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Safety Study - Performance of Lap/Shoulder Belts in 167 Motor Vehicle Crashes. Volume 1

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16. Abstract

This report is a case study presenting data from in-depth investigations of 167 motor vehicle crashes involving lap/shoulder-belted occupants. The accidents and the crashes had to meet specific criteria, and represent a wide range of accident configuration and severity. Volume 1 (NTSB/SS-88/02) of the study describes the good crash protection provided by lap/shoulder belts, residual injuries sustained, degraded protection provided by any misused lap/shoulder belts (i.e., misrouted, excess slack, reclining seat), and use of the three-point belt by children and pregnant women. Volume 2 (NTSB/SS-88/03) contains the 167 case summaries that provided the data discussed in Volume 1.

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CONTENTS

Case histories of the Safety Board investigations conducted for the Lap/Shoulder Belt Report are issued as Volume II

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

SAFETY STUDY

Adopted: March 1, 1988

PERFORMANCE OF LAP/SHOULDER BELTS IN 167 MOTOR VEHICLE CRASHES

INTRODUCTION

Lap/shoulder belts have been standard equipment in the front seats of cars sold in the United States for more than 20 years and have been recognized as providing superior crash protection, compared to other seatbelt types, since as early as the 1950s. Unfortunately, until the recent passage of State mandatory use laws, few people used their lap/shoulder belts. In 1982, only 10 percent of the drivers observed in a survey of 19 U.S. cities were buckled up, and in the first half of 1987, that figure had increased to 42 percent. 1/ While this increase is significant, still more than half of the drivers in this country are not making use of this lifesaving device.

In other words. although lap/shoulder belts have been around for years, they haven't, until recently, been "around" enough U.S. motorists to decrease substantially the number of highway casualties. Now with the increase in use associated with mandatory use laws, some experts estimate that as of the end of 1986 as many as 1,300 lives have been saved. 2/ Hopefully, the passage of more mandatory use laws, combined with effective enforcement and education campaigns, will increase use to a much higher level and save even more lives.

Lifestyle factors, that is, aspects of health that are under the individual's control (in contrast to heredity and environment), such as choosing to wear seatbelts, play a large role in the risk of death. (See figure 1.) Buckling up is a matter of intelligent risk management: by wearing a lap/shoulder belt, an occupant substantially reduces his or her chance of premature death. 3/ Motor vehicle accidents are the leading cause of death for Americans ages 1 to 35, and the third leading cause of premature death for Americans of all ages. 4/

That lap/shoulder belts are of value to reduce death and injury is undisputed, but just how valuable they are is matter of debate. Manual seatbelt systems in motor vehicles (unlike passive restraints such as air bags and automatic seatbelts) have never been required to be tested for crash protection performance; complete and accurate data on their performance in real-world crashes have been extremely limited; and basic changes

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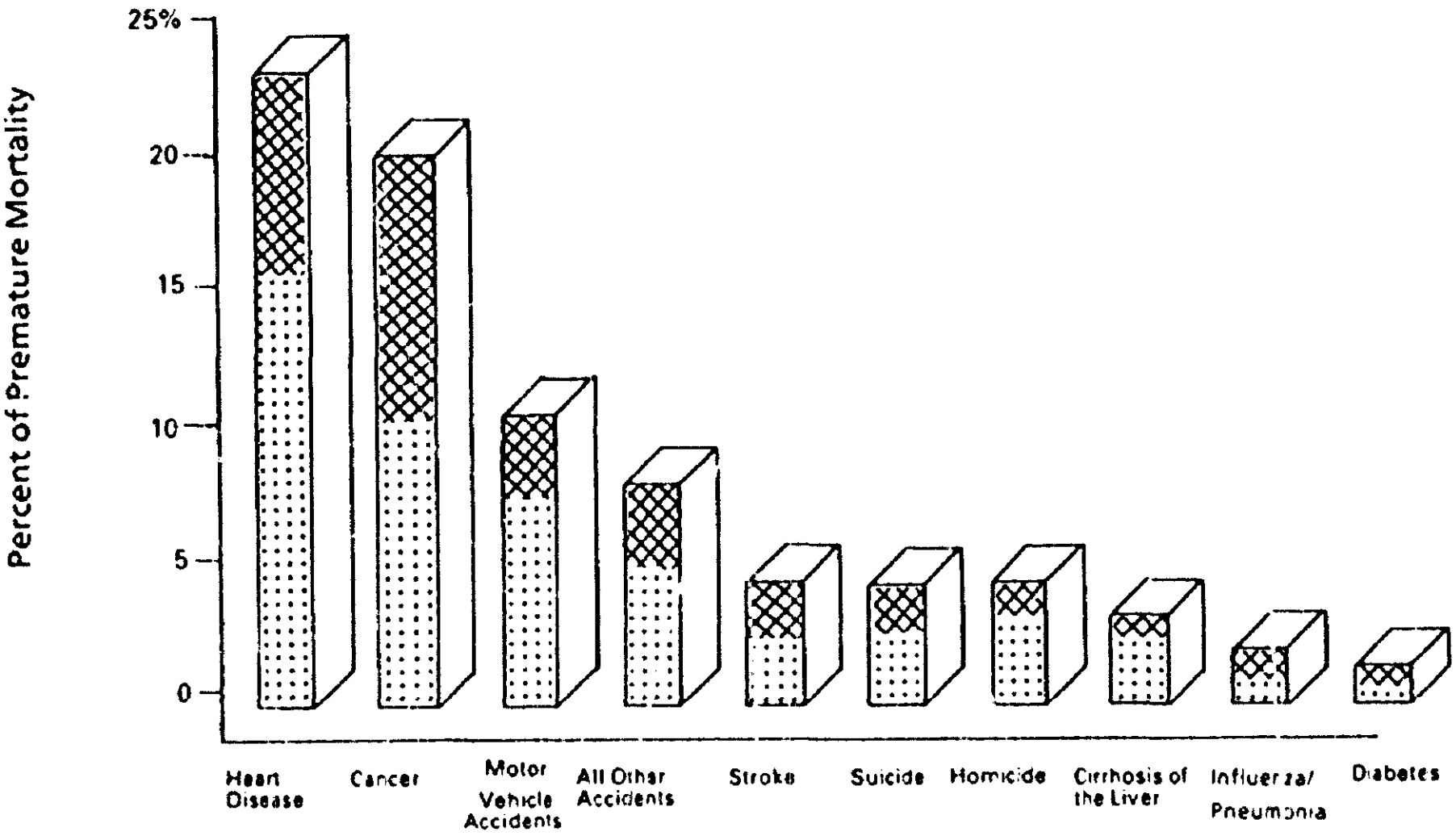
1/ U.S. Department of Transportation, National Highway Traffic Safety Administration, 19-City Survey of Restraint Use, 1982 and 1987.
2/ University of North Carolina, Highway Safety Research Center, 1987.
3/ The Center for Disease Control (CDC) defines premature morbidity as deaths occurring before age 75.
4/ Heart disease and cancer are the top two causes of premature death, according to CDC.

Lifestyle Has Major Impact on the Leading Causes of Premature Death



% Contribution of lifestyle related factors to the 10 leading causes of premature death

Source: Centers for Disease Control

Note: Premature mortality refers to deaths occurring before age 75

Figure 1.--Causes of premature death.

in vehicle design over the years could have affected belt performance. In addition, seatbelt performance is a timely topic since States are enacting mandatory seatbelt-use laws requiring front seat occupants (and rear seat occupants, in some cases) to wear their seatbelts.

With many of these factors in mind, the Safety Board conducted a study on the performance of seatbelts in real-world crashes during 1984-86. This case study emphasized the collection of accurate, complete data on a number of specific points relevant to the question of belt performance. Specifically, the Board wished to explore how well the belts protected occupants from injury during the crashes and what injuries, if any, occurred despite (or perhaps because of) the belt.

This report is the second and final publication to come out of the Board's investigations; it presents the bulk of the cases investigated as part of the seatbelt performance study. It presents data on the performance of lap/shoulder belts in 167 accidents involving 180 case vehicles 5/ and 341 case vehicle occupants. Most of the occupants were seated in the front seat and most were restrained, so this report primarily addresses the crash performance of lap/shoulder belts for the driver and right front passenger. (See figure 2.) The accident selection criteria resulted in very few unrestrained case vehicle occupants, so few comparisons between restrained and unrestrained case occupants could be drawn.

NTSB Accident Selection Criteria

The criteria for inclusion of an accident in this study were:

- Case vehicle must be a post-1974 model car, light truck, or van.
- At least one occupant in the case vehicle must have used a seat belt. 6/ (This criterion resulted in atypically high proportions of restrained occupants. Very few case vehicle occupants were unrestrained.)
- The crash must have been of sufficient severity to require that the case vehicle be towed from the scene. 7/
- The crash must not have been so severe for the case vehicle as to be deemed unsurvivable for its belted occupant(s). 8/

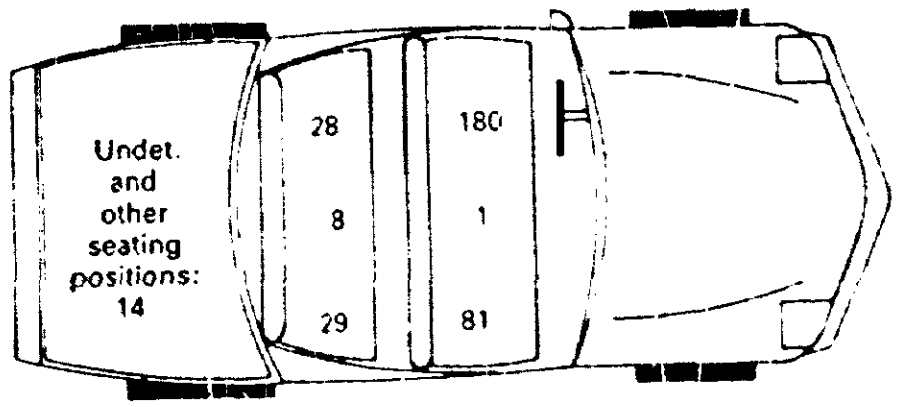
5/ More than 180 vehicles were involved in the 167 accidents investigated by the Safety Board for the lap/shoulder belt report. However, not all became case vehicles. In some cases, vital information on vehicle damage or occupant injuries was unavailable, or the vehicle did not meet the case selection criteria, and hence the vehicle and its occupants were not included in the analysis. Some data on all vehicles and occupants involved in the specific accidents, however, are presented in the individual case summaries, which constitute Volume 2.

6/ Before the program was completed, it was decided to document a few vehicles in which no occupants were restrained for comparison purposes.

7/ As the program progressed, it was found that, for a wide variety of reasons, vehicles may be towed even though they are essentially undamaged. Since in these cases the "crash" was extremely minor and seatbelts could not be expected to affect the outcome, these tow-away cases were not followed up.

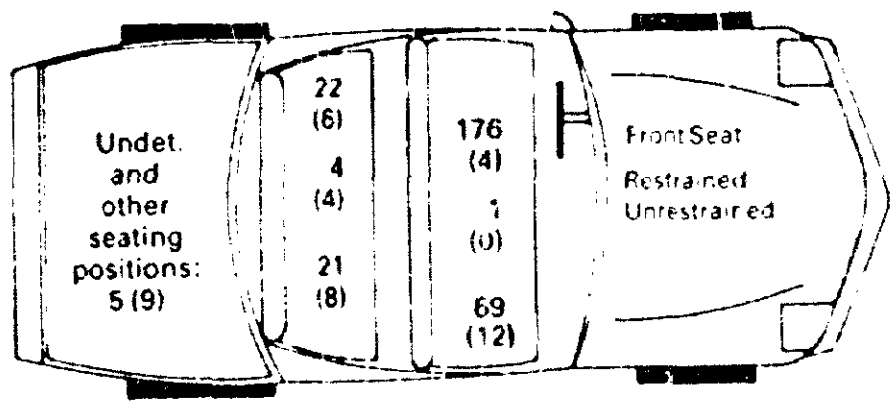
8/ That is, there must have been sufficient space after the crash at the seating locations of the belted occupants to permit survival.

Case Vehicle Occupants by Seating Position
(Number in each position)



NOTE: Data are for occupants of the 180 case vehicles only. Some of the case vehicles were vans or station wagons with more than two rows of seats; occupants of those vehicles make up the majority of persons in the "other" seating position category.

Restraint Status by Seating Position
(Numbers in parentheses are unrestrained)



NOTE: Data for occupants of 180 case vehicles only. The accident selection criterion specifying at least one belted occupant resulted in atypically high proportions of restrained occupants.

Figure 2.--Case vehicle occupants by seating position (top) and restraint use status by seating position (bottom).

As stated earlier, this report is a case study, involving in-depth investigations of accidents meeting specific criteria to collect accurate and complete data on a topic of interest--seatbelt performance, in this instance. The selection criteria described previously together with the limited number of cases in this study, mean that the cases in this report cannot be used to derive statistical estimates of seatbelt effectiveness, nor was this the Safety Board's intention. However, a case study like this one can supply accurate and complete data on crash events and severity, vehicle deformation, crash severity level, and cause of occupant injuries--data not available in police report-generated accident data files. Restraint status, along with information on belt routing and fit, was also verified by Safety Board investigators, resulting in more accurate and in-depth data on belt use than are available in police-report data bases.

Given these criteria, the 167 cases in the report do not represent all motor vehicle accidents in the United States. The study's criteria that a belted person be present in the vehicle and that the vehicle sustain tow-away damage make this certain; most people involved in crashes are not belted, 9/ and most crashes are not towaway. Indeed, it would be impossible to compare these cases directly with the U.S. crash population due to lack of information about the vast majority of U.S. crashes. For example, some 18 million accidents are "reported" each year to some authority (police, motor vehicle officials, insurance companies); however, only 6 million result in police reports. Hence even basic facts about more than 2/3 of all the accidents, such as what percent were frontal or whether minor injuries resulted, are not known.

The accident selection criteria used in this study did allow Safety Board investigators to focus on the kinds of crashes which, though occurring less frequently (relative to the total population of 18 million reported accidents), are most instructive in regard to seatbelt performance: crashes severe enough that the passenger vehicle had to be towed away. (In 1984, about 2.3 million of the 6 million accidents reported to the police were tow-away accidents.) Tow-away accidents are the crashes in which it is believed almost all of the serious injuries and all of the occupant deaths occur. Most of the 6 million police-reported accidents (which probably are more serious than the remaining 12 million accidents reported to some authority but not to the police), result in property damage only, or minor injuries at the worst, regardless of restraint status. 10/ 11/

The 167 accidents summarized in this report represent a wide range of tow-away crashes. The charts and diagrams at the end of this chapter (figure 8) provide a breakdown of the cases by crash severity, accident configuration, occupant seating position, restraint status, and lap/shoulder-belt design and use. The reader is referred to these pages for the numbers of case vehicles and occupants in each category.

9/ Furthermore, unrestrained occupants tend to be involved in more severe crashes and generally are younger than those restrained, confounding analysis. Belted drivers in crashes tend to be less likely to have been drinking, more likely to be in smaller cars, less likely to be in a crash at night, less likely to have been speeding--all factors that influence crash likelihood and injury outcome. O'Day, James, and Flora, Jairus, "Alternative Measures of Restraint System Effectiveness: Interaction with Crash Severity Factors," Society of Automotive Engineers (SAE). Technical Paper 820798, Passenger Car Meeting, Troy, Michigan, June 7-10, 1982.

10/ In 1984, 3.5 million of the police-reported accidents involved property damage only.

11/ The reader is cautioned not to interpret this statement as implying that lap/shoulder belts need not be worn every time the vehicle is in motion. A serious accident can occur at any time, and common sense dictates that the lap/shoulder belt be worn 100 percent of the time. No matter how cautious a driver you may be, you have no control over the behavior of other drivers on the road.

The Safety Board's cases provide examples of lap/shoulder belt performance at varying crash severities and accident configurations (i.e., collision and noncollision accidents, rollover, side impact, etc.). Two-thirds of the cases involve frontal impact which is a common accident configuration in fatal or injury-producing crashes. According to the National Highway Safety Traffic Administration (NHSTA), approximately 47 percent of fatal single-vehicle passenger car crashes have a frontal impact as "point of principal impact," as do 53 percent of fatal multi-vehicle passenger car crashes. 12/ About 60 percent of tow-away crashes reported to police involving passenger cars involve a frontal direction of force. 13/ A lap/shoulder belt may well provide optimal protection in a frontal (head-on or front angle) crash compared to other accident configurations.

Rollover accidents also are represented in the study. Fourteen of the cases involved overturn; in 8 instances no prior collision was involved.

The type of belt system in use, as well as its correct or incorrect use, also affects the injury outcome. Both domestic and imported passenger vehicles are represented in the study, so several lap/shoulder belt designs are discussed. In most cases, the belts were being worn properly, but in 17 cases, the lap/shoulder belt was improperly routed. Slack also was present in some of the three-point systems; slack is discussed in the misuse chapter, which follows later in the report.

If occupants were restrained in the cases presented in this report, the restraint normally was a lap/shoulder belt (231 out of 298 restrained occupants), so little data was collected on lapbelts, child restraints, or passive restraints. The outcome for the last two types of restraints is presented in appendixes E and F.

How the Investigations Were Conducted

The investigations for this study were conducted by National Transportation Safety Board (NTSB) headquarters and field staff (located in eight field offices). 14/ At the beginning of the program, each Safety Board field office set up an accident notification plan, involving a network of law enforcement and medical authorities in the multi-State region surrounding the office. These local and State authorities agreed to notify the Safety Board investigators of any crash meeting the Board's criteria as soon as they became aware of it. Upon notification, Board investigators were to go to the accident location, determine if the crash, in fact, met the selection criteria, and if so, begin a detailed investigation.

Safety Board investigators took particular care in verifying belt use. They did not rely solely on occupant or witness statements of belt use or the restraint status stated in the police report, but rather looked for physical evidence confirming use, on the belt system itself, and in terms of injury/contact point data. (See photographs, figures 3 through 7 at the end of the chapter.) In each case, information was collected on the type of belt system in use, how the belt was worn, and the interaction between the occupant and the belt system in use. Crash events were carefully reconstructed to determine how the accident configuration affected belt performance.

The age, weight, height, and seating location of each occupant was determined. For each occupant, the investigators determined whether the available seat belt was used, whether it was used correctly, the probable source of each injury, and the nature and

12/ 1985 Fatal Accident Reporting System (FARS) Report.
13/ 1985 National Accident Sampling System (NASS) Report.
14/ The Safety Board has highway investigators in the following field offices: Atlanta, Chicago, Denver, Fort Worth, Kansas City (Missouri), Los Angeles, New York, and Seattle.

severity of each injury sustained, expressed in terms of the Abbreviated Injury Scale (AIS). Throughout this report, occupants are frequently described in terms of his or her maxiumum AIS level injury (MAIS). The AIS codes used in this study are:

AIS	Severity code
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury, virtually unsurvivable
7	Injured, unknown severity
9	Unknown if injured

The events of the accidents were carefully reconstructed, and necessary measurements made to estimate the collision severity experienced by the case vehicle. These data provided the information necessary to analyze the performance of each belt system in use during the crash, and to draw some overall conclusions about the role of belt restraint systems in the crashes.

The severity measure used in the Safety Board's cases is Delta V, considered by most crash researchers to be the best single measure of collision severity. Delta V, as used in these investigations, is the instantaneous rate of speed change undergone by a vehicle at impact. The Delta V estimates were generated primarily from measurements of both the location and extent of the vehicles' structural deformation, along with the vehicles' weights. When entered into the Calspan Reconstruction of Accident Speeds on the Highway (CRASH 3) computer program, 15/ these measurements could be compared against the known results of crashes staged and documented over the past several years. This computer program analyzes such parameters as vehicle structural rigidity, force vectors with respect to vehicle center of mass, and the influence of individual vehicle weights. The result is a computer-generated estimate of the speed change acting on the crash vehicles at impact. While the program result is recognized as an estimate, the use of CRASH allows a uniformity of case study interpretation that could not be achieved by other commonly used investigative methods.

Delta V also is a far more sensitive and accurate gauge of crash severity experienced by the case vehicle occupants than scales of accident severity based on vehicle damage only. The amount of vehicle deformation may not reflect the severity of crash forces; the bodies of some vehicles "give" at lower crash forces than others and, therefore, absorb crash forces before they are transmitted to the vehicle occupant. Hence, the reader is cautioned not to judge crash severity by vehicle damage alone.

Lapbelt Report

After about a quarter of the investigations were initiated, several cases involving lapbelted rear seat occupants began to draw the Safety Board's attention to these belt systems in particular. The results of the lapbelt investigations, along with analysis of the accident databases used in the past to derive lapbelt effectiveness, a review of medical

15/ The program was developed with funding from the U.S. Department of Transportation as an "accident investigation aid aimed at achieving accuracy and uniformity in the interpretation of physical evidence from traffic accidents."

literature on lapbelt-induced injuries, and other research on lapbelt performance, were published in 1986 as the first report to come out of NTSB's investigations of seatbelt performance. 16/

As a result of its investigation of crashes involving lapbelted occupants, and its review of the history of the limitations of this type of seatbelt, the Safety Board recommended to auto manufacturers and the NHTSA that they provide lap/shoulder belts in place of lap-only belts. Domestic manufacturers were urged to provide voluntarily lap/shoulder belts in rear outboard seating positions in new vehicles, and to provide retrofit kits for existing models. Foreign manufacturers were asked to undertake similar efforts in respect to any models not already equipped with rear seat lap/shoulder belts. The Board also recommended that manufacturers and the NHTSA work together to explore the possibility of providing lap/shoulder belts at the rear center seating position.

The Board issued several recommendations to the NHTSA--most importantly, that it "immediately initiate rulemaking action" to require lap/shoulder belts at all outboard seating positions in new vehicles. (For the full text of the Board's recommendations, see appendix A.)

The Safety Board is pleased with the automobile industry's response to the lapbelt report recommendations: virtually all car manufacturers have agreed to install, as standard equipment, lap/shoulder belts at rear outboard seating positions within the next few model years. Many manufacturers have retrofit programs underway, with General Motors (GM) having the most comprehensive program. Both GM and Chrysler are advertising the availability of their retrofit kits.

The NHTSA's response to the Board's recommendations has been disappointing, however. The Board had hoped, for a number of reasons, that the agency would act quickly to require lap/shoulder belts in rear outboard seats of new vehicles. Lap/shoulder belts are widely acknowledged to provide superior protection and are provided in the rear seats of many foreign models. The design problems of providing them in all cars should be minimal, since the NHTSA has for many years required that all cars be designed to be capable of being retrofitted with rear seat shoulder belts. Furthermore, a number of manufacturers announced soon after the release of the Board's lapbelt report that they would begin voluntarily providing rear seat lap/shoulder belts within just a few months. Nevertheless, more than 10 months passed before the NHTSA took any action on this recommendation, and even then the agency declined to propose actual rulemaking. Rather, it published only an Advance Notice of Proposed Rulemaking (ANPRM), announcing that rulemaking was being considered and describing why the agency does not believe such a regulation would be cost beneficial.

The Safety Board has submitted extensive comments on NHTSA's action, as have a number of manufacturers, safety organizations, and some members of Congress. Legislation is also pending that directs the NHTSA to require rear seat lap/shoulder belts. The Board is hopeful that the NHTSA will proceed at once to issue a draft rule to implement this long-overdue improvement in passenger vehicle crash protection. Rear seat occupants should not be denied the superior protection offered by lap/shoulder belts, which is routinely available to front seat occupants.

16/ Safety Study--"Performance of Lap Belts in 26 Frontal Crashes," July 28, 1986, NTSB/SS-86-03. The report is available through the National Technical Information Service, Springfield, Virginia 22161. Some of the cases described in the lapbelt report had lap/shoulder-belted occupants in the vehicle. These cases were also included in this report.

Organization of This Report

As stated previously, this safety study is the second and final report to come out of the Board's examination of seatbelt crash performance and presents the bulk of the investigations conducted in the course of the study. Figure 8 shows the type of information gathered for the lap/shoulder belt report. The next chapter discusses the overall crash performance of lap/shoulder belts in the report's cases, followed by a chapter on injuries sustained by lap/shoulder-belted occupants, and a chapter on the misuse of lap/shoulder belts. Chapters on topics of special interest follow: lap/shoulder belt use by children and by pregnant women. The final section presents the conclusions and recommendations of the study. Appendixes present additional data.

Volume 2 presents, in brief format, all of the report's cases, describing the facts of each case and discussing the Safety Board's interpretation of these facts.

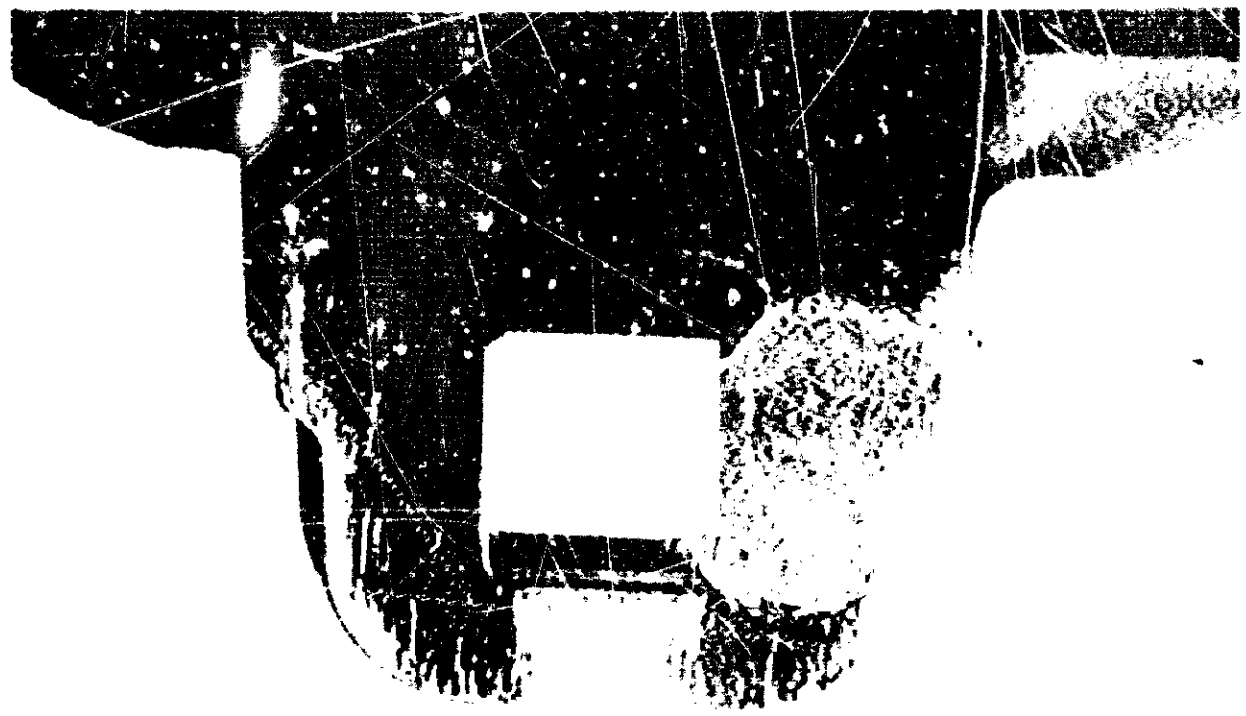


Figure 3.---A scratched latchplate indicates that the seatbelt has been worn often, but does not tell the investigator whether it was worn at the time of the crash. Evidence such as that shown in figure 4 is sought.

Figure 4.--Safety Board investigators look for this type of evidence to determine if the lap/shoulder belt was in use. Shown are the plastic D-rings of two lap/shoulder belts. The upper ring is abraded from the belt loading during the crash. (An occupant's body exerts tremendous force on the belt.) The bottom D-ring is smooth and shiny, indicating no loading; this belt was not being worn at the time of the crash.

Figure 5.--Lap/shoulder belt use is confirmed by matching transfer marks. Leather jacket abraded by shoulder portion of belt (top); leather dye transferred onto belt (bottom).

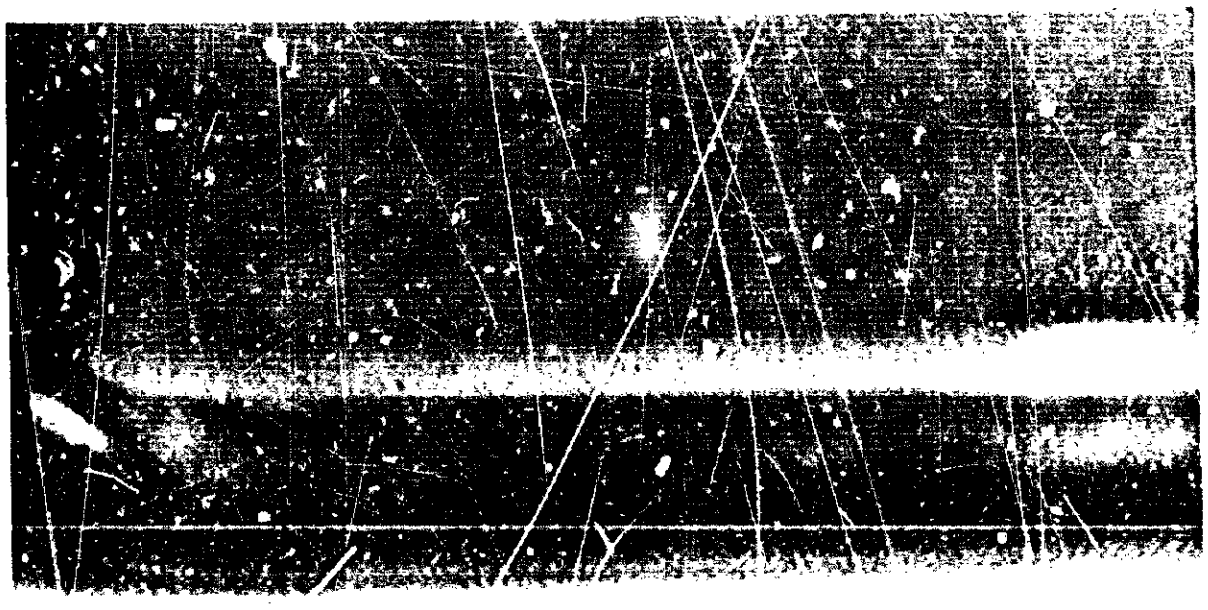


Figure 6.--Evidence that the lap/shoulder belt was in use at the time of the accident--load marks on D-ring (top); fabric of the belt webbing melted from load (bottom).

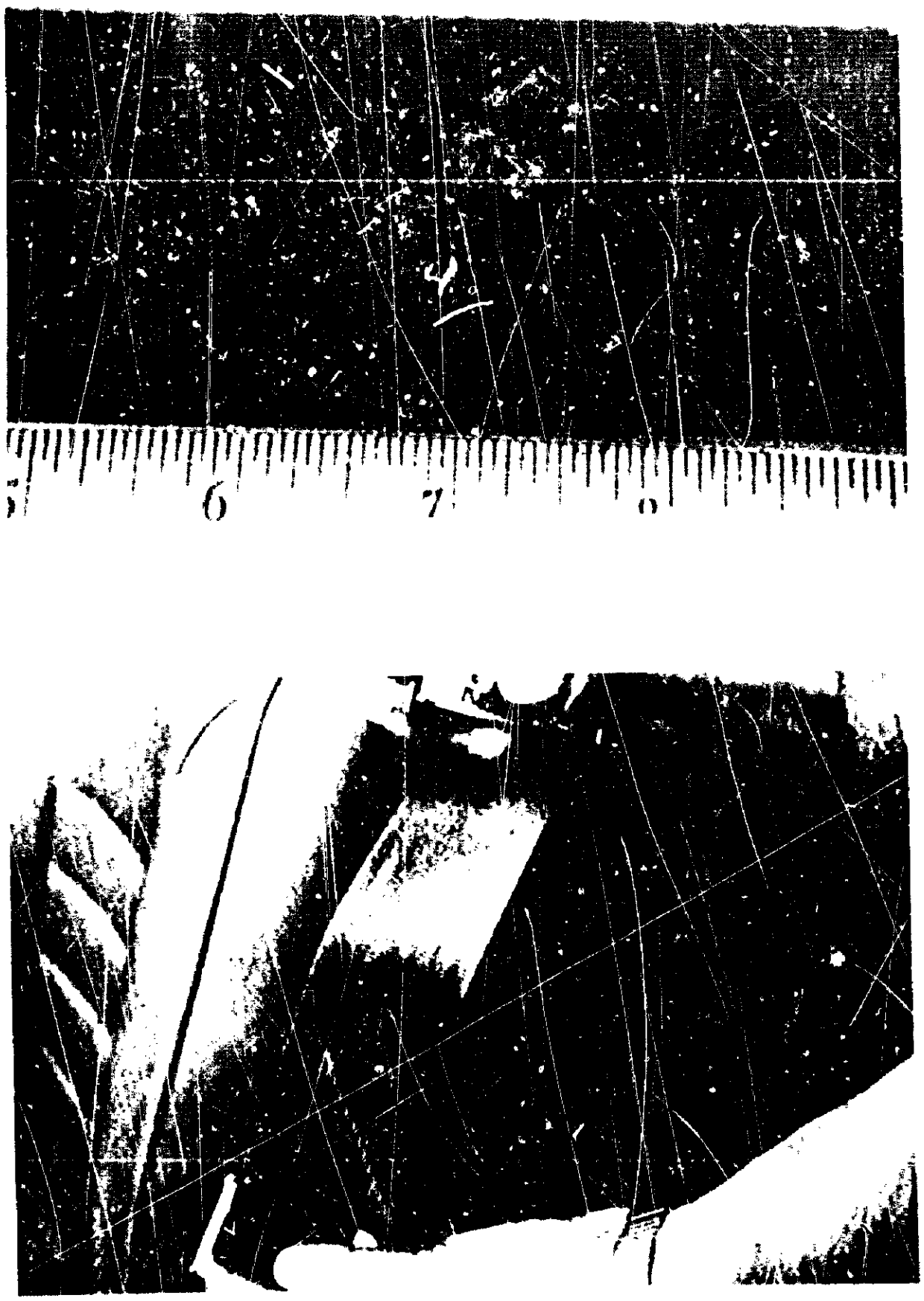
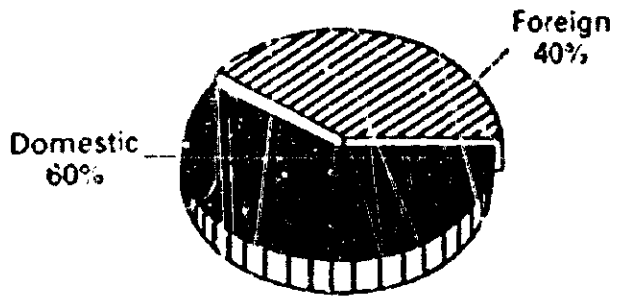


Figure 7.-D-ring load scar (top); latchplate load (bottom).

NTSB INVESTIGATIONS AT A GLANCE:

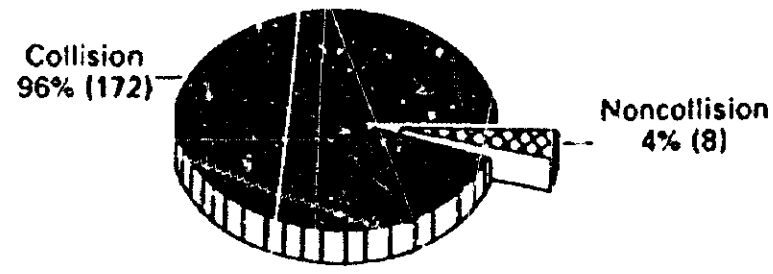
The types of vehicles, accidents, occupants, and restraint systems included in this report.

Majority of vehicles in study were domestic cars



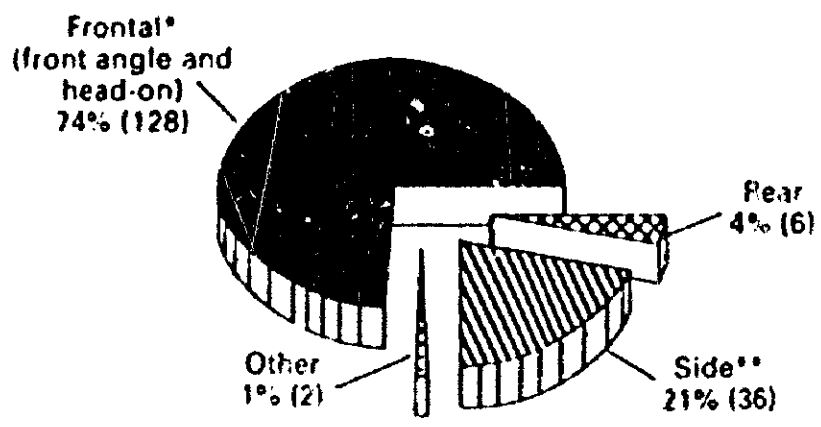
Median year for all vehicles (domestic and foreign): 1982
Mode: 1984

Most case vehicles were in a collision accident



The Safety Board collected data on 180 case vehicles.

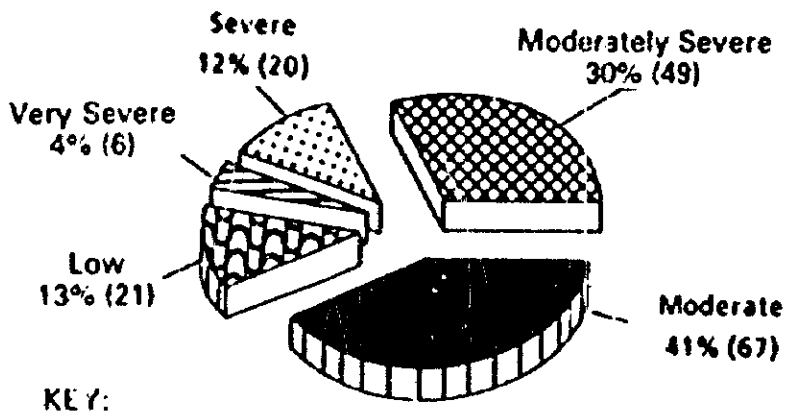
Frontal was the most common angle of impact in collision accidents



* More than half of all injury-causing towaway accidents are frontal in nature.
** Equally divided between left and right side impacts.

NOTE: The Safety Board investigated six collision accidents involving subsequent rollover. These are included in the chart above. The Board also investigated eight noncollision rollovers; these are not included in the chart since they did not involve initial collision.

Most collision crashes were survivable

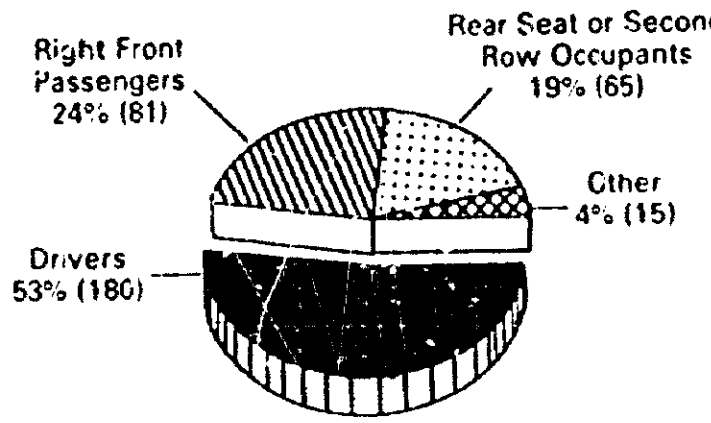


KEY:
Low = DV ≤ 10 mph
Moderate = DV 10.1-20 mph
Moderately Severe = DV 20.1-30 mph
Severe = DV 30.1-40 mph
Very Severe = DV > 40 mph

NOTE: Delta V was not calculable for 9 of the 172 case vehicles involved in collision accidents, due to the nature of the collision (sideswipe, undercarriage impact, rollover, etc.). In addition, eight of the crashes investigated for the study involved no collision. (All were noncollision rollovers.)

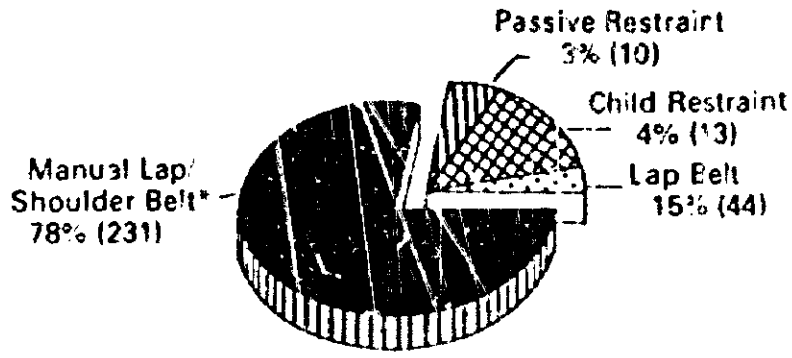
Figure 8.--Overview of Safety Board investigations of accidents for lap/shoulder belt safety study.

Most case vehicle occupants were in the front seat; most were drivers



The Safety Board collected data on 341 occupants of case vehicles.

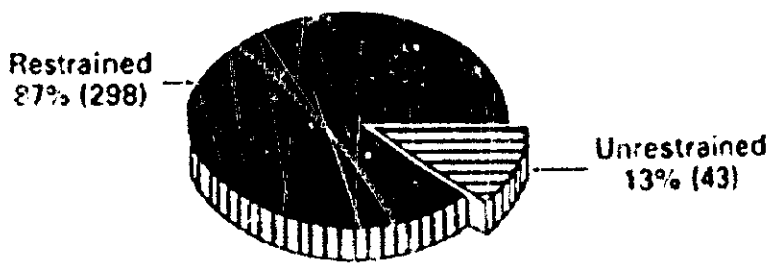
Most restrained occupants were using a lap/shoulder belt



* Includes lap/shoulder belts with shoulder portion improperly routed behind back or under arm.

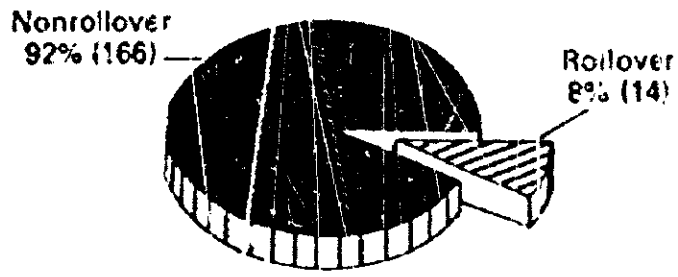
Lap/shoulder belted occupants ranged from 2 to 83 years old. The majority were between 18 and 50 years old.

Few case vehicle occupants were unrestrained



NOTE: Accident selection criterion specifying at least one belted occupant resulted in atypically high proportions of restrained occupants

A few cases involved rollover



Most case vehicle occupants were wearing their lap/shoulder belts properly routed

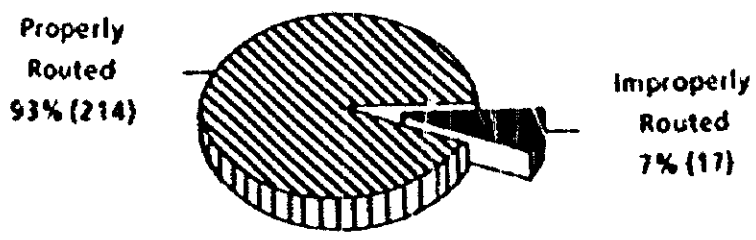
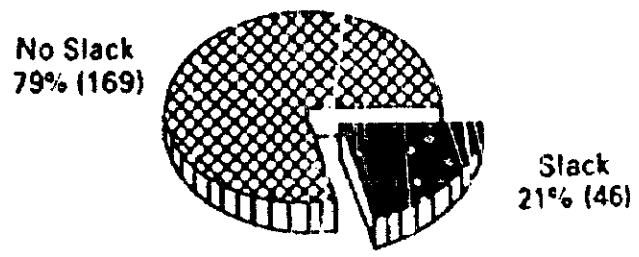
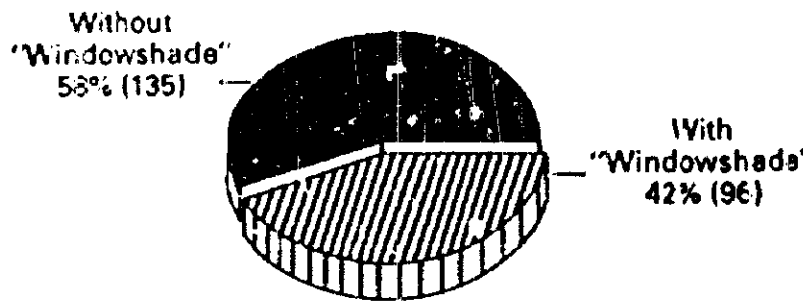


Figure 8.--Page 2.

Most lap/shoulder belted* case vehicle occupants did not have excess slack** in the belt



Many lapIshoulder belts in use by case vehicle occupants did not have a "windowshade" device



* Properly routed lap/shoulder belts only.
** Slack could be in shoulder, or lap portion of belt, or both.

* Properly and improperly routed lap/shoulder belts.

Type of Restraint by Seating Position

Seating Position	Lap Belt	Lap/ Shldr. Belt	Inprop. Routed Lap/Shldr.	Passive Belt	Air Bag*	Child Restr.	No Restr.	Total	Pct.
Undetermined	0	0	0	0	0	0	3	3	.9
Driver	1	157	9	5	4	0	4	180	52.8
Center Front	1	0	0	0	0	0	0	1	.3
Right Front	0	56	3	1	0	4	12	81	23.8
2nd seat, left	17	1	0	0	0	4	6	28	8.2
2nd seat, center	3	0	0	0	0	1	4	8	2.3
2nd seat, right	17	0	0	0	0	4	8	29	8.5
Other**	5	0	0	0	0	0	6	11	3.3
Total	44	214	17	6	4	13	43	341	100.0
Pct.	12.9	62.8	5	1.8	1.2	3.8	12.6	100.0	

* Includes air bags used with available seat belt. If the belt was used along with an deployed air bag, the occupant and the belt were excluded from charts and tables relating to belt performance.
** A few case vehicles were vans or stationwagons with more than two rows of seats.

PERFORMANCE OF LAP/SHOULDER BELTS IN THE STUDY

A 1982 Chevrolet Camaro went off the road when the driver lost control, struck a utility pole head-on, and then rolled over onto its roof--a Delta V 23-mph collision followed by a 180-degree overturn. The vehicle was deformed along the entire front of the vehicle, with maximum crush of 27.5 inches in the area of impact and moderate roof deformation. The driver, restrained by a lap/shoulder belt, received minor injuries only (multiple scalp lacerations from left A-pillar and shattered windshield). The vehicle had a T-top roof with glass inserts removed, so ejection during the overturn was probably prevented by belt use.

This was just one of many examples of the excellent crash protection provided by lap/shoulder belt use documented by the Safety Board during the study. In several quite serious crashes, the good outcome, indeed the survival, of the lap/shoulder-belted occupant came close to the miraculous. In many instances, lap/shoulder-belted occupants fared dramatically better, in terms of crash outcome, than unrestrained occupants or occupants wearing lapbelts only. Furthermore, in the cases investigated, the Safety Board saw no evidence that proper use of a lap/shoulder belt results in the type of serious or fatal belt-induced injuries often associated with lap-only belt use and described in the Board's lapbelt report 17/ -- that is, injuries induced by the restraint itself which are more serious than the injuries likely if the occupant had been unrestrained at the time of the crash.

The following pages present some of the lap/shoulder "success stories," crashes in which occupants benefitted dramatically from the use of this type of belt. More examples are to be found in the case summaries contained in Volume 2.

Examples of Lap/Shoulder Belt Effectiveness

Noncollision Accident.--A 1981 Toyota pickup truck, travelling at an estimated 55 mph, struck a truck tire and rim in the roadway, went out of control, and overturned. During the 630-degree overturn, the pickup's roof was partially torn from its attachment points and displaced, creating a large open space. Two unrestrained occupants of the pickup (one seated on the console, the other in the right front seat) were ejected through this space and fatally injured. However, the lap/shoulder-belted driver received minor injuries only: a contusion to his left shoulder from the shoulder strap and one to the right thigh from the lap portion of his belt. No driver contact marks were found on the steering assembly or instrument panel. (Case 21)

Collision Accidents.--A 1980 Dodge Colt collided head-on into a tree, a Delta V 27.7-mph collision. The Dodge was occupied by a lap/shoulder-belted driver, a lap/shoulder-belted right front passenger, and a lapbelted right rear passenger. Both lap/shoulder-belted occupants received minor injuries only. The rear seat occupant sustained severe lapbelt-induced intra-abdominal injuries. (Case 179)

A 1978 Chrysler Cordoba crossed into the opposite lane of traffic and struck a 1978 Toyota Celica nearly head-on. The Chrysler sustained a Delta V 24.6-mph collision, and the Toyota, a Delta V 40.3-mph collision. Both vehicles were totalled; the Chrysler's front had a maximum inward crush of 36 inches, and the Toyota's, 37 inches. The Chrysler driver, restrained by a lap/shoulder belt, sustained minor injuries only (contusions to chest, forehead, and abdomen). Both unrestrained occupants of the Toyota sustained fatal head injuries. (Case 155)

17/ Ibid.

A 1977 Buick Skylark collided head-on into the left front corner of a 1976 Chevrolet LUV pickup truck. The truck sustained a Delta V 35-mph collision. The Chevrolet sustained maximum crush of 24 inches at the left front, and the Buick sustained a maximum inward collapse of 36 inches at its left front. The collision resulted in minor injuries (laceration and contusions), to the lap/shoulder-belted Chevrolet driver, while the unrestrained Buick driver sustained serious injuries. (Case 126)

A 1983 Chevrolet Malibu was struck in the front center by the left rear corner of an out-of-control 1980 Ford Mustang; the Malibu sustained a Delta V 23.3-mph collision. The Malibu was occupied by three adults: a lap/shoulder-belted driver, an unrestrained right front passenger, and a right rear passenger restrained by a correctly positioned lapbelt. (Contusions on the abdomen indicate the lapbelt was correctly positioned on the iliac crests at the moment of loading.) The lap/shoulder belted driver received minor injuries (leg contusions and neck sprain), and the unrestrained right front passenger, a woman of approximately the same size and age as the rear passenger, sustained a moderate injury (a 2-inch laceration of left temple). The lapbelted rear seat passenger, in contrast, died from lapbelt-induced internal abdominal injuries caused when she jackknifed over the belt at impact. (Case 121)

The driver of a 1976 Mercury Capri lost control of his vehicle, veered to the left onto a grass median, crossed two highway lanes, impacted a W-beam guardrail, vaulted over the rail, and was airborne until the car impacted the ground and rolled over onto its top. In all, the vehicle sustained a Delta V 21-mph collision with the guard rail, a ground impact, and 180-degree rollover. The driver, restrained by a lap/shoulder belt, sustained minor injuries only (bruises and contusions from contact with the belt and steering assembly). A right front passenger, restrained by a lap/shoulder belt but reclined in the seat prior to the collision, sustained moderate injuries (fractured ribs), attributed to unusual belt loading due to the improper seatback position. (Case 57)

Lack of Federal Standards for Minimum Belt Effectiveness

The examples presented on the preceding pages illustrate the ability of a lap/shoulder belt to provide crash protection to occupants in a variety of crash configurations. In many of the Safety Board's cases, death and serious injury were clearly prevented by belt use, even though, Federal standards do not specify the minimum crash protection a manual lap/shoulder belt must provide. Only passive (automatic) restraint systems have been, up to now, required to be crash tested to determine that they meet occupant protection requirements, outlined in Federal Motor Vehicle Safety Standard (FMVSS) 208--i.e., that they provide a minimum level of occupant protection in a 30-mph frontal crash test into a fixed barrier. 18/ 19/ The NHTSA's associate administrator for

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18/ Starting September 1, 1989, if 2/3 of the U.S. population are covered by acceptable State belt use laws, the passive restraint requirements of FMVSS 208 will be rescinded. In that case, manual lap/shoulder belts in new passenger cars will have to meet the crash performance requirements mandated in FMVSS 208 for passive restraints. (Manual lapbelts would remain exempt from this dynamic testing requirement.)

19/ The NHTSA has collected some data on manual lap/shoulder belt performance as part of its New Car Assessment Program (NCAP), but these tests involve 35-mph frontal barrier crash tests--5 mph faster and 36 percent more severe than the FMVSS 208 test requirements. Approximately 40 percent of the passenger cars tested each year in the NCAP program have "passed" the tests--i.e., met the injury criteria specified in FMVSS 208. However, the NCAP data are very limited, since the NHTSA tests only a few models of passenger vehicles each year and tests each model only once.

rulemaking recently explained, "Nobody thought manual systems would need to be (crash) tested, because passive systems were always expected to be coming." 20/

However, few accidents in real life exactly duplicate the crash tests specified in FMVSS 208. Most of the cases presented in this report involve more complex crash scenarios than a 30-mph frontal crash into a fixed barrier; many included multiple impacts, rotation, sudden braking, or rollovers.

Injury Outcome for Case Vehicle Occupants in Study

Overall, front seat occupants wearing lap/shoulder belts fared quite well: more than half received only minor injuries or none at all, while the most severe injuries for another 20 percent were only moderate. Figure 9 shows the injury outcome for all front seat lap/shoulder-belted occupants in the study. (This figure excludes any occupant who had grossly misused the belt by placing the shoulder portion behind the back or under the arm. With the exception of the chapter on misuse, all remaining tables and charts in the report refer only to properly routed lap/shoulder-belted occupants.) Injury severity for drivers and right front passengers restrained by properly routed lap/shoulder belts appeared to be relatively similar. (See figure 10.)

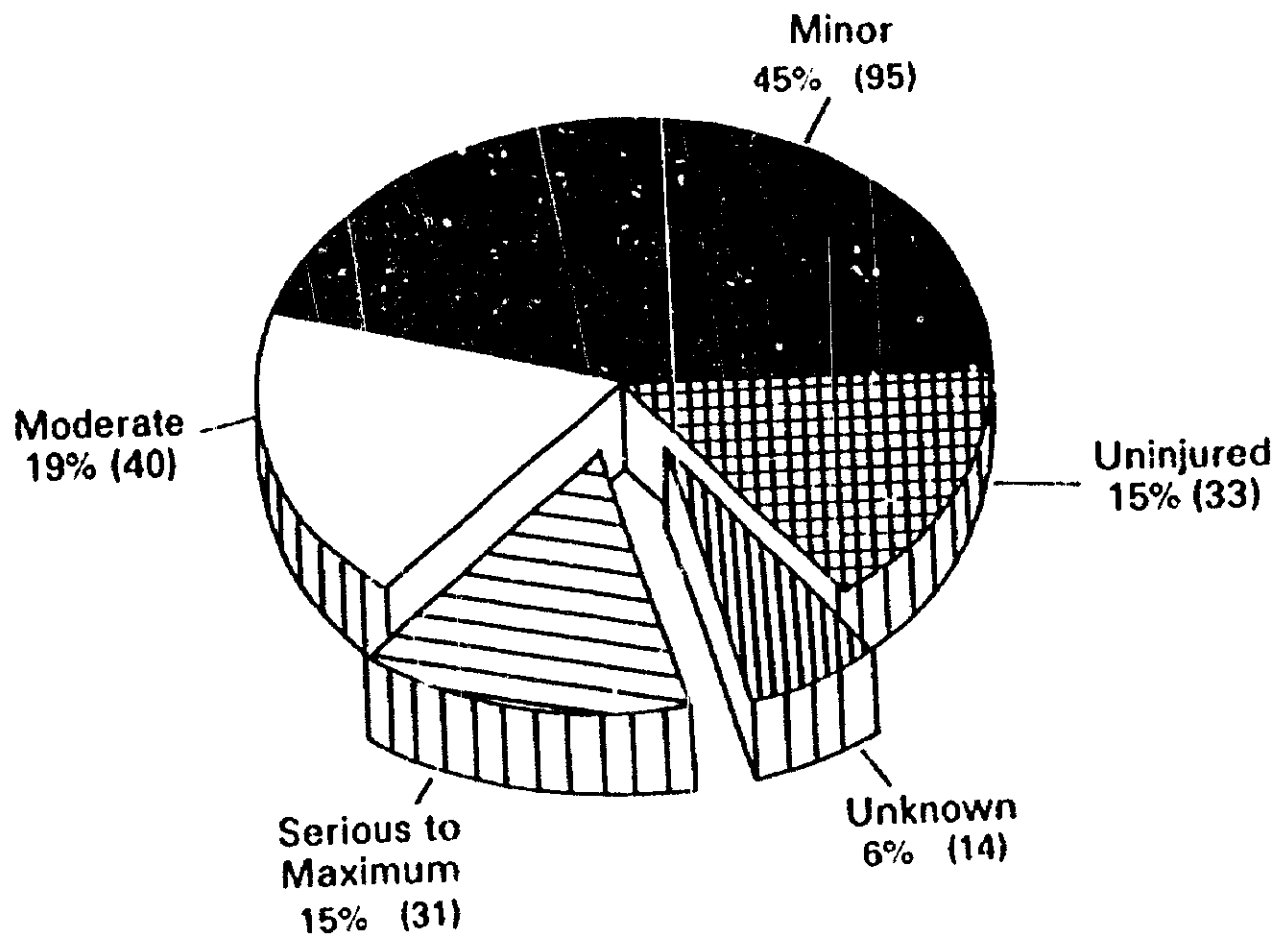
The good overall performance of three-point belts would have little significance if all the occupants in the case vehicles had been involved in crashes of low severity. 21/ This was not the case. Many of the crashes were severe enough to "test" the restraint system's ability to prevent serious injury: more than 46 percent of the lap/shoulder-belted occupants were in crashes of Delta V 20 mph or above. An unrestrained front seat occupant would probably be at risk of more than minor injury in such tow-away crashes.

On the other hand, the accidents included in this report also were not so severe as to preclude the protection offered by the belt. In other words, they were not so severe as to exceed reasonable expectations that use of a lap/shoulder belt would reduce injury. The majority of the lap/shoulder-belted occupants were involved in crashes between Delta V 15 and 35 mph. Only seven of the case vehicle occupants were in crashes above Delta V 40 mph. Hence the Safety Board believes the cases presented in this report represent a range of crash severities in which belt performance can realistically be evaluated.

As stated earlier, the Federal government specifies occupant protection crash tests in terms of a 30-mph frontal crash into a fixed barrier (approximately a Delta V 30 mph), and the New Car Assessment Program uses a 35-mph frontal crash test (approximately a Delta V 35 mph). It is very important to consider crash severity when evaluating the performance of a restraint system. In the past, crash severity often has not been adequately considered in studies of belt effectiveness. The Safety Board documented several cases illustrating the limitations of restraint effectiveness in crashes of low and high severity. In very "high" Delta Vs (i.e., very severe crashes), intrusion into the passenger compartment can be an important injury-producing factor, as is the potential

20/ Wall Street Journal, "Federal Rules About Belts Don't Require Crash Tests," July 31, 1987.

21/ In low severity crashes, the benefit of lap/shoulder belt use would be minimized; belted and unbelted adult occupants would be more likely to have similar outcomes. Small children, on the other hand, are at special risk and need to be restrained in a child safety seat, which can protect them from the real possibility of injury in a crash of low severity or in a noncrash event, such as sudden braking.



80% received minor, moderate or no injuries

Figure 9.--Front seat occupants wearing properly routed lap/shoulder belts by most severe injury.

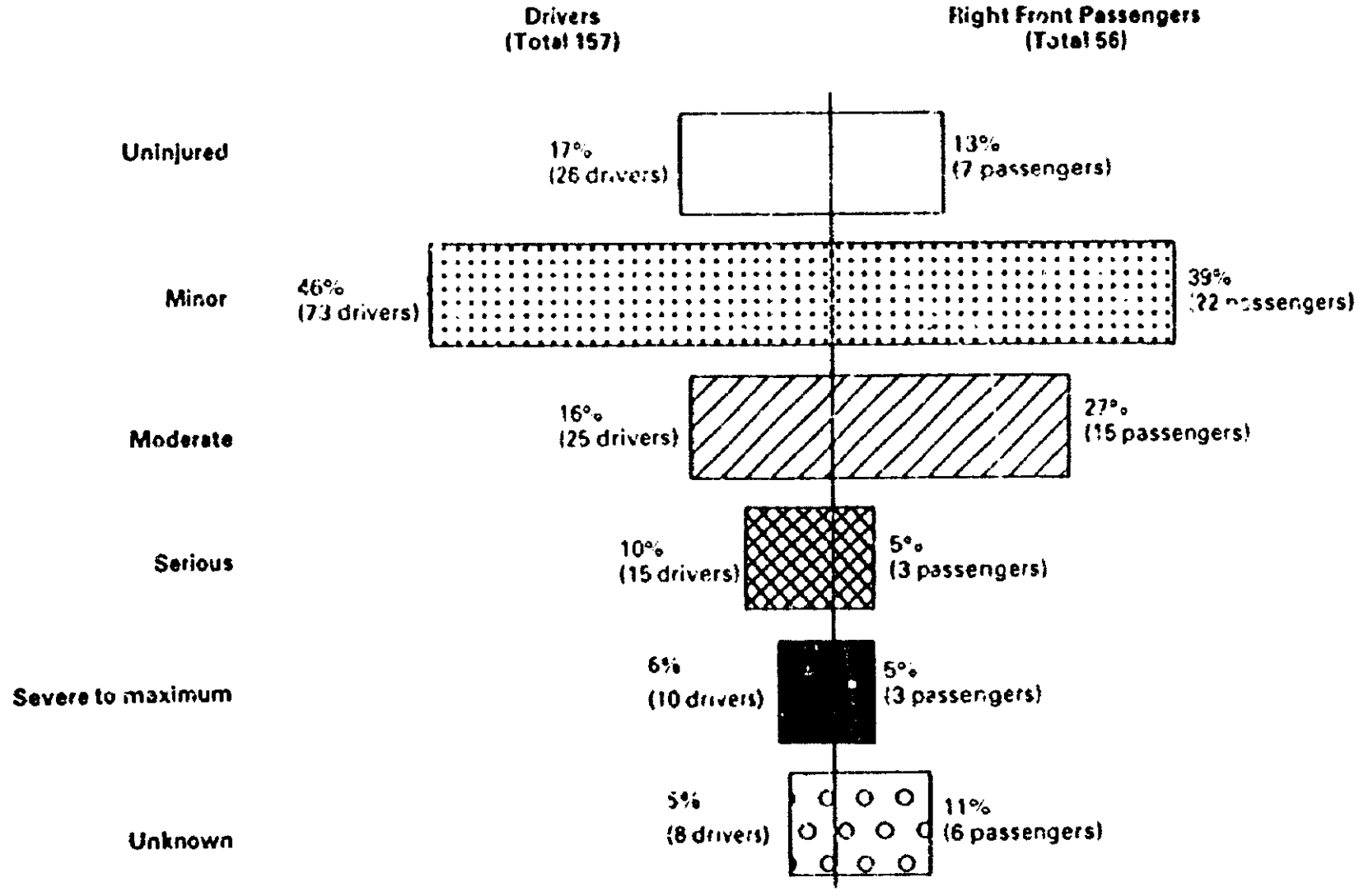


Figure 10.--Injury outcome (MAIS): drivers and right front passengers wearing properly routed lap/shoulder belts.

for unavoidable injury from the lap/shoulder belt itself. (The latter type of injuries probably will be less severe than the injuries sustained by unrestrained occupants, however.) 22/ 23/

Case 214 is an example of high Delta V. In this collision between a Chevrolet Nova and a Datsun 210, crash forces were so severe that even lap/shoulder belt use could not prevent serious injuries. The initial collision, Delta V 43.6 mph for the Datsun, caused massive damage to its front with structural collapse of more than 27 inches. The lap/shoulder-belted driver received fatal injuries when the steering assembly intruded into her seating position.

In addition to crash severity, the occupant's seating position and the crash configuration may combine to reduce or negate the protection offered by the lap/shoulder belt. 24/ For example, other than preventing possible ejection, a lap/shoulder belt can provide little or no protection in a side impact at the occupant's position. 25/ Thus in case 138, the lap/shoulder-belted driver of a 1984 Dodge Colt received a serious head injury and contused left kidney when the vehicle was struck on the driver's door by the front of a 1981 Subaru stationwagon, a side impact of Delta V 18.1 mph for the Dodge. The car was crushed inward 22 inches at the driver's position. The lap/shoulder-belted right front passenger, on the other hand, a 4-year-old boy seated away from the impact, sustained only a minor laceration. The lap/shoulder belt was able to protect the passenger, seated on the far side of the impact, but not the driver, seated at the area of greatest intrusion.

22/ For cases in which the circumstances of the accident rendered restraint use immaterial, i.e., extremely low Delta V, extreme crush at the seating position of the individual, etc., see cases 100, 103, 104, 125, 128, 132, 128, 132, 136, 139, 14, 178, 183, 194, 206, 210, 211, 214, 22, 24, 39, 45, 47, 48, 51, 59, 71, 77, 87, 89, 91. 92, and 94.

23/ Throughout this report, the severity of a crash is described in terms of the Delta V severity categories presented in the pie chart on page 14. These classifications are: low--Delta V less than or equal to 10 mph; moderate--Delta V of 10.1 to 20 mph; moderately severe--Delta V of 20.1 to 30 mph; severe--Delta V of 30.1 to 40 mph; and very severe--Delta V of more than 40 mph. Occasionally, the reader may find the term "high" substituted for "severe" in the text.

24/ The occupant may also receive less than optimal protection if the lap/shoulder belt is worn too loose or misrouted around the body. The experience of case occupants with misused lap/shoulder belts is described in a chapter to follow.

25/ A lap/shoulder belt provides only limited protection in a side impact, especially for the near side occupant. The far side occupant may gain more protection, although he or she can slide out from under the shoulder harness and contact other occupants or the surrounding vehicle interior. For these reasons, research by the NHTSA and the Motor Vehicle Manufacturers Association on occupant protection in side impact has focused on the need for changes in vehicle design (B-pillar padding and design, improved door panel strength), rather than on changes in the restraint systems. One research paper states: "Likewise, there is little to recommend belts in side collisions other than the prevention of total ejection (itself a diminishing return)." Another (Australian) researcher reported:

> Clearly, however, in those side impacts which do occur, those occupants who are wearing seat belts are afforded little protection thereby and therefore the effects of American legislation which requires minimum standards for side intrusion should be examined as a matter of urgency.

The range of crash severities and crash types in which lap/shoulder belts can make a difference in injury outcome is, as one researcher at GM calls it, "the window of opportunity":

> Basically, a sufficient number of crashes occur at such extreme levels of severity that there is little opportunity for mitigation of injuries. The great majority of crashes are at so low a severity that even the unprotected occupant is not harmed, so that the [seat belt] can generate no injury reducing benefit. Laboratory testing naturally focuses, as it ought to, on the crash severity regime where the device is expected to provide benefits.... An additional important consideration is that a surprisingly large number of fatal crashes are of a bizarre nature not readily encompassed in any laboratory testing program.... Thus, the "window of opportunity" for occupant protection devices to generate benefits is sufficiently narrow that very high effectiveness is unlikely to be achieved by any practical means. 26/

Furthermore, other factors besides restraint status influence injury outcome. Age, sex, physical characteristics such as height and weight, and preexisting health conditions all interact to influence outcome. In addition, vehicle design can greatly influence the location and severity of occupant injuries for both restrained and unrestrained occupants. Improvements in side panel strength, design of A-pillars, steering assemblies (i.e., different steering wheel design, collapsible steering columns, etc.), 27/ gear shift assemblies, and dashboard design could reduce occupant injuries and enhance the effectiveness of seatbelts. Many of these improvements, including the addition of airbags, can produce a more "friendly interior" and can benefit restrained and unrestrained occupants alike.

Severity of Injuries Increases with Crash Severity

Just as the "window of opportunity" is partially defined by crash severity, the severity of injuries to lap/shoulder-belted occupants increases with crash severity. Since most lap/shoulder-belted occupants in the study were drivers, the Safety Board analyzed the relationship of crash severity to driver injury severity. Figure 11 presents the numbers of drivers at each AIS injury level by the Delta V (crash severity) of the collision.

Figure 12 is based on the same injury data as figure 11, but adjusts for the different number of drivers involved at each level of crash severity. That is, figure 12 compensates for the fact that fewer drivers were involved in high Delta V accidents than were involved

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26/ Evans, L., "Occupant Protection Device Effectiveness in Preventing Fatalities," General Motors Research Laboratories, April 14, 1987.

27/ Saul, Roger, ("Steering Column Intrusion--Restrained and Unrestrained Occupant Effects," NHTSA Vehicle Research and Test Center, 1987):

> Accident data indicate that the highest ranking body-to-vehicle contacts in frontal crashes are the chest and abdomen into the steering column. The harm associated with steering column contact accounts for 25 percent of the total societal costs due to motor vehicle accidents.... Until recently, the situation for the restrained driver could not be documented, due to low incidence of belt use. With the advent of State safety belt-use laws, however, there appear to be indications that safety belts reduce the harm for restrained occupants, and the injury pattern is shifted from the chest and abdomen to head and facial injuries caused by steering wheel impacts.

Crash Severity (Delta V in mph)

Injury Outcome (MAIS)	0.1 to 10.0	10.1 to 20.0	20.1 to 30.0	30.1 to 40.0	40.1 or More	Total	Percent
0-Uninjured	8	17	1	0	0	24	17.0
1-Minor	9	33	17	3	0	62	44.0
2-Moderate	1	7	13	2	1	24	17.0
3-Serious	0	1	7	3	3	14	9.9
4-Severe	0	0	3	3	0	6	4.3
5-Critical	0	0	1	2	1	4	2.8
7-Injured, Unknown Sev.	0	2	2	2	0	6	4.3
9-Unknown if Injured	0	1	0	0	0	1	0.7
Total	16	61	44	15	5	141	100.0
Percent	11.3	43.3	31.2	10.6	3.5	100.0	-

Figure 11.--Injury outcome for drivers restrained by properly routed lap/shoulder belts in collision crashes for which Delta V is known (all directions of impact).

in lower Delta V crashes. Figure 11 also shows injury data only for those drivers for whom injury outcome is known; those with "unknown" status (AIS 7 or AIS 9) are not represented in the chart.

Figure 12 shows the injury outcome for lap/shoulder-belted drivers in all types of collisions (frontal, side, and rear impact) for which Delta V could be estimated. Figure 13 presents similar driver injury data for frontal, nonrollover accidents only. (FMVSS 208, Occupant Crash Protection, addresses principally frontal crash protection.)

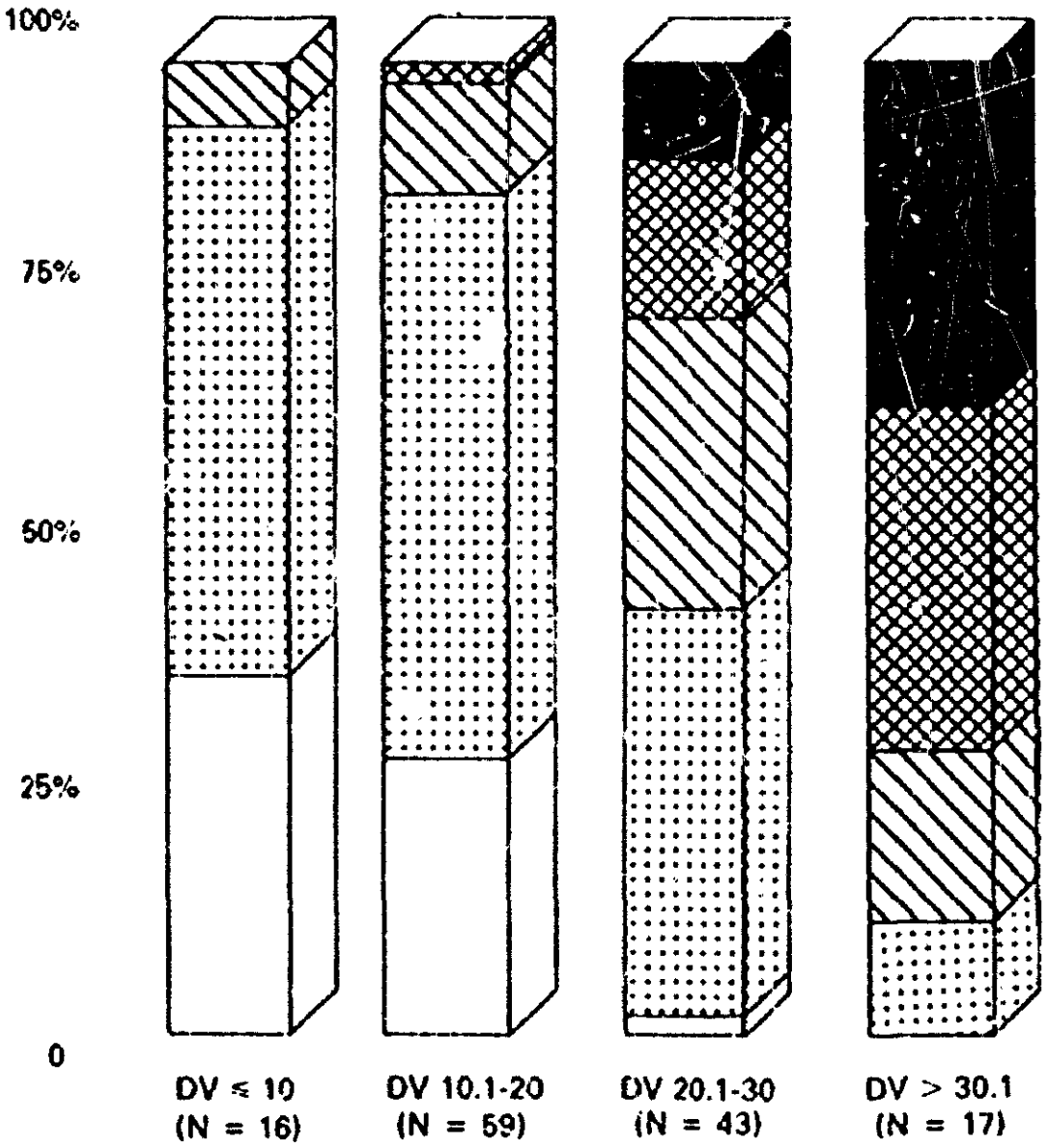
As both figures show, some lap/shoulder-belted drivers in the study sustained injuries categorized as serious or worse when Delta V exceeded 20 mph; this outcome became more common as Delta V exceeded 30 mph. (Appendix L presents data on injury outcome by crash severity for right front passengers wearing properly routed lap/shoulder belts.)

Lap/Shoulder Belt Use in Noncollision Accidents

Much of the discussion so far has focused on the relationship of collision severity to the severity of injuries sustained by lap/shoulder belted occupants in the study. Not all accidents, however, involve collision. During this study, the Safety Board investigated eight accidents that did not involve collision--all were rollover accidents. (Six additional accidents involved both rollover and collision.) 28/

These rollover accidents provided some of the most striking instances of good lap/shoulder belt performance, despite the fact that the degree of rollover was quite great in many cases. (See figure 14.) Half of the rollover cases were 360 degrees or more.

28/ For the 14 cases involving rollover, see cases 10, 12, 21, 36, 44, 50, 53, 55, 57, 88, 97, 105, 187, and 208. Cases 36, 53, 55, 57, 97, and 187 are the collision accidents.



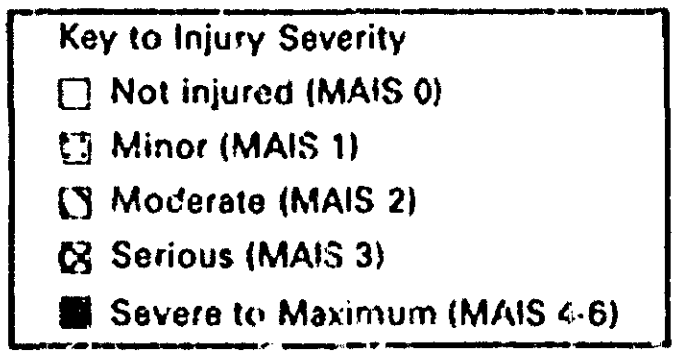


Figure 12.--Injury outcome by crash severity for drivers restrained by properly routed lap/shoulder belts in collision accidents. (Cases in which both Delta V and MAIS level of injury could be determined. The chart adjusts for different numbers of drivers at each Delta V severity category.)

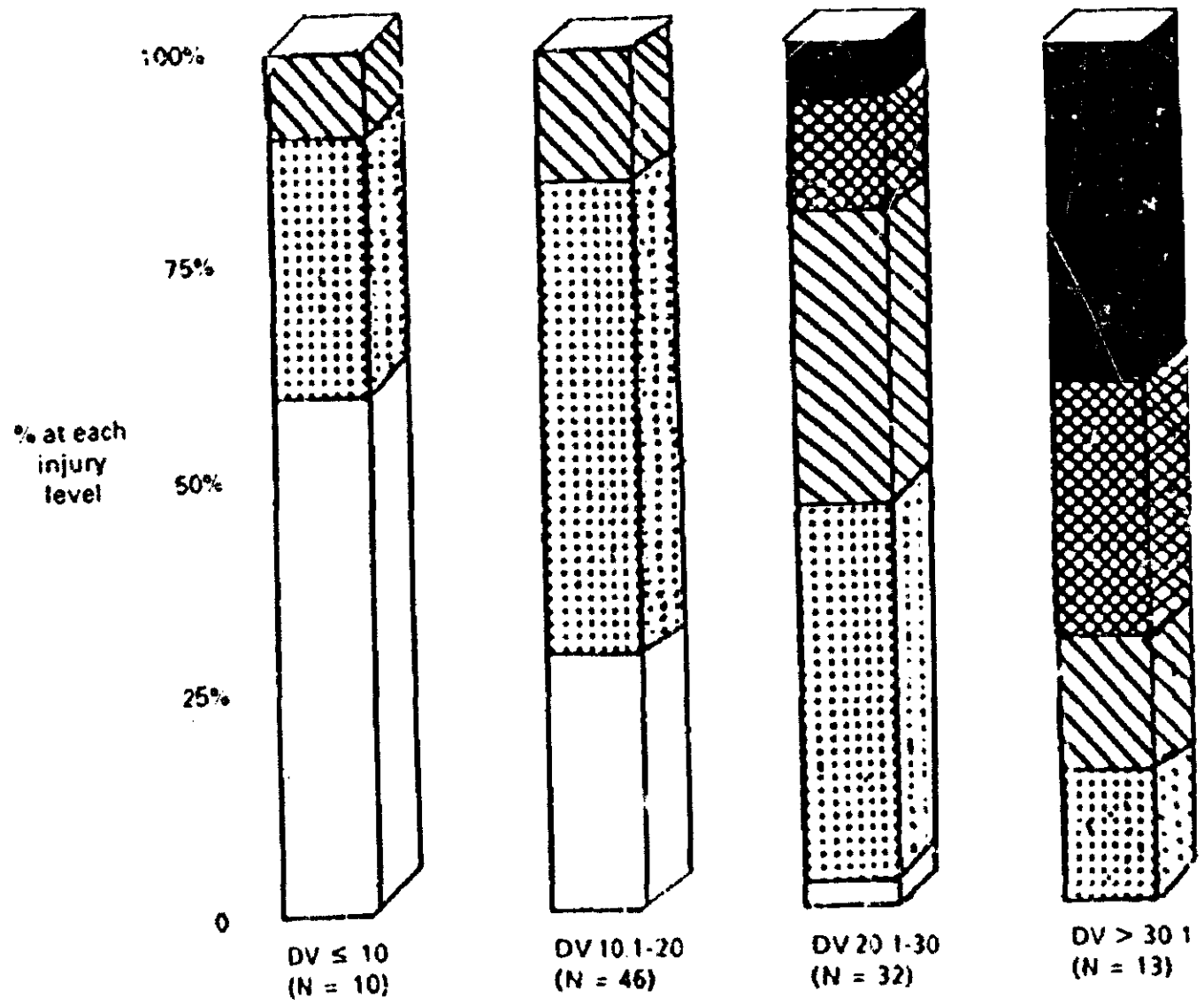


Figure 13.--Frontal nonrollover collision accidents only: injury outcome by crash severity for drivers restrained by properly routed lap/shoulder belts. (Cases in which both Delta V and MAIS are known.)

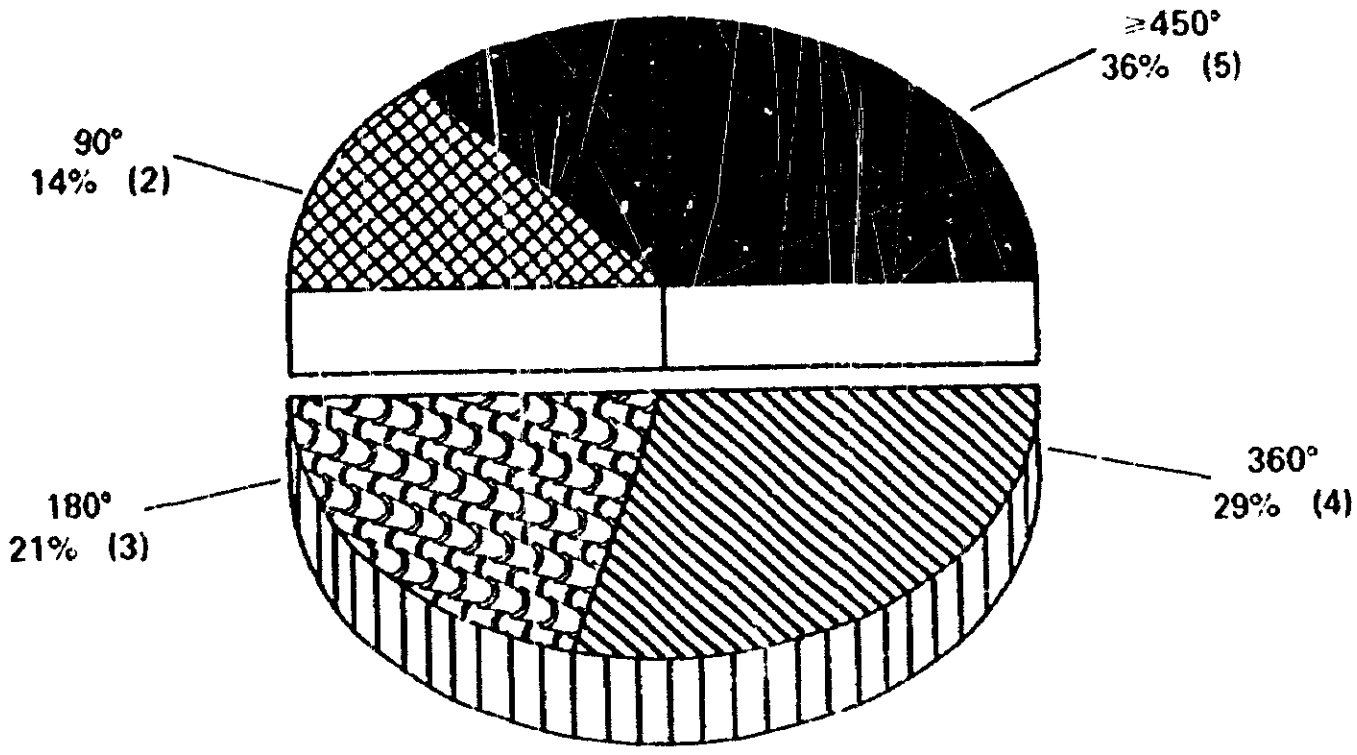


Figure 14.--Degree of rollover (by number of case vehicles)

Case 21, which involved a 630-degree rollover, was perhaps the most striking example of the protection afforded by lap/shoulder belt use. (The case is one of the "success stories" described at the beginning of this chapter.) The lap/shoulder-belted driver sustained minor injuries only.

In another case (case 50), use of a lap/shoulder belt protected the driver of a 1979 Audi 5000 involved in a more than 360-degree rollover from all but minor injuries; because of roof crush, another lap/shoulder-belted occupant was not saved from moderate head injuries due to intrusion. An unrestrained occupant was ejected and fatally injured.

In addition to protecting the occupant from uncontrolled impact with large areas of the vehicle's interior and thus sparing him or her from serious injury, lap/shoulder belt use prevented ejection in the rollover accidents investigated for the study.

Case 44 provides a dramatic example:

> A 1983 Subaru station wagon veered off the road and rolled over twice (a 720-degree rollover). The vehicle sustained moderate exterior damage with moderate roof crush. The unrestrained right front passenger was ejected and sustained massive head injuries that proved fatal. This passenger had been wearing his lap/shoulder belt, but moments before the crash, had unbuckled it to tend to the children in the rear seat.

> The driver, restrained by a lap/shoulder belt, sustained a minor injury only (contusion over the left eye from contact with steering wheel). The two children in the rear seat, aged 10 months and 3 years, were both restrained in child safety seats. Both children received minor injuries only.

The chance of ejection, partial or total, is influenced by crash severity and type of crash, with rollovers creating the highest risk of ejection. This was true in the Safety Board's cases; most of the ejections took place in rollover accidents. A total of six case occupants 29/ were ejected in the cases investigated by the Safety Board. All but one were unrestrained. The five unrestrained ejectees died, while restrained occupants in the same vehicles survived the crash, some with minor injuries only.

In case 94, a driver wearing a lap/shoulder belt was ejected and received moderate injuries. This unusual case involved a lap/shoulder belt system compromised by vehicle damage. When the passenger car struck a 15-inch diameter metal light pole with its left side, a Delta V 22.4-mph impact, the left side of the car was crushed inward 28 inches over an 89.5-inch area, and the driver's door popped open. The car then rotated 180 degrees around the pole. The damage to the left B-pillar, where the belt retractor was located, most likely caused the driver's belt retractor to malfunction and allow excessive slack ("spool-out"). The driver was found lying outside the car with his back against the door sill, still wearing his lap/shoulder belt, which was still attached to the vehicle.

Overall Importance of Ejection as Injury-Causing Event

Ejection clearly is an event to be avoided, since it exposes the occupants to injuries sustained as they "exit" the vehicle and strike the ground; it also introduces the possibility of being further harmed by a passing or oncoming vehicle. Seatbelt use obviously has a role in preventing ejection.

However, since the early days of seatbelts, their relative role in preventing ejection has declined. In the 1950s and '60s, ejection was a major source of death and serious injuries, and seatbelt use was correctly identified as the then-primary way to reduce those losses. Since that time, other means of preventing ejection (i.e., improved door locks, glazing retention, etc.) are also proving effective. A 1973 research paper noted, for instance:

> One recent study of U.S. accidents brings encouraging news of improvement in vehicle performance with respect to ejection rates of unbelted occupants to be significantly lower in accidents involving younger automobiles. Compared to the 1951-55 vintage, where ejection rates were about 10 percent, ejections of unbelted occupants from 1966-71 makes were reduced to less than 3 percent. Hence, the need for belts as ejection preventatives has been further reduced substantially. Further improvements in door and glazing retention could promote this trend. 30/

29/ Three of the four accidents involving ejection were rollovers; one involved a left side impact of Delta V 22.4 mph. (Occupants of noncase vehicles also were ejected.)

30/ Warner, C., Professor of Mechanical Engineering, Brigham Young University, "Belt Occupant Restraint Effectiveness."

Since that work was published, ejection has continued to decline as the design of automobiles has improved, despite low belt use. According to the 1984 NHTSA National Accident Sampling System (NASS) report (before belt use rates began to increase), about 1 percent of occupants in tow-away crashes were reported partially or totally ejected.

Thus, though the role of lap/shoulder belts in preventing ejection is still important, ejection rates for unrestrained occupants have apparently been declining steadily, due to vehicle design changes. Furthermore, it is not at all clear to what extent the severe injuries that are often sustained by ejected persons are associated with the ejection itself. Some researchers believe that the injuries were sustained within the vehicle before ejection and are due more often to the severity of the crash that precipitated the ejection than to the ejection itself. 31/

Finally, it is also true that belts may not be entirely effective in preventing partial ejection, especially if they are worn improperly or are damaged in the collision, as in case 94.

31/ Huelke, D., Compton, C., and Studer, R. Injury Severity, "Ejection, and Occupant Contacts in Passenger Car Rollover Crashes," (SAE 850336) Proceedings, Conference, 1985.

INJURIES TO LAP/SHOULDER-BELTED OCCUPANTS

The Safety Board's cases document, in numerous instances, the fine crash performance of lap/shoulder belts. More than half of the lap/shoulder-belted occupants in the study received only minor injuries or none at all, while for another 20 percent, injuries were only moderate.

As pointed out in a previous chapter, Federal standards do not set a minimum level of crash protection that manual belt systems must provide for occupants, nor is there universal agreement on how effective lap/shoulder belts, in fact, are in reducing injuries. Effectiveness studies have produced a wide range of estimates over the years. For example, estimates of the fatality "effectiveness" 32/ of lap/shoulder belt use have varied over the years, from 31 percent 33/ to 91 percent. 34/ The NHTSA's own estimates of lap/shoulder belt fatality effectiveness have varied from 60 percent in 1974 35/ to 40-50 percent 36/ in 1985. Some researchers now estimate the effectiveness of a lap/shoulder belt in preventing fatalities among front seat occupants to be closer to 40 percent. 37/ 38/

Like the fatality estimates, estimates of the injury-reducing effectiveness of lap/shoulder belts have also varied widely. The U.S. Department of Transportation (DOT) currently estimates that a manual lap/shoulder belt is 45 to 55 percent effective against moderate and above injuries, and only 10 percent effective against minor injuries. These estimates apply to all types of accidents combined. The effectiveness will vary according to the accident configurations.

Some of the variations in effectiveness studies arise from differences in definition of effectiveness criteria (what is meant by "seat belt effectiveness in injury reduction"); differences in injury scaling; interactions and confounding in data (age, sex, type of car, accident type, and crash severity); differences in sample structure and statistical

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32/ The effectiveness is expressed as the percent of the fatalities among a totally unrestrained population that would be prevented if 100 percent of the population used this belt 100 percent of the time without otherwise changing their behavior.
33/ Wilson, R.A. and Savage, D.M., "Restraint System Effectiveness-A Study of Fatal Accidents," GM Automotive Safety Engineering Seminar, 17-39, June 20-21, 1973.
34/ Huelke, D.F.; Lawson, T.E.; Scott, R.; and Marsh, J.C. "The Effectiveness of Belt Systems in Frontal and Rollover Crashes," SAE International Automotive Engineering Congress and Exposition, Detroit, February 28-March 4, 1977.
35/ DOT, NHTSA, "Review of Safety Belt Usage and Effectiveness in Accidents," Washington, D.C., September 17, 1974.
36/ NHTSA, Final Regulatory Impact Analysis of the Amendment to FMVSS 208: Passenger Car Front Seat Occupant Protection, July 11, 1984.
37/ Mackay, M., "Two Years' Experience with the Seat Belt Law in Britain," SAE Technical Paper Series, No. 851234, Washington, D.C., May 20-23, 1985.
38/ Evans, L., "Occupant Protection Device Effectiveness in Preventing Fatalities," GM Research Laboratories, GMR-5809, April 14, 1987.

technique; and bias resulting from use of data based on police reporting. 39/ These variations were discussed in detail in the Safety Board's lapbelt study and the reader is referred to that report for analysis of their impact on effectiveness estimates.

British Study Documents Change in Injury Patterns Following Passage of Mandatory Use Laws

The low number of persons historically who voluntarily wear their lap/shoulder belts has handicapped attempts to estimate overall belt effectiveness and forecast how injury types will be affected if lap/shoulder belt use can be increased substantially. Countries that have achieved high-use rates after passage of a mandatory use law have conducted studies using medical data following passage of the law, but they have often lacked comparable data for the years preceding the law or have collected data for certain injuries only.

In 1985, Great Britain's Department of Health and Social Security published a report 40/ that overcame these problems. The report, "The Medical Effects of Seatbelt Legislation in the United Kingdom," provided statistically sound evidence of the changes in hospital casualties among car occupants injured in road accidents following the introduction of Britain's mandatory belt-use law. The report was a direct outgrowth of the law. On July 28, 1981, the House of Parliament passed the Transport Bill, providing for the mandatory use of seatbelts for the drivers and front seat passengers in cars for a trial period of 3 years, starting in February 1983. At the end of that time, the law was to be evaluated. (Subsequent legislation has been passed making the law permanent.) Two studies were initiated to provide data for the evaluation.

The first was an in-hospital study comparing car crash victims arriving at 15 hospitals in the United Kingdom during the year before and the year following the implementation of the seatbelt-use law. The second was a study collecting data from coroners concerning fatalities in eight districts during the 6-month period before and the same 6-month period after the law (April 1-September 30).

Between 1981 and 1984, Great Britain had experienced a dramatic increase in belt use by front seat occupants, from 25 to 35 percent prior to passage of the mandatory use law to over 90 percent the second year the law was in effect. This increase provided a good basis for comparing the effects of increased lap/shoulder belt use on motor vehicle occupants' injuries.

In the year following passage of the law, the number of injury-producing accidents decreased 13 percent (and the number of involved vehicles decreased 14 percent); there was a 15 percent reduction in the number of patients brought to the hospital, a 25 percent

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39/ The accuracy of police-reported restraint data will probably decline further as more and more people are covered by State mandatory-use laws--if involved in a crash, they would understandably be loath to admit to a law enforcement official that they were disobeying a law by being unrestrained. For this reason, perhaps, starting in 1988, the NHSTA will no longer rely on police reporting of restraint use for its NASS data. The NHSTA will use its own NASS investigators to determine occupant restraint status by consideration of physical evidence on the belt system and the occupants' injuries.

40/ Rutherford, W.H.; Greenfield, T.; Hayes, H.R.M.; and Nelson, J.K., "The Medical Effects of Seatbelt Legislation in the United Kingdom," Research Report No. 13, Department of Health and Social Security, Office of the Chief Scientist, United Kingdom, 1985.

reduction in those requiring admission to wards, and a 25 percent reduction in bed-occupancy. When researchers examined the types of injuries that occurred, they found a statistically significant reduction in the numbers of patients with severe injuries, as well as a decrease in the numbers of injuries (both major and minor) sustained by each patient. When front seat occupants were considered together (i.e., combining both driver and front seat passenger outcomes), the study found a significant reduction in the total number of major and minor brain injuries, a reduction in minor injuries to the face (eye and face "wounds"), and a reduction in lung injuries. The study's data suggested that kidney injuries and fractures of the femur also decreased, but the improvements could not be conclusively proven. Data from the hospital study did not confirm a reduction in the average severity of injuries (i.e., mean injury severity scores were not significantly changed), or overall reduction in skull fractures or face fractures--hypotheses originally advanced by the researchers. 41/ The study also found overall, a significant increase in sprained necks (19 percent) and fractures of sternum (108 percent), and a 44 percent increase among drivers in major head injuries, "possibly due to contact between the driver's head and steering wheel." Britain and the European Economic Community (EEC) are considering changes to the steering wheel and seatbelt legal requirements to provide protection against these head and face contacts by restrained drivers. This will lead to "softer" steering wheel designs or hub-mounted supplementary airbags, and seatbelt pre-tensioning systems and belt web-locking devices to reduce forward motion of the occupant in the crash.

Over a wide range of injuries, the hospital-based study showed that drivers and front seat passengers both derived considerable benefits from increased belt use, but front seat passengers enjoyed the greater improvement.

The coroners' study, the second part of the British report, collected data on those who died prior to reaching the hospital, in an attempt to supplement the hospital-derived injury data. The accidents represented in the coroners' study could reasonably be expected to be more severe than those typically found in the hospital study. Data for 101 deaths in the first 6-month period and 75 in the second (a decrease of 25.7 percent) were examined. Belt use was lower among the fatally injured in the study than was true in the hospital-based study, which itself was lower than in the population as a whole. Of the types of injuries incurred by the fatally injured front seat car occupants, the study found an overall 27 percent decrease in total head and neck injuries, 42/ a 26 percent decrease in chest injuries, and a 20 percent decrease in abdominal injuries. 43/

The United States, at this time, cannot conduct studies like those just described. Seatbelt use rates, although rising, are too low, especially among accident-involved motor vehicle occupants. The Safety Board's study does provide, however, data on injuries sustained by lap/shoulder belt occupants.

41/ In the hospital study, there was a 71 percent reduction in skull fractures for front seat passengers but a 2.6 percent increase for drivers. As there were three times as many injured drivers, there was no overall reduction. As for face fractures, drivers increased by 10 percent and front seat passengers decreased by 46 percent.

42/ There was little change in the number of brain injuries among fatally injured drivers in the coroners' study, but it was more than offset by the decrease of about a third among fatally injured passengers.

43/ The liver is the abdominal organ most often injured in fatal cases and there was a decrease of 58 percent among front seat passengers in the coroners' study.

If a crash is serious enough to "test" the protective ability of the three-point belt system, minor injuries are likely to occur. Hence, in conducting the injury analysis for this chapter, the Safety Board gave little attention to minor injuries. (However, all injuries sustained by a case vehicle occupant, including minor injuries and their probable contact points, are described in the individual case summaries in Volume 2.) The analysis focuses solely on injuries of moderate severity or worse (MAIS 2 and greater) sustained by lap/shoulder belted-case vehicle occupants.

Location of Most Severely Injured Body Part

As noted in the introduction to this chapter, many studies have documented the fact that lap/shoulder-belted occupants, overall, have better crash outcomes in terms of injury severity than unrestrained occupants. Lap/shoulder belt use cannot guarantee, however, that the occupant will be uninjured or will not receive minor injuries. (Lap/shoulder belt effectiveness has been estimated by the NHTSA at only 10 percent for minor injuries.) Very few (33 of 213) of the study's front seat occupants wearing properly routed belts sustained no injuries; but for 95 occupants, minor injuries were all they received.

The patterns of injury of restrained occupants do differ from those of unrestrained occupants, although even with belt use, certain injuries persist (injuries to knee region from contact with the dashboard, lower leg injuries, and arm and hand injuries caused by "flailing" during the crash). The following tables present the location of the most seriously injured body part of the lap/shoulder-belted occupants in the study. This information is presented with the knowledge that injuries cannot be completely eliminated by the lap/shoulder belt. Perhaps changes in belt design and the vehicle interior could further reduce these injuries, and the data to follow may be of use to researchers in considering these possibilities.

For every occupant who sustained moderate injuries or worse, the Safety Board investigators coded the location of the most severe injury. 44/ 45/ Sometimes, the lap/shoulder-belted occupant had more than one injury at the most severe level. For these cases, the analysis included the body locations of each injury at that level. Therefore, the number of injuries exceeds the number of occupants who sustained moderate injuries or worse.

The head and skull (excluding face) was the most common site of the most severe injury, followed by upper torso injuries (other than clavicle, sternum, or ribs) as the most common site. The abdomen was a distant third. 46/ (See figure 15, which presents injury data for the front seat occupants restrained by properly routed lap/shoulder belts by body location and MAIS.) Neck injuries and fractured ribs, sternum, or clavicle were only very rarely the most severe injury. 47/

44/ Safety Board investigators used the NHTSA NASS body region classifications for classifying injuries. Body regions used in analysis of the location of the most severe injury are an adaptation from NASS.

45/ The location of injuries codable only as AIS 7--"injured, unknown severity," due to lack of medical information, also was tabulated because in some instances, the AIS 7 injury proved fatal, i.e., "massive head trauma."

46/ See cases 26, 65, 82, 86, 137, 148, 183, 195, 197, 157, and 176 for examples of abdominal injuries.

47/ See cases 28, 135, 196, and 216 for examples of neck injuries that were the most severe injury sustained by the lap/shoulder-belted occupant.

Location of Most Severely Injured Body Part	MAIS (injury severity)						
	2	3	4	5	6	7	Total
Head/skull (excludes face)	8	5	3	1	1	5	23
Forehead	6	0	0	0	0	0	6
Other facial injury	2	1	0	0	0	0	3
Neck	1	0	0	0	0	3	4
Clavicle	2	0	0	0	0	0	2
Sternum	2	0	0	0	0	1	3
Ribs	5	0	0	0	0	0	5
Other chest/upper torso injury	9	6	3	2	0	2	22
Back	2	1	0	0	0	1	4
Abdomen	4	6	2	1	0	0	13
Pelvis	1	0	0	0	0	0	1
Arm or hand	6	2	0	0	0	0	8
Thigh	3	1	0	0	0	0	4
Knee	3	0	0	0	0	0	3
Other lower leg injury (includes foot)	5	2	0	0	0	0	7

Figure 15.--Location of most severely injured body part by injury severity (MAIS) for lap/shoulder-belted front seat occupants in the study. (Data for properly routed belts only; occupants with MAIS 2 or greater injuries only. If the occupant had minor injuries only (MAIS 1)-- the location of these minor injuries is not shown in the table.)

Head and skull injuries were largely at the moderate or serious injury level, but some were at the severe or worse level. In addition, some head and skull injuries were codable only at the AIS 7, "injured, unknown severity" level, but were responsible for the occupant's death. Hence, the tables include AIS 7 injuries.

Figure 16 shows how the location of the most severely injured body part changed with collision severity.

Intrusion-Related Injuries

Although few intrusion-related injuries to lap/shoulder-belted occupants were documented in the study, when they did occur, they generally were quite severe and frequently fatal. Intrusion caused the most severe injury for 27 of the 213 front seat occupants wearing properly routed lap/shoulder belts. 48/ For six of these occupants, the intrusion proved fatal.

In looking at the types of cases in which intrusion caused the most severe injury sustained by the lap/shoulder-belted occupant, the Safety Board found they included a wide range of crash configurations and severity. (See appendix L.) Intrusion was not necessarily the result of a collision: two cases involved noncollision rollovers. When the

48/ Intrusion was responsible for the most severe injury sustained by a lap/shoulder-belted driver or front seat passenger in 25 case vehicles in the Safety Board's study. See cases 1, 14, 26, 36, 50, 53, 61, 82, 91, 92, 94, 97, 110, 111, 137, 139, 143, 148, 183, 184, 189, 196, 197, 208, and 214.

Location of Most Severely Injured Body Part	Delta V (crash severity)					
	0.1 to 10.1	10.1 to 20.0	20.1 to 30.0	30.1 to 40.0	40.1 or More	Total
Head/skull (excludes face)	0	3	10	5	4	22
Forehead	0	1	4	0	0	5
Other facial injury	0	0	1	2	0	3
Neck	0	0	2	1	1	4
Clavicle	0	0	1	1	0	2
Sternum	0	1	2	0	0	3
Ribs	0	0	3	2	0	5
Other chest/upper torso injury	0	3	8	8	2	21
Back	0	0	1	2	1	4
Abdomen	0	4	6	1	1	12
Pelvis	0	0	0	1	0	1
Arm or hand	1	2	4	0	1	8
Thigh	0	1	1	2	0	4
Knee	0	0	1	1	0	2
Other lower leg injury (includes foot)	0	1	2	3	1	7

Figure 16.--Location of most severely injured body part by crash severity (Delta V) for lap/shoulder-belted front seat occupants in study. (Data for properly routed belts only. Occupants with MAIS 2 or greater injuries only and in collision crashes for which Delta V could be calculated.)

intrusion resulted from a collision, the collision did not have to be of high Delta V to cause severe intrusion-related injuries to the lap/shoulder-belted occupants seated adjacent to the intrusion; in 11 cases, crash forces were below Delta V 30 mph; 4 of these were below Delta V 20 mph. Such crashes generally involved side impact.

Intrusion most frequently injured the occupant's head/skull, followed by chest/upper torso, and then abdomen. However, lap/shoulder-belted occupants in the Board's cases sustained their most severe injuries overall, from interaction with the vehicle interior and the belt system, not because of intrusion at their seating positions.

Incidence of Head or Facial Injuries

Use of a lap/shoulder belt clearly can help a motor vehicle occupant avoid many facial or head injuries. Unlike an unrestrained occupant, a front seat occupant wearing a properly routed lap/shoulder belt 49/ will probably be prevented from making violent contact with the dashboard or windshield, thus avoiding injury from these components. During rotation, overturn, or impact, a restrained occupant also will not be "thrown around" in the vehicle, thus limiting body contacts with interior components in the immediate vicinity. Facial or head injuries, however, can still occur despite lap/shoulder belt use. For example, a lap/shoulder-belted occupant can still impact the side door, side window glass, A- and B-pillars, headrest or seatback, and in the case of the driver, the

49/ Case vehicle occupants restrained by misrouted lap/shoulder belts (i.e., shoulder harness under the arm or behind the back) are excluded from this discussion and all subsequent tables. Such misuse degrades the belt performance and increases the possibility of head injuries.

steering wheel. If slack is present in the belt system, depending on the accident and the amount of slack, the possibility of injury can increase, since the lap/shoulder-belted occupant can then strike objects in the immediate vicinity with greater force or vehicle components normally out of reach (i.e., windshield and rear view mirrors).

Fortunately, in the Safety Board's study, if a case occupant wearing a lap/shoulder belt did sustain a head or facial injury, it most likely was a minor injury (i.e, a facial abrasion, laceration, or contusion). Many case vehicle lap/shoulder-belted occupants received no head or facial injury at all. 50/

However, some (41 of 213) front seat occupants wearing correctly routed lap/shoulder belts still did sustain moderate or more severe head/facial injuries (or injuries of unknown severity). 51/ Since researchers are interested in learning more about head/facial injuries incurred by lap/shoulder-belted occupants, with the goal of eliminating, as far as possible, these residual injuries, the Safety Board took a look at the types of cases in which they occurred. (See cases, 1, 4, 20, 26, 27, 28, 50, 56, 58, 61, 63, 67, 68, 75, 82, 86, 91, 94, 110, 137, 139, 143, 148, 161, 178, 182, 183, 184, 187, 188, 189, 196, 197, 201, and 214.)

Most (30 of the 41) lap/shoulder-belted occupants who received these injuries were in frontal, nonrollover accidents; many occurred in moderate crashes (i.e., Delta V of less than 30.1 mph). Serious head injuries also occurred in crashes of Delta V of less than 20.1 mph. (See figure 17.) Combined, these 30 occupants sustained more than 50 individual head/facial injuries of MAIS 2 or greater (or MAIS 7). All but four of these injuries were contact-induced. Safety Board investigators identified the steering assembly as the most common probable point of contact. The windshield, instrument panel, and A- and B-pillar were other points of contact.

Crash Severity (Delta V)	Drivers	Right Front Passenger	Total	Percent
Not calculable*	1	1	2	6.7
10.1 to 20.0	3	0	3	10.0
20.1 to 30.0	11	2	13	43.3
30.1 to 40.0	6	2	8	26.7
40.1 or more	3	1	4	13.3
Total	24	6	30	100.0
Percent	80.0	20.0	100.0	-

*Delta V was not calculable for some of the collision accidents due to the nature of the collision or lack of physical evidence.

Figure 17.--Lap/shoulder belted front seat occupants with head or facial injuries moderate and above by crash severity in frontal nonrollover crashes. (Data for properly routed belts only. Injuries include AIS 7 head injuries.)

50/ Of the 213 front seat occupants wearing properly routed lap/shoulder belts, 172 received minor or no head/facial injuries.
51/ Head injuries codable only as AIS-7, "injured, unknown severity," were included since they generally were not of a minor nature and sometimes were fatal.

In the Safety Board's cases, a greater proportion of drivers wearing properly routed lap/shoulder belts sustained head and facial injuries, compared to right front passengers similarly restrained. In a frontal crash, passengers have more head "ride-down" space, compared to drivers who are close to the steering wheel.

The greater incidence of head injuries among belted drivers compared to belted passengers in the Safety Board's study is consistent with the British hospital study referred to earlier and with other studies. 52/ 53/ 54/ The interaction of the driver's lap/shoulder belt system and steering assembly clearly deserves additional study. Furthermore, modifications to the vehicle might help reduce head injuries in side impacts and should be explored further.

Incidence of Fractured Ribs, Sternum, or Clavicle

Lap/shoulder-belted occupants can sustain fractured ribs, sternum, or clavicle from a properly routed belt if the crash is severe enough since the belt must exert considerable force to hold the body in place. Such belt-induced injuries, however, usually are a "trade-off." If unrestrained, the occupant probably would have sustained more serious injuries.

In the Safety Board's cases, lap/shoulder-belted occupants sustained fractured ribs, sternum, or clavicle less frequently than they sustained head or facial injuries of moderate or greater severity. Only 28 of 213 front seat occupants wearing a properly routed lap/shoulder belt sustained fractured ribs, clavicle, or sternum. Once again, most (21) of these injuries occurred in frontal, nonrollover crashes. 55/

A greater proportion of lap/shoulder-belted right front passengers in the study sustained fractures of their ribs, clavicles, or sternums compared to drivers. (This is consistent with other studies.) The difference was more pronounced in frontal crashes. (See table in appendix L.)

The reader is referred to the chapter on misrouted lap/shoulder belts for a discussion of chest injury induced by underarm routing of the shoulder belt.

How the Board's Injury Analysis Was Performed

Summary data are largely in terms of front seat occupants as a group. The report distinguishes between the outcome for drivers wearing properly routed 56/ lap/shoulder belts versus similarly restrained passengers in only some discussions. (Appendix L, however, presents additional injury data by seating position.) The number of lap/shoulder-belted right front passengers (56) compared to drivers (157) did not permit extensive examination of the relationship of seating position and injury patterns in a given

52/ Nilsson, S. and Planath, I., "Facial Injury Occurrence in Traffic Accidents and Its Detection by a Load Sensing Face," Volvo Car Corporation, May 1987.
53/ Otte, D.; Suedkamp, N.; and Appel, H., "Residual Injuries to Restrained Car-Occupants in Front and Rear-Seat Positions," Accident Research Unit, Hannover, West Germany, May 1987.
54/ Hobbs C. A., Lowne, R. W., Penoyre, S., and Petty, S.P.F. "Progress Towards Improving Car Occupant Protection in Frontal Impacts," 11th International Technical Conference on Experimental Safety Vehicles, May 1987.
55/ Fourteen case vehicle occupants received both a head, skull, or facial injury of moderate or greater severity and rib, clavicle, or sternum fracture.
56/ Front seat occupants wearing misrouted three-point belts are excluded from this analysis. The outcome for these occupants is described in the chapter on misuse.

accident configuration. Further confounding the analysis is the fact that drivers and right front passengers tend to differ in age and sex--factors that influence injury. 57/ The small number of front seat passengers precluded analysis of these factors.

The Safety Board notes, nonetheless, that a considerable body of data suggests that differences in injury patterns and injury sources between lap/shoulder-belted drivers and similarly restrained front seat passengers exist and merit attention. These differences were summarized recently in a paper co-authored by researchers from DOT and Transport Canada (the Canadian counterpart of DOT). Looking at the injury patterns and injury sources of occupants involved in injury-producing front collisions, they found that lap/shoulder-belted passengers received a higher proportion of severe and greater injuries and a higher proportion of belt-related thorax and abdominal injuries, while lap/shoulder-belted drivers received more head and face injuries (steering wheel-related), and leg injuries (instrument panel-related). The authors hypothesized that the relatively better injury outcome for the driver may be related to the following factors:

1. the driver's body posture is more erect and better centered on the steering wheel, which permits the belts to load the occupant's skeletal structure more efficiently;

2. his knees may be better positioned than those of the passenger in terms of "riding down" the impact;

3. the driver exercises some initial control of his kinematics by his arms on the steering wheel and through his legs against the toe board; and

4. the steering system may provide a relatively efficient load path and load distribution for the chest and abdomen of the driver. 58/

The Safety Board believes the interaction of the steering assembly with the lap/shoulder-belted driver warrants further study. The introduction of slack into the three-point system may also have different injury consequences for a driver compared to a right front passenger.

57/ Evans, L., "Occupant Protection Device Effectiveness in Preventing Fatalities," GM Research Laboratories, April 14, 1987.
58/ Backaitis, S.H., NHTSA, and Dalmotas, D., Transport Canada, "Injury Patterns and Injury Sources of Unrestrained and Three Point Belt Restrained Car Occupants in Injury Producing Frontal Collisions," 29th Annual Conference Proceedings, American Association for Automotive Medicine (AAAM), October 7-9, 1985, Washington, D.C.

MISUSE OF LAP/SHOULDER BELTS

A motor vehicle occupant wearing a lap/shoulder belt clearly has an added margin of safety that an unrestrained occupant does not have. A lap/shoulder belt also clearly provides superior crash protection to that provided by a lapbelt or diagonal belt. However, if the occupant is to receive the full benefit of the lap/shoulder belt, the belt must be worn properly. Improper use can degrade the belt's ability to prevent serious injury and, given certain accident circumstances, may introduce the possibility of serious belt-induced injuries. The protection offered by a lap/shoulder belt can be compromised, for example, if its user has the seatback reclined while the vehicle is in motion. The three-point belt cannot provide proper protection to an occupant in this position. Other forms of lap/shoulder belt misuse include deliberately or unwittingly introducing slack into the belt system, misrouting the shoulder portion, or sharing the belt with another occupant. The Board's cases included examples of all of these forms of misuse. Fortunately, accident circumstances were such that, in many cases, occupants who were wearing their belts improperly suffered few consequences. In a few cases, however, the misuse caused serious injuries.

As more and more people buckle up, the safety community is becoming aware that motorists need to be taught that correct use of a seatbelt is critical if they are to obtain optimum protection. For this reason, Physicians for Automotive Safety recently produced a 14-minute film entitled "Buckle Up--and Do It Right," focusing on how belts should be worn for maximum benefit and to avoid belt-induced injuries. The American Automobile Association (AAA) Foundation for Traffic Safety has also released nationwide a 30-second TV public service announcement and comic book featuring Hanna Barberra's Flintstone characters to encourage vehicle occupants not only to wear seatbelts, but to wear them properly. The materials also illustrate the inadequacy of lap-only belts.

Much of the AAA promotion is based on a 4-year study recently completed under the direction of John D. States, M.D., Chairman and Professor at the University of Rochester's Department of Orthopaedics. 59/ Dr. States' study, according to the AAA, "has provided significant evidence of the serious consequences of wearing the shoulder belts under the arm rather than over the shoulder." This particular form of misuse was also seen in the Safety Board's cases.

Lap/shoulder belt misuse was rarely noted in the police-generated accident reports collected as part of the Board's case documentation. The lack of information on whether the seatbelt was misused or not can have several consequences. First, it can lead to inaccurate assessment of lap/shoulder belt performance. Before the crash performance of the belt can be evaluated, basic questions must be answered: was the occupant using the three-point belt at the time of the crash; if used, was it worn correctly or incorrectly; and to what extent did the accident circumstances "test" this misuse?

Second, the lack of information can lead to incorrect claims of "belt failure" when in fact it was the occupant who failed to wear the restraint properly, not the restraint system that failed. But unless this distinction is made, exaggerated fears of unreliable and "broken" belts will continue to hamper efforts to increase belt use among nonusers.

59/ States, John D.; Huelke, Donald F.; Dance, Murray; and Green, Robert N., "Fatal Injuries Caused by Underarm Use of Shoulder Harnesses," Journal of Trauma, July 1987. Copies can be obtained by writing Department of Orthopaedics, University of Rochester School of Medicine, 601 Elmwood Avenue, Rochester, New York 12620.

Third, the extent of misuse will not be documented, and misuse will continue to be ignored as a safety problem that needs to be addressed. As more States enact belt-use laws, misuse probably will grow. As a paper by the Insurance Institute of Highway Safety (IIHS) suggested: "It is possible that people who wear belts in response to a law may be less likely to wear them correctly than voluntary users." 60/ Michigan, one of the first States to pass a mandatory use law, asked the University of Michigan Transportation Research Center (UMTRI) to conduct a use survey and found "tentative evidence that the number of people using seat belts incorrectly increased with the increase in the proportion of motorists using seat belts after the law took effect." 61/

The true incidence of misuse may never be known. Observers are handicapped by the difficulty of observing misuse, especially routing errors. (See figure 18.) Slack may be easier to spot, but it still requires a trained observer. (See figure 19.) Indeed, verification of lap/shoulder belt use is by itself difficult enough for observers to discern. For example, a study conducted by the Maryland State Police of restraint use in vehicles coming in and out of selected State police barracks relied on color photos of the drivers to determine if the driver was belted. 62/ Even after clearly unusable photographs were eliminated, reviewers were unable to determine belt status in 258 of the 637 usable prints.

In another study conducted in Maryland, a State that has a seatbelt use law, the IIHS filmed drivers as they approached stop signs. The film was studied by a trained panel to ascertain belt use and misuse. More than half the 1,580 drivers observed were restrained by properly routed lap/shoulder belts. An additional 2 percent were wearing the shoulder harness improperly routed under the arm or over the wrong shoulder with underarm routing the more common of these two errors. More women than men wore improperly routed belts. (IIHS did not count the number of lap/shoulder belts with the shoulder portion behind the back--this was regarded as a three-point belt not in use.) Of the drivers with properly routed belts, 25 percent had slack in their shoulder portion.

A larger body of data on lap/shoulder belt use comes from the NHTSA 19-city survey of restrained drivers conducted from January through June 1986 (11,529 vehicles). The observational survey found that 2.9 percent of drivers wearing lap/shoulder belts misused them: 1.6 percent wore the shoulder portion under the arm, 0.6 percent had the shoulder portion behind the back, and 0.8 percent wore the shoulder portion "loose." (See appendix J for tables from the NHTSA report.) The differences between the NHTSA and IIHS survey in terms of percent of drivers with belt slack are due, no doubt, to differing definitions of slack. The shoulder portion had to be practically "falling off" the occupant's body before the NHTSA recorded it as "slack."

60/ Williams, A. F. and O'Neill, B., "Seat Belt Laws: Implications for Occupant Protection," SAE Technical Paper Series (SAE Publication 790683), 1979.
61/ Wagenaar, A. and Wiviott, M., "Effects of Mandating Seatbelt Use: A Series of Surveys on Compliance in Michigan," Public Health Reports, September-October 1986, Volume 101, No. 5.
62/ NHTSA-sponsored Law Enforcement Summit Meeting on Occupant Protection, "Use of Safety Belts by Law Enforcement Officers Following Passage of Safety Belt Law," July 31, 1987.

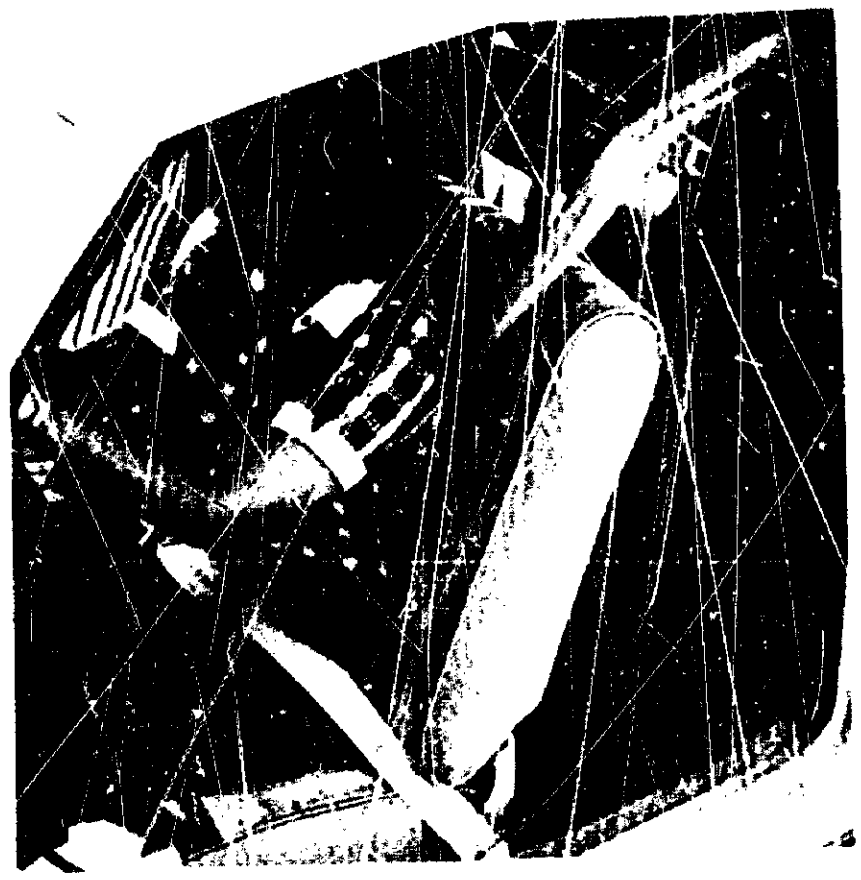

Figure 18.--Observers who attempt to determine the frequency of belt routing errors among lap/shoulder belt wearers are handicapped by the difficulty of seeing the misrouting. Viewing angle and position and the clothes and size of the occupant all combine to make determination difficult. The drivers illustrate shoulder portion under arm (top); shoulder portion over arm (middle); and shoulder portion behind back (bottom). The belt is the same color as the seat, also adding to the viewer's problems.

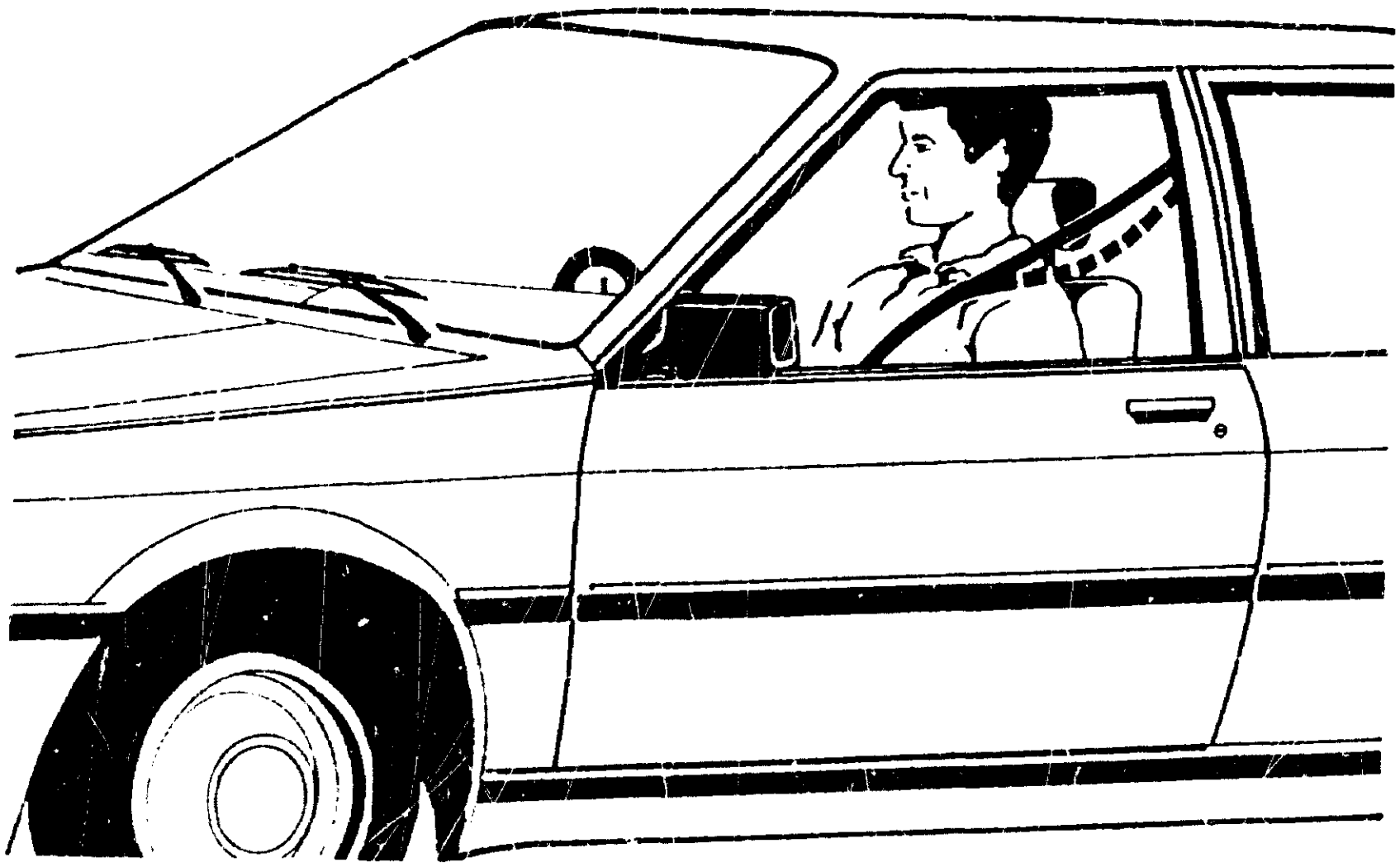

Figure 19.--Typical appearance of lap/shoulder belt when the shoulder portion is snug (solid line) and when it is slack (dashed line). (Reproduced courtesy of the IIHS.)

TYPES OF MISUSE

Reclining Seatback

Lap/shoulder belts offer good protection in a variety of crash configurations to occupants who wear the belts properly. Part of proper use involves sitting upright so that crash forces can be spread over the body by the three-point belt. A person reclined in a seat while wearing a lap/shoulder belt is not "centered" in the belt.

The Safety Board notes with concern that many vehicles are being marketed with reclining seats, most often in the front but sometimes in the rear as well. The existence of such seats may tempt adults, and children in particular, to combine belt use with a reclined seat. At best, lap/shoulder belts, indeed any type of seatbelt, offer reduced effectiveness when used with a reclined seat. At worst, a lap/shoulder belt and a reclined seat may be a potentially dangerous combination in a moving vehicle--proper fit is impossible. (See figures 20 and 21.)

Some owner's manuals do warn of the dangers of reclining seatbacks while the vehicle is in motion or that seatbelts are designed to be worn only by upright occupants. Below is typical language from an owner's operating manual:

> Seatback Position When Moving
>
> ---
>
> Caution: To reduce the risk of sliding under the belt during a collision, an occupied reclining seat should not be reclined any more than needed for comfort. The seatback and seat belts provide best restraint ONLY when the rider is sitting well back and straight up in the seat. (The lap belt is designed to spread the force of a collision over the hip-bone. If you are reclined, the lap belt may slide past your hips and apply restraint forces directly to the abdomen. Therefore, in the event of a frontal collision, the risk of personal injury may increase with increasing recline of the seatback.)
>
> Do not adjust the reclining seatback on the driver's seat while the vehicle is moving. The seatback could move suddenly and cause the driver to lose control of the vehicle.
>
> ---

However, despite such warnings, some advertisements for cars equipped with reclining seats show a right front passenger reclined in a seat while wearing a lap/shoulder belt with the vehicle obviously in motion. Such advertisements undermine the already limited effectiveness of owner's manual warnings (especially if the warnings are unclear, as in advising not to recline the seat "any more than is needed for comfort"). Should an occupant misusing a lap/shoulder belt in this way be injured in a crash, the belt should not be described as having "failed."

The dangerous combination of a reclined seatback and lap/shoulder belt use caused the death of a young boy in case 216. Before the accident, the right front passenger, a 7-year-old boy, was asleep with his seatback reclined 43 degrees in a 1977 Honda sedan. He was wearing his lap/shoulder belt, but it could not be positioned against his body

Figure 20.--Safety Board employee demonstrates possible positions of a lap/shoulder belt used in combination with a reclining seat. The seatback angle is varied, and belt positioning is far from ideal. The vehicle is a 1987 Hyundai Excel. The top photo shows the seat reclined at a 30-degree angle; at the bottom it is fully reclined. The investigator posing for the above photos is 6 feet, 165 pounds. (See also figure 23)

Figure 21.--The top photo shows the seat reclined 30 degrees; the bottom photo shows the seat fully reclined. The woman shown is 5 feet 1 inch, 114 pounds.

correctly: the reclined seat position caused the shoulder portion of the belt to be suspended in front of his face, with substantial space between the shoulder strap and his body.

The Honda ran off the road at a curve, across a field, and hit a tree head-on (a Delta V 30-mph collision). Maximum crush of the front end was 26 inches. Because of his reclined position, the child submarined under the lap portion of his belt at impact; at the same time, his upper torso pivoted upward and forward, striking the shoulder portion of the belt with his neck. He sustained injuries to his neck, chest, and upper torso, including a contusion of the right lung and fractured left clavicle and was found dead at the scene. The coroner determined the cause of death to be a "vagovagal" reflex (carotid body reflex) caused by the shoulder harness blow to his neck. Perhaps in this type of seat orientation, a larger child would be vulnerable to a vasovagal attack resulting from a blow to the chest. 63/(See figures 22 and 23 for the relationship of the boy's body and belt before and after the crash.) It is unlikely that, had the lap/shoulder belt been used properly, the boy would have been killed.

The Safety Board investigated two cases involving adults in reclined seats, but in these cases, the consequences of misuse were less severe In case 57, a 30-year-old man was reclined in the right front seat of a 1976 Mercury Capri, but his body became more upright as the accident sequence began. The car underwent a Delta V 21-mph frontal collision, followed by a 90-degree rollover. He sustained moderate injuries, including two fractured ribs from the shoulder strap. Investigators attributed these fractures to the abnormal loading of his body; he had more space between his belt and body than usual, due to the reclined angle of his seat. In the other case, case 65, the adult passenger in the right front position had reclined the seat 45 degrees. When the 1982 Nissan Sentra was struck head-on (Delta V 19.6 mph), he sustained moderate injuries--major chest contusions from contact with the shoulder portion of his belt, as well as major contusions to his abdomen from the lap portion. Once again, his reclined position probably contributed to his injuries.

Misrouting

As stated earlier in this report, lap/shoulder belts provide superior crash protection compared to lap-only belts and diagonal belts. Unlike lap belts, three-point belts provide upper torso restraint, helping protect the head and skull. In contrast to other belt systems, a lap/shoulder belt spreads collision forces over a much larger area of the body. Researchers warn that the lap portion of the three-point belt should cross the lower

63/ Vagovagal is a transient vascular and neurogenic reaction marked by pallor, nausea, sweating, bradycardia, and rapid fall in arterial blood pressure which, when below a critical level, results in loss of consciousness and characteristic electronencephalographic changes. The boy could have died from blunt trauma to his chest as he struck the shoulder strap suspended in front of him. A severe blunt impact to the upper torso could result in cardiac arhythmia, followed by either ventricular fibrillation or ventricular standstill. The basic biomechanics of the fatal chest impact could be similar to those seen in baseball/softball-related deaths for children ages 5-14: the ball hits the pliable sternum, and the sternum puts the chest wall in motion. The heart is slapped by this inner wall at approximately 50 percent of the speed of the ball; ventricular fibrillation or standstill and respiratory arrest are the results.

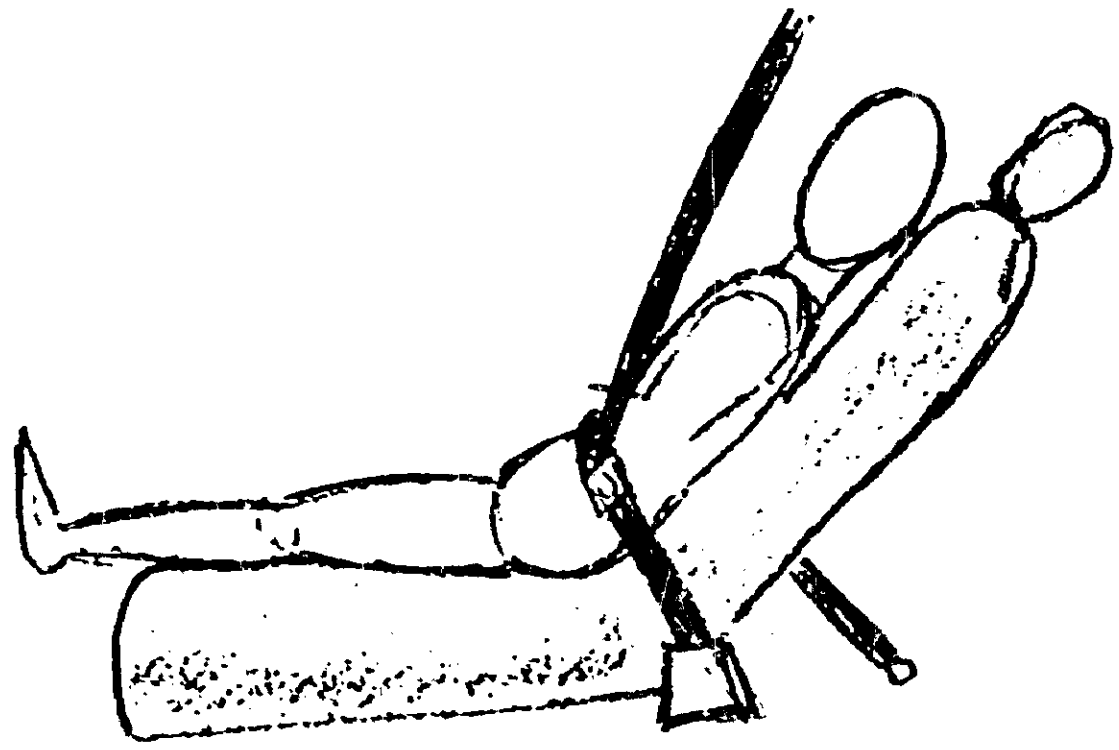

Figure 22.--Sketch of the belt position prior to the crash.

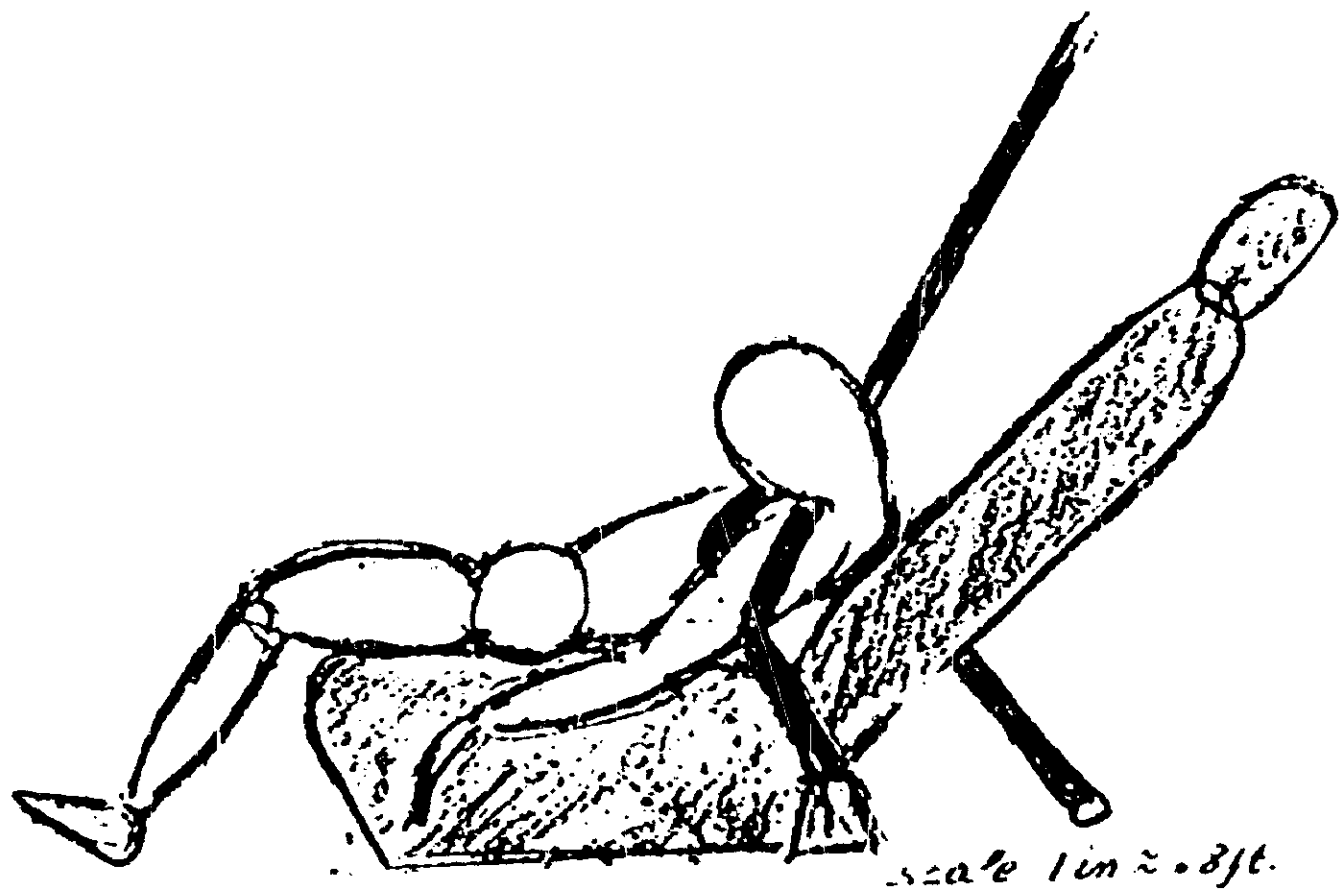

Figure 23.--Sketch of belt position following crash, as the body was found. The fatally injured occupant submarined under the lap portion of the belt (it went up into his arm pit), and his torso moved forward, causing his neck to strike the shoulder portion.

abdomen below the iliac crests. The shoulder portion should be worn over the shoulder so that it rests on the clavicle, the top part of the shoulder, and crosses the middle of the chest. 64/ In this way, the lap/shoulder belt can distribute the crash forces over large areas of skeletal structure.

Positioning the shoulder portion of the belt under the arm, behind the back, or behind the neck and over the inside shoulder are forms of belt routing errors. Such errors effectively defeat the upper torso protection provided by the three-point belt and increase the possibility of belt-induced injuries. The Safety Board investigated at least nine cases involving adult occupants who had misrouted their lap/shoulder belts (see appendix B); one died as a direct result of this misrouting (case 215). In other cases, the resulting injuries ranged from minor to critical injuries. (Other misrouting cases involving children are discussed in the chapter on children and lap/shoulder belts.)

Under the Arm Routing.--The shoulder portion of a lap/shoulder belt must be placed over the shoulder so crash forces can be spread over the clavicle, shoulder, and chest. Placing the shoulder portion under the arm may result in broken ribs and injuries to intestines, mesenteries, liver, spleen, kidneys, aorta, and other organs. In addition, because of the unusual position of the shoulder strap, the occupant's diaphragm can be ruptured and the heart and lung injured.

The circumstances and severity of a particular accident will determine whether and to what degree this form of the misuse is harmful to an occupant. For example, in case 215, misrouting caused the death of one young woman. A 1982 Datsun, occupied by two young women wearing lap/shoulder belts, ran off the road into a grass median and struck a tree head-on, a Delta V 26-mph collision. There was no intrusion into the passenger compartment. (See figure 24.) The driver, who was wearing a lap/shoulder belt properly, sustained moderate injuries--a fractured finger and nose, facial lacerations, and knee abrasions. In contrast, the right front passenger, who was wearing her lap/shoulder belt with the shoulder portion routed under her right arm, sustained critical injuries that proved fatal. Her injuries were almost all directly traceable to the misused lap/shoulder belt. She sustained an almost complete transection of the duodenum, laceration of the pancreas, laceration of the splenic artery and vein, transection of the portal vein-superior mesenteric vein junction, laceration of the left side of the diaphragm, transection of the upper spinal cord, and fractured 12th thoracic vertebra. Four of her ribs (8, 9, 10, and 11) were fractured on her lower left side and two (10 and 11) on the right, showed clear evidence of the abnormal belt loading. She also had an oblique linear abrasion across her abdominal wall. The dead passenger was found slumped forward toward the console with her head tilted to the right. This case (case 215) puzzled police, who initially reported it as a case involving a reclining seat. Safety Board investigators found that rescuers, not the occupant, had reclined the seat.

Misrouting has only gradually been recognized as an injury source. One of the first warnings about the dangers of underarm routing came in 1961 when Swedish researchers studied injuries caused by underarm use of a single diagonal seatbelt. 65/ Not until 1978 was the first case involving a fatality from underarm placement of a lap/shoulder belt documented and published in this country:

64/ States, op. cit.
65/ VonBahr, V. and Eriksson, E., Skador av Sakerhetbalten, UXKZVT S. Venska Lakartidningen 58: 141- 146, 1961. Cited in States, J. op. cit.

Figure 24.--Interior view of Datsun (case 215). Media reports explaining the death of the right front passenger claimed the crash was not survivable; it was. There was no intrusion into the passenger compartment and the crash forces (Delta V 26 mph) were survivable. (The properly restrained driver survived with only moderate injuries.) Media also portrayed the accident as a "success story" for restraint use because one of the two lap/shoulder-belted occupants survived. However, the passenger would have survived if she had not placed the shoulder portion of her belt under her arm.

> A 1978 Oldsmobile Cutlass Supreme was attempting to pass another vehicle on a two-lane undivided country road. The driver of the Cutlass, apparently observing an oncoming car, applied the brakes, fish-tailed on the ice-covered roadway, went off the roadway, and impacted a snowbank. The car re-entered the roadway and both lanes into the path of an oncoming Valiant. In this head-on crash, the Delta V for the Cutlass was calculated to be 25 mph.
>
> The 30-year-old, 5-foot 10 1/2-inch male driver of the Cutlass sustained fatal chest injuries. He was observed at the scene of the accident to have the shoulder belt under his arm. Autopsy revealed fractures of the right ribs 2-9 and left ribs 2-5, transection of the aorta 1 cm distal to the subclavian artery, and minor lacerations and contusions of his right eye, lips, and lower legs.

This case and five others involving fatal injuries due to misrouting belts under the arm are described in the paper by Dr. States cited earlier. He concluded:

> Lacerations of the liver, spleen, intestines, mesentery, diaphragm and aorta, and spine injury have occurred in accidents, most of which should have been survivable. The motoring public must be warned that underarm use of shoulder belts is hazardous and may cause fatal injuries in otherwise survivable accidents.

The practice of placing the shoulder portion underneath the arm can, the paper warns, result in loads "far in excess of the injury tolerances of the lower chest and upper abdomen."

Other cases involving serious or fatal injury due to belt routing errors and other forms of misuse of lap/shoulder belts were described by Canadian researchers in 1986 and are presented in appendix K. 66/

Behind-the-Back Routing.--If the shoulder portion of the three-point belt is placed behind the back, the occupant loses the advantage of the shoulder portion of the belt. In effect, the occupant is restrained by a lap-only belt--no upper torso restraint is provided, and the occupant's head can come in violent contact with interior components. In addition, the lap portion of the belt can induce severe abdominal and spinal injuries. When the lap/shoulder belt is routed properly, jackknifing will not occur and crash forces are diffused over a larger portion of the body than with a lap-only belt. Excessive abdominal loading is, therefore, less likely to occur.

The Safety Board investigated only two cases involving adults who had routed their belts behind their backs. Children were more frequently observed with this misuse.

Behind-the-back routing resulted in severe injuries for the driver of a Nissan pickup truck who lost control of his vehicle and struck a wooden utility pole. The vehicle received major structural damage to its front with more than 40 inches of collapse at the right front. The driver sustained a critical injury: avulsion of the colon caused by the lap

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66/ Green, R.; German, A ; et. al., "Improper Use of Occupant Restraints: Case Studies From Real-World Collisions," 30th Annual Proceedings, AAAM, October 6-8, 1986, Montreal, Quebec.

portion of his belt. By eliminating his upper torso restraint--the shoulder portion of his belt--the lap portion conveyed much of the crash loading to his abdomen. The driver also sustained numerous lacerations to his face and knees from contact with the steering assembly, but these injuries were minor (case 192).

In the other case involving an adult with the belt routed behind his back--a rear-end crash--the misrouting made little difference because of the accident configuration (case 29). The occupant accelerated back into the seat at impact.

Slack

For optimal crash performance, both the lap and shoulder portion of the three-point belt should be "snug" and properly positioned. In a frontal crash, a seatbelt so used will arrest or at least minimize the body's forward motion and will minimize the body's contact with the injury-causing elements of the vehicle's interior. (The arms and legs, of course, are free to flail, as with any belt system.)

If "slack" is present in the lap/shoulder belt system, particularly in the shoulder portion, the opportunity for a degraded level of occupant protection exists. 67/ The crash consequences of the slack will depend in part on the occupant's seating position (front or rear seat, driver or passenger, etc.); the occupant's height, weight, and other physical characteristics; the design of the car interior; the amount of slack in the system; the crash configuration; and the severity of the accident. The last two factors can be quite important, since slack would probably have little consequence in a rear-end or side collision of minor severity.

Perhaps the most perplexing problem in any discussion of the crash consequences of "slack" in a three-point belt system is the lack of a precise definition of "slack." Slack, like "snug," has no uniform definition. Safety advocates do not agree at what point slack can prove injurious. For example, in a pamphlet on "Seat Belt Use During Pregnancy" developed by the American College of Obstetricians and Gynecologists under a contract from the DOT, 68/ the following statement appears: "Up to 3 inches of slack between the belt and the chest appears to be safe." Owner's manuals produced by car manufacturers, on the other hand, refer to excess slack as "more than 1 inch" of shoulder belt webbing pulled out from the retractor after the belt is snug against chest or enough to insert a fist between the belt and the chest. In the IIHS "slack" surveys, it was defined in terms of "no slack, 1 or 2 inches of slack, and 3 or more inches." In its 19-city survey, the NHTSA instructs observers that "the distance between the shoulder belt and the driver's chest should not be much more than the width of a normal fist, as a general rule. If the shoulder belt is excessively loose or falling off the shoulder, record as ['loose']." In the Safety Board's investigations, occupants were asked to define shoulder belt fit in terms of space for inserting the palm of the hand, a clenched fist, or more than a clenched fist between belt and chest. Of course, objective evidence such as loading marks on the webbing helped in the consideration of the more subjective evidence of the user.

67/ Slack in the lap portion of a three-point belt can increase the possibility that the lap/shoulder-belted occupant will "submarine" under the belt in a crash or sustain abdominal injuries, but such cases appear to be quite rare. Slack in the shoulder portion of a three-point belt is far more common and of more concern to safety advocates.

68/ "The Healthy Pregnancy: Seat Belt Use During Pregnancy," American College of Obstetricians and Gynecologists, December 1983.

In some cases in the Safety Board's study, the amount of slack (in combination with the users' size and the particular accident circumstances) was not sufficient to produce injuries more serious than those sustained by occupants restrained by a lap/shoulder belt worn "snugly." In some cases, however, the amount of slack was so great it did prove injurious, even fatal. Case 84 is such an example:

> A 1983 Buick Regal four-door sedan, occupied by a driver and right front passenger wearing lap/shoulder belts, veered off the right side of the roadway and struck a utility pole head-on, a Delta V of 28 mph. The Buick received substantial structural damage with inward collapse of up to 36 inches. There was no passenger compartment intrusion. The lap/shoulder-belted driver, a 62-year-old man, sustained minor injuries (lacerations and contusions), while the passenger, a 58-year-old woman, sustained massive chest trauma and died in the emergency room 49 minutes after the accident. She bled to death from a possible rupture of the aorta and/or heart. All of her ribs on the left side were fractured, and her sternum was fractured as well.
>
> Rescue personnel had found the passenger leaned forward in the seat in a fetal position with her buttocks resting on the front edge of the bench seat. Her knees and lower legs were against the lower part of the dashboard. She was still wearing her lap/shoulder belt. Rescuers described the shoulder portion of her lap/shoulder belt as over her right shoulder and the lap portion slightly above the navel. Force loading marks were found in the area of the latch plate and D-ring and the belt webbing was scarred--further documenting that the belt was in use at the time of the crash. The driver's lap/shoulder belt also showed force loading marks in the webbing in the area of the cinching latchplate and D-ring, indicating use at the time of the accident (case 84).

In this accident, both occupants were restrained by a continuous loop lap/shoulder belt equipped with emergency locking retractor sensitive to vehicle motion, 69/ a windowshade tension relief device, and a cinching latchplate. However, the driver had introduced only a small amount of slack in both the lap and shoulder portion of his belt, which did not prove harmful in his case. The passenger, in contrast, had introduced a large amount of slack, so much that during the crash, her body may have "submarined" under the belt until she was almost off the seat, stopping only when her knees contacted the glove box and dashboard. 70/ In her case, the slack she had introduced into the belt system proved fatal by allowing her body to move forward in such a way that massive chest trauma occurred.

"Tension Relief" Devices.--Most lap/shoulder belts in passenger vehicles in the U.S. are designed to allow occupants to introduce slack in one of two ways: by positioning a "comfort clip" or by activating a "windowshade" device. In the accident just described, the occupants of the Buick had belts equipped with "windowshades."

69/ "Sensitive to vehicle motion" is the term commonly used to describe such a retractor, but it actually is sensitive to vehicle acceleration or deceleration.
70/ One possible reason for the loose restraint was that she was wearing an ileocystoplasty (waste bag) on her right side.

Much of the concern about slack in lap/shoulder belt systems has been focused on windowshade-equipped belts. Since the 1970s, most cars designed and manufactured in the United States have used these devices to allow slack to be introduced into the shoulder portion in much the same manner as a windowshade operates. When the shoulder belt is slowly extended, slack is introduced until a pause is made, and then the shoulder harness "locks" at that position. If the belt is further extended, the system will relock at the new length. Owner's manuals warn that no more than 1 inch of slack, or the equivalent of a clenched fist, should be introduced between the body and belt. But far more slack is possible in windowshade-equipped belts--more than 16 inches in many cases. (See figure 25.) An occupant can introduce slack by deliberately extending the belt or through voluntary or involuntary body movement; the slack remains in the system until the occupant deliberately reactivates the windowshade and resets the belt more snugly. Contrary to the belief held by many occupants in the Board's study, the slack existing at the beginning of the crash will not be taken out of the belt as the crash progresses--i.e., the belt will not tighten up as the crash takes place. 71/

Some cars have "comfort clips" for introducing slack--a plastic sleeve attached to the shoulder belt, which, depending on its location, can prevent the belt from retracting fully. (See figure 26.) This amount of slack will remain in the shoulder belt until the clip is repositioned. If positioned improperly, the clip too can introduce a dangerous amount of slack. If positioned low on the belt, however, it may not affect belt fit at all. (See figure 27.) Unlike a windowshade-equipped belt, the occupant with a comfort clip-equipped belt cannot increase the amount of slack in the system involuntarily. The amount of slack possible in the system is determined by the position of the comfort clip on the belt.

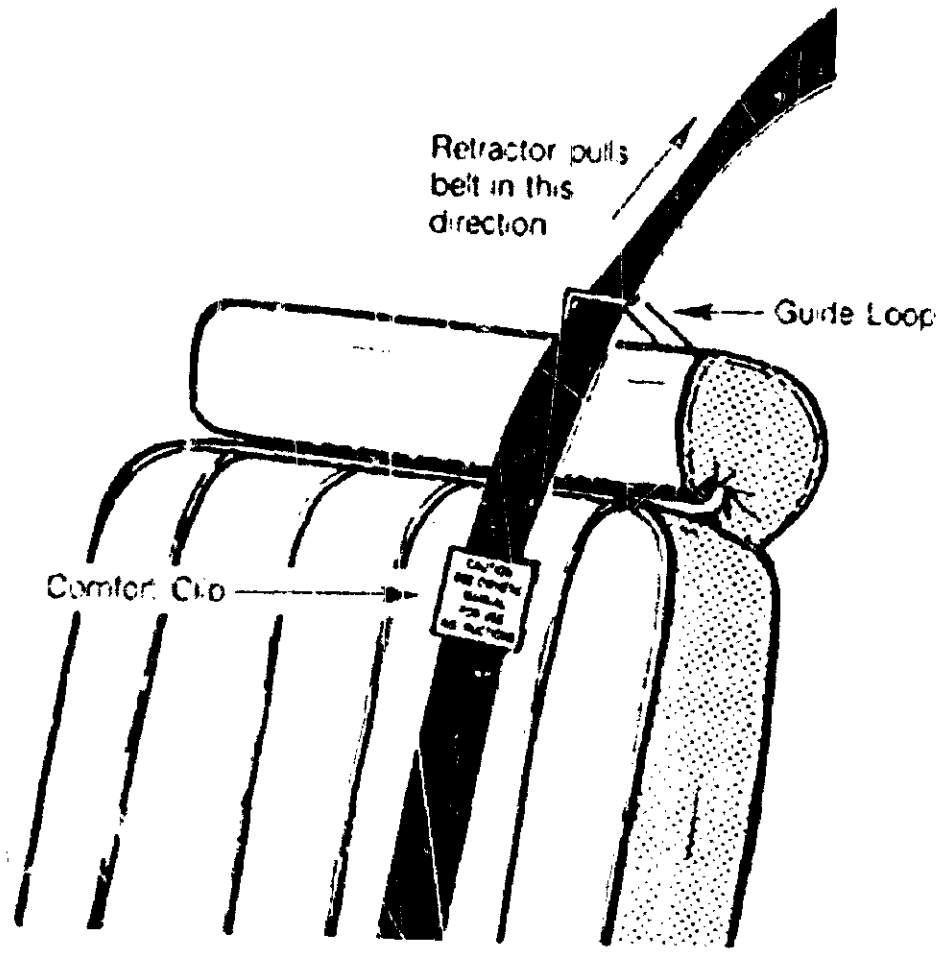
Domestic cars may have either windowshades or comfort clips as slack devices; imported cars, on the other hand, are almost never manufactured with windowshade-equipped systems (windowshades are outlawed in many foreign countries) and only sometimes come equipped with comfort clips. Imported vehicles commonly have no slack devices. (See figure 28.)

Prevalence of Slack in Safety Board Cases.--The Safety Board collected data on the fit of both windowshade- and nonwindowshade-equipped lap/shoulder belts worn by case occupants. About 40 percent of the lap/shoulder belts in use in the cases were windowshade-equipped, and 60 percent were not.

Slack was present for 23 percent of the case vehicle drivers restrained by lap/shoulder belts, and it was more often found in the shoulder than in the lap portion. (Only eight drivers had slack in the lap portion).

71/ Unless, of course, the belt has a "pretensioner," which causes the belt to take up the additional slack and become snug if sensors sense a crash impulse. Pretensioners (more accurately called emergency tensioning retractors) have been standard equipment on all models of Mercedes Benz since 1986, and are standard in certain models of Saab, Volvo, and other imported cars. (BMW lap/shoulder belts come equipped with a "snubber," a mechanical device, not sensor-activated, which clamps on the belt webbing during a crash and reduces "spool-out.")

Figure 25.--Examples of the varying degrees of slack that can be present in a windowshade-equipped emergency locking retractor (ELR) lap/shoulder belt. In the top photo, little if any slack is present. In the middle photo, the driver has introduced slack in the shoulder portion so that it is quite loose. In the bottom photo, he has introduced a lesser, but still significant, amount of slack into the shoulder portion (note the "dipping" of the shoulder harness below the headrest), but now he also has introduced slack into the lap portion of the belt. (The cinching latchplate allows slack in the lap portion.) The lap/shoulder belt in the 1985 Chevrolet Monte Carlo is equipped with a vehicle sensitive ELR with windowshade device and cinching latchplate.



Comfort clip is used to limit retraction of belt. Window shade devices also limit belt retraction but the mechanism is hidden inside the retractor housing.

Figure 26.--Shoulder belt comfort clip. (Drawing reproduced with permission of the IIHS.)

Figure 27.--Position of the comfort clip (see arrow) is too low to affect belt tension. Belt shown has unusual configuration: a roof-mounted stalk with D-ring attached.

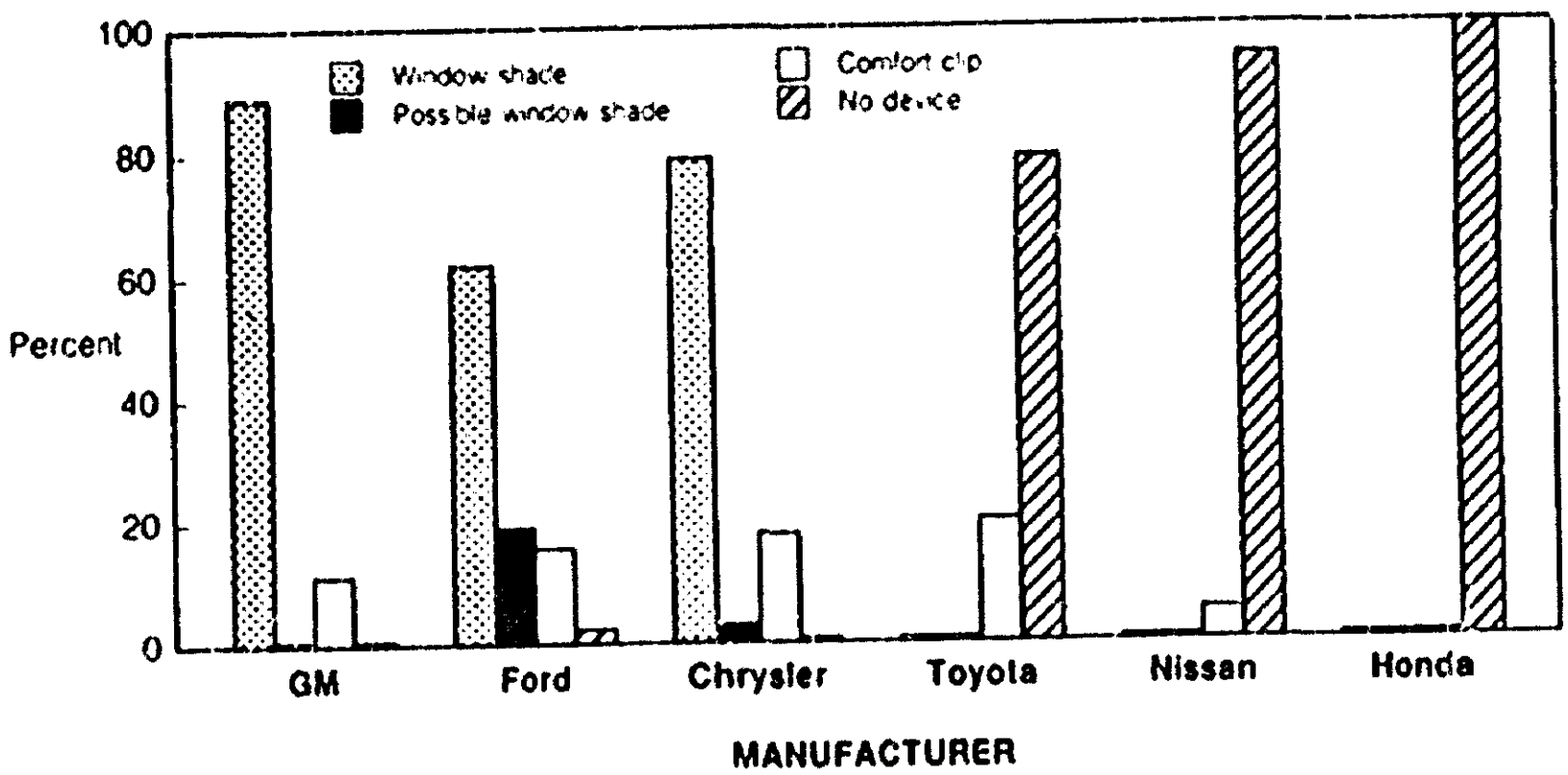


Figure 28.--Shoulder belt slack devices in surveyed 1974-87 model cars in Maryland.

NOTE: In general, IIHS assigned slack device types to vehicle makes and models on the basis of how these models were equipped at the time of manufacture. In some cases, however, more than one type may have been provided by the manufacturer or the belt may have been an aftermarket conversion. (Reproduced with permission from IIHS.)

Shoulder belt slack was more common in windowshade-equipped belts than in those without windowshade. If slack was present, nonwindowshade-equipped belts had slack more often in both the lap and shoulder portions (compared to shoulder only), but this reflects the fact that many nonwindowshade belts have free-sliding latchplates, which automatically apportion slack between the lap and shoulder portions.

Prevalence of Slack Nationwide.--Just how many lap/shoulder belt users routinely wear their belts with slack is not known. The NHTSA 19-city survey of restraint use found that fewer than 1 percent of the more than 11,000 lap/shoulder-belted drivers observed had slack in their belt systems. Drivers aged 50 and older were more likely to wear their belts "loose" than were younger drivers. (Two percent of older drivers in model year 1984-1987 vehicles wore their belts loose.) "Loose" belts were far more common in domestic than in imported vehicles.

Other studies have found slack to be a much more common occurrence. For example, in 1987, IIHS researchers analyzing films of Maryland drivers found that, although they had routed their lap/shoulder belts across their bodies correctly, close to 1/4 of all drivers were still using the belts improperly--excess slack was present in the shoulder harness. Of the restrained drivers of domestic cars, 27 percent had 1 to 2 inches of slack in the shoulder portions of their belts, and 8 percent had 3 or more inches. In contrast, only 5 percent of the restrained drivers of imported cars had 1 to 2 inches of slack, and none had 3 or more inches. The windowshade slack device, found only in domestic vehicles, was most often associated with slack. (See figure 29. See also appendix J.) 72/

Comfort Clips.--In the 14 case vehicles in which dealer or manufacturer-supplied comfort clips were present, only one clip was positioned on the belt so that it could introduce slack (case 132). In this case, however, it made only a minor difference in injury outcome. In all the other cases, comfort clips were apparently positioned so low on the shoulder portion of the belt that they could not introduce slack.

In case 20, a homemade "comfort clip" (a large safety pin) did degrade the three-point belt's performance by introducing slack. A 66-year-old woman driver of a 1978 Subaru station wagon, anxious to prevent the shoulder strap from rubbing her sore left shoulder, inserted a safety pin through the webbing below the D-ring, thus introducing a significant amount of slack in the shoulder portion. (The lap portion remained snug.) This increased the severity of her injuries when the car ran off the road and head-on into a

72/ The IIHS called for the elimination of windowshade-equipped belts because, in their opinion, they allow vehicle occupants to wear belts too loosely:

> The various devices used in North American cars for relieving shoulder belt pressure and neck chafing caused by poor fit can also result in the introduction of excessive slack. They may be useful in attempting to increase voluntary use of 3-point belts, but they are probably counterproductive when permitted in conjunction with mandatory use laws, because they seem to cause significant numbers of people to use at least the shoulder belt portion of the system improperly. Such devices are not even permitted in Australia and much of Europe.

Brian, O'Neill, President of IIHS, Summarizing Discussion after Session 1, at the Organisation for Economic Co-operation and Development Meeting on the Effectiveness of Safety Belt Use Laws, November 11-14, 1985, Washington, D.C.

Estimated Slack in Shoulder Belts Worn by Maryland Drivers in 1974-87 Model Vehicles

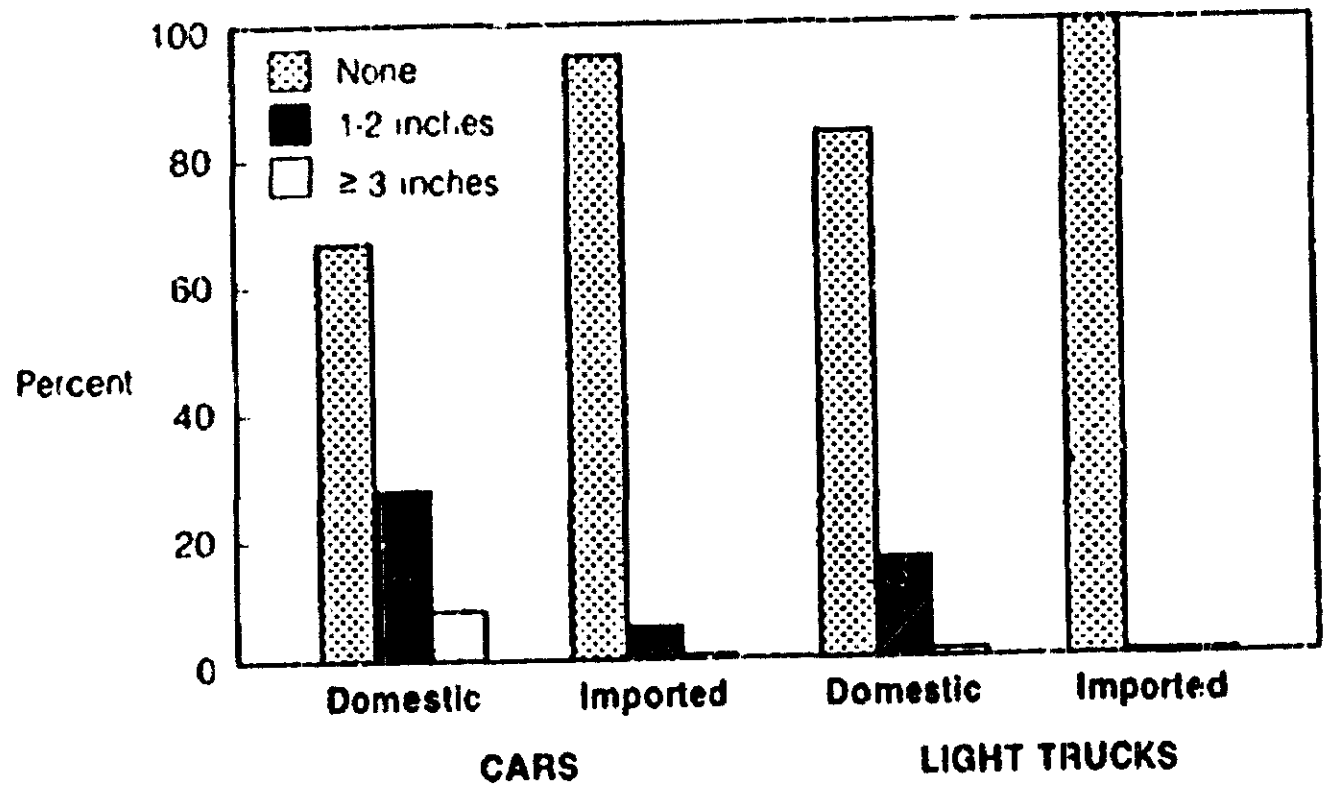


Figure 29.--Table from IIHS study, "Improper Shoulder Belt Use by Maryland Drivers," June 1987.

large tree (Delta V 24.1 mph). She sustained serious injuries, including a basilar skull fracture and cervical fracture from contact with the steering wheel, and a fractured clavicle and ribs from contact with the steering wheel and shoulder strap. 73/

Crash Consequences of Slack.--"Safety experts agree that anything more than an inch or two of additional slack can have profound consequences for safety." 74/ The extra inches of movement permitted by a slack lap/shoulder belt can harm a motor vehicle occupant in a variety of ways: by impacting an interior component that would not be within reach if the occupant were snugly belted, by impacting a nearby object with greater force than usual, or by sustaining more serious belt-induced injuries than expected. Increased slack in the shoulder portion of the belt, in particular, may lead to increased head injuries.

73/ Even if properly belted, she would have contacted the steering wheel--her seat was adjusted far forward (she was only 5 feet 4 1/2 inches tall), but the slack allowed her to strike the steering wheel with increased force, increasing the severity of her injuries.

74/ Robert Dewey, Center for Auto Safety, quoted in "Seatbelt Verdict Costs General Motors $800,000," Fuel Line, March 1987.

NHTSA Crash Test Data on Slack.--Crash test data support the view that slack increases the chances of head injury. In 1982, the NHTSA conducted four "informal" sled crash tests. 75/ Dummies wearing lap/shoulder belts equipped with windowshade devices were placed in the right front passenger position in a sled containing the front section of a car. The lap portion of the three-point belt was snug in all tests, but researchers varied the tests by introducing different amounts of slack in the shoulder portion ranging from 0 (no slack), 1 inch, 2 inches, and 16 3/4 inches (the maximum amount of slack possible). Instrumentation on the dummies during the 30-mph frontal crash tests recorded the following head impacts in terms of Head Injury Criterion (HIC):

Slack (inches)	HIC
0	439
1	641
2	796
16 3/4	1,802

The higher the HIC, the greater the likelihood of serious or fatal injuries; 1,000 is the threshold above which serious or fatal head injuries are thought to be likely. As the figures above show, slack increased the likelihood of head injuries in NHTSA's crash tests.

The Safety Board notes that the data were for right front passengers only; the consequences of slack for a driver may well be more severe in terms of head injury.

Examples of the Injurious Effect of Slack in Safety Board Cases.--The Safety Board's cases include examples of lap/shoulder-belted occupants who sustained more serious injuries due to slack than the injuries that would have been expected with a snug belt. In some of the cases, slack in the shoulder portion allowed the lap/shoulder-belted driver or right front passenger to strike the windshield or rear view mirror and sustain head and face injuries that otherwise could have been avoided. In other cases, slack in the shoulder portion allowed the driver to contact the steering assembly with increased force. Two examples follow showing the effect of slack for drivers in different crash severities. The lap/shoulder belt system in each example was a continuous loop system with an emergency locking retractor sensitive to vehicle motion equipped with a windowshade tension-releasing device and cinching latchplate.

In case 67, the driver of a 1984 Ford Tempo rear-ended the back of a truck tractor being towed by another truck tractor--a Delta V 27.5-mph collision for the Ford. It received extensive damage across the front with maximum crush of 29 inches. The 55-year-old male driver (170 pounds, 5 feet 8 inches tall), restrained by a lap/shoulder belt with slack in both the lap and shoulder portions, sustained moderate injuries, including a large contusion on his forehead from contact with the steering wheel rim. At impact, he moved forward 15 to 17 inches and struck the steering wheel rim with his face with sufficient force to deform the rim 2 inches. When the Safety Board investigator interviewed the driver and reconstructed the events of the crash, he found that the driver had degraded the crash protection of his belt in several ways. The driver had removed the belt webbing from the B-pillar-mounted guide clip. He also introduced approximately 2 inches of slack in the lap portion of the belt. (This determination was possible because the latchplate loading mark showed the original position of the cinching latchplate.) The driver also showed the investigator how he had deliberately introduced several inches of

75/ Esser, R. C. "Restraint Model Validation Tests, Phase I," NHTSA, February 1983.

slack into the shoulder portion of his belt by activating the windowshade. Finally, the swiveling stalk on which the D-ring is mounted in that model of Tempo might also have introduced additional slack into the shoulder portion as the driver's body went forward in the crash; this stalk design was discontinued in the 1986 models. Hence, slack played a part in permitting the driver's head to hit the steering wheel. 76/

Case 201 is another example, this time of a more minor crash, in which slack contributed to the severity of the driver's injuries. A 1978 Buick Regal was struck in the front by an oncoming 1982 Dodge Aries, a Delta V 21.1-mph collision for the Buick. The Buick received substantial structural damage with inward collapse of up to 20.5 inches across the entire front end. The 39-year-old female driver (110 pounds, 5 feet, 2 1/2 inches tall) was wearing a lap/shoulder belt.

The driver had been restrained by a windowshade-equipped lap/shoulder belt of design similar to that of the Tempo described earlier, but without the swiveling D-ring and belt guide. The lap portion of the belt reportedly was snug, and the shoulder portion was reportedly adjusted so that at least a clenched fist could be placed between the webbing and chest. (No force loading marks were present on the system webbing to confirm the fit description.) The driver received a long forehead laceration from contact with the steering wheel hub. Again, slack in the belt system probably allowed this injury to occur. 77

The study contains other examples of the injurious effects of slack in a lap/shoulder belt system. These cases provide detailed documentation of the factors relevant to the question of windowshade performance (details not provided in larger data bases). However, while windowshade-equipped belts in the Safety Board's study were more likely to be worn with slack than were nonwindowshade lap/shoulder belts, there did not appear to be any direct relationship between this fact and the frequency or severity of injuries. 78/ When all front seat occupants wearing lap/shoulder belts equipped with a windowshade feature were compared to all front seat occupants wearing nonwindowshade lap/shoulder belts, no large differences in overall injury severity (MAIS) emerged. Neither did the two groups differ, overall, in the frequency of AIS 2 or greater head or facial injuries or frequency of fractured ribs, clavicle, or sternum.

Occupants of both groups were involved in similar types of accidents (angle of impact and Delta V), so differences were not masked by this factor. It could be hypothesized that slack would be most harmful in a frontal crash, but differences did not emerge when only frontal nonrollover crashes were examined.

76/ It should be noted that in the Safety Board investigators' view, even with slack in his lap/shoulder belt system, the driver was better off than if he had been unrestrained.
77/ Once again, though, Safety Board investigators believed that the misused belt system probably prevented more serious injuries.
78/ In considering this, several points should be remembered. First, slack cannot always be measured or determined. In windowshade-equipped cars, opening the door takes up all slack in the system, so it is difficult for investigators to reconstruct belt fit. Physical evidence of belt adjustment was not always present on the belt webbing. Second, the precrash track adjustment--how far forward the seat was on the track--and seatback angle could not be determined in many cases. Third, occupants' characteristics--age, sex, weight, seated height--and clothing may also have obscured differences in belt performance due to slack. Lastly, vehicle size may play a large role in determining how injurious slack will be, since vehicle size influences crash pulse. It may be that the effect of slack is masked by the larger size of windowshade-equipped domestic cars versus the nonwindowshade systems in smaller imports.

The same also held true when the Board compared cases of front seat occupants restrained by windowshade-equipped belts with slack to those restrained by nonwindowshade belts with no slack. Even with Delta V constant, few differences emerged, and those that did emerge involved small numbers of occupants.

Given the nonrandom nature of the Board's cases (cases to meet specific criteria) and the relatively small number of cases represented in the report, further research is clearly needed to determine whether windowshade-equipped belts, by their design, provide crash protection of statistically significant inferiority.

Rulemaking History of Windowshade-Equipped Belts.--Much of the debate over the years regarding windowshade-equipped belts has focused on the tradeoff between the perceived need to encourage belt use through improved "comfort and convenience" and the potential for associated loss in belt system effectiveness, depending on how manufacturers chose to improve "comfort and convenience." As one GM official explained, "We had to introduce a slight decrease in safety--to get more people to use the belts. It is kind of a trade-off." 79/

As early as 1970, the NHTSA considered amendments to FMVSS 208 to improve the "comfort and convenience" of seatbelts (35 FR 7187, May 7, 1970), but the first rulemaking proposal that specifically addressed the issue came in December 1976. The Advance Notice of Proposed Rulemaking discussed new seatbelt requirements "intended to increase their rate of usage and effectiveness . . . ." Vehicle-sensitive emergency locking retractors (ELRs) were proposed for lap/shoulder belts. The ANPRM recognized that these improvements had opened the door to "potential loss of seatbelt effectiveness that could result from the addition of comfort and convenience features" (41 FR 54961, December 16, 1976).

American manufacturers addressed the need for comfort and convenience by adding the "windowshade" device on ELR-equipped belts. In 1979, NHTSA issued rulemaking calling for the elimination of slack in the shoulder portion of the three-point belt (44 FR 77215, December 31, 1979), but the proposal was not enacted. Instead, in 1981, a "final" comfort and convenience rule was issued, permitting tension-relief devices such as windowshades, but requiring that the eventual testing of these systems be conducted with the shoulder belt at its maximum extension (46 FR 2064, January 8, 1981). This, of course, would have effectively eliminated windowshade devices, since the belts could not meet the crash injury protection criteria if they were tested when fully extended.

The effective date of the "final" rule was delayed several times. Furthermore, in early 1985, the NHTSA proposed that testing of windowshade belts be conducted, not with the shoulder position set at its fully extended position, but with only "the maximum amount of slack that is recommended . . . in the owner's manual . . ." (50 FR 14580, April 12, 1985). In comments to the docket, the Safety Board objected to this change in the proposed testing procedure, noting that many owners and passengers of "windowshade-equipped vehicles are not familiar with the proper adjustment of these belts," and questioning whether many owners and passengers are likely to read and follow the manual's instructions. Moreover, the Board pointed out, "Research has shown that it is possible inadvertently to introduce excessive slack. . . through normal movements

79/ Assistant Director of Automotive Safety Engineering, GM, interview with Cleveland Plain Dealer, cited in "Impact," Center for Auto Safety Newsletter, November-December 1986.

involved in operating a vehicle." The Board urged that "Dynamic tests of belts equipped with windowshade devices be performed with the windowshade adjusted for the maximum slack permitted by the system."

Later that year, however, the NHTSA announced its decision to require that the dynamic testing to be eventually required of manual lap/shoulder belts be conducted (in the case of windowshade-equipped belts) with only the amount of slack "recommended" by the manufacturer, even if a great deal more slack was possible in the system (50 FR 46056, November 6, 1985).

Recent Court Rulings on Windowshade-Equipped Belts.--The advisability of allowing windowshade-equipped lap/shoulder belts has emerged with renewed vigor as a topic of contention, due to a recent court ruling. The U.S. District Court in Akron, Ohio, ruled that such a belt system is inherently defective and was responsible for the death of an Ohio neurosurgeon who died of massive head and chest injuries after his 1979 Pontiac Grand Am collided head-on with a tree at 30-40 mph. The court awarded $800,000 to the widow on December 15, 1986, after testimony by some seatbelt experts that slack in the lap/shoulder belt allowed the doctor's head injuries to occur. GM denied that the windowshade feature played a part in the doctor's death: "Our analysis of the accident indicated that the comfort feature did not play any role in [the doctor's] death in this extremely severe impact." A representative from the American Seat Belt Council, a trade association representing seatbelt manufacturers, termed the case "a blatant misuse of a comfort device mandated by the public." 80/

In early 1987 in a Rhode Island Federal court, GM won a case involving the death of a 39-year-old man in 1984 that raised similar questions about windowshade-equipped belts. The Wall Street Journal also reports that GM has settled at least two other cases involving allegations about windowshade devices. 81/

Nonetheless, the Ohio court decision has added fuel to an ongoing discussion over the safety of windowshade-equipped belts. Some safety advocates argue that the reason for the windowshade design--to try to make a lap/shoulder belt more comfortable so more people will voluntarily wear the belt--has been superseded by the passage of State mandatory-use laws.

As pointed out earlier, there is no doubt that State mandatory-use laws have increased seatbelt use in the U.S. Furthermore, there is no evidence that measures adopted to increase the "comfort and convenience" of belts lead to significantly increased use; despite publicity campaigns to convince the public to wear seatbelts and the availability of the more "comfortable" windowshade-equipped belts, little increase in seatbelt use in the United States took place until the advent of State seatbelt-use laws. In contrast, buyers of European and Japanese cars, which do not have windowshade features in their belts, have not resisted wearing the belts. In the NHTSA's latest 19-city survey of restraint use, drivers of imported vehicles were observed to have higher safety belt usage rates than drivers of domestic vehicles (47.2 percent versus 29.2 percent). (Differences in the income and education levels between drivers of domestic and imported vehicles are also a factor in their higher use rates.)

80/ "Seatbelt Verdict Costs General Motors $800,000," Fuel Line, March 1987.
81/ Wall Street Journal, July 31, 1987.

CHILDREN AND LAP/SHOULDER BELT USE

Seatbelts were designed for adult use. Restraint use among child passengers increased with the passage of child passenger protection laws in all 50 States and the District of Columbia by 1985. The increase in restraint use was largely in terms of child safety seat or booster seat use since the laws typically applied only to children 4 years old and younger; however, many laws did permit use of a seatbelt in lieu of a child restraint if the child was older than 2 years. Restraint usage among children has further increased as States have passed mandatory seatbelt use laws. Older children are now being restrained. Hence, much of the recent increased use of child restraints has been in terms of increased seatbelt use among children past the toddler stage. 82/ 83/

National estimates of seatbelt use among child passengers are derived from the NHTSA's 19-city survey of restraint use, which in 1986 included eight cities in States with mandatory seatbelt use laws in effect for the entire year. Five additional cities in the survey were covered by such laws during the second half of 1986. Of the subteens (aged 5-12) surveyed in 1986, 30.2 percent were restrained by seatbelts compared to 24.7 percent in 1985 and 14.7 percent in 1984. Of the teenagers (aged 13-19) surveyed in 1986, 19.1 percent were wearing seatbelts compared to 12.7 percent in 1985 and 7.2 percent in 1984.

Although most children ride in the back seat, children wearing seatbelts are usually found in the front seat and almost all are seated in the right outboard position. 84/ Hence, the majority of seatbelts in use by children are lap/shoulder belts.

Parents who have a child who has "graduated" from a child safety seat or booster seat may wonder if lap/shoulder belts are effective and safe for children to wear. The Safety Board's cases, along with the results of other studies (many conducted in foreign countries where rear seat lap/shoulder belts are routinely available) suggest they are. Nevertheless, the Safety Board strongly recommends use of a child safety seat or booster for as long as possible in preference to a seat belt. A restraint especially designed for a child's body is always to be preferred over a seat belt which is designed for an adult's body.

Safety Board investigators collected data on 36 lap/shoulder belted children (aged 2-17) who were occupants of 28 case vehicles; half of the children were younger than 15 years old. With one exception, 85/ they were seated in the front seat and the majority were in the right front seating position. (See appendix C for a description of the age and injury outcome for lap/shoulder-belted child passengers in the Safety Board's investigation.)

The cases involving children were primarily frontal impacts and included a wide range of crash severity; those involving young children tended to be less severe in terms of Delta V than those involving teenagers. (Many of the teenagers were drivers.) A few of the accidents involved rollover or side impact.

82/ NHTSA, "Restraint System Usage in the Traffic Population," DOT HS 807 080, 1986 Annual Report.

83/ Belt use among toddlers (1-4 years) decreased between 1984 and 1986. In 1986, the NHTSA observers found 5.9 percent of all toddlers surveyed to be restrained by seatbelts, compared to 9.3. percent in 1985 and 7.4 percent in 1984. This decrease was a reflection of a 20-percent increase in child safety seat use.

84/ The NHTSA "Restraint System Usage in the Traffic Population," op. cit.

85/ One child was seated in the rear restrained by a lap/shoulder belt. See case 26.

Data on the age, weight, height, restraint use, and restraint fit combined with accident reconstruction and determination of probable contact points causing the child's injuries are rarely available in studies of child passengers. For instance, data for children wearing lapbelts, lap/shoulder belts, and diagonal belts often appear combined under the heading "children restrained by safety belts." Information on belt fit or routing and crash severity is almost always lacking. Although few in number, the Board's cases do provide these crucial data. In the cases investigated for this report, the Board found:

(1) No evidence that properly used lap/shoulder belts presented hazards to children. Specifically, the Board did not find that the shoulder portion of the lap/shoulder belt caused dangerous injuries to the neck or chest of children wearing a lap/shoulder belt correctly. No matter what the seated height of the child (some were only 3 years old), the shoulder strap did not cause anything worse than minor abrasions, provided the child was seated upright and not reclined in a seat. 86/

(2) Children in the Board's cases often wore the lap/shoulder belts improperly--the shoulder portion was misrouted or worn with slack, belts were shared, and in one case, the lap/shoulder belt was worn while the child was asleep in a reclined seat. (This particular misuse led directly to his death.) 87/

Properly worn lap/shoulder belts provide superior crash protection without the drawbacks of lapbelt use--such as causing head injury through the lapbelt's jackknife effect in frontal crashes or lapbelt-induced abdominal or spinal injuries, as documented in the Safety Board's study in 1986 and in numerous other studies. A case from this study dramatically illustrates the importance of the upper torso restraint provided to a child using a lap/shoulder belt.

In case 161, the lap/shoulder belted child passenger was in a 1978 Buick Estate wagon that was struck center front by a 1963 Chevrolet van. In the Delta V 28.9-mph crash, the Buick sustained extensive frontal damage and the front was deformed rearward. The adult driver of the Buick, restrained by a lap/shoulder belt, sustained moderate injuries to her head. A 6-year-old boy, seated in the right front and properly restrained by his lap/shoulder belt, received only minor injuries--lacerations and abrasions. In strong contrast, a 5-1/2-year-old boy seated next to him, in the center position, restrained by a lapbelt, received severe injuries, including a fractured skull from contact with the instrument panel.

Not only does a lap/shoulder belt provide upper torso restraint to a child, it spreads crash forces by contacting the occupant's body at three points--the sternum (chest) and at the right and left hips. The full force of restraint does not fall on the lower portion of the body, the child's vulnerable abdomen, but is absorbed over a wider area, including the shoulder and the chest. The diffusion of crash forces is probably to the child's advantage, since the anterior iliac crests, the hip anchor points needed for proper positioning of a lapbelt, do not develop until around age 10.

86/ The Safety Board did, however, investigate cases of improperly used lap/shoulder belts causing serious injuries.

87/ For cases involving children and misused belts, see cases 29, 111, 130, 131, 144A, 157, 191, 213, 214. See cases 130, 131, and 144A for slack. See case 216 for a fatal accident involving a reclined seat. This case was described in the chapter on misuse.

Some researchers have suggested that children need more load distribution than adults. (See appendix G.) If children do indeed require distribution of crash forces over their bodies to avoid serious injuries, the Board's finding that many of the children in its cases were restrained by misused lap/shoulder belts is disturbing. Without the upper torso restraint provided by a properly used lap/shoulder belt, crash forces will be concentrated on the abdomen and the upper body will be free to flail in all directions.

Misuse

More children than adults in the Board's investigations were restrained by improperly worn lap/shoulder belts. Approximately 1/3 of the child occupants in the study did not receive the full benefits of their lap/shoulder belts at the time of the crash because of the way they were wearing their belts. Nine of the 36 child occupants were grossly misusing their lap/shoulder belts: children shared a single belt, had the shoulder portion misrouted, either behind the back or under the arm, or wore a lap/shoulder belt with the seatback reclined. Still others wore their lap/shoulder belts with slack in the shoulder portion.

The injury consequences to the child depended on the mode of misuse and the dynamics and severity of the particular crash. Most, but not all, children were quite fortunate in that the crash forces were so low, below 15 mph, that the misuse made little difference.

Belt Sharing.--The Safety Board investigated one case (case 157) in which two 2-year-old boys shared a lap/shoulder belt. The driver had placed both of them in the right front bucket seat of the 1977 Plymouth Arrow, secured the lap portion of the three-point belt snugly around both of them, and then routed the shoulder portion behind both of their backs.

When the Plymouth impacted a 1985 Chevrolet S-10 pickup, right front to left front (Delta V 19.6 mph for the Plymouth), both children struck the instrument panel, receiving facial lacerations and abrasions. One received abdominal contusions from the lap portion of the belt as well. Safety Board investigators partially attributed the abdominal injuries sustained by the inboard passenger to loading caused by the other boy sharing the belt.

The Board does not know how often such belt-sharing occurs. Certainly, whether it is advisable to secure two children in one belt is a common question parents ask child safety advocates. As recently as 1984, the NHTSA stated, "If an emergency situation arises where there are more children than seat belts, two children can be secured within one belt." 88/

The Safety Board does not agree. No child or adult should ever share a seatbelt. If a child shares a belt with an adult, the child's body is likely to be crushed as the larger mass of the adult's body moves forward or sideways in a frontal angle or side impact. If the child shares a belt with another child, abdominal and head injuries that normally would not have occurred can result.

Crash tests performed at UMTRI have demonstrated the hazards associated with more than one child using the same seatbelt. 89/ The result can be a tremendous increase

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88/ "Child Safety Seats for Your Automobile," NHTSA, DOT HS 805 174, 1983.
89/ Weber, K. and Melvin, J.W., "Injury Potential With Misused Child Restraining Systems," SAE/NHTSA Child Restraint and Injury Conference Proceedings, San Diego, October 17-18, 1983.

in the injury severity to both occupants as they collide violently with one another. The heads and shoulders of the children can strike one another, and unusual loading of the pelvis can occur as one child impacts another. Proper fit, a crucial requirement of a lapbelt, which is what such a misrouted lap/shoulder belt becomes, is impossible; there is no way the lap portion can be properly positioned over the pelvic girdle of two children if they differ in size.

Shoulder Portion Behind Back.--The most common belt routing error--indeed the most common form of misuse by children in the Board's study--was placement of the shoulder harness behind the child's back. Such misuse essentially reduces the lap/shoulder belt to a lapbelt. This form of misuse may well be more prevalent among children than adults. Parents may route the shoulder strap behind child's back in an effort to "protect" the child from the shoulder strap.

This misuse mode puts the child in a lap-only belt. A lap belt can cause serious spinal, head, or abdominal injuries to a child, as discussed in the Board's lap belt report. In the Safety Board's cases, no child occupants sustained more than minor injuries attributable to this misrouting because most of these crashes were of low severity.

In only one crash did Delta V exceed 13 mph and that crash was quite severe--Delta V 35.6 mph. In this case, the 15-year-old right front passenger restrained by a misrouted belt did receive serious and severe abdominal injuries from the lap portion of the belt. Analysis of the seatbelt's performance is complicated, however, by the fact that her seat came off the track (but the belt remained secured).

Sometimes, the accident configuration made the misuse irrelevant. In case 29, for example, a 14-year-old girl had placed the shoulder portion of her belt behind her back, just as the adult driver of the vehicle had done. As their 1979 Pontiac Bonneville waited to make a left turn, they were rear-ended by a 1983 Chevrolet pickup truck. Safety Board investigators determined that the crash severity was a Delta V 28 mph for the Pontiac. At impact, both occupants of the Pontiac accelerated back into their seats, and the seatbacks collapsed rearward 40 degrees. The seat collapse absorbed most of the crash force and rebound was minor. Both occupants received minor injuries only (cervical strains). If, however, this crash had been a frontal impact of the same severity, the consequences of misrouting the lap/shoulder belt probably would have been quite marked. Upper torso restraint would have been needed in a frontal crash of that severity.

Even the frontal impacts were of low crash severity. In case 130, for example, the frontal crash was so minor--Delta V 10.5 mph--that the 3-year-old boy suffered few consequences from misusing the seatbelt. The 1982 Honda four-door station wagon in which he was riding ran off the road and struck right front into the left front of a parked 1969 Chevrolet Impala two-door car. The boy was seated in the right outboard position with the lapbelt portion of his three-point belt snug but the shoulder portion behind his back; his mother (the driver) had placed it there. His mother told Safety Board investigators that the boy was thrown forward and down at impact, striking his face on his legs. According to his mother, he received a minor nose bleed only. No further injury information is available. Once again, the child was fortunate that crash forces were so low. The Safety Board has investigated car crashes with similar age children restrained by lap-only belts, who, when involved in a more severe head-on crash, sustained much more serious injuries when they struck their legs with their head.

When questioned, this mother could give no reason why she had placed the shoulder portion of the belt behind the child's back. Other parents who restrained their children in lap/shoulder belts in this fashion cited fears that the shoulder strap was too close to the child's face or neck.

Certainly, many safety advocates have advised parents to misroute the lap/shoulder belts in this manner if the child is small. For example:

> If the child must sit in the front seat or if the outboard rear seats are equipped with shoulder belts, the shoulder strap should be placed behind the child unless you are certain that it will not make contact with the child's neck or face (AAA, "A Guide to Child Car Safety Seats," 1984, #3400).
>
> If the shoulder belt crosses the child's face or neck, the shoulder belt should be placed behind the child's back after the buckle has been fastened. Parents should check to make sure the child's head will not hit the dash in a crash or sudden stop. If this could happen, the child should be placed in the rear seat (NHTSA, "Child Safety Seats for Your Automobile," DOT HS 805174, 1983).
>
> Do not use the shoulder belt if it falls across the neck. Instead use the lapbelt only and fasten it snugly and as low as possible across a child's hips. The safest place to use safety belts for youngsters is in the rear seat of your car (NHTSA, "Child Safety In Your Automobile," 1987). 90/
>
> If an attached shoulder strap crosses the child's face or neck, place the shoulder belt behind the child's back, not under the arm, after the belt has been buckled (The University of North Carolina, Highway Safety Research Center, "it's Your Child's Life---But It's Your Decision," CTP 197-A).

The Safety Board does not agree for the reasons listed below.

First, as demonstrated in a variety of studies from Europe and Australia, where lap/shoulder belts are more commonly used by children, there is little evidence that small children (or short adults) are likely to be harmed by the shoulder portion of a lap/shoulder belt. 91/ 92/ 93/

90/ The NHTSA also distributes a handout on child passenger protection compiled by the American Academy of Pediatrics, which clearly states, "A shoulder belt that crosses the child's face and/or neck should be tucked behind the child's back." ("Protecting Your Child's Health," DOT HS 807 179, September 1987.)

91/ Lowne, R., et al., "The Effect of the UK Seat Belt Legislation on Restraint Use by Children," in Advances in Belt Restraint Systems: Design, Performance and Usage, Detroit (1984).

92/ Dejeammes, M., et al. "Exploration of Biomechanical Data Towards a Better Evaluation of Tolerance for Children Involved in Automotive Accidents" (SAE 840530), in Advances in Belt Restraint Systems: Design, Performance and Usage, (Detroit 1984).

93/ Norin, H. and Andersson, B., "The Adult Belt--A Hazard to the Child" Proceedings, 6th International Association for Automotive and Traffic Medicine Conference, Melbourne, 1977.

Second, misrouting the shoulder strap behind the back reduces the belt to a lap-only belt, which provides inferior crash protection compared to a lap/shoulder belt. A child in the front seat restrained in this manner can make violent contact with frontal and side interior components. (The Safety Board investigated cases involving 2-year-olds who struck the dashboard while lapbelted.) In addition, children have larger heads than adults do in proportion to the rest of their bodies; this makes them "top heavy" and more apt to jackknife than an adult. 94/ During a jackknife, the head gains momentum and strikes the dashboard or seat with increased force.

Third, rerouting the shoulder portion behind the back introduces the possibility of other serious lapbelt-induced injuries (intra-abdominal, spinal, etc.) as were documented in the Board's lapbelt study.

A lap/shoulder belt should be used correctly, just as a child safety seat must be used correctly to receive the full crash protection. 95/ Indeed, most of the children in misrouted belts should have been in properly used child restraints, and not in seatbelts at all. For example, in the Safety Board's cases, most of the children with the shoulder strap routed behind the back were younger than 4 years of age. These children belonged in child safety seats or toddler seats. (See figures 30 and 31.) Some researchers in the United States have suggested that children's bodies need specially designed restraint systems, not adult belt systems, up to age 10. 96/ 97/

Ways to Improve Shoulder Harness Fit

If parents are concerned about lap/shoulder belt fit for the child, they may be able to move the seat on its track to try to position the shoulder strap correctly. In some models of cars, primarily imports, the angle of the shoulder strap can also be adjusted at the roof line so that the belt can cross closer to the sternum. The child may also be placed in a booster seat to ensure correct positioning of the three-point belt.

94/ Herbert, D.C., and Cutting, D., "Crash Protection for Children After Their Third Birthday," Traffic Accident Research Unit, New South Wales, July 1978.

95/ The Safety Board has issued recommendations to States to collect data on the incidence of child restraint misuse in traffic accidents and to initiate programs. To educate parents about the need for proper use and installation of child restraints, some States have fulfilled the Board's requests; others are considering action. More gratifying has been the child safety seat industry response to the Board's recommendation that child safety seats be clearly labeled as to how the seatbelt should be routed through the restraint. For a listing of the Safety Board's recommendations regarding child restraints, see appendix A. See also Safety Study--"Child Passenger Safety Symposium: Ways to Increase Use and Decrease Misuse of Child Restraints," September 4, 1985. (NTSB/SS-85/03). Available through the National Technical Information Service, Springfield, Virginia 22161.

96/ Agran, P.; Dunkle, D.; and Winn, D., "Injuries to a Sample of Seat-Belted Children Evaluated and Treated in a Hospital Emergency Room," in press, Journal of Trauma.

97/ Burdi, A.R., and Huelke, D.F., "Infants and Children in the Adult World of Automobile Safety Design: Pediatric and Anatomical Considerations for Design of Child Restraints," American Society of Mechanical Engineers Third Biomechanical and Human Factors Division Conference, University of Michigan, June 12-13, 1969.

Adjustable Upper Anchorages.--Britain has a solution to the problem of poor shoulder harness fit for both children and adults. When that country passed a mandatory seatbelt-use law effective January 31, 1983, short people, particularly small females, complained of the uncomfortable position and seatbelt tension of the shoulder portion of their lap/shoulder belts in certain cars. Indeed, certain models of cars manufactured in the mid and late 70s, particularly those with the upper mounting points located in the roof rather than on the B-pillar, posed difficulties to good belt fit. The solution was:

> . . . to produce an accessory drop link which lowers the effective position of the upper mounting point to take the lie of the diagonal section away from the neck and down onto the clavicle. The requirements have been changed for new cars to allow adjustable upper anchorages to be built into the car, and these are appearing in some 1984/85 model year vehicles. 98/

Currently, a large number of new model vehicles sold in Britain have adjustable upper mounting points, but this is not a legislative requirement. Most new vehicles in Britain have at least one of the lower anchorages mounted on the seat.

GM currently provides adjustable upper anchorages in its 1988 four-door Pontiac LeMans, and Chrysler as well as others plan to offer this feature in the future. Fords marketed in Europe, but not in the United States, have adjustable upper anchors. (Many countries, Austria for example, require adjustable upper anchors.) In contrast, many foreign manufacturers have routinely offered adjustable upper anchorages. For example, all models except two marketed by Mercedes Benz have adjustable anchorages. Saab, in its 9000 Series, and Volvo, in all its models, plan to provide such anchorages in the future; in the meantime, Volvo offers dealer-installed adjustable anchors for certain models. BMW also offers a dealer-assisted adjustment feature and a feature that automatically adjusts the shoulder harness according to seat track location.

However, the absence of such adjustable upper anchorages in most American cars has meant parents continue to be concerned about the placement of the shoulder portion of a three-point belt relative to the child's face or neck; such concern can lead them to misroute the belt. Short adults also share the fear of neck injury from an ill-fitting shoulder harness and also may be tempted to misroute the belt. Such misrouting not only degrades the crash protection a lap/shoulder belt can offer, it introduces the possibility of belt-induced injuries where there need be none.

The Safety Board believes that lap/shoulder belts in passenger vehicles should provide the occupants with the opportunity to adjust the shoulder strap to an angle compatible with their body size. The NHTSA should work with manufacturers to explore the possibility of providing adjustable upper anchorages for lap/shoulder belts in new cars.

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98 Mackay, op. cit.

Figure 30.--A child this small belongs in a child restraint, not an adult seatbelt. Note the poor fit of the lap portion of the lap/shoulder belt even when the belt is worn properly routed.

Figure 31.--These photos portray only a small measure of the "squirming" such a small child can do.

PREGNANT WOMEN AND LAP/SHOULDER BELT USE

A pregnant woman traveling by automobile may wonder if she and her unborn child are better or worse off if she is restrained by a seatbelt. Motor vehicle travel for a pregnant woman presents a special set of problems, such as belt fit, distance from the steering wheel, etc., especially in cases of advanced pregnancy. Maternal death has been identified by some researchers as the leading cause of fetal death in motor vehicle crashes. 99/ 100/ In addition, researchers have reported several cases of minor maternal injuries involving blunt trauma, which resulted in severe trauma to the developing fetus. 101/ - 104/

If the seatbelt in question is a lap/shoulder belt, the Safety Board's cases indicate that the expectant mother should buckle up. Unlike a lapbelt, which places great pressure on the placenta and uterus and can rupture the uterus, 105/ 106/ especially if positioned incorrectly, a lap/shoulder belt spreads the load over a wide portion of the pregnant woman's body, providing restraint without concentrating pressure on the vulnerable abdominal area. The mother-to-be thus is provided with protection superior to a lapbelt or a diagonal two-point belt, both of which have been cited in studies as causing seatbelt-induced injuries to the uterus, placenta, and fetus. 107/ Sled tests using pregnant baboons restrained by various types of belts suggest that lap/shoulder belts provide improved protection to the placental, uterine, and fetal structures compared to a lap belt because crash forces are more diffused. 108/ 109/

Description of Cases

The Safety Board investigated six accidents involving pregnant women wearing lap/shoulder belts. (See appendix D.) All but one of the women were far along in their pregnancies, in the second or third trimester; three were 7 or more months pregnant.

99/ Crosby, W.; King, A.I., and Stout, L.C., "Fetal Survival Following Impact: Improved Protection with Shoulder Harness Restraint," American Journal of Obstetrics and Gynecology: 1101-1106, 1972.
100/ Rothenberger, D.; Quattlebaum, F.W.; Perry, J.F.; Zabel, J.; and Fischer, R.P., "Blunt Maternal Trauma: A Review of 103 Cases," The Journal of Trauma, 18: 173-179, 1978.
101/ Cumming, D.C. and Wren, F.D., "Fetal Skull Fracture from an Apparently Trivial Motor Vehicle Accident," American Journal of Obstetrics and Gynecology, 132:342-343, 1978.
102/ Ravengard, F. and Porter, C. V., "Traumatic Laceration of the Placenta," West Virginia Medical Journal, 76: 125-129, 1980.
103/ Stuart, G.C.E.; Harding, P.G.R.; and Davies, E.M., "Blunt Abdominal Trauma in Pregnancy," CMA Journal, 122: 901-905, 1980.
104/ Agran, Dunkle, Winn, and Kent, "Fetal Death in Motor Vehicle Accidents," in press, Annals of Emergency Medicine.
105/ Williams, J. S., "The Nature of Seat Belt Injuries," 14th Stapp Car Crash Conference, 1970, Paper No. 700896.
106/ Synder, R.G.; Crosby, W.; Snow, C.C.; Young, A.M.; and Hanson, P., "Seat Belt Injuries in Impact," Highway Safety Research Institute, University of Michigan, 1967.
107/ Synder et al., op.cit.
108/ Ibid.
109/ Crosby, W. and Costiloe, J.P., "Safety of Lap-belt Restraint for Pregnant Victims of Automobile Collisions," New Engiand Journal of Medicine, 284: 632-636, 1971

All of the women had their lap/shoulder belts properly routed, i.e., the shoulder portion of the belt was not behind her back or arm, and the lapbelt portion was snug and positioned below the abdomen, and in all but one case (case 38), the shoulder portion also was snug. (See figure 32 for an illustration of the correct way for a pregnant woman to position a lap/shoulder belt. It is important that the lap portion of the belt be placed under, not over, the belly.)

In most cases, 110/ both mother and fetus survived the crash, and the child subsequently was carried to full term and delivered successfully. Safety Board investigators also contacted the parents more than a year after delivery and found that no child had been diagnosed as impaired due to crash trauma sustained before birth.

Overall, expectant mothers fared well in the crashes investigated. In all but one of the six cases, the Safety Board investigators determined that the pregnant woman benefited from use of the lap/shoulder belt; in the one exception (case 137), the dynamics of the accident were such that the belt was able to provide little or no benefit. Since this was the only case in which the fetus was killed during the crash, a discussion of this accident follows.

A lap/shoulder belt, like any other restraint system, provides little or no protection if the user's seating area is penetrated. Case 137 was such an example. In this accident, a Toyota Celica, driven by a woman 8 months pregnant, pulled out into the path of a Ford pickup truck; the pickup struck the Toyota at the driver's door and penetrated 24 inches into the pregnant driver's seating area. She had been wearing her lap/shoulder belt correctly, and she survived but sustained critical injuries, including lacerated spleen and liver, fractured pelvis, and a ruptured uterus; many of the injuries were caused by the side intrusion. The fetus died from a crushed skull.

Some readers may be tempted to view this accident as a good example of the dangers of being held in place by a seatbelt when struck by a penetrating vehicle. It is not. This pregnant woman would not have been safer if she had been unrestrained. (See figure 33, which illustrates the amount of crush at her seating position.) In cases of severe maternal trauma, fetal death would not be unexpected. Considering the impact location, impact severity (Delta V 27.6 mph), and amount of intrusion, the pregnant driver probably would nave sustained injuries of similar severity if unrestrained. In the case just discussed, if the pregnant woman had been unrestrained, she would still have been flung violently to the left, striking the penetrated interior with her whole body. In these circumstances, Safety Board investigators believe her unborn child still could have been killed.

Driver's Position Presents Risks for Pregnant Women

All of the pregnant women studied were the drivers of the vehicles. In several of the Safety Board's cases, the pregnant driver was accompanied by an adult passenger in the front seat, and in almost all cases, the passenger was less seriously injured than the driver. (All but one of the cases were frontal crashes in which both front seat occupants experienced similar crash forces.)

110/ In case 137 and case 147, the woman survived the crash, but the fetus did not. In case 147, the fetus in all probability had died before the crash, and the mother was carrying a dead child.

Proper use of a safety belt: the lapbelt under the body and tight over the upper thighs; the shoulder belt over the shoulder and across the center of the chest (NEVER slip under the arm).

Figure 32.-The correct way to wear a lap/shoulder belt when pregnant. (Drawing courtesy of the American College of Obstetricians and Gynecologists.)

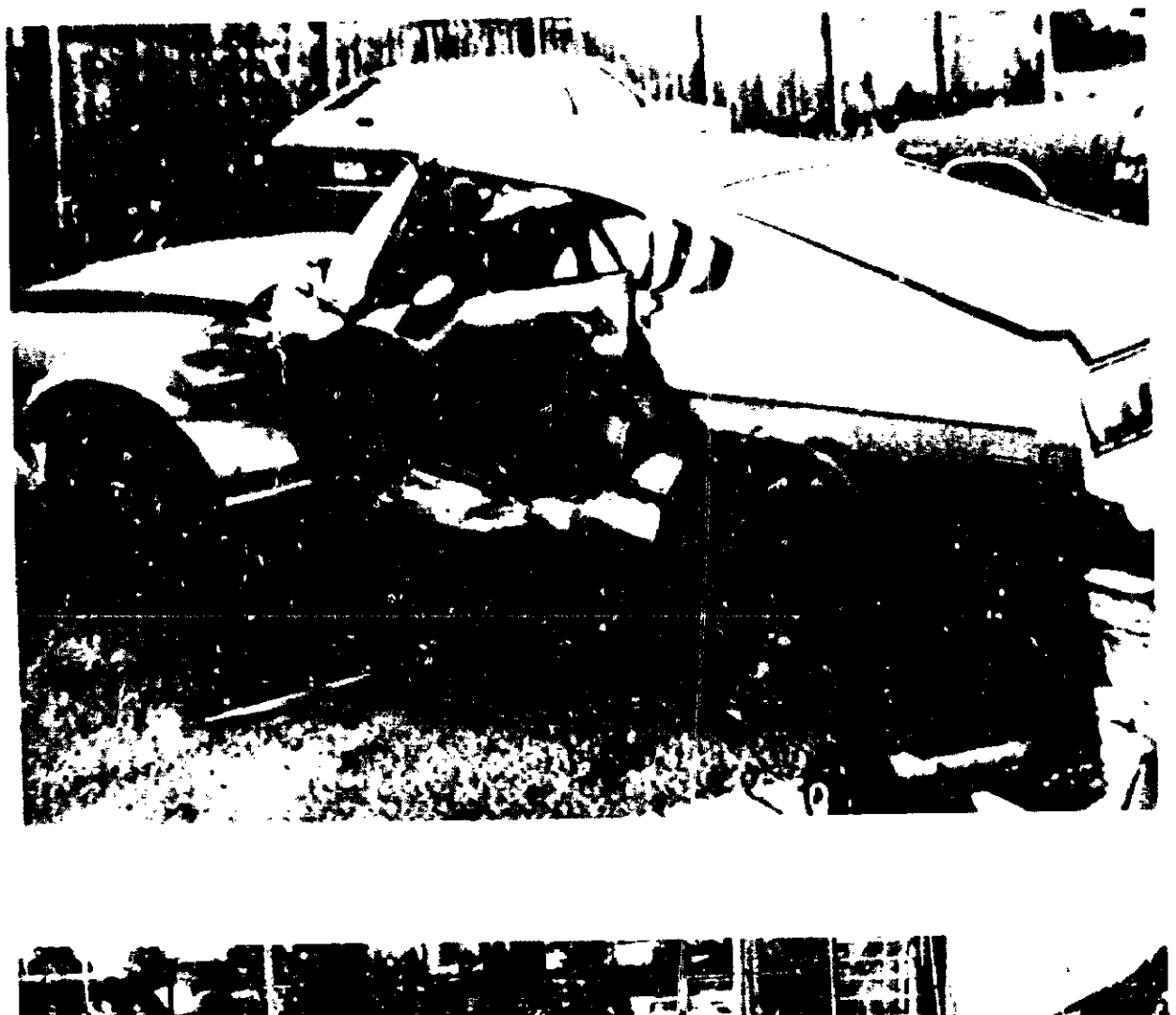


Figure 33.--Exterior views of the 1976 Toyota Celica in which the lap/shoulder-belted driver of the car, an 8-month pregnant woman, survived, but the fetus did not. Safety Board investigators determined that the violent side impact (Delta V 27.6 mph) at the driver's position and subsequent crushing of the area negated the protection offered by the lap/shoulder belt.

The driver's environment, specifically the steering wheel, poses additional problems for a pregnant woman. Occupant contact with the steering system has been identified by some researchers as the source of 1/4 of all harm to all car occupants in all crash modes; in a frontal crash, the involvement of the steering wheel as a source of injury is even higher. 111/ The pregnant driver is at special risk: as the size of her abdomen increases, she comes closer to the steering wheel, and there are practical limits to how far back she can move her seat and still have her feet reach the brake and gas pedals.

The driver's seating position thus has a built-in disadvantage in terms of both the expectant mother's and the fetus's safety. A researcher at the Pediatrics Department of the University of California at Irvine goes so far as to call the driver's seating position the "uterine crusher" position for an unrestrained pregnant woman:

> The pregnant woman in the vehicle, especially behind the steering wheel, is analogous to the on-lap position of the child, i.e., the "child crusher" position, resulting in the child being crushed between the adult and the dashboard. However, in these cases, the fetus is rarely injured, but rather the placenta sustains injury from maternal impact with the steering wheel, i.e., the " uterine crusher" position. 112/

Lap/shoulder belt use does not eliminate contact with the steering wheel, and crash forces obviously will determine just how dangerous the driver's seating position is for the pregnant driver. In case 127, for example, a driver in the eighth month of her pregnancy, wearing a lap/shoulder belt, spun out of control on an icy road and struck a bridge rail head-on. The crash was minor (Delta V 9.6 mph), and the only part of her body that contacted the interior of the vehicle was her abdomen, which struck the steering wheel. The driver complained of stomach pain following the crash but sustained no injuries and delivered a healthy child at full term. If this crash had been more severe, the fetus or placenta could have been injured by the steering wheel contact.

Stage of pregnancy also will affect the outcome. If the driver in case 147 had been more advanced in her pregnancy, the steering wheel could have caused more harm in the Delta V 32-mph head-on crash. She was only 12-13 weeks pregnant, hardly enough to enlarge her abdomen. As it was, investigators found the steering wheel of her car had been bent forward by body contact with 6 inches of deformation at the 6 o'clock position. The driver had been restrained by a lap/shoulder belt.

If the driver has introduced slack into the shoulder portion of the belt, the risk of injury is increased. Such was the case in case 58. The pregnant driver had introduced slack into the upper portion of her windowshade-equipped lap/shoulder belt and was bending down to the right to pick up something from the floor when she lost control of the car. Luckily, her position when the crash occurred was away from the steering column. In this head-on Delta V 25-mph accident, she was thrown forward toward the right side of the steering wheel and center dashboard. The driver complained of abdominal pain, but was uninjured and carried the child to full term.

111/ Wilson, R. A., "Improved Crashworthiness Independent of Belts or Airbags," Tenth International Technical Conference on Experimental Safety Vehicles, 1985.
112/ Agran et al., op. cit.

Unrestrained Drivers or Lapbelted Drivers at Increased Risk from Contact with Steering System

Clearly, pregnant drivers who are unrestrained or restrained by a lapbelt only are at even greater risk of injury from contact with the steering wheel. Unlike lap/shoulder-belted occupants, their upper torsos are not restrained. For a lapbelted driver in a frontal crash, the jackknifing over the lapbelt that occurs would bring a pregnant driver into even more violent contact with the steering system.

A study of all fetal deaths secondary to maternal involvement in motor vehicle accidents that occurred in Orange County during 1982-1985 suggests that unrestrained pregnant drivers are at considerable risk in a frontal crash. 113/ Nine fetal deaths connected with a passenger car crash were reported to the county coroner's office during that period. All of the pregnant women had been the drivers of the vehicles and all had been unbelted. The study found ". . . the mechanism of injury generally was impact with the steering wheel. In approximately 50 percent of the cases, other injuries to the victim, excluding injuries related to the pregnancy, were minor." Placental abruption was present in almost all of the Orange County cases.

Summary

In conclusion, in the cases investigated, the Safety Board found that lap/shoulder belt use improved the injury outcome for the pregnant occupants. Many of the pregnant women in the Safety Board's cases were in moderate to severe crashes, yet sustained minor injuries only. The crash outcome for the unborn children thus was also improved.

Nonetheless, regardless of restraint use/nonuse or type of restraint, many doctors caution that, as expressed by one doctor:

> Pregnant women involved in a motor vehicle crash should be closely monitored by medical personnel both immediately following the crash and throughout the remaining months of her pregnancy and subsequent delivery to ascertain whether the fetus was injured during the crash. The risks associated with pregnancy and the altered physiologic and anatomic conditions which occur during pregnancy must be considered by paramedics, emergency room physicians, obstetricians, trauma surgeons and neonatalogists. 114/

The Safety Board agrees with this cautious approach.

A pregnant woman should wear a lap/shoulder belt every time the vehicle is in motion. It is the best thing she can do to protect herself and her unborn child; both will benefit from the superior crash protection offered by the three-point belt. Indeed, the lap/shoulder-belted mother functions as the "child safety seat" for the unborn child.

113/ Ibid.
114/ Ibid.

Because of the special importance of upper torso restraint for pregnant occupants, the Safety Board emphasizes that a mother-to-be should never defeat the protection offered by her lap/shoulder belt by routing the shoulder harness behind her arm or back. In addition, pregnant women should be especially alert not to introduce slack into their three-point restraint system. The shoulder portion of the lap/shoulder belt should be as snug as possible across the chest, and the lap portion should be as snug and low as possible.

CONCLUSIONS

Highway fatalities account for more than 90 percent of all transportation-related deaths in the United States. More than 2/3 of the highway victims were occupants of passenger cars. Last year more than 24,000 passenger car occupants were killed and more than 2.5 million were injured.

Increasing the level of occupant protection in passenger cars is one of the most important steps this country can take to lower the number of transportation casualties. Since the vehicle always has a driver but other seating positions are not always occupied, drivers constitute the largest group of occupants killed or injured in crashes. Countermeasures aimed at protecting the front seat occupants--particularly the driver and right front passenger--have the greatest potential safety payoff.

One way to increase the level of occupant protection for the driver and right front passenger is for these occupants to wear the lap/shoulder belt (three-point belt system) available at their seating positions. Since January 1, 1968, the Federal Government has required that all cars newly manufactured for sale in the United States have lap/shoulder belts installed for the two front outboard seating positions (32 FR 2408, February 3, 1967). Indeed, this requirement was one of the first standards promulgated by the National Highway Safety Bureau, the predecessor of the NHTSA, when it was created in 1966 as part of the U.S. Department of Transportation. 115/ Before this, some car manufacturers had offered lap/shoulder belts as an option, but most provided only lapbelts for occupants.

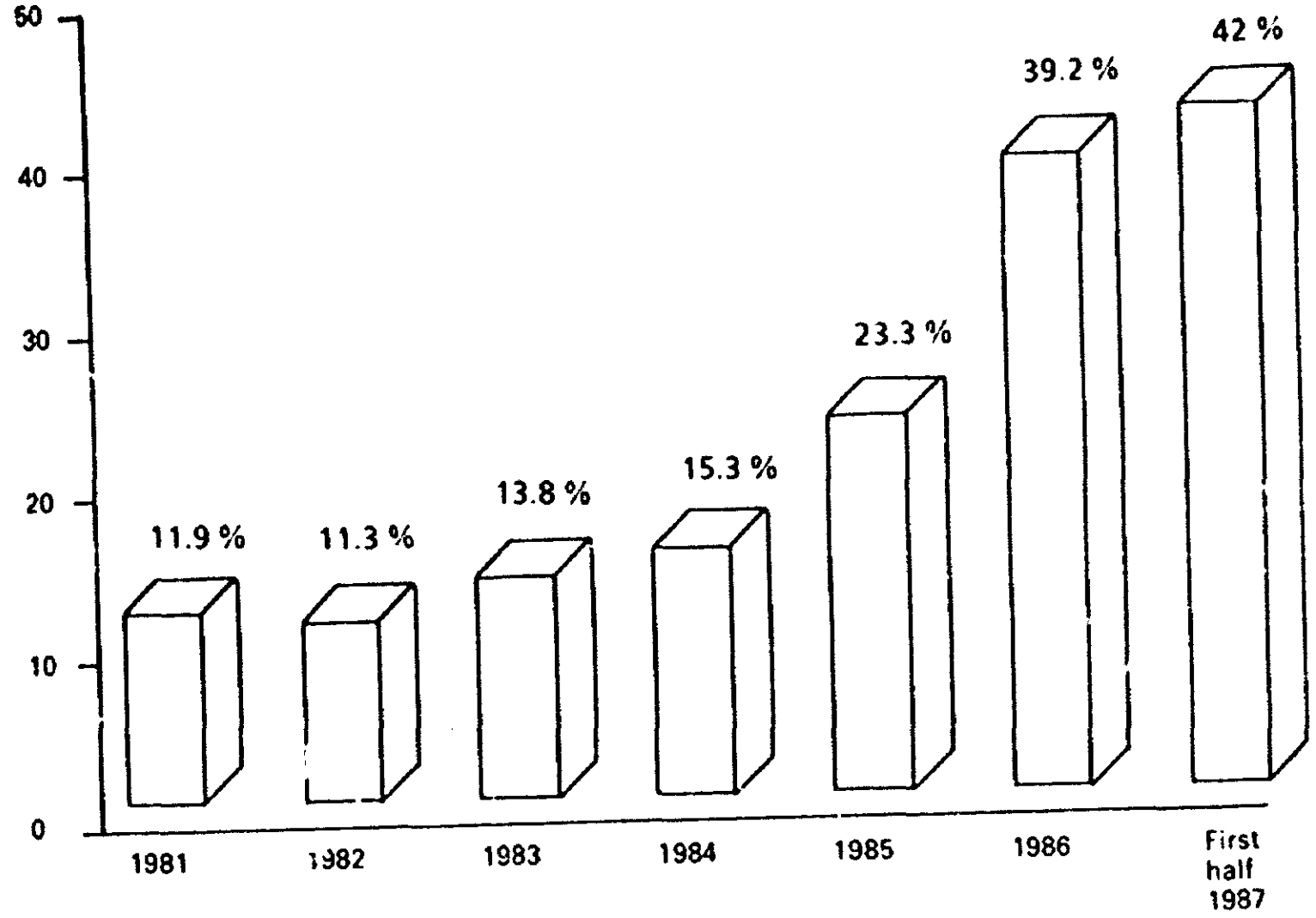
Today, manual lap/shoulder belts are standard equipment for the driver and right front passenger in most cars sold in the United States 116/; some cars are equipped with automatic two- or three-point belts or other passive restraints. In addition, lap/shoulder belts for the rear seat occupants are now starting to be offered in domestically made cars; many imports have had them as standard equipment for years.

Public awareness of the need to be restrained in an automobile increased dramatically in the 1980s and, combined with the passage of mandatory seatbelt-use laws in many States, have resulted in increased seatbelt use in the United States. More drivers wear their lap/shoulder belts than ever before. (See figure 34.)

To the Safety Board's knowledge, the NHTSA 19-city survey of occupant restraints is the only source of historical restraint-use data from which to extrapolate national belt-use trends. In 1983, 8 of the 19 cities were in States with mandatory seatbelt-use laws. Figure 34, based on the NHTSA's 19-city survey, shows how use rates were stagnant until the passage of belt-use laws. Nationwide, the actual percentage of drivers who wear their lap/shoulder belts is still unknown.

115/ Type 2 lap/shoulder belt assemblies were required to be installed at "each outboard passenger car seat position that includes the windshield header within the head impact area." (Docket No. 3, Notice 1, 31 FR 15212, 15220, December 3, 1966.) Other positions could meet requirements by a lap-only belt. MVSS 208 later was retitled FMVSS 208, "Occupant Crash Protection."

116/ Convertibles have traditionally been exempt; in these vehicles, lapbelts are all that are required.



Source: National Highway Traffic Safety Administration (NHTSA).

Figure 34.--Estimated percentages of drivers who are restrained, based on the NHTSA's 19-city survey.

Lap/shoulder belts clearly offer occupants of motor vehicles substantial protection in a wide variety of crashes. In the Safety Board's cases, which were all tow-away crashes, 80 percent of the 214 front seat occupants wearing properly routed lap/shoulder belts sustained only minor or moderate injuries or no injuries at all; 34 percent of these crashes exceeded Delta V 20 mph. In the Safety Board's cases, the injury-reducing effectiveness of lap/shoulder belt use during rollover accidents was particularly striking: in overturns of more than 360 degrees, many lap/shoulder-belted occupants sustained minor injuries only.

Furthermore, properly worn lap/shoulder belts provided crash protection without the introduction of serious or fatal belt-induced injuries of the type seen in the Safety Board's lapbelt study--that is, injuries induced by a properly worn belt that were more serious than the injuries to be expected if the occupant had been unrestrained at the time of the crash. This further supports the Safety Board's previous recommendations that lap/shoulder belts replace lap belts in the rear seats of passenger cars.

The Safety Board supports the passage of State mandatory lap/shoulder belt-use laws. Thirty-one States and the District of Columbia have enacted mandatory seatbelt-use laws. Lives have been saved as a direct result of this legislation, since use rates have increased substantially in several States with laws. This increase in belt use has had a corresponding beneficial effect on highway casualties.

To evaluate the impact of the laws, researchers at the Highway Safety Research Center at the University of North Carolina examined statistics in the 24 States and the District of Columbia which have had mandatory seatbelt-use laws in effect for more than a full year. 117/ They found that these States, as a group, 118/ had 6.6 percent fewer fatalities and 10 percent fewer serious injuries among front seat occupants than researchers thought they would have had without such laws. 119/ This, according to the North Carolina researchers, translated into a saving of 1,300 lives and 100,000 fewer serious injuries spread over the 25 jurisdictions since 1984. Greater gains could be realized, the researchers suggested, if enforcement of the laws were "tougher" and belt-use rates thus increased. The researchers also estimated that if all 50 States had had laws during the same period requiring motorists to buckle up, approximately 500 additional lives would have been saved.

Analysis conducted by the NHTSA estimated that, during 1985, mandatory seatbelt-use laws saved more than 250 motor vehicle occupants from crash-related deaths. 120/ (Eight States were used for this evaluation.) The DOT estimates some 1,500 lives have been saved by seatbelt-use laws since 1984 and 20,000 moderate to critical injuries avoided. 121/

As a result of this study, the Board made the following conclusions:

1. Properly used lap/shoulder belts can reduce the level of serious injuries or chance of death in a wide range of motor vehicle crash types and crash severities.

2. A properly used lap/shoulder belt provides good protection to both the pregnant woman and her unborn child and should be preferred over use of a lap-only belt. The lap/shoulder belt diffuses crash forces over a larger area of the mother's body and minimizes the possibility of placental or fetal injury.

3. The shoulder portion of a properly worn three-point belt, in the Safety Board's cases, was not a common source of serious injuries. Neck injuries, fractured ribs, sternum, or clavicle were rarely the most severe injury sustained by a lap/shoulder belted occupant. In the cases investigated, the Safety Board found that the shoulder portion of a lap/shoulder belt induced minor injuries to a child at worst, provided the child was not reclined in the seat.

117/ Campbell, B.J.; Stewart, J.R.; and Campbell, F.A., "1985-1986 Experience with Belt Use Laws in the United States," Highway Safety Research Center, University of North Carolina, under grant provided by Traffic Safety Now, September 1987.

118/ Use rates and the laws' success in reducing traffic fatalities varied widely among the 24 States examined, with traffic deaths actually increasing in three States (North Carolina, Missouri, and Nebraska) over forecasts. Limited enforcement was partially to blame in the North Carolina researchers' view.

119/ Between 1985 and 1986, traffic deaths increased in all States, but the increase was smaller in States with seatbelt-use laws: 2.4 percent compared to 8.4 percent in States without laws.

120/ Partyka, S., "Mandatory Belt Use Law Effects in 1985," Research Notes, National Center for Statistics and Analysis, NHTSA, February 1987.

121/ Burnley, J., U.S. Secretary of DOT, guest editorial in USA Today, December 1987.

4. The most common form of lap/shoulder belt misuse in the United States appears to be slack in the shoulder portion. Drivers aged 50 and older and female occupants have a higher incidence of this misuse, according to the NHTSA 19-city survey of restraint use.

5. The Safety Board's cases and a survey of Maryland drivers by the IIHS suggest that comfort clips are rarely used to introduce slack and that windowshade-equipped lap/shoulder belts are more frequently worn with slack than are belt systems without windowshade-equipped belts. Since most imported cars do not have windowshade systems, occupants of domestic cars are more likely to have slack in their belt systems than are occupants of imported cars.

6. The NHTSA crash test data suggest that the possibility for increasing slack in a windowshade-equipped lap/shoulder belt increases the chance of serious or fatal head injuries. Although the Safety Board's cases include examples of increased injuries due to the slack in a windowshade-equipped belt system, the cases as a whole do not demonstrate that occupants of windowshade-equipped cars are injured more often or more seriously than occupants of nonwindowshade-equipped cars.

7. Improper routing of the shoulder portion of the lap/shoulder belt seems to be a less common error than introduction of slack, but may be a more harmful error under some circumstances. Placing the shoulder portion of the lap/shoulder belt under the arm can have fatal consequences.

8. Teenage drivers and child passengers had the highest incidence of misrouted belts in the Safety Board's study. The most common error was placement of the shoulder portion of the belt behind the back. Such misuse has the potential for serious belt-induced injuries, and seriously degrades the protective capabilities of the lap/shoulder belt, reducing it to a lap-only belt with inferior crash protection.

9. Traveling with the seatback reclined diminishes the protection offered by a lap/shoulder belt and is potentially dangerous. The fatal injuries sustained by one lap/shoulder belted child in the study were due to this misuse.

10. The head and skull (excluding the face), followed by the upper torso, were the most common locations of the most severe injury sustained by lap/shoulder-belted front seat occupants; the abdomen was a distant third.

11. Lap/shoulder-belted drivers had a higher incidence of head or facial injuries, of moderate or worse severity, than similarly restrained right front passengers in the study.

12. Lap/shoulder-belted right front passengers more often fractured their ribs, clavicles, or sternums in crashes than did similarly restrained drivers. Such injuries, however, were rare and occurred less frequently than head injuries.

13. In the few cases (27 of 214) in which intrusion caused the most severe injury sustained by a lap/shoulder-belted occupant, the injury generally was quite severe and associated with fatal outcome. Six lap/shoulder-belted occupants died because of intrusion at their seating positions. Restraint can offer little protection in such circumstances.

RECOMMENDATIONS

As a result of this Safety Study, the National Transportation Safety Board made the following recommendations to the National Highway Traffic Safety Administration:

Revise publications on child passenger protection to eliminate the suggestion that parents, concerned about the relationship of the shoulder harness to the child's body, misroute the child's lap/shoulder belt, or that parents allow children to share a seatbelt. (Class II, Priority Action) (H-88-7)

Amend Federal Motor Vehicle Safety Standard 208 to require that windowshade-equipped lap/shoulder belts either be tested with the maximum amount of slack that can be introduced or that they be equipped with a pretensioner as part of the belt system to ensure, during a crash, the elimination of any slack introduced into the system prior to the accident. (Class II, Priority Action) (H-88-8)

Limit the angle of inclination allowable in reclining seats in passenger vehicles to no greater than the maximum angle that can safely be used with a lap/shoulder belt. (Class II, Priority Action) (H-88-9)

Evaluate the possibility of requiring an adjustable upper anchorage point for the shoulder portion of lap/shoulder belts in newly manufactured motor vehicles. (Class II, Priority Action) (H-88-10)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ JAMES L. KOLSTAD
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

March 1, 1988

APPENDIXES

APPENDIX A

SAFETY BOARD RECOMMENDATIONS REGARDING OCCUPANT RESTRAINTS

RECOMMENDATION: H-86-38
DATE OF ISSUE: August 8, 1986

The NTSB recommends that U.S. Manufacturers of Passenger Vehicles: Provide after market retrofit assemblies for passenger vehicles to convert Lap-Only belts systems at outboard positions to integrated, continuous loop, self-storing lap/shoulder belt system; make the availability of those retrofit systems widely known to vehicle owners and installation of them as simple and inexpensive as possible.

RECOMMENDATION: H-86-39
DATE OF ISSUE: August 8, 1986

The NTSB recommends that U.S. Manufacturers of Passenger Vehicles: Provide, on a voluntary basis, the newly manufactured passenger vehicles, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions.

RECOMMENDATION: H-86-40
DATE OF ISSUE: August 8, 1986

The NTSB recommends that U.S. Manufacturers of Passenger Vehicles: Cooperate with the National Highway Traffic Safety Administration in determining the technical feasibility of providing lap/shoulder belts at non-outboard seating positions of passenger vehicles, and work toward providing such systems in newly manufactured vehicles at the earliest practicable time.

RECOMMENDATION: H-86-41
DATE OF ISSUE: August 8, 1986

The NTSB recommends that Foreign Manufacturers of Passenger Vehicles: For any passenger vehicles with lap-only belts at outboard positions, provide aftermarket retrofit assemblies to convert these belts to integrated, continuous loop, self-storing lap/shoulder belt systems; make the availability of these retrofit systems widely known to U.S. vehicle owners and installation of them as simple and inexpensive as possible.

RECOMMENDATION: H-86-42
DATE OF ISSUE: August 8, 1986

The NTSB recommends that Foreign Manufacturers of Passenger Vehicles: Provide, on a voluntary basis, in newly manufactured passenger vehicles that do not already have them, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions.

RECOMMENDATION: H-86-43
DATE OF ISSUE: August 8, 1986

The NTSB recommends that Foreign Manufacturers of Passenger Vehicles: Cooperate with the National Highway Traffic Safety Administration in determining the technical feasibility of providing lap/shoulder belts at non-outboard seating positions of passenger vehicles, and work toward providing such systems at the earliest practicable time in newly manufactured vehicles sold in the United States.

RECOMMENDATION: H-86-44
DATE OF ISSUE: August 8, 1986

The NTSB recommends that the National Highway Traffic Safety Administration: Encourage manufacturers of passenger vehicles to provide aftermarket retrofit assemblies to convert lap-only belt systems at outboard positions to integrated, continuous loop, self-storing lap/shoulder belt system; urge manufacturers to make the availability of these retrofit systems widely known to vehicle owners and installation of them as simple and inexpensive as possible.

RECOMMENDATION: H-86-45
DATE OF ISSUE: August 8, 1986

The NTSB recommends that the National Highway Traffic Safety Administration: Require that lap/shoulder belt be installed at all outboard seating positions in newly manufactured passenger vehicles manufactured for sale in the United States; initiate rulemaking action to this end immediately.

RECOMMENDATION: H-86-46
DATE OF ISSUE: August 8, 1986

The NTSB recommends that the National Highway Traffic Safety Administration: Until such time as they are required to do so, encourage manufacturers of passenger vehicles to provide, on a voluntary basis in newly manufactured vehicles, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions.

RECOMMENDATION: H-86-47
DATE OF ISSUE: August 8, 1986

The NTSB recommends that the National Highway Traffic Safety Administration: Determine the feasibility of requiring that 3-point lap/shoulder belts be provided at every seating position in newly manufactured passenger vehicles manufactured for sale in the United States; if found technically feasible, undertake rulemaking to require such lap/shoulder belts.

RECOMMENDATION: H-86-48
DATE OF ISSUE: August 8, 1986

The NTSB recommends that the International Association of Chiefs of Police: Dissiminate information to your members on the possibility for serious head, spine, and internal injuries to motor vehicle crash victims who were using a lap be't; ensure that your members are aware that these injuries, particularly internal injuries by lap belt use, may not be apparent for some time, and that it may be prudent even for seemingly uninjured lap belt users to be provided early medical attention by physicians familiar with treatment of trauma.

RECOMMENDATION: H-86-49
DATE OF ISSUE: August 8, 1986

The NTSB recommends that Associations and Groups Concerned with Emergency Medicine: Through communication with your organization's members and with other medical personnel, disseminate informed guidance to those called on to treatmotor vehicle crash victims concerning the nature, severity, and appropriate handling of injuries that can be sustained by those using belt restraint systems. Ensure that emergency medical personnel receive training on the internal, head, and spine injuries that should be suspected in the case of crash victims who were using a lap belt, and the urgency of propre diagnosis and treatment. Encourage those emergency personnel who transport injured crash victims to relate accurate information to hospital emergency room personnel concerning the circumstances of the victim's involvement in the crash (seating location, use or nonuse of seat belt, type of belt used, etc.)

RECOMMENDATION: H-82-60
DATE OF ISSUE: December 7, 1982

The NTSB recommends that the Governors or Governors-Elect of Alaska, Arizona, Arkansas, Colorado, Georgia, Hawaii, Idaho, Indiana, Iowa, Louisiana, Maine, Maryland, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, Nevada, North Dakota, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Texas, Utah, Vermont, Washington, and Wyoming. Develop a statewide child passenger safety program including aggressive enforcement of laws requiring use of child safety seats, public information and education programs on their need and proper use, child safety seat loan or similar programs, and ongoing evaluation of such activities.

RECOMMENDATION: H-83-49
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the Governors and Legislative Leaders of Alaska, Idaho, Iowa, Louisiana, South Dakota, Texas, Utah, Vermont, Wyoming, American Samoa, Guam, Puerto Rico, and the Virgin Islands: Enact legislation requiring the proper protection of children traveling in motor vehicles, following as closely as possible the elements set forth by the National Transportation Safety Board in its Safety Study, "Child Passenger Protection Against Death, Disability, and Disfigurement in Motor Vehicle Accidents."

RECOMMENDATION: H-83-50, H-83-51
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the Governors and Legislative Leaders of states with child passenger protection laws, include as part of a statewide child passenger safety program, public information and education activities specifically aimed at combating misuse of child safety seats.

RECOMMENDATION: H-83-53
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the National Highway Traffic Safety Administration: Expedite the issuance of a final rule requiring that newly-manufactured vehicles under 10,000 pounds gross vehicle weight be equipped with tether anchorages or predrilled holes for the installation of such anchorages at all rearmost seating locations.

RECOMMENDATION: H-83-54
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the National Highway Traffic Safety Administration: Examine the consequences in accidents of nonuse and misuse of tether straps with safety seats requiring use of tether straps to determine whether such safety seats should be required to meet all the requirements of Federal Motor Vehicle Safety Standard 213, Child Restraint Systems, without the tether strap attached.

RECOMMENDATION: H-83-55
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the National Highway Traffic Safety Administration: Examine the incidence of nonuse and misuse of a tether strap with child safety booster seats when used in a rear vehicle seat and the consequences in accidents of such nonuse or misuse to determine whether the advantages offered by such booster seats outweigh the disadvantages.

RECOMMENDATION: H-83-57
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the National Highway Traffic Safety Administration: Conduct research and developmental crash testing to explore the feasibility and desirability of developing abdominal and neck load criteria, anthropomorphic dummies, and test procedures for child safety seats and other child restraint systems.

RECOMMENDATION: H-83-59
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the National Highway Traffic Safety Administration: Conduct crash tests and accident research to examine the use and accident performance of safety belts with children at various ages to better identify the benefits and limitations of such use.

RECOMMENDATION: H-83-60
DATE OF ISSUE: November 30, 1983

The NTSB recommends that Each Child Safety Seat Manufacturer: Review and revise instructions for use of child safety seats and other child restraint devices as needed to improve the clarity of the instructions and to establish specific height, weight, or other thresholds for required actions which depend on a child's physical characteristics (such as conversion between forward and rear-facing modes and harness rerouting on convertible child safety seats).

RECOMMENDATION: H-83-61
DATE OF ISSUE: November 30, 1983

The NTSB recommends that Each Child Safety Seat Manufacturer: Attach permanent labels to safety seats to identify correct safety belt routing points, harness routing points, and correct recline positions for use in motor vehicles.

RECOMMENDATION: H-83-62
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the International Association of Chiefs of Police: Coordinate and promote the development of training programs for state and local law enforcement officers on the use and misuse of child safety seats and safety belts for law enforcement and accident investigation purposes.

RECOMMENDATION: H-83-63
DATE OF ISSUE: November 30, 1983

The NTSB recommends that the International Association of Chiefs of Police: Promote the use of statewide traffic accident data systems to collect and analyze specific data identifying the use and misuse of child safety seats and safety belts in motor vehicles involved in accidents and the consequences of such use and misuse.

RECOMMENDATION: H-85-22
DATE OF ISSUE: November 12, 1985

The NTSB recommends that the Governors of the 50 States, 4 U.S. Territories, and the Mayor of the District of Columbia: Incorporate in state and local accident records information regarding use of restraints and injury, if any, of all child occupants (injured and uninjured) covered by the State Child Passenger Protection Law. Also, incorporate in accident report forms a category for child restraint use separate from any category for vehicle seatbelt use and record whether the child restraint was used properly or improperly, and the mode of misuse.

RECOMMENDATION: H-85-23
DATE OF ISSUE: November 12, 1985

The NTSB recommends that the National Highway Traffic Safety Administration: Revise fatal accident reporting system data forms to include the categories "Child Restraint--Used Properly" and "Child Restraint--Used Improperly," along with "Child Restraint--Unknown if used properly."

RECOMMENDATION: H-85-24
DATE OF ISSUE: November 12, 1985

The NTSB recommends that the National Highway Traffic Safety Administration: Revise National Accident Sampling System Data forms to record additional information on the type of misuse, specifically harness errors, vehicle seatbelt routing errors, improper positioning of the child restraint, as well as tether nonuse or misuse.

RECOMMENDATION: H-85-25
DATE OF ISSUE: November 12, 1985

The NTSB recommends that the National Highway Traffic Safety Administration: Encourage states to conduct workshops for local police precincts and state police on child restraints and their proper use and installation.

RECOMMENDATION: H-85-26
DATE OF ISSUE: November 12, 1985

The NTSB recommends that the National Highway Traffic Safety Administration: Conduct special training for National Accident Sampling System Accident Investigation teams on the types of the child restraints in use, the ways they are misused, and field investigation techniques.

APPENDIX B

INDEX TO SAFETY BOARD CASES INVOLVING ADULTS RESTRAINED BY MISROUTED/SHOULDER BELTS

Case No.	Seating Position	Age	Belt Routing/ Fit	Injury Severity (MAIS)	Vehicle	Accident Type and Severity
153	Driver	18	Shoulder portion under arm	Moderate	1984 Honda Civic 2-door	Right Front (D.V. not calculable)
19	Driver	32	Shoulder portion under arm	Moderate	1984 Toyota Tercel	Left front Delta V 10.2 mph
76	Driver	24	Shoulder portion under arm	Minor	1974 Ford Pinto Station-wagon	Head-on Delta V 15 mph
92B	Driver	51	Shoulder portion under arm	None	1980 Jeep Cherokee 4-door Station-wagon	Left front Delta V 6.8 mph
215	Right front	24	Shoulder portion under arm	Critical (fatal)	1981 Datsun 2-door	Frontal Delta V 29.3 mph
192	Driver	27	Shoulder portion behind back	Critical	1985 Nissan Pickup	Right Front Delta V 35.9
29	Driver	65	Shoulder portion behind back	Minor	1979 Pontiac Bonne-ville	Rear impact Delta V 28 mph

Case No.	Seating Position	Age	Belt Routing/ Fit	Injury Severity (MAIS)	Vehicle	Accident Type and Severity
117	Driver	66	Shoulder portion under arm	Minor and AIS-7 facial injuries	1979 Ford LTD 4-door	Right front Delta V 28.5 mph
100A	Driver	33	Shoulder portion under arm	Minor	1982 Chevrolet	Head-on Delta V 11.1 mph
189	Right front	62	Possible misuse: shoulder portion under arm	Moderate	1978 Mercury Monarch	Frontal Delta V 37.6 mph

*See cases 130, 131, 144A, 157, 191, 111, and 29, which involve children with misrouted belts. Case 195 may have involved an adult with misrouted 3 point belt. Case 138 involves a misrouted passive belt.

APPENDIX C

INDEX TO SAFETY BOARD CASES INVOLVING CHILDREN, AGE 2-17, WEARING LAP/SHOULDER BELTS (BY AGE)

Case No.	Description of Accident	Age of Child	Seating Position	Belt Use	Injuries to Child	Comments
157	Frontal (DV 19.6 mph)	2 2	Sharing right front passenger position (bucket-seat)	Sharing one lap/shoulder belt with shoulder portion placed behind back	Minor injuries sustained by both children	
130	Frontal (DV 10.5 mph)	3	Right front passenger	Shoulder portion placed behind back	Unknown if injured. No doctor's exam but mother reported child thrown forward and down at impact, striking head on knees; nose bleed	
131	Frontal (DV 11.7 mph)	3	"	"	Minor	
144A	Frontal (DV 10.8 mph)	3	"	"	Minor	
132	Frontal (DV 10.6 mph)	4	"	Proper	Uninjured	
183	Left side impact (DV 18.1 mph)	4	"	Proper	Minor	

Case No.	Description of Accident	Age of Child	Seating Position	Belt Use	Injuries to Child	Comments
161	Frontal (DV 28.9 mph)	6	Right Front	Proper	Minor	Compare outcome of lapbelted child seated next to him
140	Right side (DV 13.7 mph)	7	Right front	Uncertain; slack in lap portion	Minor	
216	Frontal (DV 30 mph)	7	Right front	Belt worn while seat	Serious (Fatal): a next injury of unknown severity proved fatal	Reclined seat made belt fit very poor
148	Right front (DV not calculable)	8	Right front	Proper but belt webbing severed in crash	Severe: fatal injuries, belt compromised, and seatback deformed forward due to unrestrained back seat passenger	Belt severed so no statement as to effectiveness possible
26	Left right (DV 32.2 mph)	8	Left rear	Proper	Minor	
82	Left side (DV 21.1 mph)	11	Right	Proper	Minor	
105	360° Rollover (DV not calculable)	12	Right front	Uncertain	Minor	
69	Frontal (DV 18.3 mph)	13	Right front	Proper	Minor	
111	Frontal (DV 9.8 mph)	13	Right front	"	Minor	

Case No.	Description of Accident	Age of Child	Seating Position	Belt Use	Injuries to Child	Comments
29	Rear impact (DV 28.0 mph)	14	Right front	Shoulder portion placed behind back	Minor	Driver also routed shoulder portion of his belt behind back. Rear impact minimized consequences
26	Left front (DV 32.2 mph)	14	Right front	Proper	Serious	See 8-year-old also restrained by 3 pt in same car
50	360° Rollover (DV not calculable)	15	Right front	Proper	Moderate	
114	Frontal (DV 22.7 mph)	15	Driver	Proper	Minor	
149	Frontal (DV 14.3 mph)	15	Driver	Proper	Uninjured	
191	Frontal (DV 35.6 mph)	15	Right front	Shoulder portion placed behind back	Critical	Seat came off track
160	Frontal (DV 21.0 mph)	15	Driver	Excess slack in shoulder portion	Moderate	
89	Left side (DV 11.5 mph)	16	Driver	Proper	Uninjured	

Case No.	Description of Accident	Age of Child	Seating Position	Belt Use	Injuries to Child	Comments
106	Frontal (DV 24.6 mph)	16	Driver	Proper	Minor	
129	Frontal (DV 15.0 mph)	16	Right front	Proper	Uninjured	
206A	Frontal (DV 6.1 mph)	16	Driver	"	"	
179	Frontal (DV 27.1 mph)	16	Driver	Proper	Minor	See 17-year-old front passenger. Compare outcome of lapbelted passenger
50	360° Rollover (DV not calculable)	17	Driver	Uncertain	Minor	
97	Frontal (DV 23.0 mph)	17	Driver	Proper	Minor	
114	Frontal (DV 22.7 mph)	17	Right front	Proper	Minor	See 15-year-old driver
129	Frontal (DV 15.0 mph)	17	Driver	Proper	Uninjured	See 16-year-old right front passenger
132	Frontal (DV 10.6 mph)	17	Driver	Uncertain, probable excessive slack in shoulder portion	Minor	See 4-year-old right front passenger

Case No.	Description of Accident	Age of Child	Seating Position	Belt Use	Injuries to Child	Comments
136	Frontal (DV 9.C mph)	17	Driver	Proper	Uninjured	
111	Frontal (DV 9.8 mph)	17	Driver	Shoulder portion placed under arm, with slack	Moderate	
179	Frontal (DV 27.7 mph)	17	Right front	Proper	Minor	

APPENDIX D

INDEX TO SAFETY BOARD CASES INVOLVING PREGNANT OCCUPANTS WEARING LAP/SHOULDER BELTS

Old Case No.	Type of Accident and Severity	Seating Position of Pregnant Occupant	Term of Pregnancy	Type of Restraint Used	Belt Fit	Injuries: Maternal	Injuries: Fetal	Outcome
33	Frontal DV 17 mph	Driver	7 mos	Lap/Shoulder Belt (continuous loop with ELRs & freesliding latchplate)	Proper	Minor: Neck abrasion & contusion right knee. Complained of sharp pains in left side	None	Fetus carried full term, delivered healthy infant
58	Frontal DV 28 mph	Driver	5 mos.	Lap/Shoulder Belt (continuous loop, cinching latchplate, ELR with windowshade)	Slack in shoulder portion; driver was bending down to pick up item on floor at time of crash; lap portion snug	Undefined closed head and minor injuries; fractured finger, lacerated lip and chin	None	Fetus carried full term, delivered healthy infant
74	Frontal DV 21 mph	Driver	5 1/2 mos.	Lap/Shoulder belt (continuous loop, ELR with windowshade and locking latch-plate)	Proper: lap portion low and snug on hips, shoulder portion adjusted so palm of hand could be inserted	Minor: Contusion of lower left arm, strained abdominal muscles; complained of soreness in neck and abdomen	None	"
112	Frontal DV 9 6 mph	Driver	8 mos.	Lap/Shoulder belt (continuous loop, ELR with windowshade and cinching latchplate)	Proper: both lap and shoulder portions snug	None; complained of stomach pain	None	"
137	Left side impact at driver's position. DV 27.0 mph (24 inches of crush into driver's compartment)	Driver	8 mos	Lap/Shoulder belt (dual ELR retractors, sewn-in latchplate, comfort clip)	Proper: both lap and shoulder portions snug	Critical: ruptured uterus, lacerated liver and spleen, tear in vaginal wall, head injuries	Fractured Skull	Fetus died; Mother survived
147	Head-on (DV 32.2 mph)	Driver	12-13 weeks	Lap/Shoulder belt (continuous loop, ELR, freesliding latchplate)	Proper: both lap and shoulder portions snug	Moderate: fractured tibia lacerated right knee, fractured foot, laceration on left elbow, abrasion of lower abdomen	Not known	Woman did not know she was pregnant until hospital admittance. Was diagnosed as "missed abortion"; fetus probably died before crash.

APPENDIX E

INDEX TO SAFETY BOARD CASES INVOLVING PASSIVE RESTRAINTS

(Case No.)	Seating Position	Age	Maximum Injury	Restraint	Vehicle	Accident Config.
Automatic Belts						
104	Driver	23	Serious	2 pt diagonal belt	1980 VW Rabbit 2-door	Left side (DV 9.4 mph) w. deformation
209	Driver	34	Serious	2 pt diagonal belt (not using available manual lap belt)	1985 Toyota Cressida 4-door	Head-on (DV 36.9 mph)
115	Driver	35	Serious	2 pt diagonal belt (not using available manual lap belt)	1982 Toyota Cressida station-wagon	Frontal (DV 33.4 mph)
96	Driver	21	Minor	2 pt diagonal belt	1979 VW Rabbit 2-door	Head-on (DV 26 mph)
96	Right front passenger	21	Serious	2 pt diagonal belt	1979 VW Rabbit 2-door	Head-on (DV 26 mph)
138	Driver	26	Minor	Misrouted 2 pt diagonal belt (worn under arm)	1982 VW Rabbit 2-door	Left front (DV 25.3 mph)
Air Bags						
210	Driver	46	Moderate	Airbag only (Available manual lap/ shoulder belt not used)	1985 Ford Tempo	Left side, then head-on (DV not calculable)
213	Driver	38	Minor	Airbag with manual lap/ shoulder belt	1985 Ford Tempo	Head-on (DV 11.8 mph)
194	Driver	32	Minor	Airbag with manual lap/ shoulder belt	1985 Ford Tempo	Frontal (DV 6.3 mph)
193	Driver	22	Minor	Airbag with manual lap/ shoulder belt	1985 Ford Tempo	Head-on (DV 19.9 mph)

APPENDIX F

INDEX TO SAFETY BOARD CASES INVOLVING CHILD RESTRAINTS

(Case No.)	Seating Position	Age	Maximum Injury	Restraint	Accident Config.
154	Left rear	1	None	Child safety seat	Head-on (DV 15 mph)
163	Right rear	1	Minor	Child safety seat	Frontal (DV 22.1 mph)
71A	Right front	4	Minor	Booster seat (w. lap/shoulder belt)	Head-on (DV 14.1 mph)
44	Right rear	3	Minor	Child safety seat	720° rollover
"	Left rear	10 mos	Unspecified "minor injuries" AIS-7	Child safety seat	"
72	Left rear	3	None	Child safety seat	Right front (DV not calculable)
144A	Right rear	9 mos	Minor	Child safety seat	Head-on (DV 12.9 mph)
82	Left rear	4	Moderate w. AIS-7 head injury	Booster seat (w. lap belt)	Left side (DV 21 mph)
"	Right rear	5	Minor	Booster seat (w. lap belt)	"
106	Right front	8 mos	None	Child safety seat (rear-facing)	Frontal (DV 22.9 mph)
33	Right front	1	Minor	Child safety seat	Frontal (DV 17 mph)
5	Right front	5	None	Booster seat (w. lap/shoulder belt)	Head-on (DV 10.8 mph)
182	Center rear	5 mos.	Serious	Misused child safety seat (improperly installed)	Frontal (DV 33.6 mph)

See also Case 132. A 2-weeks-old infant restrained by an infant seat was in a non-case vehicle involved in a right side impact. The infant was uninjured.

APPENDIX G

CHILDREN ARE NOT MINIATURE ADULTS

Impact tolerances differ from adults, distribution of body mass is different (influencing body kinematics and injury), injury thresholds to various parts of the body change with the child's age, etc. -- all factors which make studies of adult restraint use of questionable validity when applied to children. Children, as a group, vary widely by age categories, and even within one age category can be quite disparate, i.e., one 13-year-old male may have a body far closer to that of an adult than another slower maturing 13-year-old male.

Below are the anatomical considerations related to seat belt configuration in three age groups as determined by a California pediatrician.

Infant/Toddler (0-3 years). These children have a proportionately larger head size and a higher center of gravity compared to the older children. Internal chest and abdominal organs are less protected by overlying bony structures and muscles. In motor vehicle crashes, these children tend to undergo rotational movement, become airborne more easily and move head first toward a site of impact.

School aged child (4-9 years). During these growth years, the center of gravity moves toward the umbilicus, thus reducing the "top-heaviness" evident in the younger age group. Nonetheless, the iliac crests are not adequately developed at this age so as to serve as a lap belt anchor point. And, proper upright seated posture is difficult to maintain secondary to lordosis in this age group The seat belt tends to slide up and lie over the abdomen.

The adolescent (10-14 years). The physical characteristics of this age group are more like that of an adult. By the age of 10, the anterior iliac crests are adequately developed to serve as anchor points for the lap portion of the belt. In addition, upright seated posture can be maintained.

Source: Phyllis Agran, M.D.,M.P.H.;
Debora E. Dunkle, Ph.D.; and Diane G. Winn, R.N., M.P.H., "Injuries to A Sample of Seat-Belted Children Evaluated and Treated in a Hospital Emergency Room," paper to be published in the Journal of Trauma,

APPENDIX II

GLOSSARY OF INJURY AND SEATBELT TERMS

This glossary briefly defines certain terms, as they have been used in this study and its appendices, that may be unfamiliar to the reader. Many of them refer to highly complex objects or processes; the definitions here are not intended to be exhaustive discussions of all aspects or nuances of these terms. Some of the definitions are based on Dorland's Illustrated Medical Dictionary (W.B. Saunders Co., 1981; 26th ed.); others are based on Johannessen and Vos, The Changing Shape of Seat Belt Systems (SAE 820796) and on Moffatt et al., Diagnosis of Seat Belt Usage in Accidents (SAE 840396).

For a fuller understanding of the anatomical parts referred to in the case summaries, consult the anatomical drawings reproduced from Dorland.

ABDOMINAL FASCIA. Fibrous tissue forming part of the inner investing layer of the abdominal wall.

ANTERIOR. Situated in front of or in the forward part of an organ, toward the head end of the body.

AUTOMATIC LOCKING RETRACTOR (ALR). A retractor (see definition, below) that allows belt webbing to be withdrawn and then rewound, but will not permit a second withdrawal until the webbing is almost completely rewound. ALR's are most commonly seen in lap/shoulder belts with two retractors and in rear seat lap belts. The user pulls the lap belt out to a length greater than required, then latches it. The ALR rewinds the slack and then locks securely. These began appearing in American cars around Model Year 1968.

AVULSION. The tearing away of a part of a body structure.

BRAIN STEM. The stemlike portion of the brain connecting it with the spinal cord.

CERVICAL. Pertaining to the neck.

COMMINUTED. Broken or crushed into small pieces, as a comminuted fracture.

COMPRESSION FRACTURE. A fracture produced by compression (for example, a fracture of vertebrae)

CONTINUOUS LOOP. The most common type of lap/shoulder belt system in U.S. passenger cars today. One end of the lap belt is fixed to the vehicle, near the door sill, without a retractor; a continuous webbing extends across the occupant's lap, through a latch plate (either cinching or free-sliding), then up across the shoulder to a guide assembly or to an ELR. The lap belt length (snugness) must be manually adjusted by pulling webbing through the latchplate. The retractor is supposed to adjust the snugness of the shoulder belt portion automatically (perhaps affected by operation of any tension relief device in place).

CONTUSION. Bruise; injury of a part without a break in the skin.

DELTA V. Instantaneous rate of speed change at impact.

ECCHYMOSIS. A small hemorrhagic spot in the skin or mucous membrane, forming a nonelevated, rounded or irregular, blue or purple latch.

EDEMA. The presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body; usually applied to demonstrable accumulation of excessive fluid in the subcutaneous tissues.

EMERGENCY LOCKING RETRACTOR. A retractor (see definition, below) that allows the webbing to be withdrawn and rewound freely, except when the retractor is caused to lock by vehicle acceleration, rapid webbing withdrawal, or some other non-manual system.

HEMOPERITONEUM. An accumulation of blood in the peritoneal cavity.

HEMOTHORAX. A collection of blood in the pleural cavity (thorax).

INFARCTION. An area of necrosis (dead tissue) in an organ caused by a cut-off in blood supply.

LACERATION. A torn, ragged, mangled wound.

LAPAROTOMY. Surgical opening of the abdomen.

LATCHPLATE (or "tongue"). The flat metal plate attached to one end of the belt webbing and extending inside the other part of the buckle. It usually has a hole through it or notches in its dies, which engage in the buckle when it is latched. (moffatt)

Le FORT I FRACTURE. A horizontal segmented fracture of the supporting bone of the upper teeth, in which the teeth are usually contained in the detached portion of the bone.

Le FORT II FRACTURE. Unilateral or bilateral fracture of the supporting bone of the upper teeth, in which the body of this bone is separated from the facial skeleton and the separated portion is pyramidal in shape; the fracture may extend through the body of the bone down the midline of the hard palate, through the floor of the orbit, and into the nasal cavity.

Le FORT III FRACTURE. A fracture in which the entire maxilla (supporting bone for the teeth) and one or more facial bones are completely separated from the brain case.

LIGAMENT. A band of fibrous tissue that connects bones or cartilages, to support and strengthen joints; a double layer of peritoneum extending from one visceral organ to another.

MANDIBLE. The bone of the lower jaw, the largest and strongest bone of the face.

MAXILLA GINGIVA. The gums of the upper teeth.

MESENTERY. A membranous fold attaching various organs to the body wall. When used alone, the term usually signifies the peritoneal fold attaching the small intestine to the dorsal body wall.

PARACENTESIS. A surgical puncturing of a body cavity to remove fluid (by aspiration).

PARIETAL (bone). One of the bones of the side of the head (see drawing of skeleton).

PERISTALSIS. The muscle movement by which the intestines move their contents.

PNEUMOTHORAX. An accumulation of air or gas in the pleural cavity.

POSTERIOR. Situated in back of, or in the back part of.

PULMONARY CONTUSION. Bruising of the lungs.

RETRACTOR. A device for storing part of the seat belt webbing by rolling it up.

RETROPERITONEUM HEMATOMA. A localized collection of (clotted) blood in the space behind the peritoneum (the membrane lining the abdominopelvic walls and covering the viscera).

SCAPULA. The shoulder blade (see drawing of skeleton).

SEPSIS. Infection.

SEROSA. Any serous membrane. (Deserosalization is a separation of serosa from the organ or part of the body to which it had been connected.)

SUBARACHNOID HEMORRHAGE. Intracranial hemorrhage into the subarachnoid space.

SUBDURAL HEMATOMA. Accumulation of blood in the subdural space (intracranial). In the severe acute form, both blood and cerebrospinal fluid enter the space through laceration of the brain and a tear in the arachnoid (a membrane within the brain), adding subdural compression to the direct injury to the brain. In the chronic form (a gradual process, occuring weeks after the injury), only blood effuses into the subdural space through rupture of the bridging veins, usually due to closed head injury.

SUBLUXATION. A partial dislocation.

SUBMARINING. A possible event during some crash decelerations, in which belted occupants slide downward and forward, resulting in the lap belt being repositioned above the iliac crests and over the abdominal area; it may also be possible for the same results to occur by a process involving the lap belt being pulled up past the iliac crests. Submarining is not a well-understood concept and some researchers have concluded it rarely if ever occurs.

TENSION RELIEF DEVICE. A device for reducing the tension in the shoulder belt portion of a lap/shoulder belt. The most common forms are the "comfort clip," a small clip positioned on the belt webbing to limit its ability to be taken up into the retractor, and the so-called "windowshade" device. In the latter device, by extracting webbing, pausing or rewinding slightly, then extracting slightly again, the locking mode of the retractor is triggered but with slack in the shoulder belt. The slack mode is supposed to be overridden automatically by some operation such as opening the occupant's door.

TRANSECTION. A division by cutting transversely, a cross-section cut.

TRAUMATIC THROMBOSIS. Formation of coagulated blood in a part following an injury.

TYMPANIC MEMBRANE. The membrane separating the middle from the external ear.

ULNAR STYLOID PROCESS. Part of the inner, larger bone of the forearm, on the side opposite that of the thumb

VEHICLE SENSITIVE RETRACTOR. A type of emergency locking retractor (see definition above) that locks when the vehicle tilts or when it changes velocity sharply in any direction.

WEBBING SENSITIVE RETRACTOR. A type of emergency locking retractor (see definition above) that lockes when the webbing is suddenly withdrawn from the retractor, as in the early phase of a crash, but does not lock when the webbing is withdrawn slowly (normal use). (Webbing sensitive ELRs are required by European regulation; European retractors also include the vehicle sensitive feature as well.)

APPENDIX I

SEVERITY MEASUREMENT

ABBREVIATED INJURY SCALE

Motor vehicle occupant injuries were coded in the Board's safety study according to the 1983 Abbreviated Injury Scale (AIS). 1/ Injuries are described in the text of case summaries in terms of the maximum (MAIS) level injury sustained by an occupant. Hence, if an individual sustained two AIS 3 injuries, one AIS 2, and seven AIS 1 injuries, the individual is described as receiving an MAIS 3 injury.

A University of Michigan study substantiated that approximately 98 percent of multiply injured persons would be properly assessed using most severe injury as an index. 2/ Description of all the injuries, however, appears in the case summaries in Volume 2.

The AIS codes used in the study were:

AIS Code	Description	Examples
1	Minor	Bruises, abrasions, superficial lacerations (less than 2 inches on face or 4 inches on body, provided they do not extend into subcutaneous tissue), fractured finger, sprained wrist
2	Moderate	Deep laceration, mild concussion, head injury with amnesia about accident and no neurological damage, fractured clavicle, sprained knee, fractured foot, fractured ulna
3	Serious	Fractured femur, dislocated hip, brain swelling, contused bladder, fractured pelvis, crushed forearm, hand amputation, head injury with prior unconsciousness with neurologic deficit
4	Severe	Ruptured spleen, amputation of leg above knee, brain hematoma less than 100 cc
5	Critical	Pulmonary artery laceration, complete spinal cord lesion (quadriplegia or paraplegia), ruptured liver, unconscious more than 24 hours or penetrating skull injury, brain hematoma more than 100 cc
6	Maximum injury, virtually unsurvivable	Torso transection, massive skull crush, spinal cord crush with total transection C-3 or above, crushed brain stem
7	Injured, unknown severity	Insufficient information is available or outcome rather than injury is described, i.e. arm trauma, closed head injury, kidney injury
9	Unknown if injured	Medical report states "redness over eye" or "suspicion of---", or no information is available on accident outcome for the individual

1/ AIS is a standardized, universally accepted system for assessing impact injury severity by coding individual injury codes. The first AIS was published in 1971 under sponsorship of a joint committee of the American Medical Association, the American Association for Automotive Medicine, and the Society of Automotive Engineers. Since 1973, the American Association for Automotive Medicine has been the parent organization.

2/ Huang, L.C., and March, J.C., "AIS and Threat to Life," Proceedings, American Association for Automotive Medicine 22; 242-254, 1978.

CRASH SEVERITY MEASUREMENT

The severity measure used in the Safety Board's cases is Delta V, considered by most crash researchers the best single measure of collision severity. Delta V as used in these investigations is the instantaneous rate of speed change undergone by a vehicle at impact. The Delta V estimations were generated primarily from measurements of damage sustained by the crash-involved vehicles. These measurements, of both the location and extent of structural deformation, along with the vehicles' weights, were entered into the CRASH 3 1/ computer program, through which they could be compared against the known results of crashes staged and documented over the past several years. This computer program analyzes such parameters as vehicle structural rigidity, force vectors with respect to vehicle center of mass, and the influence of individual vehicle weights. The result is a computer-generated estimate of the speed change acting on the crash vehicles at impact. While the program result is recognized as an estimate, the use of CRASH allows a uniformity of case study interpretation which could not be achieved by other commonly used investigative methods.

1/ CRASH stands for Calspan Reconstruction of Accident Speeds on the Highway. The program was developed with funding from the U.S. Department of Transportation as an "accident investigation aid aimed at achieving accuracy and uniformity in the interpretation of physical evidence from traffic accidents."

APPENDIX J

TABLES SHOWING MISUSE DATA FROM NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION'S 19-CITY SURVEY OF RESTRAINT USE, 1986, and INSURANCE INSTITUTE OF HIGHWAY SAFETY SURVEY OF MARYLAND DRIVERS, 1987

The most comprehensive data on the rate of misuse among U.S. lap/shoulder belt wearers comes from the NHTSA 19-city survey of restraint use conducted during January-June 1986 (11,528 vehicles with restrained drivers). The survey found that 2.9 percent of drivers wearing lap/shoulder belts misused them. Misuse was apportioned as follows: 1.6 percent: shoulder portion under arm; 0.6 percent: shoulder portion behind back; 0.8: loose.

Other findings included:

- Overall misuse decreased slightly as car model became more recent.
- Shoulder belt misuse was higher among females than among males (3.6 percent versus 2.5), due mainly to the difference in underarm use.
- Misuse was highest among those age 50 and older (4.9 percent): they favored underarm use. Drivers under 20 also favored underarm use (3.6 percent).
- Drivers of domestic vehicles were much more likely than drivers of imported cars to wear the shoulder portion of their belts loosely, "probably due to windowshade design," according to NHTSA.

Tables from the NHTSA study follow:

Driver shoulder belt misuse by age group

Age Group	Base	Percent Misused: Under Arm	Behind Back	Loose	Total Percent Misused
Under 20	812	1.8	0.5	0.6	2.9
20-24	3,894	1.5	0.4	0.7	2.6
25-49	24,294	1.3	0.5	0.7	2.5
50 or over	8,193	1.7	0.9	1.3	4.9
Total	37,193	1.6	0.6	0.8	3.0

Driver shoulder belt misuse by driver gender

Driver Gender	Base	Percent Misused: Under Arm	Behind Back	Loose	Total Percent Misused
Male	21,115	1.2	0.5	0.8	2.5
Female	16,078	2.1	0.6	0.9	3.6
Total	37,193	1.6	0.6	0.8	3.0

Driver shoulder belt misuse by vehicle size for all model years

Vehicle Size	Base	Percent Misused: Under Arm	Behind Back	Loose	Total Percent Misused
Subcompact	5,503	1.5	0.3	0.4	2.2
Compact	4,095	1.7	0.4	1.0	3.1
Intermediate	1,834	1.8	0.6	1.4	3.8
Full Size	440	2.5	1.4	1.4	5.3
Total	11,872	1.6	0.5	0.8	2.9

Driver shoulder belt misuse by vehicle make for all model years

		Percent Misused			
Vehicle Group	Base	Under Arm	Behind Back	Loose	Total Percent Misused
Domestic	7,431	1.8	0.6	1.3	3.7
Import	4,441	1.3	0.2	0.1	1.5
Total	11,872	1.6	0.5	0.8	2.9

Driver shoulder belt misuse by vehicle size for all model years

		Percent Misused			
Vehicle Size	Base	Under Arm	Behind Back	Loose	Total Percent Misused
Subcompact	5,503	1.5	0.3	0.4	2.2
Compact	4,095	1.7	0.4	1.0	3.1
Intermediate	1,834	1.8	0.6	1.4	3.8
Full Size	440	2.5	1.4	1.4	5.3
Total	11,872	1.6	0.5	0.8	2.9

Driver shoulder belt slack by vehicle manufacturer for all model years

		Percent Misused			
Vehicle Group	Base	Under Arm	Behind Back	Loose	Total Percent Misused
AMC	122	1.6	0.0	0.0	1.6
Chrysler	774	2.2	0.3	0.6	3.1
Ford	1,838	1.9	0.6	1.8	4.3
GM	4,697	1.7	0.6	1.2	3.5
VW	462	2.4	0.6	0.0	3.0
Toyota	1,151	1.7	0.4	0.1	2.2
Datsun/Nissan	714	0.6	0.1	0.1	0.8
Honda	762	1.1	0.0	0.1	1.2
Other Imports	1,352	1.1	0.1	0.1	1.3
Total	11,872	1.6	0.5	0.8	2.9

More recent data was collected by the Insurance Institute for Highway Safety (IIHS) and published in a paper, "Improper Shoulder Belt Use by Maryland Drivers," written by Michael Ciccone and JoAnn Wells, June 1987. Excerpts from this study follow:

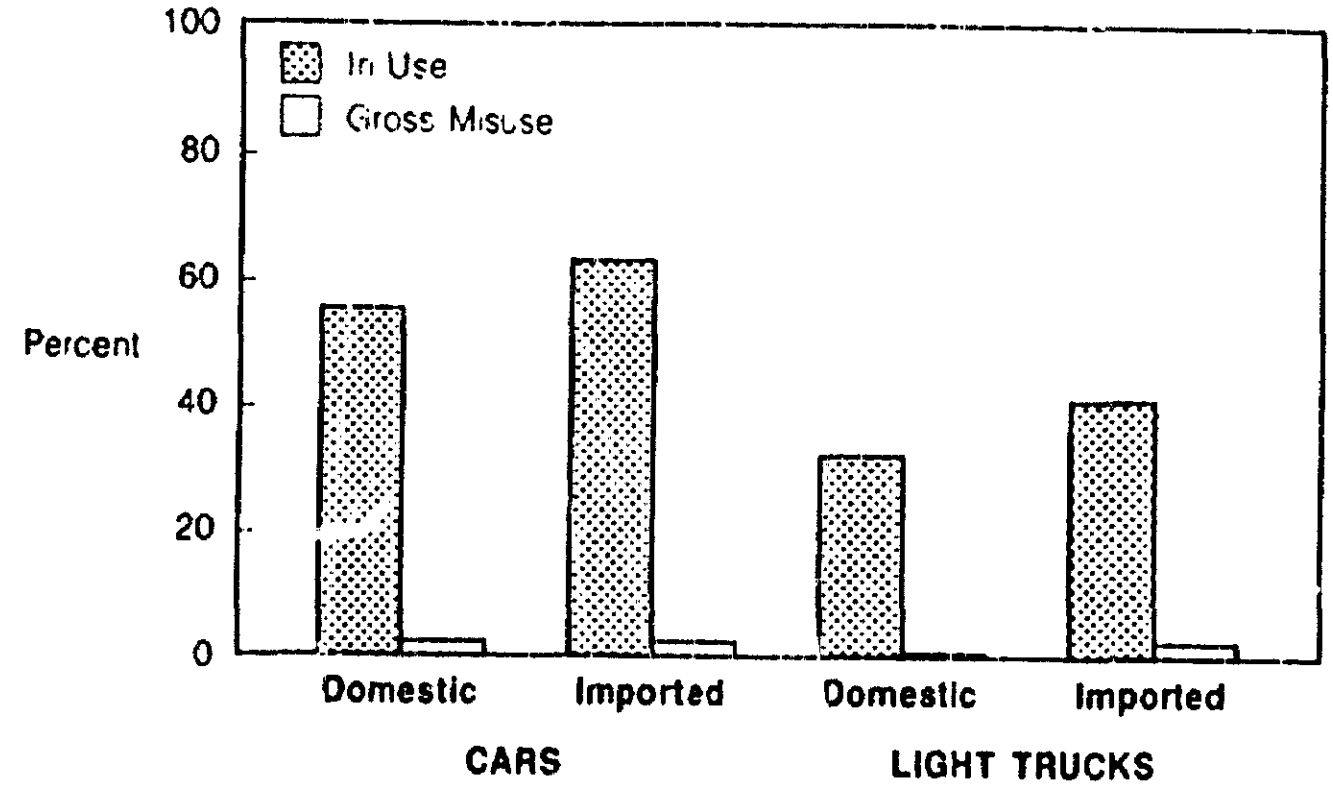
> The IIHS study was undertaken to more clearly determine the types and frequency of improper shoulder belt use, with particular emphasis on belt slack, in a mandatory seat belt use state. Motion picture films of drivers approaching stop signs in Maryland were analyzed by a trained panel to ascertain belt use and misuse. Over half of the drivers of 1974-1987 model vehicles were observed to be belted. Slack in shoulder belts was the most common type of misuse and was much more prevalent among drivers of domestic cars than among those of imported cars. For restrained drivers of domestic cars, 27 percent had 1 to 2 inches of slack in their belts, and 8 percent had 3 or more inches. In imported cars, only 5 percent of belted rivers had 1 to 2 inches of slack, and none had 3 or more inches. The window shade slack mechanism, found only in domestic vehicles, was most often associated with the slack.

A study in Switzerland by Niederer, Walz, and Zollinger (1977) of 410 restrained vehicle occupants who suffered severe or fatal injuries in 304 crashes identified excessive belt slack as an important contributor to the injuries in a subset of 54 frontal crashes with little or no passenger compartment intrusion. Other crash investigators (NHTSA, 1985; States, Huelke, Dance, and Green, in press) have shown that improper routing of the shoulder belt under the arm can result in severe or fatal injuries to crash-involved vehicle occupants. The lower rib cage and abdomen cannot withstand strong loading by the belt, and liver, lung, heart, or spinal cord damage results. In contrast, a properly worn shoulder belt transmits the crash loads to the clavicle, shoulder, and sternum, which are far more capable of withstanding these stresses (States et al., in press).

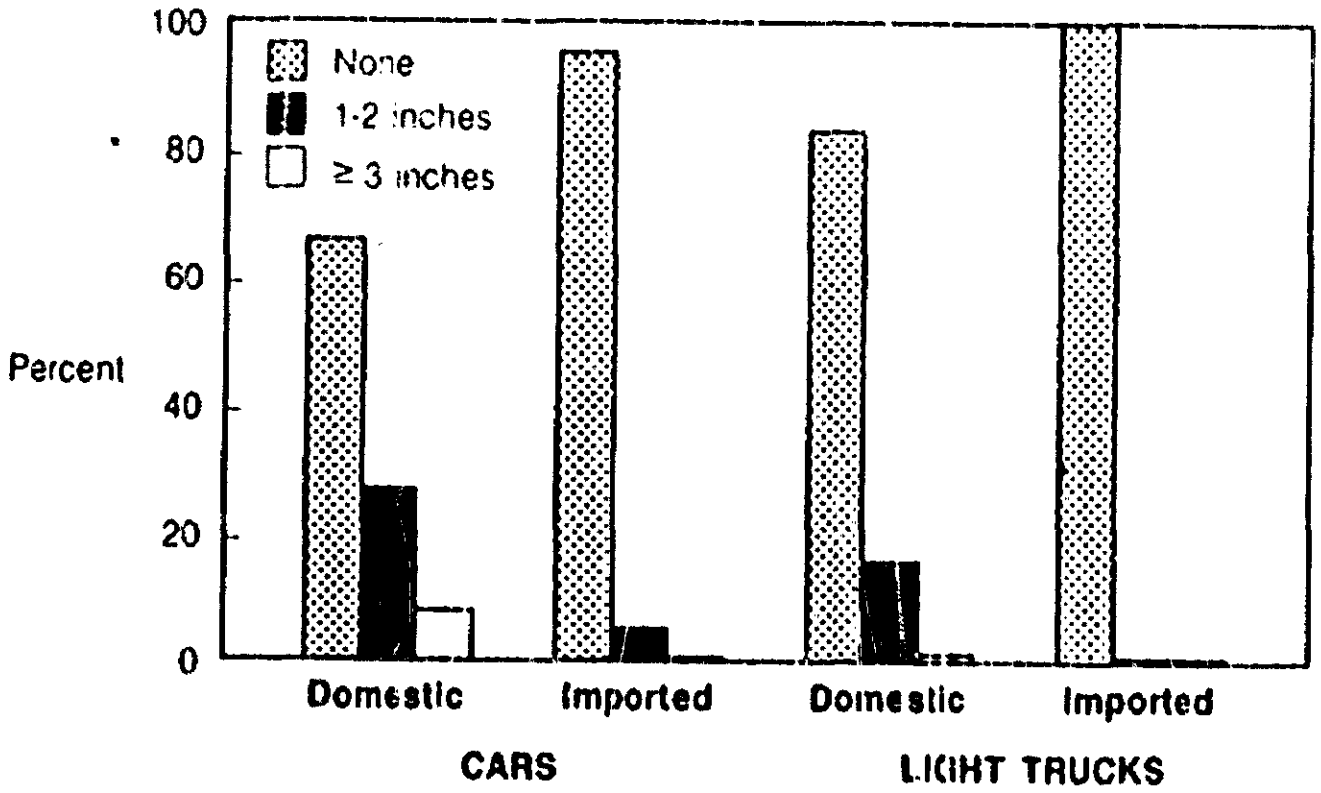
Surveys of seat belt use by the California State Automobile Association (1986), Bowman (1987), and Wagenaar, Molnar, and Businski (1987) have included estimates of the frequency of improper belt routing. However, belt slack was either considered in an informal manner (only obvious slack was noted) or was ignored altogether. The present study was undertaken to determine more clearly the types and frequency of imroper shoulder belt use, with particular emphasis on belt slack. The study was conducted in Maryland, a state with a belt use law. It has been suggested that when belt use is mandatory, some people who wear belts only because it is required will do so improperly, resulting in a higher rate of improper use among belt wearers than when seat belt use is voluntary (Williams and O'Neill, 1979).

Tables from the IIHS study follow:

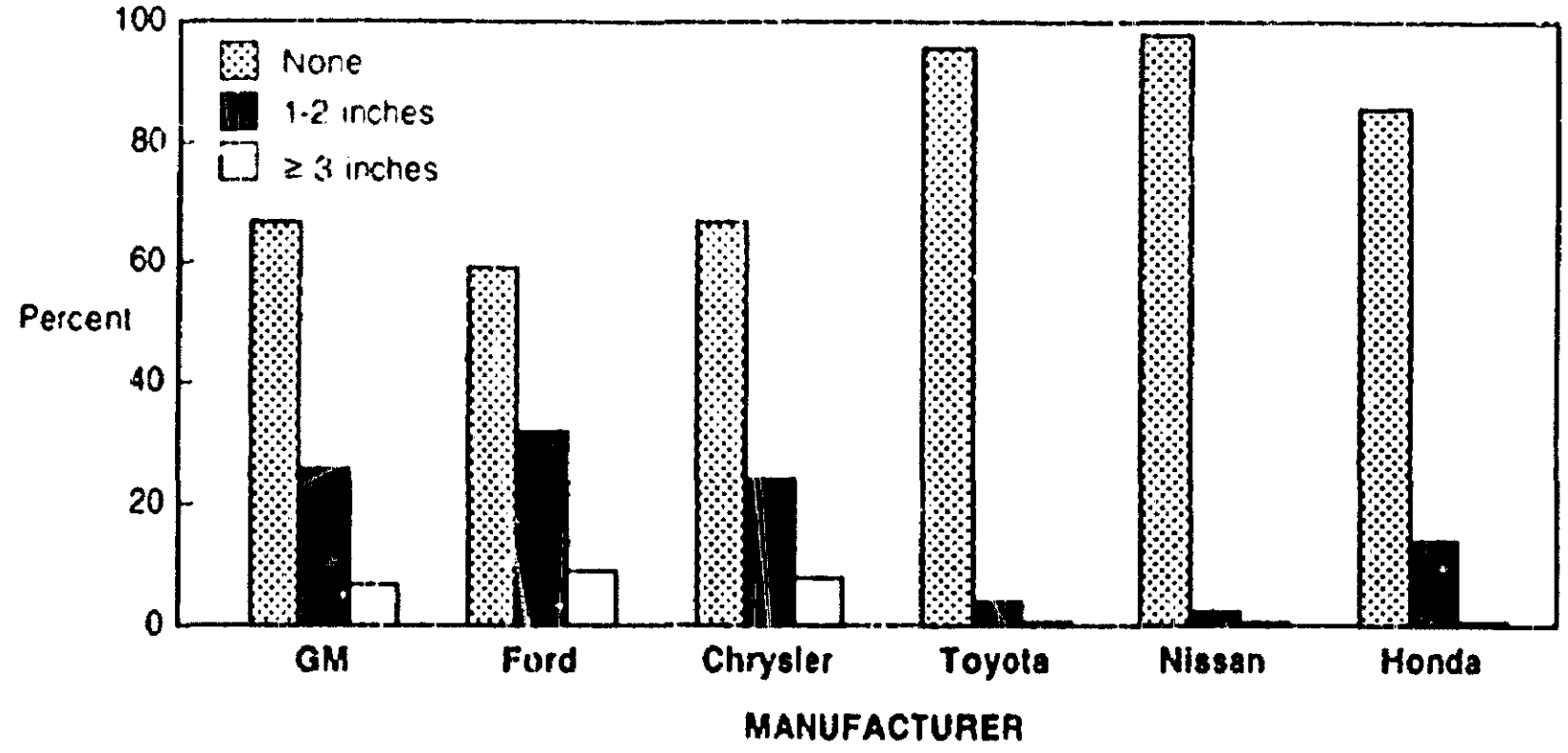
Shoulder Belt Use by Maryland Drivers In 1974-87 Model Vehicles



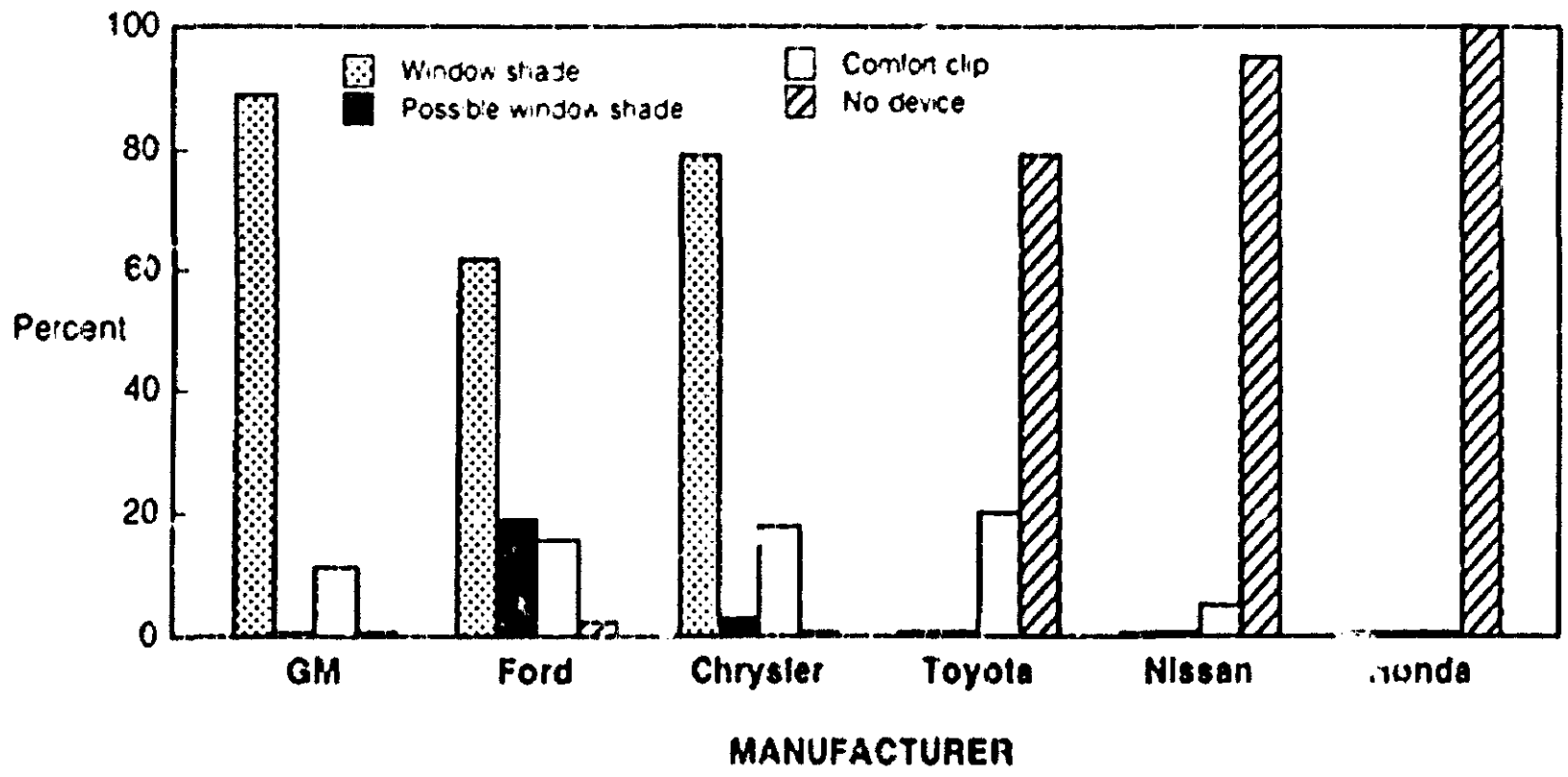
Estimated Slack In Shoulder Belts Worn by Maryland Drivers In 1974-87 Model Vehicles



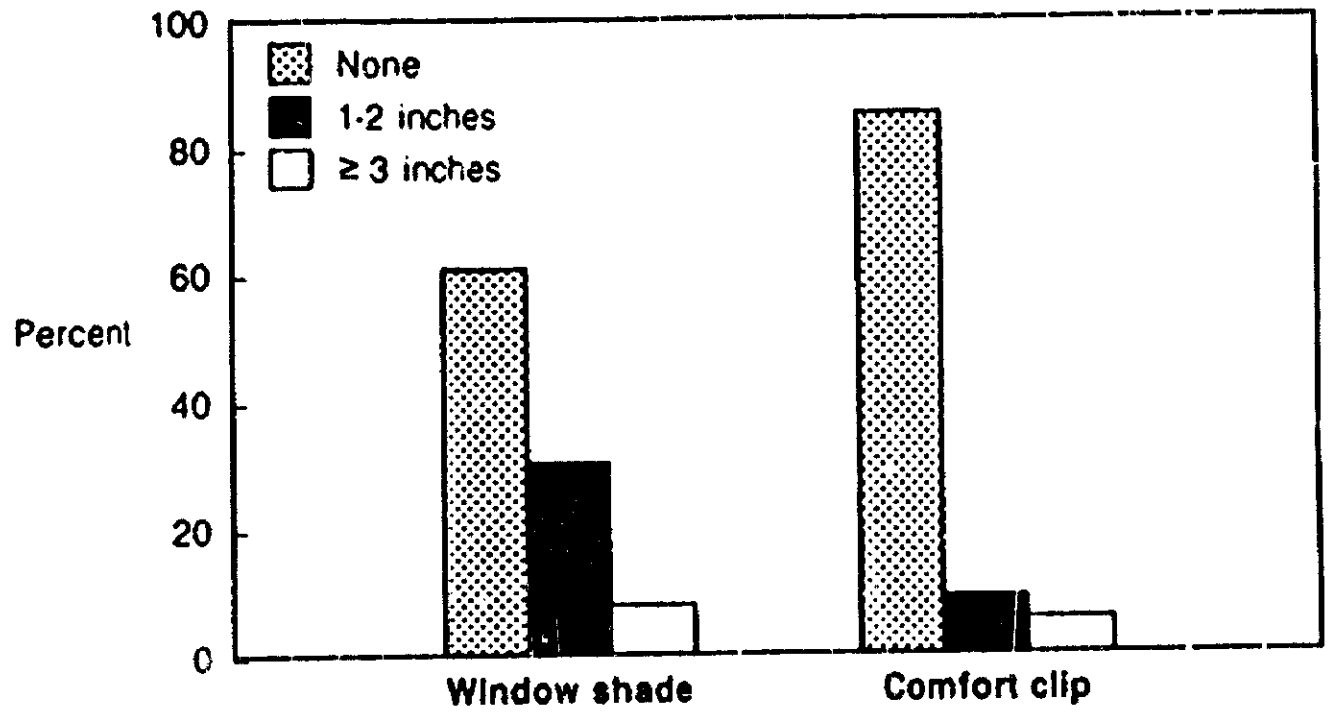
Estimated Slack in Shoulder Belts Worn by Maryland Drivers in 1974-87 Model Cars



Shoulder Belt Slack Devices in Surveyed 1974-87 Model Cars



Estimated Slack in Shoulder Belts Worn by Maryland Drivers in 1974-87 Model GM, Ford, & Chrysler Cars



APPENDIX K
ADDITIONAL CASES OF FATAL INJURIES CAUSED BY UNDERARM USE OF A SHOULDER HARNESS

Cases involving serious or fatal injury due to belt routing errors and other forms of misuse of lap/shoulder belts were described by Canadian researchers in 1986 and published in the 30th Proceedings of the American Association for Automotive Medicine. *

One case in the Canadian paper involved a right front passenger with a misrouted belt. The passenger sustained lumbar spine injuries attributed to the misuse:

Canadian Case Study No. 7 - 1984 GMC S-15 Pickup truck/1979 Lada/T-Type Collision

The case vehicle, a 1984 GMC High Sierra pickup truck, was travelling westbound along a two lane, rural highway. It was dark and snow was falling. Vehicle 2, a 1979 Lada four door sedan, was travelling eastbound along the same roadway. Vehicle 2 drove partially onto the south shoulder. In attempting to return to the roadway, the driver oversteered and his vehicle skidded sideways, out of control, into the westbound lane. The front of the case vehicle struck the center right side of Vehicle 2. The case vehicle sustained a broad frontal crush measured as 47 cm at the left front end, and 4 cm at the right front end. The barrier equivalent speed for the case vehicle in this collision was established at 30 km/hr.

The occupant of interest in the case vehicle is the right front passenger, a 26-year-old female, 157 cm tall and weighing 50 kg. She was wearing the available lap and torso restraint system. This occupant suffered an abrasion to the forehead from contact with the upper dashboard. She also received contusions to the right kidney; a bilateral laminar fracture of L1, with the body of L1 displaced posteriorly; fractured transverse processes of L1 and L2; subluxation of T12 and L1 by 5 mm, requiring spinal fusion.

In a collision of this severity, one would not expect a properly restrained right front occupant to make contact with the upper dashboard, nor to sustain injuries of the severity described above. The right front restraint system was removed and, upon examination and testing, was found to be completely operational. The abdominal and spinal injuries reported above suggest that the torso belt was worn improperly, being placed under the occupant's arm rather than over the shoulder.

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* Green, Robert; German, Alan; Gorski, Zygaunt, Proceedings, American Association for Automotive Medicine, Montreal, Quebec, October 6-8, 1986.

Another Canadian case involved fatal injury to a driver due to his underarm use of the belt. Misrouting permitted excessive excursion:

Canadian Case Study No. 6 - 1978 Oldsmobile Cutlass/1970 Plymouth Valiant/Head-on Collision

The case vehicle, a 1978 Oldsmobile Cutlass Supreme two door coupe, was travelling westbound on a two lane, undivided, county road. Visibility was good in the daylight hours; however, the roadway surface was covered in ice and extremely slippery. In attempting to complete a passing manoeuver, the driver of the case vehicle lost directional control. The vehicle crossed the roadway centerline and collided head-on with a 1970 Plymouth Valiant two door coupe, which was travelling eastbound on the same roadway. As a result of the collision, the case vehicle received a wedge-shaped frontal crush measured at 71 cm at the left front end, and 13 cm at the right front end. The barrier equivalent speed for the case vehicle in this collision is estimated to be 40 km/h.

The driver of the case vehicle, a 30-year-old male, was approximately 180 cm tall and weighed 81 kg. The investigating police officer found the driver slumped forward over the steering wheel. The driver was wearing the available three point restraint system, but the torso portion of the belt system was found to be located under the driver's arm rather than over the shoulder.

The occupant sustained a transection of the aorta; massive anterior and posterior hemomediastium; massive left hemothorax, with 2.5 l of blood in the left pleural cavity; a contusion to the left lung on the upper lobe near the hilum; bilateral intra-alveolar hemorrhage; a fracture of the manubriosternal joint; and fractures, along the mid-clavicular line, to the left ribs numbers 2 through 5, and to the right ribs numbers 2 through 9 (MAIS 6).

In discussion of these cases, the authors concluded:

Drivers or front passengers, often for reasons of confort and convenience, defeat the function of the shoulder harness by placing it in the axilla. This creates the effect of wearing a lap belt only, and in some belt systems may introduce excessive slack in the lap belt portion. During a frontal collision, the occupant is retained within the seating position, but is free to flex forward at the waist. In Case 6 the driver's upper torso loaded the steering column, which collapsed to its base limit and inflicted fatal injuries to the driver's chest. From our investigation we concluded that a properly worn shoulder harness would have prevented this death.

In Case No. 7 a properly restrained right front passenger in the pickup truck should be protected from all but minor bruising injury. This right front passenger was free to flex forward at the waist at the time of frontal collision and sustained head contact with the instrument panel and hyperflexion injury of the lumbar spine. This type of lumbar spine injury due to flexion across a lap belt during frontal collision was described and discussed by Smith and Kaufer * and in many reports by other investigators since then. Adequate restraint of the upper torso will prevent this injury.

Six additional cases involving fatal injuries due to underarm use of the shoulder portion of a three-point belt are described in a paper published in the Journal of Trauma, July 1987.**

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* Smith, W. S. and Kaufer, H., "Patterns and Mechanisms of Lumbar Injuries Associated with Lap Seat Belts," J. Bone and Joint Surgery, Vol. 51-A, No. 2; p. 239, 1969.

**States, John; Huelke, Donald; Dance, Murray, and Green, Robert, "Fatal Injuries Caused by Underarm Use of Shoulder Harness."

APPENDIX L

ADDITIONAL INJURY DATA FOR CASE VEHICLE OCCUPANTS

Uninjured lap/shoulder belted front seat occupants:
Distribution by crash severity (N=33).

Crash Severity (Delta V)	Drivers	Rt. Front Passenger	Total	Percent
Delta V not calculable*	2	0	2	6.1
0.1 to 10.0	6	1	7	21.2
10.1 to 20.0	17	5	22	66.7
20.1 to 30.0	1	1	2	6.1
Total	26	7	33	100.0
Percent	78.8	21.2	100.0	

(Data for properly routed lap/shoulder belts only; a total of 213 case vehicle occupants.)

Lap/shoulder belted front seat occupants with minor injuries as most severe injury: Distribution by crash severity (N=95).

Crash Severity (Delta V)	Drivers	Rt. Front Passenger	Total	Percent
Delta V not calculable*	4	1	5	5.3
0.1 to 10.0	9	3	12	12.6
10.1 to 20.0	33	9	42	44.2
20.1 to 30.0	17	7	24	25.3
30.1 to 40.0	3	0	3	3.2
Noncollision accident	7	2	9	9.5
Total	73	22	95	100.0
Percent	76.8	23.2	100.0	

(Data for properly routed lap/shoulder belts only; a total of 213 case vehicle occupants.)

*Delta V was not calculable for some of the collision accidents due to the nature of the collision or lack of physical evidence.

Lap/shoulder belted front seat occupants
with fractured ribs, sternum, or clavicle
in frontal nonrollover crashes by crash severity.

Crash Severity (Delta V)	Drivers	Right Front Passenger	Total	Percent
Not calculable*	1	1	2	9.5
10.1 to 20.0	1	1	2	9.5
20.1 to 30.0	6	3	9	42.9
30.1 to 40.0	4	2	6	28.6
40.1 or more	1	1	2	9.5
Total	13	8	21	100.0
Percent	61.9	38.1	100.0	

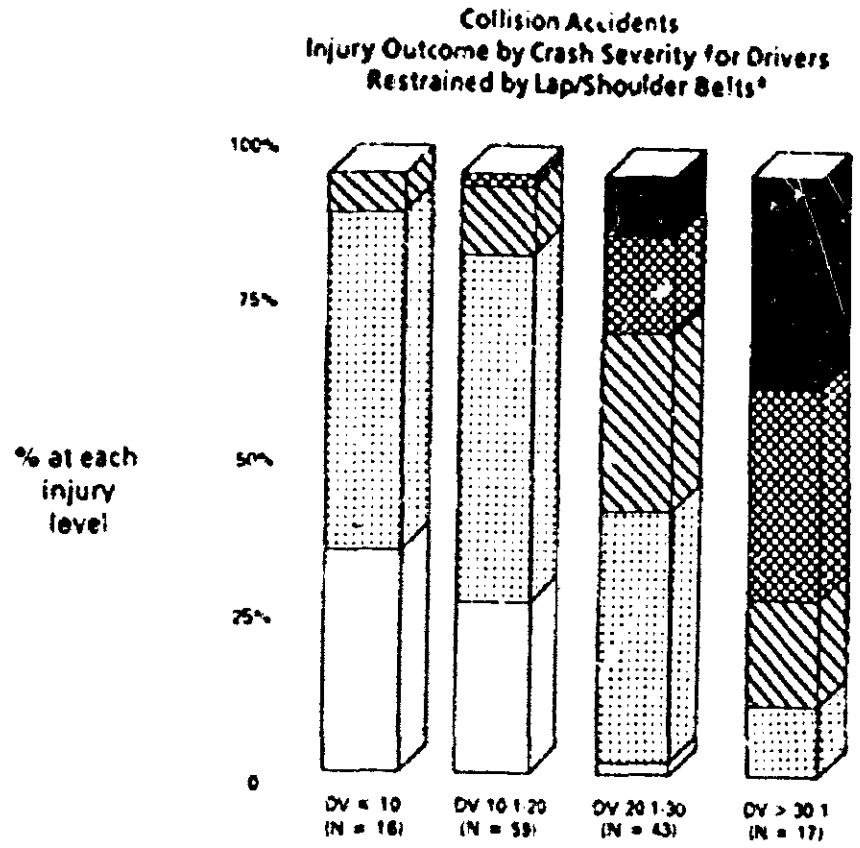
(Data for properly routed belts only.)

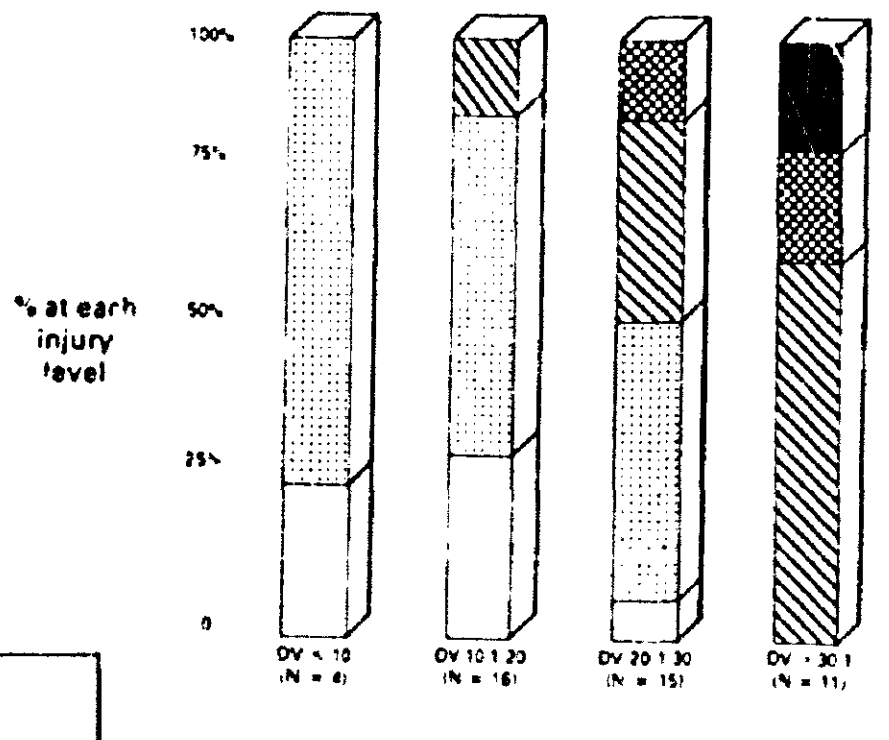
Crash severity and configuration of crashes resulting in intrusion
causing most severe injury of lap/shoulder belted front seat occupant.

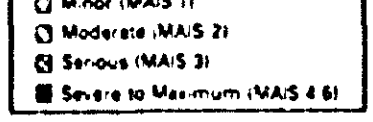
Crash Severity (Delta V)	Frntl	Right Side	Left Side	Rear	Other Collision	Non-Collision	Total
Not calculable*	1	0	0	0	1	0	2
0.1 to 10.0	1	1	1	0	0	0	3
10.1 to 20.0	0	0	2	0	0	0	2
20.1 to 30.0	2	0	4	0	0	0	6
30.1 to 40.0	5	1	1	0	0	0	7
40.1 or more	1	1	0	1	0	0	3
Other noncollision	0	0	0	0	0	2	2
Total	10	3	8	1	1	2	25

(Data for properly routed belts only and occupants with MAIS 2 or greater.)

*Delta V was not calculable for some of the collision accidents due to the nature of the collision or lack of physical evidence.







* Properly routed belts only.

Injury outcome by crash severity for drivers and right front passengers restrained by properly routed lap/shoulder belts in collision accidents. (Cases in which both Delta V and MAIS level of injury could be determined. Chart adjusts for different numbers of occupants at each Delta V severity category.)

Incidence of head/facial injuries (AIS-2 or greater)
by seating position for lap/shoulder belted* case occupants

All Cases in Study

Drivers: 20.3% (32 of 157)
Right Front: 16.1% (9 of 56)

Frontal, Nonrollover Cases Only

Drivers: 21.4% (24 of 111)
Right Front: 16.7% (6 of 36)

(Properly routed belts only.)

Incidence of fractured ribs, clavicle, or sternum
by seating position for lap/shoulder belted* case occupants

All Cases in Study

Drivers: 10.8% (18 of 157)
Right Front: 17.9% (10 of 56)

Frontal, Nonrollover Cases

Drivers: 10.7% (13 of 111)
Right Front: 36% (9 of 36)

(Properly routed belts only.)

(Properly routed belts only.)

*U.S. GOVERNMENT PRINTING OFFICE:1988- 771-513:81003

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