviation of $r_1 - r_2$, two independent variables, is

$$s = \sqrt{(0.025666)^2 + (0.028589)^2} = 0.038419\,.$$

And the significance test is

$$\frac{r_1 - r_2}{s} = \frac{0.77127 - 0.88205}{0.038419} = -2.88.$$

The absolute value of the test value needs to be greater than 1.96 for statistically significance. So the 14 percent increase in lap/shoulder belt fatality rate for ± 3 years in non-frontal crashes is statistically significant. Table 3-9 shows the percentage increase in fatality rates from Table 3-8 and significance test results.

TABLE 3-9
"AS USED" PERCENTAGE INCREASE IN FATALITY RATE AND SIGNIFICANCE TEST RESULT BY YEARS BEFORE AND AFTER THE TRANSITION TO LAP/SHOULDER BELTS AND CRASH MODE FOR "MATCHING MAKE/MODEL" CARS

Crash Mode		Percentage Increase in Fatality Rate	Significance Test Results
± 1 year			
	Non-frontal	-3%	-0.48
	Frontal	-14%	-1.55
± 2 years			
	Non-frontal	-7%	-1.33
	Frontal	-8%	-1.21
± 3 years			
	Non-frontal	-14%	-2.88*
	Frontal	-9%	-1.52

* Statistically significant

The 14 percent increase in lap/shoulder belt fatality rate ± 3 years in non-frontal crashes is the only statistically significant result. Therefore, this analysis is inconclusive given the vehicle age bias even present in the ± 1 model year of data and the non-significant results.

We performed a regression analysis to control for the vehicle age effect. This also allowed us to use all the data in 3 model years before and after the transition year. Table 3-10 shows the regression analysis for frontal crashes. The independent variables describe the back seat outboard occupant's restraint type as equipped and vehicle's age. These variables are actually definable on the Polk data as well as the FARS data. The procedure is to split the Polk and FARS data into cells by restraint type equipped, calendar year, and model year (total of 80 cells). (In each cell, VEHAGE = CY - MY.) The fatality rate per 100,000 registered cars in frontal crashes is computed in each cell and is the dependent variable. (We also tried the logarithm fatality rate but got even lower R^2 values.) Since some cells are more important than others, because they contain more data, the regression is weighted by REGS, the number of 100,000 registered vehicles in each cell. Weighted linear regression is performed by the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS)[35]. The R^2 value for this analysis is 0.009, indicating that the largely random variation of the fatality rate among the cells is only little explained by vehicle age or restraint type.

TABLE 3-10

LINEAR REGRESSION OF FATALITIES PER 100,000 REGISTERED CARS BY BACK SEAT OUTBOARD RESTRAINT TYPE AND VEHICLE AGE IN FRONTAL CRASHES

Dependent Variable: FRRATE (Fatality rate in frontal crashes)

N of Observations: 80

Weighting Factor: REGS (N of 100,000 registered cars)

REGRESSION COEFFICIENTS

Independent Variable	Regression Coefficient	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	5.243132539	4.96	0.0001	1.05709325
BKLS	-0.265784641	-0.56	0.5758	0.47296947
VEHAGE	0.024038395	0.24	0.8074	0.09824649

The average vehicle age was 4.95 in these crashes. Using the average vehicle age and effect of vehicle age, we adjust the intercept to eliminate the vehicle age effect. The adjusted intercept is 5.243 - (4.95 * 0.02) = 5.144. Therefore, -0.266/5.144 is a 5 percent reduction in the fatality rate in frontal crashes for lap/shoulder belts “as used.” The reduction, however, is not statistically significant, as evidenced by the t value of only -0.56.

The same regression analysis was repeated for non-frontal crashes. Table 3-11 shows the results. The R^2 value, here, is 0.005. Adjusting the intercept to eliminate the vehicle age bias, we get 8.433 - (4.95 * .07) = 8.087. Thus, -0.269 / 8.087 is a 3 percent reduction in the fatality rate in non-frontal crashes for lap/shoulder belts. This reduction is also non-significant (t = -0.46).

The more complicated “as used” fatality rate analyses, regression analyses controlling for vehicle age, produce favorable results for lap/shoulder belts. Here, we found a slightly higher reduction in the fatality rate per 100,000 registered cars in frontal crashes than non-frontal crashes. Moreover, the 5 percent “as used” reduction for lap/shoulder belts in frontal crashes is fairly

[35] SAS (1990).

consistent with the other findings of this chapter and the "when used" results of Chapter 2. But neither regression produces statistically significant coefficients for the effect of lap/shoulder belts.

TABLE 3-11
LINEAR REGRESSION OF FATALITIES PER 100,000 REGISTERED CARS
BY BACK SEAT OUTBOARD RESTRAINT TYPE AND VEHICLE AGE
IN NON-FRONTAL CRASHES

Dependent Variable: NRRATE (Fatality rate in non-frontal crashes)

N of Observations: 80

Weighting Factor: REGS (N of 100,000 registered cars)

REGRESSION COEFFICIENTS

Independent Variable	Regression Coefficient	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	8.433177562	6.45	0.0001	1.30669462
BKLS	-0.269318228	-0.46	0.6463	0.58464726
VEHAGE	-0.073466690	-0.60	0.5470	0.12144451

3.5 INJURY REDUCTION BY BELTS IN STATE DATA

A State data file is a census of police-reported crashes occurring on roadways in the state. All severity levels of police-reported crashes that occur in the state, not just fatal crashes, but also nonfatal injury and property-damage-only crashes are included. Therefore, an analysis of state data can show the injury reducing effects that lap/shoulder belts have on back seat outboard occupants.

Pennsylvania and Florida state data files were evaluated in this analysis. Both of these states have an adequate number of crashes and the information required for this analysis. Information on all injured and non-injured occupants involved in crashes are contained on these state data files as well as the VIN which was essential for this analysis.

The "as used" analysis was performed since reported belt use in state data files is unrealistically high. In Pennsylvania's data file, almost 60 percent of the back seat outboard occupants are reported as belted and in Florida, 70 percent. The National Occupant Protection Use Survey (NOPUS) observational study reports 40 percent belt use by back seat outboard occupants. (See

Chapter 1 for more on belt use.) Therefore, a "when-used" analysis is not appropriate on state data files, since many of the reported belt users were, in fact, probably unrestrained.

The state data analysis was based on seven years of data, calendar years 1990 through 1996. Two vehicle-level files were created similar to the FARS vehicle-level file described in Section 2.1.1: one using Pennsylvania's vehicle and person data file and the other using Florida's data files. Separate analyses were done on each state. Only the back seat outboard occupants were analyzed.

Pennsylvania and Florida, like other States, use a 5 point scale to classify occupant injury severity. It is commonly referred to as the KABCO scale where each letter represents a different severity of injury as follows:

	Pennsylvania	Florida
K	Killed	Killed
A	Major injury	Incapacitating injury
B	Moderate injury	Non-incapacitating injury
C	Minor injury	Possible injury
O	No injury	No injury

These levels are heuristic indicators of relative severity and do not necessarily correspond to objective scales used by physicians. In general, A is rarer and, on the average more severe than B, which in turn is rarer and more severe than C. Level C injuries are typically of such low severity that they are only marginally affected by belt use. Therefore, it is most appropriate to study K, A, and B injuries and, if sample size are sufficient (in Florida only), just K and A injuries.

3.5.1 Analysis Using The Pennsylvania Data

Using a method similar to the one described in Section 3.1, we calculate the "as used" effectiveness of reducing injuries to back seat outboard occupants in cars equipped with lap/shoulder belts. In this method, we assume that shoulder belts have little or no effect on the injury risk in non-frontal crashes, but have an effect in frontal crashes. We believe this assumption is valid since we found this for fatality injured occupants. Then the ratio of frontal to non-frontal injuries of back seat outboard occupants in cars equipped with lap/shoulder belts ought to be lower than the corresponding ratio in cars equipped with lap belts. The incremental effectiveness of shoulder belts in frontal crashes is estimated by the relative difference in the ratios.

Table 3-12 shows the "as used" data needed to calculate the injury reduction for back seat outboard lap/shoulder belts in frontal crashes by analysis type. In cars equipped with lap belts, there were 995 non-frontal KAB injuries and 1,327 frontal KAB injuries in the "all make/model" cars. In cars equipped with lap/shoulder belts, there were 945 non-frontal KAB injuries. If lap/shoulder belts had no advantage over lap belts, we would have expected 945 * (1,327/995) =

1,260 frontal KAB injuries. But there were only 1,107. This is a 12 percent relative reduction of frontal KAB injuries for back seat outboard lap/shoulder belts. It is statistically significant at the .05 level ($\div^2 = 4.52$). The incremental injury reduction for the shoulder belt in frontal crashes is 13 percent in the "matching make/model" cars, also shown in Table 3-12. It is not statistically significant ($\div^2 = 2.40$).

TABLE 3-12
PENNSYLVANIA 1990-1996
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF FRONTAL KAB INJURIES RELATIVE TO NON-FRONTAL KAB INJURIES BY ANALYSIS TYPE

		Back Seat Outboard KAB Injuries		Injury Reduction
		Lap belt equipped	Lap/shoulder belt equipped	
"All make/models"				
	Non-frontal	995	945	
	Frontal	1,327	1,107	12%
"Matching make/models"				
	Non-frontal	536	413	
	Frontal	714	480	13%

This analytical method of using non-frontal crashes as a control group was repeated for different age and sex groups. Table 3-13 shows the results. The injury reduction for lap/shoulder belts in frontal crashes is consistent for children, females and seniors, 17 - 19 percent injury reduction. Males aged 15 - 54 have a -4 percent injury reduction for lap/shoulder belts in frontal crashes. By combining males and females into one group, adults aged 15 - 54 have 9 percent injury reduction for lap/shoulder belts in frontal crashes. (This combined adult group was included so comparison can be made between Pennsylvania and Florida data.)

Studies have shown that lap belts may harm back seat occupants. The National Transportation Safety Board (NTSB) report[36] concludes that lap belts increase the risk of abdominal injuries to back seat occupants. It was hoped that these data could be used to analyze the effect of lap/shoulder belts on abdominal injuries. These hopes were not realized. Pennsylvania does not classify abdominal injuries separately but lumps them with chest as "torso" injuries. Even "torso" injuries are too rare for meaningful statistical analyses, since police are only allowed to code one body region per person, and the overwhelming majority of cases are head injuries (which are more readily visible, even if they are not as severe as the torso injuries).

[36] NTSB (1986).

TABLE 3-13 PENNSYLVANIA 1990-1996 "AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF FRONTAL KAB INJURIES RELATIVE TO NON-FRONTAL KAB INJURIES BY AGE AND SEX FOR "ALL MAKE/MODELS"				
		Back Seat Outboard KAB Injuries		Injury Reduction
		Lap belt equipped	Lap/shoulder belt equipped	
Children ages 5-14				
	Non-frontal	263	214	
	Frontal	347	233	17%
Males ages 15-54				
	Non-frontal	314	260	
	Frontal	416	357	-4%
Females ages 15-54				
	Non-frontal	289	313	
	Frontal	394	344	19%
Adults ages 15-54				
	Non-frontal	603	573	
	Frontal	810	701	9%
Seniors ages 55+				
	Non-frontal	129	158	
	Frontal	170	173	17%

A more traditional method was also used to calculate the incremental injury reduction of back seat outboard shoulder belts. This method does not rely on double-pair comparison but on the computation of injury rates per 100 crash involved occupants. This "traditional" method is possible with State data, since all occupants, uninjured as well as injured, are reported. If back seat outboard occupants receive less injuries in cars equipped with lap/shoulder belts than in cars with only lap belts, then the ratio of back seat outboard injuries to total occupants in cars equipped with lap/shoulder belts ought to be lower than the corresponding ratio in cars with lap belts only. The incremental injury reduction of shoulder belts is estimated by the relative difference in the ratios.

Table 3-14 shows the injury reduction for back seat outboard lap/shoulder belts vs. lap belts by age and sex. The risk factor is 610/13,531 = 0.045 for back seat outboard children in cars equipped with lap belts. But, the risk factor is 0.032 for back seat outboard children in cars equipped with lap/shoulder belts. Thus, a back seat outboard child in a lap belt equipped car is more at risk than a child in a lap/shoulder belt equipped car. The probability of an injury is 1 -

(0.032 / 0.045) = 30 percent lower for children in lap/shoulder belt equipped cars than lap belt equipped cars.

TABLE 3-14
PENNSYLVANIA 1990-1996
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED KAB INJURED OCCUPANTS RELATIVE TO ALL BACK SEAT OUTBOARD OCCUPANTS BY AGE AND SEX FOR "ALL MAKE/MODELS"

		KAB Injured Occupants	All Occupants	Risk Factor	Injury Reduction
Children ages 5-14					
	Lap belt equipped	610	13,531	0.045	
	Lap/shoulder belt equipped	447	14,082	0.032	30%
Males ages 15-54					
	Lap belt equipped	730	10,655	0.069	
	Lap/shoulder belt equipped	617	10,296	0.060	13%
Females ages 15-54					
	Lap belt equipped	683	10,388	0.066	
	Lap/shoulder belt equipped	657	11,586	0.057	14%
Seniors ages 55+					
	Lap belt equipped	299	3,162	0.095	
	Lap/shoulder belt equipped	331	4,237	0.078	17%

Table 3-14 shows that all age and sex group of back seat outboard occupants benefit from lap/shoulder belts. Children aged 5 - 14 appear to benefit the most from lap/shoulder belts. They have a 30 percent injury reduction in cars equipped with lap/shoulder belts. Males and females aged 15 - 54 appear to benefit the least from lap/shoulder belts. Lap/shoulder belts appear to reduce injuries by 13 - 14 percent for males and females. Seniors appear to benefit more from lap/shoulder belts than adult male and female back seat outboard occupants but not as much as children.

Table 3-15 shows the injury reduction estimates by crash type and age and sex. The estimates for all crashes are copied from Table 3-14. Table 3-15 shows that all age and sex groups appear to benefit from lap/shoulder belts in frontal crashes. The injury reductions range from 9 to 35 percent in frontal crashes. In non-frontal crashes, all age/sex groups appear to benefit from lap/shoulder belts except females. Females have a 2 percent injury reduction in cars equipped with lap/shoulder belts. Children appear to benefit the most from lap/shoulder belts in both frontal and non-frontal crashes. Their injury reduction percentages are the largest. The injury reduction estimates in frontal crashes are larger than the estimates in non-frontal crashes for all age and sex groups except males. Males appear to benefit more from lap/shoulder belt in non-frontal crashes than in frontal crashes.

TABLE 3-15
PENNSYLVANIA 1990-1996
“AS USED” EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED KAB INJURED OCCUPANTS RELATIVE TO ALL BACK SEAT OUTBOARD OCCUPANTS BY CRASH TYPE AND AGE AND SEX FOR “ALL MAKE/MODELS”

	Crash Type		
	All Crashes	Frontal Crashes	Non-Frontal Crashes
Children ages 5-14	30%	35%	23%
Males ages 15-54	13%	9%	17%
Females ages 15-54	14%	22%	2%
Seniors ages 55+	17%	22%	11%

3.5.2 Analysis Using The Florida Data

We repeated the same “as used” analysis on Florida’s data using non-frontal as a control group. Table 3-16 shows the injury reduction estimates by analysis type found in cars equipped with lap/shoulder belts involved in frontal crashes. In both the “all make/model” and “matching make/model” cars, the injury reduction for lap/shoulder belts in frontal crashes is consistent at 5 - 6 percent. In the “all make/models” analysis, the chi square is statistically significant at the .05 level ($\div^2 = 5.02$). But in the “matching make/models” analysis, it is not statistically significant ($\div^2 = 1.62$).

Table 3-17 shows the “as used” effectiveness of back seat outboard lap/shoulder belts by age. We could not classify back seat occupants by their gender, since the gender is only reported for drivers and pedestrians on Florida’s data file. So we classified occupants in three age groups: children age 5-14, adults age 15-54, and seniors age 55 and older.

Table 3-17 shows that children appear to benefit the most from lap/shoulder belts in frontal crashes. Children have the highest injury reduction percentage, 12 percent. Adults and seniors do not benefit as much as children from lap/shoulder belts in frontal crashes. They experience a relatively small injury reduction from lap/shoulder belts in frontal crashes, 3-4 percent. The enhanced “as used” effect for children could be a reflection of their higher belt use rate and/or a higher effectiveness when used.

TABLE 3-16
FLORIDA 1990-1996
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF FRONTAL KAB INJURIES RELATIVE TO NON-FRONTAL KAB INJURIES BY ANALYSIS TYPE

		Back Seat Outboard KAB Injuries		Injury Reduction
		Lap belt equipped	Lap/shoulder belt equipped	
"All make/models"				
	Non-frontal	4,535	5,951	
	Frontal	3,794	4,661	6%
"Matching make/models"				
	Non-frontal	2,486	2,171	
	Frontal	2,103	1,737	5%

TABLE 3-17
FLORIDA 1990-1996
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF FRONTAL KAB INJURIES RELATIVE TO NON-FRONTAL KAB INJURIES BY AGE FOR "ALL MAKE/MODELS"

		Back Seat Outboard KAB Injuries		Injury Reduction
		Lap belt equipped	Lap/shoulder belt equipped	
Children ages 5-14				
	Non-frontal	1,143	1,504	
	Frontal	1,081	1,255	12%
Adults ages 15-54				
	Non-frontal	2,604	3,247	
	Frontal	2,160	2,589	4%
Seniors ages 55+				
	Non-frontal	788	1,200	
	Frontal	553	817	3%

We also calculated the "as used" lap/shoulder belt effectiveness estimates for killed and seriously injured (K and A) back seat outboard occupants in frontal crashes. Table 3-18 shows the "as used" lap/shoulder belt effectiveness estimate for all back seat outboard occupants is 5 percent. This is not statistically significant ($\div^2 = 0.83$).

TABLE 3-18
FLORIDA 1990-1996
"AS USED" EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS BASED ON REDUCTION OF FRONTAL KA INJURIES RELATIVE TO NON-FRONTAL KA INJURIES BY AGE AND SEX FOR "ALL MAKE/MODELS"

		Back seat outboard KA Injuries		Injury Reduction
		Lap belt equipped	Lap/shoulder belt equipped	
All ages				
	Non-frontal	1,323	1,726	
	Frontal	971	1,203	5%

CHAPTER 4

FATALITY REDUCTION BY BACK SEAT BELTS, WHEN USED, IN PASSENGER VANS AND SPORT UTILITY VEHICLES

In Chapter 2, we found in passenger cars that:

- Lap and lap/shoulder belts when used are effective in reducing fatalities in all crashes relative to unrestrained occupants,
- Lap/shoulder belts when used are effective in reducing fatalities in all crashes relative to lap belted occupants,
- Lap belts when used are not effective in reducing fatalities in frontal crashes relative to unrestrained occupants,
- Lap/shoulder belts when used are effective in reducing fatalities in frontal crashes relative to unrestrained occupants, and
- Lap/shoulder belts when used are effective in reducing fatalities in frontal crashes relative to lap belted occupants.

But are lap and lap/shoulder belts effective in passenger vans and Sport Utility Vehicles (SUVs), a class of vehicles with growing popularity? Are lap/shoulder belts more beneficial than lap belts alone in passenger vans and SUVs? Are these belts effective in frontal crashes? Are lap and lap/shoulder belts just as effective in passenger vans and SUVs as they are in passenger cars? This chapter will address these questions.

This chapter will estimate the fatality reduction of back seat belts "when used" in passenger vans and SUVs. We will estimate the effectiveness of lap belts alone and lap/shoulder belts for back seat occupants, relative to unrestrained occupants. We will also estimate the effectiveness of lap/shoulder belts relative to lap belted back seat occupants.

4.1 DATA PREPARATION

This chapter will use the main analytical method that was used in Chapter 2 for passenger cars, the "double paired comparison" method. This method measures the fatality risk of back seat outboard occupants relative to front seat outboard occupants. This method requires the fatality data to be "paired together" from both the front and back seat outboard occupants who had been riding in the same crash-involved vehicle. In order to pair occupants together from the same vehicle, we had to create a vehicle-level file.

4.1.1 Vehicle-level File

We created a vehicle-level file for certain light trucks, vans, and utility vehicles similar to vehicle-level file created in Section 2.1.1 for passenger cars. We used the same Fatality Analysis Reporting System (FARS) data, calendar years 1988 through the first six months of 1997. The only difference is this vehicle-level file has all outboard occupants in the first seat, second seat, and third seat. So each record contains information on the vehicle and the occupants in the driver seat, the front right (FR) passenger seat, the second left (2L) passenger seat, the second right (2R) passenger seat, the third left (3L) passenger seat, and the third right (3R) passenger seat. These six seat positions are coded 11,13, 21, 23, 31, and 33, respectively, on FARS.

First, we analyzed the VIN of light trucks, vans, and SUVs, model year 1985-1996, to determine the specific vehicle make and model. We determined the specific restraint type available in these vehicles at the front, second, and third seating positions. Light trucks, vans, and SUVs manufactured after September 1, 1991 are required to have lap/shoulder belts in the rear outboard seating positions, except the rear outboard seats which have a walkway between the seat and the vehicle exterior. Similar to cars, some light trucks, vans, and SUVs were equipped with lap/shoulder belts prior to the requirement, as were some rear outboard seats that were exempt from the requirement because of walkway exception. Appendix B lists the installation dates by make/model for the passenger vans and SUVs included in the analysis. We excluded pickup trucks and cargo vans from this analysis because most only have a front seat and are exempt from this requirement.

Then, we extracted records of outboard occupants in the front right, second, and third seats (age 5 or more) and the drivers (age 14 or more) from FARS. Finally, we combined the vehicle information and the occupant information to create a vehicle-level file which had one record for each vehicle that had a second or third seat outboard occupant. (Similar to the passenger car analysis, only the first occupant in FARS records that show two or more occupants in the same seat position was included in the analysis.)

4.1.2 Paired-occupant File

One vehicle-level record could generate up to eight paired-occupant records where at least one of the occupants died. The possible records generated are:

Driver and 2L passenger
Driver and 2R passenger
Driver and 3L passenger
Driver and 3R passenger
FR passenger and 2L passenger
FR passenger and 2R passenger
FR passenger and 3L passenger
FR passenger and 3R passenger

In the passenger car analysis, up to four paired occupant records could be generated from one vehicle record, because we only considered the second seat outboard occupants.

This method involves "double counting" similar to the paired-occupant file for passenger cars. But it also involves "quadruple counting" since the same occupant may appear on four paired-occupant records. For example, a mini-van with 6 occupants and a driver fatality, will generate four paired-occupant records: the driver with each back seat outboard occupant. The paired-occupant records and their number of front and back seat fatalities for this example are such:

	Back seat fatalities	Front seat fatalities
Driver and 2L passenger	0	1
Driver and 2R passenger	0	1
Driver and 3L passenger	0	1
Driver and 3R passenger	0	1
FR passenger and 2L passenger	no records generated, since both survived	
FR passenger and 2R passenger	no records generated, since both survived	
FR passenger and 3L passenger	no records generated, since both survived	
FR passenger and 3R passenger	no records generated, since both survived	
Total contributed to the analysis	0	4

If the 2L passenger had also died, the paired-occupant records and their number of front and back seat fatalities are such:

	Back seat fatalities	Front seat fatalities
Driver and 2L passenger	1	1
Driver and 2R passenger	0	1
Driver and 3L passenger	0	1
Driver and 3R passenger	0	1
FR passenger and 2L passenger	1	0
FR passenger and 2R passenger	no records generated, since both survived	
FR passenger and 3L passenger	no records generated, since both survived	
FR passenger and 3R passenger	no records generated, since both survived	
Total contributed to the analysis	2	4

This method appears to bias the analysis because the total number of paired-occupant records that contributed to the analysis can vary by the seat position of the occupant and the number of occupants in the vehicle. But the inconsistent number of paired-occupant records that contributed to the analysis do not bias the results of this method. Proof 1 of Appendix C shows that this method does not create biases when four occupants, two front and two back seat outboard occupants, are involved in a fatal crash. Proof 2 in Appendix C shows that this method does not create biases when three occupants, two front and one back seat outboard occupant, are involved in a fatal crash. This method does not create biases when there are five (two front and three back seat outboard occupants) or six occupants (two front and four back seat outboard occupants) involved in a fatal crash. These proofs are not contained in this report, but are similar to Proof 1 and Proof 2 in Appendix C.

The only bias this method does create is that it generates fewer records when there is only a driver and no FR passenger than when there is a driver and a FR passenger. This bias is negligible because 88 percent of the passenger vans and SUVs included in this analysis with a back seat outboard occupant also have a FR occupant.

4.2 "WHEN-USED" ANALYSIS

For this analysis, we combined and reported the front seat outboard restraint use and restraint type available in 4 categories: unrestrained, lap/shoulder belted, air bag alone, and air bag plus lap/shoulder belted. For the back seat occupants, we reported the restraint use and restraint type available in 3 categories: unrestrained, lap belted, and lap/shoulder belted. These categories are defined the same way the restraint categories were defined in the passenger car analysis, Section 2.1.3. The front restraint category of "2-point belted" used in the passenger car analysis is not applicable for passenger vans and SUVs in this analysis, because all passenger vans and SUVs in this analysis were equipped with manual lap/shoulder belts.

Other FARS restraint use codes such as "unknown" were excluded from the analysis, i.e., "unknown" restraint use by at least one of the occupants in the paired-occupant record causes the paired-occupant record to be excluded. (Mercury Villager and Nissan Quest were excluded since it was unknown from the VIN if the vehicle had 2-point or 3-point belts in the front seat.)

Table 4-1 shows the number of back seat outboard fatalities and front seat outboard fatalities by back seat restraint type and use and front seat restraint type and use in passenger vans and SUVs. In Table 2-1 for passenger cars, we analyzed 1,809 back seat outboard lap/shoulder belted fatalities. In this table, there are only 250 + 18 + 4 + 101 = 373 back seat outboard lap/shoulder belted fatalities. This is less than one-quarter of the data analyzed in the passenger car analysis.

There was a total of 1,370 unrestrained back seat occupants who died in passenger vans and SUVs and 498 lap/shoulder belted front seat occupants who died. The risk factor for unrestrained back seat occupants (relative to lap/shoulder belted front seat occupants) is 1,370 / 498 = 2.751. The risk factor for lap belted back seat occupants (again, relative to the control group of lap/shoulder belted front seat occupants) is 315 / 305 = 1.033. With the plausible assumption that the two control groups of lap/shoulder belted front seat occupants are subject to about equal risk, the probability of fatality is 1 - (1.033 / 2.751) = 62 percent lower for lap belted back seat occupants than unrestrained back seat occupants.

The preceding can be repeated for lap/shoulder belted back seat occupants accompanied by lap/shoulder belted front seat occupants. The risk factor is 250 / 296 = 0.845. The same assumption that the two control groups of lap/shoulder belted front seat occupants are equal still applies, so the probability of fatality is 1 - (0.845 / 2.751) = 69 percent lower for lap/shoulder belted back seat occupants than unrestrained back seat occupants. Table 4-1 includes the preceding calculations and carries out three more: for "unrestrained," "air bag alone," and "air bag plus lap/shoulder belted" front seat outboard occupants as control groups.

The overall effectiveness of lap/shoulder belts is calculated similar to the estimate for passenger cars. The overall effectiveness is the weighted average of the four fatality reduction estimates. The passenger car analysis used the weighted average of five estimates, because it had the 2-point belted front seat occupant control group which is not applicable here. The overall effectiveness for lap/shoulder belts in back outboard seats is

$$1 - \left[\frac{250 + 18 + 4 + 101}{250(2.751/.845) + 18(.727/.113) + 4(.878/.114) + 101(3.962/.927)} \right] = 73\%$$

Later model year light trucks and vans equipped with air bags have only lap/shoulder belts in the back outboard seat positions. So the restraint combinations of back seat lap belt and front seat air bag alone or back seat lap belt and front seat air bag plus lap/shoulder belt are impossible in this analysis. Therefore, the overall effectiveness of lap belts is based on only the lap/shoulder belted and unrestrained front seat occupant control groups. The overall effectiveness for lap belts in back outboard seats is

$$1 - \left[\frac{315 + 24}{315(2.751/1.033) + 24(.727/.202)} \right] = 63\%$$

The data in Table 4-1 also shows that the back seat is safer than the front seat in these vehicles. An unrestrained back seat occupant is safer than an unrestrained front seat occupant. There were only 1,096 unrestrained back seat fatalities but 1,507 unrestrained front seat fatalities. A lap/shoulder belted back seat occupant is safer than lap/shoulder belted front seat occupant. And a lap/shoulder belted back seat occupant is also slightly safer than lap/shoulder belted front seat occupant with the extra protection of an air bag. But a lap belted back seat occupant is slightly less safe than a lap/shoulder belted front seat occupant.

TABLE 4-1 FARS 1988- FIRST 6 MONTHS OF 1997 EFFECTIVENESS OF ALL BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS RELATIVE TO BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE AND RESTRAINT TYPE IN PASSENGER VANS AND SUVS					
Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities	Risk Factor	Fatality Reduction
Unrestrained	1,370	Lap/shoulder belted	498	2.751	
Lap belted	315		305	1.033	62%
Lap/shoulder belted	250		296	0.845	69%
Unrestrained	1,096	Unrestrained	1,507	0.727	
Lap belted	24		119	0.202	72%
Lap/shoulder belted	18		160	0.113	85%
Unrestrained	108	Air bag alone	123	0.878	
Lap/shoulder belted	4		35	0.114	87%
Unrestrained	206	Air bag plus lap/shoulder belted	52	3.962	
Lap/shoulder belted	101		109	0.927	77%
Weighted average for lap belted vs. unrestrained back seat outboard occupants:					63%
Weighted average for lap/shoulder belted vs. unrestrained back seat outboard occupants:					73%

* “Double pair comparison” method relative to front seat outboard occupants.

Table 4-2 shows the confidence bounds, effectiveness estimates, and t test values for lap and lap/shoulder belts vs. unrestrained back seat outboard occupants. Both estimates are statistically significant given the large t test values. We used the jackknife estimate of variance, described in Section 2.4.1, to calculate the confidence bounds and t test values shown in Table 4-2.

TABLE 4-2 EFFECTIVENESS, CONFIDENCE BOUNDS AND T TEST VALUES OF BACK SEAT LAP AND LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS *				
	Lower Bound	Estimate	Upper Bound	t Test
Lap belts	**52%**	**63%**	**71%**	**- 6.09**
Lap/shoulder belts	**64%**	**73%**	**79%**	**- 5.98**

* "Double pair comparison" method relative to front seat outboard occupants.

The back seat lap and lap/shoulder belts are highly effective in reducing fatalities when compared to unrestrained occupants in passenger vans and SUVs. One reason is that 48 percent of the unrestrained back seat outboard fatalities in these vehicles were ejectees. Since the use of either a lap belt or a lap/shoulder belt nearly eliminates the risk of ejection, it is not surprising that the effectiveness of both exceed 48 percent.

Belts are more effective in passenger vans and SUVs than in passenger cars. In passenger cars, lap belts are 32 percent effective and lap/shoulder belts are 44 percent effective when compared to unrestrained occupants (Table 2-1). Only 25 percent of the unrestrained back seat outboard fatalities in passenger cars are ejectees, as opposed to 48 percent in these vehicles. Thus, it is plausible that both types of belt systems would be considerably more effective here than in passenger cars.

4.2.1 Lap/shoulder Belt Effectiveness Vs. Lap Belt Only

The preceding analysis shows that both lap and lap/shoulder belted back seat outboard occupants are significantly safer than being unrestrained in passenger vans and SUVs. It also suggests that the lap/shoulder belt may be safer than the lap belt, because the effectiveness of the lap/shoulder belts relative to unrestrained occupants is higher than the corresponding effectiveness of lap belts.

The fatality reduction for lap/shoulder belted back seat occupants relative to lap belted back seat occupants ought to be calculated similar to fatality reduction for lap/shoulder belts relative to unrestrained occupants. In this analysis, the unrestrained occupants would be replaced with lap belted occupants. But in the front seat air bag control groups, there are no lap belted back seat occupants because newer model year vehicles were equipped with lap/shoulder belts in the back seat outboard positions.

In the passenger car analysis (Section 2.5), we had a similar problem. Instead of having no data for the lap belted back seat occupants in the front seat air bag control groups, we had a small number of lap belted back seat fatalities. If we had eliminated the air bag control groups from our effectiveness estimate, then we would have eliminated a substantial portion of the lap/shoulder belted data. This would have potentially biased our results because we would have eliminated the newer model year vehicles, vehicles with air bags. To produce unbiased results and avoid eliminating data, we "transformed" the air bag protected front seat occupant fatalities into non-air bag fatality counts and added them to the non-air bag control groups. We used the conclusion from NHTSA's *Fatality Reduction by Air Bags*[37] report to transform the data. The report concludes:

- air bags are about 13 percent effective in reducing fatalities for unbelted drivers and FR passengers in all crashes, and

- air bags are about 9 percent effective in reducing fatalities for belted drivers and FR passengers in all crashes.

Therefore, each unbelted front seat fatality with an air bag corresponds to 1/(1 - 13%) unbelted fatalities without air bags. Each belted front seat fatality with an air bag corresponds to 1/(1 - 9%) belted fatalities without air bags.

Since the same problems exist in the passenger van and SUV data, we used the same data "transformation" procedure here. Below are line 6 and line 8 from Table 4-1:

Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities
Lap/shoulder belted	18	Unrestrained	160
Lap/shoulder belted	4	Air bag alone	35

The 35 air bag alone front seat fatalities are "transformed" into 35 * 1/(1 - 13%) = 40.2 unbelted front seat fatalities. In other words, if those unbelted front seat outboard occupants had not been protected by air bags, there would have been 40.2 unrestrained front seat fatalities. Therefore, there would have been 160 + 40.2 = 200.2 total unrestrained front seat fatalities when the back seat occupant was lap/shoulder belted, if air bags did not exist.

Since front seat air bags do not protect back seat occupants, the number of back seat fatalities would have remained the same if the air bag had not been available. Therefore, there are 18 + 4 = 22 lap/shoulder belted back seat fatalities regardless of whether the front seat occupant is unrestrained or "air bag alone" restrained. The risk factor for lap/shoulder belted back seat occupants (relative to unrestrained front seat occupants) is 22 / 200.2 = 0.110.

[37]Kahane (1996).

Table 4-3 shows the preceding calculations and carries out a similar one when the back seat occupant is lap/shoulder belted and the front seat occupants is air bag plus lap/shoulder belted. Here, the front seat air bag plus lap/shoulder belted fatalities (109) are “transformed” into lap/shoulder belted fatalities (119.8), using the 1/(1 - 9%) multiplier.

Columns 1, 2, 4, and 5 of Table 4-3 are copied from Table 4-1. Column 3 is the adjusted number of back seat fatalities regardless of whether the front seat had an air bag or not. Column 6 shows the number of front seat fatalities if the air bag was not available in the air bag control groups and Column 7 shows the adjusted number of front seat fatalities.

Column 9 shows the fatality reduction in the two control groups and the overall effectiveness of lap/shoulder belts vs. lap belts. Assuming the two control groups of lap/shoulder belted front seat occupants are subject to about equal risk, the probability of fatality is 1 - (0.844 / 1.033) = 18 percent lower for lap/shoulder belted back seat occupants than lap belted back seat occupants. A similar calculation for the unrestrained front seat control group, gives a fatality reduction of 46 percent for lap/shoulder belted occupants vs. lap belted occupants. So the overall effectiveness of the lap/shoulder belt relative to the lap belt in passenger vans and SUVs is 20 percent.

Table 4-4 shows the lower and upper confidence bounds of the estimate and the t test value. The t test value is too small for statistical significance. So we cannot conclude that the lap/shoulder belt is significantly safer than the lap belt alone in passenger vans and SUVs. Nevertheless, the point estimate here is quite close to the corresponding estimate for passenger cars (15 percent in Table 2-7).

TABLE 4-3
FARS 1988- FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS RELATIVE TO LAP BELTED BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE AND RESTRAINT TYPE IN PASSENGER VANS AND SUVS

Back Seat Restraint Use	Actual Back Seat Fatalities	Adjusted Back Seat Fatalities	Front Seat Restraint Use	Actual Front Seat Fatalities	Air Bag Adjustment FS Fatalities	Adjusted Front Seat Fatalities	Risk Factor	Fatality Reduction
Lap belted	315	315	Lap/shoulder belted	305		305.0	1.033	18%
Lap/shoulder belted	250	351		296		415.8	0.844	
Lap belted	24	24	Unrestrained	119		119.0	0.202	46%
Lap/shoulder belted	18	22		160		200.2	0.110	
Lap/shoulder belted	4		Air bag alone	35	40.2			
Lap/shoulder belted	101		Air bag plus lap/shoulder belted	109	119.8			
Weighted average for lap/shoulder belted vs. lap belted back seat outboard occupants:								**20%**

* “Double pair comparison” method relative to front seat outboard occupants.

TABLE 4-4 EFFECTIVENESS, CONFIDENCE BOUNDS, AND T TEST VALUE OF BACK SEAT LAP/SHOULDER BELTS RELATIVE TO LAP BELTED BACK SEAT OUTBOARD OCCUPANTS *				
	Lower Bound	Estimate	Upper Bound	t Test
Effectiveness	**-2%**	**20%**	**37%**	**1.72**

* "Double pair comparison" method relative to front seat outboard occupants.

4.2.2 Belt Effectiveness in Frontal Crashes

In this section, we will calculate the effectiveness of belts in passenger vans and SUVs in frontal crashes. A frontal crash is a crash where the principal point of impact for the vehicle was clock points 11, 12, and 1. This is the same definition used in the analysis of passenger cars in Section 2.7.

Using the "double paired comparison" method, we calculated the effectiveness of lap belts relative to unrestrained back seat outboard occupants and the effectiveness of lap/shoulder belts relative to unrestrained back seat outboard occupants in frontal crashes. Table 4-5 shows that in frontal crashes, lap belted back seat occupants have a 38 percent lower fatality risk than unrestrained back seat occupants when the lap/shoulder belted front seat occupants are the control group. When unrestrained front seat occupants are the control group, lap belted back seat occupants have 63 percent lower fatality risk than unrestrained occupants. The weighted average of these two fatality reductions is 40 percent. So lap belts are 40 percent effective in reducing fatalities when compared to unrestrained back seat outboard occupants in frontal crashes.

The effectiveness of lap/shoulder belts in passenger vans and SUVs with frontal damage is not much larger than the effectiveness of lap belts in these vehicles. The weighted average of the four fatality reductions for lap/shoulder belts shown in Table 4-5 is 49 percent. This is only 9 percentage points larger than the effectiveness of lap belts when compare to unrestrained occupants. Therefore, both lap and lap/shoulder belts in passenger vans and SUVs are highly effective in frontal crashes.

Table 4-6 shows the confidence bounds for these effectiveness estimates and t test values calculated using the jackknife estimate of variance procedure described in Section 2.4.1. Given the large t test values, both lap and lap/shoulder belts in passenger vans and SUVs are statistically significant in frontal crashes relative to unrestrained occupants.

TABLE 4-5
FARS 1988- FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF ALL BACK SEAT OUTBOARD LAP AND LAP/SHOULDER BELTS RELATIVE TO BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE AND RESTRAINT TYPE IN PASSENGER VANS AND SUVS IN FRONTAL CRASHES

Back Seat Restraint Use	Back Seat Fatalities	Front Seat Restraint Use	Front Seat Fatalities	Risk Factor	Fatality Reduction
Unrestrained	264	Lap/shoulder belted	233	1.133	
Lap belted	115		165	0.697	38%
Lap/shoulder belted	81		131	0.618	45%
Unrestrained	271	Unrestrained	435	0.623	
Lap belted	6		26	0.231	63%
Lap/shoulder belted	9		35	0.257	59%
Unrestrained	27	Air bag alone	32	0.844	
Lap/shoulder belted	4		8	0.500	41%
Unrestrained	36	Air bag plus lap/shoulder belted	20	1.800	
Lap/shoulder belted	40		49	0.816	55%
Weighted average for lap belted vs. unrestrained back seat outboard occupants:					40%
Weighted average for lap/shoulder belted vs. unrestrained back seat outboard occupants:					49%

* "Double pair comparison" method relative to front seat outboard occupants.

In frontal crashes, the effectiveness of lap/shoulder belts in passenger vans and SUVs is larger than the effectiveness in passenger cars. In passenger cars, the effectiveness of lap/shoulder belts is 22-29 percent in frontal crashes (Table 2-11). In frontal crashes, the effectiveness of lap belts in passenger vans and SUVs is substantial larger than the effectiveness in passenger cars. In passenger cars, the effectiveness of lap belts is essentially zero in frontal crashes.

TABLE 4-6 EFFECTIVENESS, CONFIDENCE BOUNDS AND T TEST VALUES OF BACK SEAT LAP AND LAP/SHOULDER BELTS RELATIVE TO UNRESTRAINED BACK SEAT OUTBOARD OCCUPANTS * IN FRONTAL CRASHES				
	Lower Bound	Estimate	Upper Bound	t Test
Lap belts	**14%**	**40%**	**61%**	**- 2.55**
Lap/shoulder belts	**34%**	**49%**	**61%**	**- 4.31**

* "Double pair comparison" method relative to front seat outboard occupants.

How can the lap belt be effective in frontal crashes? One factor is that a substantial proportion, 21 percent of the unrestrained back seat outboard fatalities in these vehicles are ejectees. In passenger cars, it is only 12 percent. Since either type of belt virtually eliminates occupant ejection, the high percentage of ejectees in these vehicles is bound to bring frontal effectiveness of lap belts into the plus.

4.2.3 Lap/shoulder Belt Effectiveness Vs. Lap Belt in Frontal Crashes

To see if lap/shoulder belts are safer than lap belts in passenger vans and SUVs in frontal crashes, we calculated the effectiveness of lap/shoulder belts relative to lap belts. We used the same paired comparison method that is outlined in Section 4.2.1 for all crashes. In this section, the front seat air bag fatalities are "transformed" into non-air fatality counts and these counts are added to the non-air fatalities in the non-air bag control groups. Since air bags are more effective in frontal crashes than all crashes, the air bag adjustment factors used here are higher than the ones used for all crashes. We used the following adjustment factors in this analysis:

- air bag effectiveness is 29 percent for unbelted front seat outboard occupants in frontal crashes and

- air bag effectiveness is 19 percent for lap/shoulder belted front seat outboard occupants in frontal crashes.

These factors were calculated in frontal crashes (11:00 - 1:00 impacts excluding most harmful event rollovers) similar to the method in[38], using the most recent 1986-1997 FARS data. These adjustment factors were also used in the analysis of lap/shoulder belts vs. lap belts in frontal crashes for passenger cars (Section 2.7.1).

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[38]Kahane (1996).

Table 4-7 shows that the effectiveness of lap/shoulder belts relative to lap belted occupants is 8 percent in frontal crashes for passenger vans and SUVs. Using the jackknife estimate of variance, we calculated the confidence bounds and the t test value for this estimate. The effectiveness of lap/shoulder belts relative to lap belts in frontal crashes is from - 42 to 40 percent for passenger vans and SUVs. The t-test value is 0.38 for this estimate. This is not statistically significant. So we cannot conclude that lap/shoulder belts are significantly safer than lap belts in frontal crashes.

TABLE 4-7
FARS 1988- FIRST 6 MONTHS OF 1997
EFFECTIVENESS OF BACK SEAT OUTBOARD LAP/SHOULDER BELTS RELATIVE TO
LAP BELTED BACK SEAT OUTBOARD OCCUPANTS * BY RESTRAINT USAGE
AND RESTRAINT TYPE IN PASSENGER VANS AND SUVS IN FRONTAL CRASHES

Back Seat Restraint Use	Actual Back Seat Fatalities	Adjusted Back Seat Fatalities	Front Seat Restraint Use	Actual Front Seat Fatalities	Air Bag Adjustment FS Fatalities	Adjusted Front Seat Fatalities	Risk Factor	Fatality Reduction
Lap belted	115	115	Lap/shoulder belted	165		165.0	0.697	9%
Lap/shoulder belted	81	121		131		191.5	0.632	
Lap belted	6	6	Unrestrained	26		26.0	0.231	-22%
Lap/shoulder belted	9	13		35		46.3	0.281	
Lap/shoulder belted	4		Air bag alone	8	11.3			
Lap/shoulder belted	40		Air bag plus lap/shoulder belted	49	60.5			
Weighted average for lap/shoulder belted vs. lap belted back seat outboard occupants:								**8%**

* "Double pair comparison" method relative to front seat outboard occupants.

CHAPTER 5

FATAL INJURY RATES BY BODY REGION AND RESTRAINT SYSTEM, IN PASSENGER CARS

Previous chapters have shown that lap/shoulder belts have a substantial net benefit relative to unrestrained occupants in frontal crashes and that lap belts have little or no net benefit relative to unrestrained occupants in frontal crashes. But in non-frontal crashes, both lap and lap/shoulder belts have large and similar net benefits relative to unrestrained occupants. This chapter will investigate injuries by body region to understand why lap belts are effective in non-frontal crashes but have no net benefit in frontal crashes.

Studies have shown that lap belts may harm back seat occupants. A 1986 study by the National Transportation Safety Board (NTSB)[39], in particular, concludes the following:

- "In frontal crashes, persons using lap only belts may not be adequately protected against injury and may sustain additional injuries, induced by the lap belt itself.

- Lap belts may induce injury, ranging in severity from minor to fatal, to the head; spine; abdomen; intra-abdominal viscera, connecting tissue, and blood vessels; and intra-thoracic viscera, connecting tissue, and blood vessels. Such injuries may occur singly or in combination."

The Safety Board drew its conclusion from 26 case studies of frontal crashes involving at least one lap belted person, not by finding injury rates in nationally representative data. This chapter will perform a statistical analysis to see if NTSB was right in asserting that a problem existed (i.e., that lap belts may induce abdominal injuries in frontal crashes) and also to see if lap/shoulder belts have really remedied the problem.

The Fatality Analysis Reporting System (FARS) data does not contain information on body region injured. But a supplement to the FARS file, known as the Multiple Cause of Death (MCOD) file does contain information on body region injured, and the records on the MCOD file can be uniquely matched to fatalities in the FARS file. So combining these two data sources will allow us to analyze if lap and lap/shoulder belts reduce or increase the risk of injuries by body region to back seat outboard occupants.

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[39]NTSB (1986).

5.1 THE MULTIPLE CAUSE OF DEATH FILE

Periodically, NHTSA receives the MCOD mortality data from the National Center for Health Statistics (NCHS). In 1988, all states except Rhode Island agreed to allow the NCHS to release to NHTSA the 1987-1989 mortality records having Motor Vehicle Traffic Accident as an underlying cause of death. In 1997, NHTSA reached a new agreement with the NCHS for 1990-1999 mortality data. The second agreement included all states and a wider range of records and additional variables.

Up to fifteen causes of death are listed for each person in the MCOD file, providing information on the injury type and body region injured. Nature of injury (N-codes), Diseases, and External causes of death (E-codes) are listed for causes of death on the MCOD. The N-codes classify the injury type and body region injured. The Disease codes classify pre-existing conditions that may have contributed to the death. The E-codes classify the environmental events, circumstances, and conditions that caused the injury such as "motor vehicle crash" or "accidental injury." All the E-codes listed as causes of death are useless for our analysis because they do not specify injury information. Some of the N-codes listed are also useless because the injury information is not specific.

The NHTSA's National Center for Statistics and Analysis (NCSA) office creates a SAS version of the MCOD file that has the FARS variables ST_CASE, VEH_NO, and PER_NO. They link the MCOD file and FARS file together so each mortality record on the MCOD file is linked to a specific fatality record on the FARS file. They use death state, death certificate number, death date, age, sex, person type, and county to link the files. The 1987-1992 MCOD and FARS data were linked using a series of computer programs and manual review when the programs could not match the records. The 1993-1994 data were linked using AUTOMATCH, a probabilistic linkage software from Matchware Technologies, Inc. that automates the procedure formerly used by the NCSA staff.

Neither linkage procedure produces 100 percent match rate. Some FARS fatalities cannot be matched to a MCOD record. The FARS and Multiple Cause of Death Data Linkage Research Note[40] (to appear in 1999) discusses the linkage procedures. Table 5-1 (copied from the research note) shows the number of FARS fatalities, the percentage of FARS fatalities with matching MCOD records, and the percentage of those matched records with useable N-codes. Records with useable N-codes exclude records that had no N-codes and records with only 959.8 (other sites including multiple) or 959.9 (unspecified site) coded.

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[40] *FARS and Multiple Cause of Death Data Linkage*, NHTSA Research Note, Washington, DC, 1999.

TABLE 5-1 THE NUMBER OF FARS FATALITIES, THE PERCENTAGE OF FARS FATALITIES WITH MATCHING MCOD RECORDS, AND THE PERCENTAGE OF MATCHED RECORDS WITH USEABLE INJURY CODES BY CALENDAR YEAR			
Data Year	FARS Fatalities	MCOD Matching Rate	Useable Injury Codes
1990	44,599	97.77%	70.84%
1991	41,508	97.38%	70.24%
1992	39,250	96.79%	68.23%
1993	40,150	95.56%	66.90%
1994	40,716	96.30%	67.55%

The FARS and Multiple Cause of Death Data Linkage Research Note[41] also assesses the injury data on the MCOD file as such:

> "In order to make an assessment of the quality of the MCOD N-codes, data year 1993 fatalities in the NASS Crashworthiness Data System (CDS) were linked to FARS and the thorough, detailed injury coding in CDS was used as a benchmark. Due to the big difference in the coding systems, the comparison was necessarily somewhat subjective[;] however of the 204 matched fatalities with good N-codes, it was estimated that 93% agreed substantially as to the injuries causing death (78% on both body area and type of injury, 15% on body area alone). Injuries not contributing directly to mortality, well documented in CDS, are largely missing in the MCOD data."

This assessment shows that the MCOD file will give reliable information on the body region injured and less reliable information on type of injury. But N-codes which describe in detail the type of injury are not frequently listed as a cause of death. So most of our analysis will be limited to body region injured. But we did include one table that shows the injury rate by system/organ injured and restraint system for abdominal injuries, although the rates in this table are based on a small number of injuries.

Even though the high rate of missing data means that the MCOD file will not give valid <u>absolute</u> rates of serious injuries by body region, there is no reason to believe that the missing data rates are going to be different for unrestrained, lap belted, or lap/shoulder belted occupants. So we ought to be able to <u>compare</u> the injury rates for one to the others.

[41]NHTSA Research Note (1999).

5.2 DATA PREPARATION

The SAS version of the MCOD file is a person-level file. Each record on the file contains information on the cause of death to motor vehicle fatalities along with the FARS variables ST_CASE, VEH_NO, and PER_NO. We created a person-level file with only back seat outboard occupants using the vehicle-level file described in Section 2.1.1. We output a record to the person-level file for each back right seat occupant and each back left seat occupant on the vehicle-level file. This created a person-level file where each record contained the information on the vehicle and either the back right seat occupant or the back left seat occupant.

Next, we combined our back seat outboard occupant person-level file and MCOD file by matching on ST_CASE, VEH_NO, and PER_NO for 1988-1994 calendar years of data. (The 1994 MCOD file was the latest year available at the time of this analysis.) This combined file has a record for each back seat outboard fatality and contains information on the vehicle (back seat belt type), occupant (restraint use, age and sex), crash (crash type), and cause of death (body region injured). The file does not contain records of crash survivors.

Only the first 8 causes of death listed for each occupant were used in the analysis. Few people had 9 or more causes listed, and if they had more, it is doubtful that all of these were "causes of death" or even serious injuries. However, the specific choice of 8, as opposed to, 7 or 9, was somewhat arbitrary.

There are 4,799 back seat outboard fatalities on the "Combined" file. If each occupant had 8 causes of death listed then we would have 4,799 * 8 = 38,392 causes of death to analyze. But Table 5-2 shows there are only 22,250 causes of death listed. Table 5-2 shows the causes of death for N-codes, Disease, and E-codes by major categories. The following major Injury and Disease categories are not included in table, because our back seat outboard occupants did not have any causes of death in these categories:

N-code	960 - 979	Poisoning by drugs, medicinal and biological substances
Disease	630.0 - 679.9	Complications of pregnancy, childbirth, and the puerperium
Disease	680.0 - 709.9	Diseases of the skin and subcutaneous tissue
Disease	760.0 - 779.9	Certain conditions originating in the perinatal period

Table 5-2 shows that 55 percent of the causes of death listed are External causes. Almost all of these External causes are "motor vehicle traffic crashes," as expected. Forty-two percent of the causes of death are N-codes (Injury causes) and only 4 percent are Diseases. Only the N-codes and Disease codes will be analyzed since the External causes do not contain any injury information.

TABLE 5-2
FARS AND MCOD 1988-1994
CAUSES OF DEATH FOR BACK SEAT OUTBOARD FATALITIES BY TYPE

Total Nature of Injury Codes		9,281	42%
800 - 804	Fracture of skull	898	10%
805 - 809	Fracture of neck and trunk	988	11%
810 - 819	Fracture of upper limb	75	1%
820 - 829	Fracture of lower limb	198	2%
830 - 839	Dislocation	37	0%
840 - 848	Sprains and strains of joints and adjacent muscles	2	0%
850 - 854	Intra-cranial injury, excluding those with skull fracture	2,122	23%
860 - 869	Internal injury of chest, abdomen, and pelvis	1,896	20%
870 - 879	Open wound of head, neck, and trunk	83	1%
880 - 887	Open wound of upper limb	1	0%
890 - 897	Open wound of lower limb	7	0%
900 - 904	Injury to blood vessels	204	2%
905 - 909	Late effects of injuries	2	0%
910 - 919	Superficial injury	11	0%
920 - 924	Contusion with intact skin surface	31	0%
925 - 929	Crushing injury	20	0%
930 - 939	Effects of foreign body entering through orifice	19	0%
940 - 949	Burns	38	0%
950 - 957	Injury to nerves and spinal cord	100	1%
958 - 959	Certain traumatic complications and unspecified injuries	2,449	26%
980 - 989	Toxic effects of substances chiefly non-medical as to source	15	0%
990 - 995	Other and unspecified effects of external causes	81	1%
996 - 999	Complications of surgical and medical care	4	0%
Total disease codes		827	4%
000.0 - 139.9	Infectious and parasitic diseases	21	3%
140.0 - 239.9	Neoplasms	8	1%
240.0 - 279.9	Endocrine, nutritional and metabolic diseases, & immunity disorders	22	3%
280.0 - 289.9	Blood and blood-forming organs	18	2%
290.0 - 319.9	Mental disorders	32	4%
320.0 - 389.9	Diseases of the nervous system and sense organs	88	11%
390.0 - 459.9	Diseases of the circulatory system	355	43%
460.0 - 519.9	Diseases of the respiratory system	86	10%
520.0 - 579.9	Diseases of the digestive system	17	2%
580.0 - 629.9	Diseases of the genitourinary system	19	2%
710.0 - 739.9	Diseases of the musculoskeletal system and connective tissue	5	1%
740.0 - 759.9	Congenital anomalies	4	0%
780.0 - 799.9	Symptoms, signs, and ill-defined conditions	152	18%
Total external codes		12,142	55%
810.0 - 829.9	Motor vehicle traffic crashes	12,076	99%
830.0 - 999.9	Other external causes	66	1%
TOTAL		22,250	

TABLE 5-3
FARS AND MCOD 1988-1994 DATA
MOST FREQUENTLY LISTED CAUSES OF DEATH BY SPECIFIC INJURY

Total Nature of Injury Codes		9,281	92%
801	Fracture of base of skull	152	2%
803	Other and unqualified skull fractures	683	7%
805	Fracture of vertebral column without mention of spinal cord injury	581	6%
807	Fracture of rib(s), sternum, larynx, and trachea	300	3%
808	Fracture of pelvis	105	1%
851	Cerebral laceration and contusion	148	2%
852	Subarachnoid, subdural, and extradural hemorrhage, following injury	97	1%
854	Intracranial injury of other and unspecified nature	1,800	19%
860	Traumatic pnemothorax and hemothorax	119	1%
861	Injury to heart and lung	160	2%
862	Injury to other and unspecified intrathoracic organs	630	7%
864	Injury to liver	122	1%
865	Injury to spleen	92	1%
868	Injury to other intra-abdominal organs	326	4%
869	Internal injury to unspecified or ill-defined organs	390	4%
901	Injury to blood vessels of thorax	159	2%
952	Spinal cord injury without evidence of spinal bone injury	95	1%
958	Complications of trauma	128	1%
959	Injury, other or unspecified	2,321	25%
	Other nature of injuries	873	9%
Total disease codes		827	8%
038.9	Unspecified septicemia	17	2%
286.6	Defibrination syndrome	11	1%
305.0	Alcohol abuse	26	3%
348.1	Anoxic brain damage	17	2%
348.2	Benign intracranial hypertension	10	1%
348.4	Compression of brain	19	2%
348.5	Cerebral edema	33	4%
410	Acute myocardial infarction	15	2%
414.0	Coronary atherosclerosis	25	3%
414.9	Chronic ischemic heart disease	14	2%
415.1	Pulmonary embolism and infarction	24	3%
427.5	Cardiac arrest	132	16%
429.2	Cardiovascular disease, unspecified	17	2%
434.9	Cerebral artery occlusion, unspecified	10	1%
458.9	Hypotension, unspecified	12	1%
518.5	Pulmonary insufficiency following trauma and surgery	25	3%
586	Renal failure, unspecified	12	1%
785.5	Shock without mention of trauma	17	2%
790.3	Excessive blood level of alcohol	27	3%
799.1	Respiratory arrest	70	8%
799.9	Other unknown and unspecified cause	11	1%
	Other diseases	283	34%
TOTAL		10,108	

Table 5-3 shows the Injury and Disease causes most frequently listed as the cause of death. A complete listing is not provided because there are over 9,000 possible codes and 239 listed on the "Combined" file. Notice in Table 5-3 that 25 percent of the N-codes are also useless because the injury code is not specific, "Injury, other or unspecified." Even some of the more specific injuries such as "Injury to other and unspecified intrathoracic organs"only tell the general area of the body injured and not a specific type of injury. The N-codes which are specific such as "Fracture of pelvis" are one percent of the N-codes records.

We classified the Injury and Disease codes into 5 main body regions: head, chest, abdomen, neck and back, arms, and legs. Table 5-4 shows the Injury and Disease codes assigned to each body region.

TABLE 5-4
BODY REGION CLASSIFICATION BY INJURY AND DISEASE CODES

Head	
348.1	Anoxic brain damage
348.2	Benign intracranial hypertension
348.4	Compression of brain
348.5	Cerebral edema
348.8	Other conditions of brain
348.9	Unspecified condition of brain
800	Fracture of vault of skull
801	Fracture of base of skull
802	Fracture of face bones
803	Other and unqualified skull fractures
850	Concussion
851	Cerebral laceration and contusion
852	Subarachnoid, subdural, and extradural hemorrhage, following injury
853	Other and unspecified intracranial hemorrhage following injury
854	Intracranial injury of other and unspecified nature
870.8	Open wound of ocular adnexa
872	Open wound of ear
873	Other open wound of head
925	Crushing injury of face, scalp, and neck
Chest	
512	Pneumothorax
807	Fracture of rib(s), sternum, larynx, and trachea
810	Fracture of clavicle
860	Traumatic pneumothorax and hemothorax
861	Injury to heart and lung
862	Injury to other and unspecified intrathoracic organs
901	Injury to blood vessel of thorax

Abdomen		
	808	Fracture of pelvis
	863	Injury to gastrointestinal tract
	864	Injury to liver
	865	Injury to spleen
	866	Injury to kidney
	867	Injury to pelvic organs
	868	Injury to other intra-abdominal organs
	902	Injury to blood vessels of abdomen and pelvis
Neck and Back		
	805	Fracture of vertebral column without mention of spinal cord injury
	847	Sprains and strain of other and unspecified parts of back
	874	Open wound of neck
	952	Spinal cord injury without evidence of spinal bone injury
Arms		
	812	Fracture of humerus
	813	Fracture of radius and ulna
	818	Ill-defined fractures of upper limb
	832	Dislocation of elbow
	884	Multiple and unspecified open wound of upper limb
Legs		
	820	Fracture of neck of femur
	821	Fracture of other and unspecified parts of femur
	823	Fracture of tibia and fibula
	827	Other, multiple, and ill-defined fractures of lower limb
	890	Open wound of hip and thigh
	897	Traumatic amputation of leg(s) (complete) (partial)

5.3 "WHEN USED" ANALYSIS BASED ON "ALL MAKE/MODEL" PASSENGER CARS

From the MCOD file, we can calculate the number of abdominal injuries per 100 fatalities (let's call it R). What we really want is the number of abdominal injuries per 100 people in potentially fatal crashes (PFC's). Let P be the number of fatalities per 100 PFC's. So what we really want is R * P. P equals 100 for unrestrained occupants. For lap and lap/shoulder belted occupants, P is estimated using the effectiveness estimates (fatality reduction) found in Chapter 2. For lap belted occupants in frontal crashes, P = 100 - 1 = 99, since lap belts in frontal crashes reduce fatalities by 1 percent (Table 2-9). For lap/shoulder belts in frontal crashes, P = 100 - 29 = 71, since lap/shoulder belts in frontal crashes reduce fatalities by 29 percent (Table 2-9). If the abdominal injury rate per 100 PFC's is higher for belted occupants than unrestrained occupants, then the belts increase the risk of injury. If they are lower, then belts reduce the risk of injury.

A “when used” analyses is performed in this chapter since restraint use is available on the FARS file. The analyses in this chapter comprise calendar years 1988-1994 and model years 1985 to 1995. They include all make/models of passenger cars except those that did not have back seat or where the type of restraint system is unknown (See Appendix A).

There are 1,257 unrestrained back seat outboard occupant fatalities in frontal crashes in our “Combined” file. There are a total of 117 abdominal injuries to these occupants. Each abdominal injury listed in the first 8 causes of death for each fatality is counted once. So if a back seat occupant had three different abdominal injuries listed on the death certificate (for example, the first, fourth and fifth cause of death), then the number of abdominal injuries for this occupant is three. However, relatively few occupants have more than one injury listed per body region. The total number of abdominal injuries is the number of abdominal injuries for each occupant added together. The number of abdominal injuries per 100 fatalities is R = 117/1,257 = .09 in frontal crashes. The number of abdominal injuries per 100 PFC’s is .09 * 100 = 9 for unrestrained occupants in frontal crashes.

There are 249 lap belted back seat outboard occupant fatalities in frontal crashes, with 78 total abdominal injuries. The rate of abdominal injuries per 100 lap belted fatalities is 0.31. The number of abdominal injuries per 100 PFC’s is .31 * 99 = 31.

There are 195 lap/shoulder belted back seat outboard occupant fatalities in frontal crashes, with 42 total abdominal injuries. The rate of abdominal injuries per 100 lap/shoulder belted fatalities is 0.22. Since lap/shoulder belts are 29 percent effective in reducing fatalities in frontal crashes (Table 2-9), the number of abdominal injuries per 100 PFC’s is .22 * 71 = 15. Table 5-5 shows these three calculations for abdominal injuries and add similar calculations for head and chest injuries.

There is a dramatic increase in the risk of abdominal injuries for lap belted occupants in frontal crashes. Table 5-5 shows that the abdominal injury rate for lap belted occupant is more than 3 ½ times the rate for unrestrained occupants in frontal crashes. Quantitatively, the absolute increase in abdominal injuries with lap belts relative to unrestrained (.22) is just about the same as the decrease in head injuries (.18), leading to a net benefit of close to zero. Lap belts are essentially trading head injuries for abdominal injuries. NTSB was right, in a statistical sense, when they said that abdominal injuries were a big problem with lap belts. However, they were overcritical of lap belts to the extent they did not acknowledge their benefit on head injuries, as well as in non-frontal crashes.

Lap/shoulder belts reduce abdominal injuries by 52 percent relative to lap belts, but they increase abdominal injuries by 40 percent relative to unrestrained occupants. If lap/shoulder belts had reduced the abdominal injury rate all the way to the unrestrained level, they would have been even more effective, since they do a great job on head injuries.

The risk of head injuries for lap belted occupants is less than unrestrained back seat occupants in frontal crashes. The risk of head injuries for lap/shoulder belted occupants is less than both unrestrained and lap belted occupants in frontal crashes. Lap/shoulder belts reduce head injuries by 47 percent relative to lap belts only. So the lap belt reduces the risk of head injuries to back seat outboard occupants and the lap/shoulder belt reduces the risk even further than lap belts.

The shoulder belt does not appear to increase the risk of chest injuries for back seat outboard occupants in frontal crashes. Since the primary effect of shoulder belts is to restrict the forward upper body movement which is most likely to occurs in frontal crashes, the shoulder belt may inadvertently injure the chest of belted occupants. But this does not appear to be the case. The fatality rate of chest injuries for lap/shoulder belted occupants is only slightly higher than the rate for lap belted occupants, which is slightly higher than unrestrained occupants.

TABLE 5-5
FARS AND MCOD 1988-1994
INJURY RATE PER 100 BACK SEAT OUTBOARD OCCUPANTS IN PFC'S
BY RESTRAINT USAGE, RESTRAINT TYPE, AND BODY REGION INJURED
FOR "ALL MAKE/MODELS" IN FRONTAL CRASHES

			Abdomen		Head		Chest	
	Fatalities	PFC's	Injuries	Rate per 100 PFC's	Injuries	Rate per 100 PFC's	Injuries	Rate per 100 PFC's
Unrestrained	1,257	1,257	117	9	769	61	285	23
Lap belted	249	252	78	31	109	43	61	24
Lap/shoulder belted	195	275	42	15	63	23	69	25

Table 5-6 shows the injury rate by system/organ for abdominal injuries in frontal crashes. The system/organ injuries were defined as follows:

Pelvis	808 - Fracture of pelvis
Gastrointestinal tract (GI)	863 - Injury to gastrointestinal tract
Liver	864 - Injury to liver
Spleen	865 - Injury to spleen
Kidney	866 - Injury to kidney
Other Abdominal injuries	867 - Injury to pelvic organs, 868 - Injury to other intra-abdominal organs, and 902 - Injury to blood vessels of abdominal and pelvis.

The gastrointestinal tract injuries appears to be a principal cause for lap belted occupants having high risk of abdominal injuries in frontal crashes. The gastrointestinal tract injury rate for lap belted occupants is huge (5.57) when compared to the rate for unrestrained occupants (0.32). But the gastrointestinal tract injury rate for unrestrained occupants is based on only a few injuries, 4; so exact quantitative conclusions should not be drawn from this data. Nevertheless, these results are consistent with NTSB's assertion that rupture of the mesentery (an injury of the gastrointestinal tract) was a special problem with lap belts.

Table 5-6 also indicates that lap/shoulder belts did not fully resolve the problem. The GI injury rate, 1.82, is substantially lower than the rate with lap belts, but still substantially higher than unrestrained. Again, because all rates are based on relatively few injuries, it is difficult to draw exact quantitative conclusions.

TABLE 5-6
FARS AND MCOD 1988-1994
INJURY RATE PER 100 BACK SEAT OUTBOARD OCCUPANTS IN PFC'S
BY RESTRAINT USAGE, RESTRAINT TYPE, AND SYSTEM/ORGAN WITH
ABDOMINAL INJURIES FOR "ALL MAKE/MODELS" IN FRONTAL CRASHES

	808 Pelvis	863 GI	864 Liver	865 Spleen	866 Kidney	Other Abdominal Injuries
Unrestrained	0.48	0.32	1.83	1.27	0.24	5.17
Lap belted	1.19	5.57	2.38	1.98	0.00	19.88
Lap/shoulder belted	0.00	1.82	1.82	1.46	0.36	9.83

Table 5-7 shows the abdominal injury rate for back seat outboard occupants in frontal crashes by age and sex. The fatality reduction factors in this table are based on the effectiveness estimates shown in Table 2-16 for children, males, females, and seniors in frontal crashes. Belted children, ages 5-14, do not have an increased risk of abdominal injuries. Lap belted and lap/shoulder belted children have abdominal injury rate slightly higher than unrestrained children in frontal crashes, but at or below the injury rate of all lap belted and lap/shoulder belted occupants in frontal crashes (Table 5-5).

Lap belted seniors (aged 55 and older), males (ages 15-54), and females (ages 15-54) have an increased risk of abdominal injuries in frontal crashes. The abdominal injury rate for lap belted seniors is almost 6 times the rate of unrestrained seniors. The abdominal injury rate for lap belted males is more than 4 times the rate of unrestrained males. And the abdominal injury rate for lap belted females is more than 2 times the rate of unrestrained females. The risk of abdominal injuries for lap belted females is not as catastrophic as the risk for males and seniors, but it is still a problem.

Seniors are also being harmed in the abdomen by lap/shoulder belts in frontal crashes. But younger aged occupants are not. The lap/shoulder belted abdominal injury rate for seniors is 2 times the rate of unrestrained seniors and is one and half times the rate of all lap/shoulder belted occupants in frontal crashes (Table 5-5). The abdominal injury rate for lap/shoulder belted and unrestrained males and females age 15-54 are, for all practical purposes, equal in frontal crashes.

TABLE 5-7
FARS AND MCOD 1988-1994
ABDOMINAL INJURY RATE PER 100 BACK SEAT OUTBOARD OCCUPANTS IN PFC'S BY RESTRAINT USAGE, RESTRAINT TYPE, AGE AND SEX FOR "ALL MAKE/MODELS" IN FRONTAL CRASHES

	Children ages 5-14	Males ages 15-54	Females ages 14-54	Seniors ages 55 +
Unrestrained	9	10	7	10
Lap belted	12	44	19	57
Lap/shoulder belted	15	7	10	23

There is no direct evidence to show why the abdominal injury rate is worse for seniors and males. But we hypothesize that this could be a combination of the effect of mass, anatomy, and sensitivity to injury. Children (usually) and females (sometimes) are too light to deeply depress the seat cushion and allow the belt to ride up. Also, since their mass is less, the lap belt exerts less force on the abdomen when it restrains them in a frontal crash. Females (usually) having more protrusive hip bones may also help the lap belt stay in a correct position and not ride up to the waist.

On the other hand, seniors are more vulnerable to injury than the other groups which may account for their high abdominal injury rates when belted. Table 5-7 additionally helps explain some of the differences found in the effectiveness of lap and lap/shoulder belts by age seen in Chapter 2: in particular, the negative overall effect of lap belts for seniors is largely due to the increase in abdominal injuries.

Besides frontal crashes, we concentrated on side impact crashes in this chapter rather than all non-frontal crashes as in previous chapters. In non-frontal crashes, a large proportion of the unrestrained rollover fatalities are ejectees. The body region injured of ejectees does not tell anything about the crashworthiness performance of the belts or the vehicle interior.

Table 5-8 shows the injury rate of abdominal, head, and chest injuries per 100 back seat outboard occupants in potentially fatal side impact crashes. The injury rates in Table 5-8 are calculated similar to Table 5-5, except that the fatality reduction for lap belted occupants is 39 percent (Table 2-14) and for lap/shoulder belted occupants is 42 percent (Table 2-14).

Both lap and lap/shoulder belts reduce the risk of abdominal, head, and chest injuries in side impact. So the huge abdominal injury problem with lap belts is limited to frontal crashes. The injury rate of abdomen, head, and chest for lap/shoulder belted occupants in side impact crashes is about the same or slightly less than the rate for lap belted occupants. In fact, lap/shoulder belts may reduce the risk of a head injury in side impact crashes even more than lap belts.

TABLE 5-8
FARS AND MCOD 1988-1994
INJURY RATE PER 100 BACK SEAT OUTBOARD OCCUPANTS IN PFC'S
BY RESTRAINT USAGE, RESTRAINT TYPE, AND BODY REGION INJURED
FOR "ALL MAKE/MODELS" IN SIDE IMPACT CRASHES

			Abdomen		Head		Chest	
	Fatalities	PFC's	Injuries	Rate per 100 PFC's	Injuries	Rate per 100 PFC's	Injuries	Rate per 100 PFC's
Unrestrained	1,249	1,249	198	16	728	58	361	29
Lap belted	244	400	39	10	122	31	70	18
Lap/shoulder belted	246	424	40	9	109	26	72	17

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APPENDIX A

PASSENGER CARS
TYPE OF BACK SEAT OUTBOARD BELTS BY MAKE/MODEL AND YEAR

EXPLANATION OF COLUMN HEADINGS

bkls MY	first Model Year (MY) with standard back seat outboard lap/shoulder belts
first MY	first MY that this car or light truck existed
last MY	last MY that this car or light truck existed
ABS MY	first MY that Antilock Brake Systems (ABS) was standard or was sold on over 50 percent of cars
airbag MY	first MY that air bags were present on 50 percent or more of this make/model
remod MY1	first major remodeling
remod MY2	second major remodeling
TY	Transition Year (TY) to back seat lap/shoulder belts (usually same as bkls MY)
YT±	number of matching model years available before and after TY

EXPLANATION OF CODES

a	always had back seat outboard lap/shoulder belts, ABS, or air bags depending on which column
x	in bkls MY column - never had back seat outboard lap/shoulder belts.
x	in TY, YT± column - excluded from “matching make/models”
N/A	excluded from analysis

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
109 AMC Eagle	x	<85	88					x	x
110 AMC SX4/Kammback	x	<85	86					x	x
610/620 Chrysler 5th Ave	90	<85	93		88	90		90	3
614/618 Chrysler New Yorker	90	<85	93		90	88		90	3
615 Chrysler Laser	x	<85	87					x	x
616 Chrysler LeBaron MY 89 and Convertibles	90 N/A	<85	95		88	90		90	3
635 Chrysler Conquest	89	87	89					89	1
641 Chrysler Concorde	a	93	>95	a	a			x	x
642 Chrysler LHS/NYer	a	94	>95	a	a			x	x
643 Chrysler Sebring	a	95	>95		a			x	x
644 Chrysler Cirrus	a	95	>95		a			x	x
707 Dodge Diplomat	x	<85	89		88			x	x
708 Dodge Omni	90	<85	90		90			90	1
711 Dodge Aries	x	<85	89					x	x
713 Dodge Viper	N/A	92	>95		a			x	x
714 Dodge 600	x	<85	88					x	x
715 Dodge Daytona	90	<85	93		88			90	3
716 Dodge Lancer	x	85	89					x	x
717 Dodge Shadow Convertible	89 N/A	87	94		90			89	2
718 Dodge Dynasty	90	88	93		90			90	2
719 Dodge Spirit	a	89	>95		90			x	x
720 Dodge Neon	a	95	>95		a			x	x
734 Dodge Colt	89	<85	94		94	89	93	89	3
735 Dodge Conquest	x	<85	86					x	x
739 Dodge Stealth	a	91	>95		a			x	x

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
740 Dodge Monaco	a	90	92					x	x
741 Dodge Intrepid	a	93	>95	a	a			x	x
742 Dodge Avenger	a	95	>95		a			x	x
743 Dodge Stratus	a	95	>95		a			x	x
744 Dodge Colt Vista	N/A	<85	94		94	92		x	x
904 Plymouth Gran Fury	x	<85	89		88			x	x
907 Plymouth Caravelle	x	<85	88					x	x
908 Plymouth Horizon	90	<85	90		90			90	1
911 Plymouth Reliant	x	<85	89					x	x
917 Plymouth Sundance	89	87	94		90			89	2
919 Plymouth Acclaim	a	89	>95		90			x	x
920 Plymouth Neon	a	95	>95		a			x	x
934 Plymouth Colt	89	<85	94		94	89	93	89	3
935 Plymouth Conquest	x	<85	86					x	x
937 Plymouth Laser	a	90	94					x	x
944 Plymouth Colt Vista	N/A	<85	94		94	92		x	x
1034 Eagle Summit	a	89	>95		94	93		x	x
1037 Eagle Talon	a	90	>95		95	95		x	x
1040 Eagle Premier	90	88	92					90	2
1041 Eagle Vision	a	93	>95	a	a			x	x
1044 Eagle Summit wagon	a	92	>95		94			x	x
1203 Ford Mustang	90	<85	>95		90	94		90	3
1204 Ford Thunderbird	89	<85	>95		94	89		89	3
1206 Ford LTD	x	<85	86					x	x
1213 Ford Escort MY 1990	91 N/A	<85	>95		94	90		91	3

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
1214 Ford EXP	x	<85	88					x	x
1215 Ford Tempo	90	<85	94					90	3
1216 Ford Crown Victoria	90	<85	>95		90			90	3
1217 Ford Taurus	88	86	>95		90			88	2
1218 Ford Probe	90	89	>95		93	93		90	1
1234 Ford Festiva	90	88	93					90	2
1235 Ford Contour	a	95	>95		a			x	x
1236 Ford Aspire	a	94	95		a			x	x
1301 Lincoln Town Car	90	<85	>95	90	90			x(ABS.)	x
1302 Lincoln Mark7/8	90	<85	>95	86	90	93		90	3
1305 Lincoln Continental	88	<85	>95	86	89	88		88	2
1403 Mercury Capri	x	<85	86					x	x
1404 Mercury Cougar	89	<85	>95		94	89		89	3
1406 Mercury Marquis	x	<85	86					x	x
1413 Mercury Lynx	x	<85	87					x	x
1415 Mercury Topaz	90	<85	94					90	3
1416 Mercury Grand Marquis	90	<85	>95		90			90	3
1417 Mercury Sable	88	86	>95		90			88	2
1431 Mercury Capri XR2	a	89	94		91			x	x
1436 Mercury Tracer	90	88	>95		94	91		90	3
1437 Mercury Mystique	a	95	>95		a			x	x
1801/1810/1820 Buick Regal	89	<85	>95	93	94	88		89	3
1802 Buick LeSabre CG=1839,1852	88	<85	>95	94	92	86		88	3
1802 Buick Estate Wagon CG=1840	89	<85	91	91	91			89	2
1803 Buick Electra	89	<85	>95	91	91			89	2

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
1804 Buick Roadmaster	a	92	>95	a	a			x	x
1805 Buick Riviera	88	<85	>95	91	90	86	95	88	3
1815 Buick Skylark	x	<85	85					x	x
1816 Buick Skyhawk	89	<85	89					89	1
1817 Buick Century	89	<85	>95	94	93			89	3
1818 Buick Somerset/Skylark	89	85	>95	92	94			89	3
1821 Buick Reatta	N/A	88	91	a	90			x	x
1903 Cadillac DeVille CG=1852,1860,1864 V45=CD	89	<85	>95	91	90	90	94	89	2
1903 Fleetwood D’Elegance CG=1852,1860,1864 V45=CB	89	<85	>95	89	90	90	94	x(ABS.)	x
1903 Fleetwood Brougham CG=1842, V45=DW	88	<85	>95	90/91?	93			88	2
1905 Cadillac Eldorado	88	<85	>95	91	90	86		88	3
1909 Cadillac Allante	N/A	87	93	a	90			x	x
1914 Cadillac Seville	88	<85	>95	91	90	86	92	88	3
1916 Cadillac Cimarron	x	<85	88					x	x
2002 Chevrolet Caprice	89	<85	95	91	91			89	2
2004 Chevrolet Corvette	N/A	<85	>95	86	90			x	x
2009 Chevrolet Camaro	89	<85	>95	93	90			89	3
2010 Chevrolet Monte Carlo	x	<85	88					x	x
2013 Chevrolet Chevette	x	<85	87					x	x
2015 Chevrolet Citation	x	<85	85					x	x
2016 Chevrolet Cavalier	89	<85	>95	92	95	95		89	3
2017 Chevrolet Celebrity	89	<85	90					89	2
2019 Beretta/Corsica	88	87	>95	92	91			88	1
2020 Chevrolet Lumina	a	90	92	95				x	x

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
2031 Chevrolet Spectrum	89	85	89					89	1
2032 Nova/Prizm	88	85	>95		93	89	93	88	3
2033/2034 Sprint/Metro	89	<85	>95		95	89		89	3
2035 Geo Storm	a	90	93		a			x	x
2036 Chevrolet Monte Carlo	a	95	>95	a	a			x	x
2101/2120 Cutlass Supreme	89	<85	>95	93	94	88		89	3
2102 Olds Delta 88 CG=1839,1852	88	<85	>95	94	92	86		88	3
2102 Olds Custom Cruiser CG=1840	89	<85	91	91	91			89	2
2103 Olds 98	89	<85	>95	91	91			89	2
2105 Oldsmobile Toronado	88	<85	92	91	90	86		88	3
2116 Olds Firenza	x	<85	88					x	x
2117 Olds Ciera	89	<85	>95	94	93			89	3
2118 Olds Calais	89	85	91					89	3
2121 Olds Achieva	a	92	95	a	94			x	x
2122 Oldsmobile Aurora	a	95	>95	a	a			x	x
2202 Pontiac Bonneville CG=1844,1852	88	85	>95	92	92	87		88	3
2202 Parisienne/Safari CG=1839,1840	89	<85	89					89	1
2205 Pontiac Fiero	N/A	<85	88					x	x
2209 Pontiac Firebird	89	<85	>95	93	90			89	3
2210/2220 Pontiac Grand Prix	89	<85	>95	93	94	88		89	3
2213 Pontiac T1000	x	<85	87					x	x
2216 Pontiac Sunbird/Sunfire	89	<85	>95	92	95	95		89	3
2217 Pontiac 6000	89	<85	91					89	3

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
2218 Pontiac Grand Am	89	85	>95	92	94			89	3
2231 Pontiac LeMans	a	88	93					x	x
2401 Saturn SL sedan	a	91	>95		93			x	x
2402 Saturn SC coupe	a	91	>95		93			x	x
2403 Saturn SW wagon	a	93	>95		a			x	x
3038 VW Scirocco	x	<85	88					x	x
3040 VW Jetta	a	85	>95		93			x	x
3041 VW Quantum	a	<85	88					x	x
3042 VW Cabriolet CG=3004	N/A	<85	93		90			x	x
3042 VW Golf/GTI CG=3006	88	<85	>95		94			88	3
3044 VW Fox	88	87	93					88	1
3045 VW Corrado	a	90	>95	92				x	x
3046 VW Passat	a	90	>95					x	x
32xx Audi	<87							x	x
34xx BMW	<87							x	x
3532 Nissan 200-240SX	89	<85	>95		95	89	95	89	3
3534 Nissan 300ZX	90	<85	>95	90	91	90		x(ABS.)	x
3539 Nissan Maxima	87	<85	>95		92	89	95	87	2
3542 Nissan Stanza	89	<85	92			86-87		89	3
3543 Nissan Sentra	90	<85	>95		93	87		90	3
3544/3546 Nissan Pulsar/NX	90	<85	93		90	87	91	90	3
3547 Nissan Altima	a	93	>95		a			x	x
3548 Nissan Axxess	a	90	91					x	x
3731 Honda Civic	88	<85	>95		92	88	92	88	3
3732 Honda Accord	<87	<85	>95		90	86	90	x	x

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
3733 Honda Prelude	88	<85	>95	92	92	88	92	88	3
3735 Honda CRX	N/A	<85	>95		92	88	94	x	x
3831 Isuzu I-Mark	x	<85	89			86		x	x
3832 Isuzu Impulse	90	<85	92		90	90		90	3
3833 Isuzu Stylus	a	90	93		a			x	x
3931 Jaguar XJ-S	87	<85	>95	89	91			87	2
3932 Jaguar XJ sedan	<87	<85	>95	88	93			x	x
4134 Mazda RX-7	89	<85	>95	88	90	86	93	x	x
86-88 sales exceed 89-91 sales by 5:1									
4135 Mazda GLC/323	88	<85	>95		95	86	90,95	88	3
4137 Mazda 626	88	<85	>95		93	88	93	88	3
4143 Mazda 929	a	88	>95	89	92	92		x	x
4144 Mazda MX6	a	88	>95		93	93		x	x
4145 Mazda Miata	N/A	90	>95		a			x	x
4146 Mazda MX3	a	92	>95		94			x	x
4147 Mazda Millenia	a	95	>95		a			x	x
42xx Mercedes	<87							x	x
44xx Peugeot	<87							x	x
45xx Porsche	N/A							x	x
4637 Renault R18i	x	<85	86					x	x
4638 Renault Fuego	x	<85	85					x	x
4639 Renault Alliance	x	<85	87					x	x
4640 Renault Encore	x	85	86					x	x
4644 Renault Medallion	a	88	89					x	x
4731 Saab 900	a	<85	>95	90	90	94		x	x
4734 Saab 9000	a	<85	>95	88	89			x	x

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
4831 Subaru sedan/Loyale	89	<85	94					89	3
4834 Subaru Legacy	a	90	>95		93	95		x	x
4835 Subaru XT	89	85	91					89	3
4836 Subaru Justy	89	87	94					89	3
4837 Subaru SVX	a	92	>95	a	a			x	x
4838 Subaru Impreza	a	93	>95		a			x	x
4932 Toyota Corolla	89	<85	>95		93	93		89	3
4933 Toyota Celica	89	<85	>95		90	87	94	89	3
4934 Toyota Supra	89	<85	>95	?	90	86	93	x(ABS.)	x
4935 Toyota Cressida	88	<85	92	?		86		88?	3?
4938 Toyota Tercel	89	<85	>95		94	87		89	3
4940 Toyota Camry	88	<85	>95		92	92		88	3
4941 Toyota MR-2	N/A	<85	>95		91	91		x	x
4942 Toyota Paseo	a	92	>95		94			x	x
4943 Toyota Avalon	a	95	>95		a			x	x
51xx Volvo	<87							x	x
5231 Mitsubishi Starion	89	<85	89					89	1
5232 Mitsubishi Tredia	x	<85	88					x	x
5233 Mitsubishi Cordia	x	<85	88					x	x
5234 Mitsubishi Galant	86	<85	>95		94	94		x	x
5235 Mitsubishi Mirage	89	<85	>95		94	89	93	89	3
5236 Mitsubishi Precis MY 1989	90 N/A	87	94			90		90	1
5237 Mitsubishi Eclipse	a	90	>95		95	95		x	x
5238 Mitsubishi Sigma	a	89	91		90			x	x
5239 Mitsubishi 3000GT	a	91	>95		a			x	x

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
5240 Mitsubishi Diamante	a	92	>95		a			x	x
5244 Mitsubishi LRV	a	92	94		94			x	x
5245 Mitsubishi Expo SP	a	92	94		94			x	x
5334 Suzuki Swift	a	89	>95		95			x	x
5431 Acura Integra	88	86	95		94	90	94	88	2
5432 Acura Legend	a	86	95	88	87	91		x	x
5433 Acura NSX	a	91	>95	a	a			x	x
5434 Acura Vigor	a	92	94	a	a			x	x
5532 Hyundai Excel	90	86	94			90		90	3
5533 Hyundai Sonata	a	89	>95		94	95		x	x
5534 Hyundai Scoupe	a	91	>95					x	x
5535 Hyundai Elantra	a	92	>95		94			x	x
5536 Hyundai Accent	a	95	>95		a			x	x
56xx Merkur	a							x	x
5731 Yugo	90	86	91	few	sold	with	l/s	x	x
5831 Infiniti M30	a	90	92	a	a			x	x
5832 Infiniti Q45	a	90	>95	a	a			x	x
5833 Infiniti G20	a	91	>95	a	93			x	x
5834 Infiniti J30	a	93	>95	a	a			x	x
5931 Lexus ES-250/300	a	90	>95	a	a	92		x	x
5932 Lexus LS-400	a	90	>95	a	a	95		x	x
5933 Lexus SC-300/400	a	92	>95	a	a			x	x
5934 Lexus GS-300	a	93	>95	a	a			x	x
6031 Daihatsu Charade	a	88	92					x	x
6131 Sterling	a	87	91	a				x	x
6431 Kia Sephia	a	93	95					x	x

APPENDIX B

PASSENGER VANS AND SPORT UTILITY VEHICLES
TYPE OF BACK SEAT OUTBOARD BELTS BY MAKE/MODEL AND YEAR

EXPLANATION OF COLUMN HEADINGS

bkls MY	first Model Year (MY) with standard back seat outboard lap/shoulder belts
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EXPLANATION OF CODES

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Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
T111 Dodge Ram Wagon	91	<85	>95		95			91	3
T112 Caravan/Voyager	91	<85	>95		91	91		91	3
T112a Chrys Town&Country	91	90	>95		91	91		91	1
T120 Dodge Ramcharger	91	85	93					91	3
T121 Jeep Cherokee	91	<85	>95		95			91	3
T1210 Jeep Wagoneer	91	<85	92					91	2
T122 Jeep Wrangler	92	87	>95					92	3
T123 Jeep Grand Cherokee	a	93	>95		a			x	x
T211 Ford Club Wagon	92	<85	>95		93	92		92	3
T212 Ford Aerostar	92	86	>95		92			92	3
T213 Mercury Villager	a	93	>95					x	x
T214 Ford Windstar	a	95	>95		a			x	x
T220 Ford Bronco 2	x	<85	90					x	x
T221 Ford Big Bronco	92	<85	>95		94			92	3
T222 Ford Explorer	a	91	>95		95			x	x
T312 GM Astro/Safari	89	<85	>95		94			89	3
T311 GM Sportvan/Rally	88	<85	>95		94			88	3
T313 Lumina APV, etc.	a	90	>95		94			x	x
T321 GM Tahoe/Yukon	90	<85	>95		95	92		90	3
T322 GM S Blazer/Jimmy	89	<85	>95					89	3
T323 GM Suburban	89	<85	>95		95	92		89	3
T324 Geo Tracker	a	89	>95					x	x
T411 Nissan Quest	a	93	>95					x	x
T421 Nissan Pathfinder	90	87	>95					90	3
T521 Isuzu Trooper 4 door	87	<85	>95		95	92		87	3
T521 Isuzu Trooper 2 door	88	<85	>95		95	92		88	3

Back Seat Belt Information

make-model	bkls MY	first MY	last MY	ABS MY	airbag MY	remod MY1	remod MY2	TY	YT±
T522 Isuzu Amigo	92	89	>95					92	3
T523 Isuzu Rodeo	a	91	>95					x	x
T611 Mazda MPV	a	89	>95		93			x	x
T711 Toyota Previa	a	91	>95		92			x	x
T712 Toyota van	89	87	89					89	1
T721 Toyota 4-runner	89	<85	>95					89	3
T722 Toyota Landcruiser	89	<85	>95			91		89	3
T821 Mits Montero	89	<85	>95		94	92		89	3
T921 Suzuki Samurai	x	<85	95					x	x
T922 Suzuki Sidekick	a	89	>95					x	x
T1021 Honda Passport	a	94	>95					x	x
T1121 Kia Sportage	a	95	>95					x	x

APPENDIX C

Proof 1

Let's consider a car with four outboard occupants. Let the probabilities of a fatality in the driver position be p_1, in the right front passenger position be p_3, in the left rear passenger seat be p_4, and in the right rear passenger seat be p_6. The definition of the risk ratio of the back seat relative to the front seat is the sum of the probabilities of a fatality in the back seat divided by the sum of the probabilities of a fatality in the front seat:

$(p_4 + p_6)/(p_1 + p_3)$.

Now, here's what happens when we use FARS data and our paired-occupant method. There are 16 possible scenarios and here is how they contribute to our data file:

	Fatality at				
Scenario	DRV	FR	BL	BR	Probability of occurrence
(1)	0	0	0	0	$(1-p_1)(1-p_3)(1-p_4)(1-p_6)$
(2)	1	0	0	0	$p_1(1-p_3)(1-p_4)(1-p_6)$
(3)	0	1	0	0	$(1-p_1)p_3(1-p_4)(1-p_6)$
(4)	0	0	1	0	$(1-p_1)(1-p_3)p_4(1-p_6)$
(5)	0	0	0	1	$(1-p_1)(1-p_3)(1-p_4)p_6$
(6)	1	1	0	0	$p_1*p_3(1-p_4)(1-p_6)$
(7)	1	0	1	0	$p_1(1-p_3)p_4(1-p_6)$
(8)	1	0	0	1	$p_1(1-p_3)(1-p_4)p_6$
(9)	0	1	1	0	$(1-p_1)p_3*p_4(1-p_6)$
(10)	0	1	0	1	$(1-p_1)p_3(1-p_4)p_6$
(11)	0	0	1	1	$(1-p_1)(1-p_3)p_4*p_6$
(12)	1	1	1	0	$p_1*p_3*p_4(1-p_6)$
(13)	1	1	0	1	$p_1*p_3(1-p_4)p_6$
(14)	1	0	1	1	$p_1(1-p_3)p_4*p_6$
(15)	0	1	1	1	$(1- p_1)p_3*p_4*p_6$
(16)	1	1	1	1	$p_1*p_3*p_4*p_6$

Scenario	Number of records generated	Unweighted		Weighted by p of occurrence	
		Front seat fatalities	Back seat fatalities	Front seat fatalities	Back seat fatalities
(1)	None -- not a FARS case				
(2)	2	2	0	$2p_1(1-p_3)(1-p_4)(1-p_6)$	0
(3)	2	2	0	$2(1-p_1)p_3(1-p_4)(1-p_6)$	0
(4)	2	0	2	0	$2(1-p_1)(1-p_3)p_4(1-p_6)$
(5)	2	0	2	0	$2(1-p_1)(1-p_3)(1-p_4)p_6$
(6)	4	4	0	$4p_1{*}p_3(1-p_4)(1-p_6)$	0
(7)	3	2	2	$2p_1(1-p_3)p_4(1-p_6)$	$2p_1(1-p_3)p_4(1-p_6)$
(8)	3	2	2	$2p_1(1-p_3)(1-p_4)p_6$	$2p_1(1-p_3)(1-p_4)p_6$
(9)	3	2	2	$2(1-p_1)p_3{*}p_4(1-p_6)$	$2(1-p_1)p_3{*}p_4(1-p_6)$
(10)	3	2	2	$2(1-p_1)p_3(1-p_4)p_6$	$2(1-p_1)p_3(1-p_4)p_6$
(11)	4	0	4	0	$4(1-p_1)(1-p_3)p_4{*}p_6$
(12)	4	4	2	$4p_1{*}p_3{*}p_4(1-p_6)$	$2p_1{*}p_3{*}p_4(1-p_6)$
(13)	4	4	2	$4p_1{*}p_3(1-p_4)p_6$	$2p_1{*}p_3(1- p_4)p_6$
(14)	4	2	4	$2p_1(1-p_3)p_4{*}p_6$	$4p_1(1-p_3)p_4{*}p_6$
(15)	4	2	4	$2(1-p_1)p_3{*}p_4{*}p_6$	$4(1-p_1)p_3{*}p_4{*}p_6$
(16)	4	4	4	$4p_1{*}p_3{*}p_4{*}p_6$	$4p_1{*}p_3{*}p_4{*}p_6$

The sum of the probabilities of a fatality in the front seat is:

$2p_1(1-p_3)(1-p_4)(1-p_6) + 2(1-p_1)p_3(1-p_4)(1-p_6) + 4p_1{*}p_3(1-p_4)(1-p_6) + 2p_1(1-p_3)p_4(1-p_6) +$

$2p_1(1-p_3)(1-p_4)p_6 + 2(1-p_1)p_3{*}p_4(1-p_6) + 2(1-p_1)p_3(1-p_4)p_6 + 4p_1{*}p_3{*}p_4(1-p_6) + 4p_1{*}p_3(1-p_4)p_6 +$

$2p_1(1-p_3)p_4{*}p_6 + 2(1-p_1)p_3{*}p_4{*}p_6 + 4p_1{*}p_3{*}p_4{*}p6.$

$= [2p_1(1-p_3)(1-p_4)(1-p_6)+2p_1(1-p_3)(1-p_4)p_6] + [2(1-p_1)p_3(1-p_4)(1-p_6)+2(1-p_1)p_3{*}p_4(1-p_6)] +$

$[4p_1{*}p_3(1-p_4)(1-p_6) + 4p_1{*}p_3{*}p_4(1-p_6)] + [2p_1(1-p_3)p_4(1-p_6) + 2p_1(1-p_3)p_4{*}p_6] +$

$[2(1-p_1)p_3(1-p_4)p_6 + 2(1-p_1)p_3*p_4*p_6] + [4p_1*p_3(1-p_4)p_6 + 4p_1*p_3*p_4*p_6]$

$= [2p_1(1-p_3)(1-p_4)(1- p_6 + p_6)] + [2(1-p_1)p_3(1- p_4 + p_4)(1-p_6)] + [4p_1*p_3(1- p_4 + p_4)(1-p_6)] +$

$[2p_1(1-p_3)p_4(1- p_6 + p_6)] + [2(1-p_1)p_3(1- p_4 + p_4)p_6] + [4p_1*p_3(1- p_4 + p_4)p_6]$

$= [2p_1(1-p_3)(1-p_4)] + [2(1-p_1)p_3(1-p_6)] + [4p_1*p_3(1-p_6)] + [2p_1(1-p_3)p_4] + [2(1-p_1)p_3*p_6] +$

$[4p_1*p_3*p_6]$

$= [2p_1(1-p_3)(1-p_4) + 2p_1(1-p_3)p_4] + [2(1-p_1)p_3(1-p_6) + 2(1-p_1)p_3*p_6] +$

$[4p_1*p_3(1-p_6) + 4p_1*p_3*p_6]$

$= [2p_1(1-p_3)] + [2(1-p_1)p_3] + [4p_1*p_3]$

$= [2p_1(1-p_3) + 2p_1*p_3] + [2(1-p_1)p_3 + 2p_1*p_3]$

$= [2p_1] + [2p_3]$ or

$= 2(p_1 + p_3)$.

The sum of the probabilities of a fatality in the back seat is:

$2(1-p_1)(1-p_3)p_4(1-p_6) + 2(1-p_1)(1-p_3)(1-p_4)p_6 + 2p_1(1-p_3)p_4(1-p_6) + 2p_1(1-p_3)(1-p_4)p_6 +$

$2(1-p_1)p_3*p_4(1-p_6) + 2(1-p_1)p_3(1-p_4)p_6 + 4(1-p_1)(1-p_3)p_4*p_6 + 2p_1*p_3*p_4(1-p_6) + 2p_1*p_3(1- p_4)p_6 +$

$4p_1(1-p_3)p_4*p_6 + 4(1-p_1)p_3*p_4*p_6 + 4p_1*p_3*p_4*p_6$

$= [2(1-p_1)(1-p_3)p_4(1-p_6) + 2(1-p_1)p_3*p_4(1-p_6)] + [2(1-p_1)(1-p_3)(1-p_4)p_6 + 2(1-p_1)p_3(1-p_4)p_6]$

$+ [2p_1(1-p_3)p_4(1-p_6) + 2p_1*p_3*p_4(1-p_6)] + [2p_1(1-p_3)(1-p_4)p_6 + 2p_1*p_3(1- p_4)p_6] +$

$[4(1-p_1)(1-p_3)p_4*p_6 + 4p_1(1-p_3)p_4*p_6] + [4(1-p_1)p_3*p_4*p_6 + 4p_1*p_3*p_4*p_6]$

$= 2(1-p_1)p_4(1-p_6) + 2(1-p_1)(1-p_4)p_6 + 2p_1*p_4(1-p_6) + 2p_1(1- p_4)p_6 + 4(1-p_3)p_4*p_6 +$

$4p_3*p_4*p_6$

$= 2p_4(1-p_6) + 2(1- p_4)p_6 + 4p_4*p_6$

$= 2(p_4 + p_6)$.

Therefore, the risk ratio is $2(p_4 + p_6)/2(p_1 + p_3) = (p_4 + p_6)/(p_1 + p_3)$, so this does not bias our results.

<u>Proof 2</u>

Suppose a crash has occurred, the car has three occupants, driver, right front passenger and left rear passenger, and their probabilities of a fatality are p_1, p_3, and p_4.

Our commonsense definition of the risk ratio of the back seat relative to the front seat is

$$2p_4/(p_1 + p_3)$$

–i.e., p_4 relative to the average of p_1 and p_3.

Now, here's what happens when we use FARS data and our method. There are 8 possible scenarios. Here's how they contribute to our data file:

Scenario	Fatality at			Probability of occurrence	Number of records generated	Unweighted		Weighted by p of occurrence	
	DRV	FR	BL			Front seat fats.	Back seat fats.	Front seat fatalities	Back seat fatalities
(1)	0	0	0	$(1-p_1)(1-p_3)(1-p_4)$	None -- not a FARS case				
(2)	1	0	0	$p_1(1-p_3)(1-p_4)$	1	1	0	$p_1(1-p_3)(1-p_4)$	0
(3)	0	1	0	$(1-p_1)p_3(1-p_4)$	1	1	0	$(1-p_1)p_3(1-p_4)$	0
(4)	0	0	1	$(1-p_1)(1-p_3)p_4$	2	0	2	0	$2(1-p_1)(1-p_3)p_4$
(5)	1	1	0	$p_1*p_3(1-p_4)$	2	2	0	$2p_1*p_3(1-p_4)$	0
(6)	1	0	1	$p_1(1-p_3)p_4$	2	1	2	$p_1(1-p_3)p_4$	$2p_1(1-p_3)p_4$
(7)	0	1	1	$(1-p_1)p_3*p_4$	2	1	2	$(1-p_1)p_3*p_4$	$2(1-p_1)p_3*p_4$
(8)	1	1	1	$p_1*p_3*p_4$	2	2	2	$2p_1*p_3*p_4$	$2p_1*p_3*p_4$

Sum of these probabilities for the front seat is:

$$p_1(1-p_3)(1-p_4) + (1-p_1)p_3(1-p_4) + 2p_1*p_3(1-p_4) + p_1(1-p_3)p_4 + (1-p_1)p_3*p_4 + 2p_1*p_3*p_4$$

$$= p_1(1-p_3)(1-p_4 + p_4) + (1-p_1)p_3(1-p_4 + p_4) + 2p_1*p_3(1-p_4 + p_4)$$

$$= p_1(1-p_3) + (1-p_1)p_3 + 2p_1*p_3$$

$$= p_1(1-p_3) + p_1*p_3 + (1-p_1)p_3 + p_1*p_3$$

$$= p_1(1- p_3 + p_3) + (1- p_1 + p_1)p_3$$

$$= p_1 + p_3.$$

Sum of these probabilities for the back seat is:

$$2(1-p_1)(1-p_3)p_4 + 2p_1(1-p_3)p_4 + 2(1-p_1)p_3*p_4 + 2p_1*p_3*p_4$$

$$= 2p_4[(1-p_1)(1-p_3) + p_1(1-p_3) + (1-p_1)p_3 + p_1*p_3]$$

$$= 2p_4[(1-p_1 + p_1)(1-p_3) + (1-p_1 + p_1)p_3]$$

$$= 2p_4[(1-p_3) + p_3]$$

$$= 2p_4.$$

Thus, here too, the risk ratio of back seat to front seat is $2p_4/(p_1 + p_3)$. In other words, this method does not create biases in favor or against the back seat.