

PB86-917006



# NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

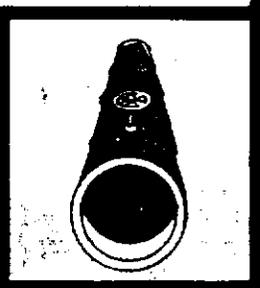
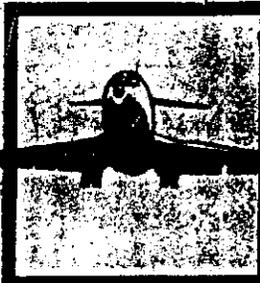
## SAFETY STUDY

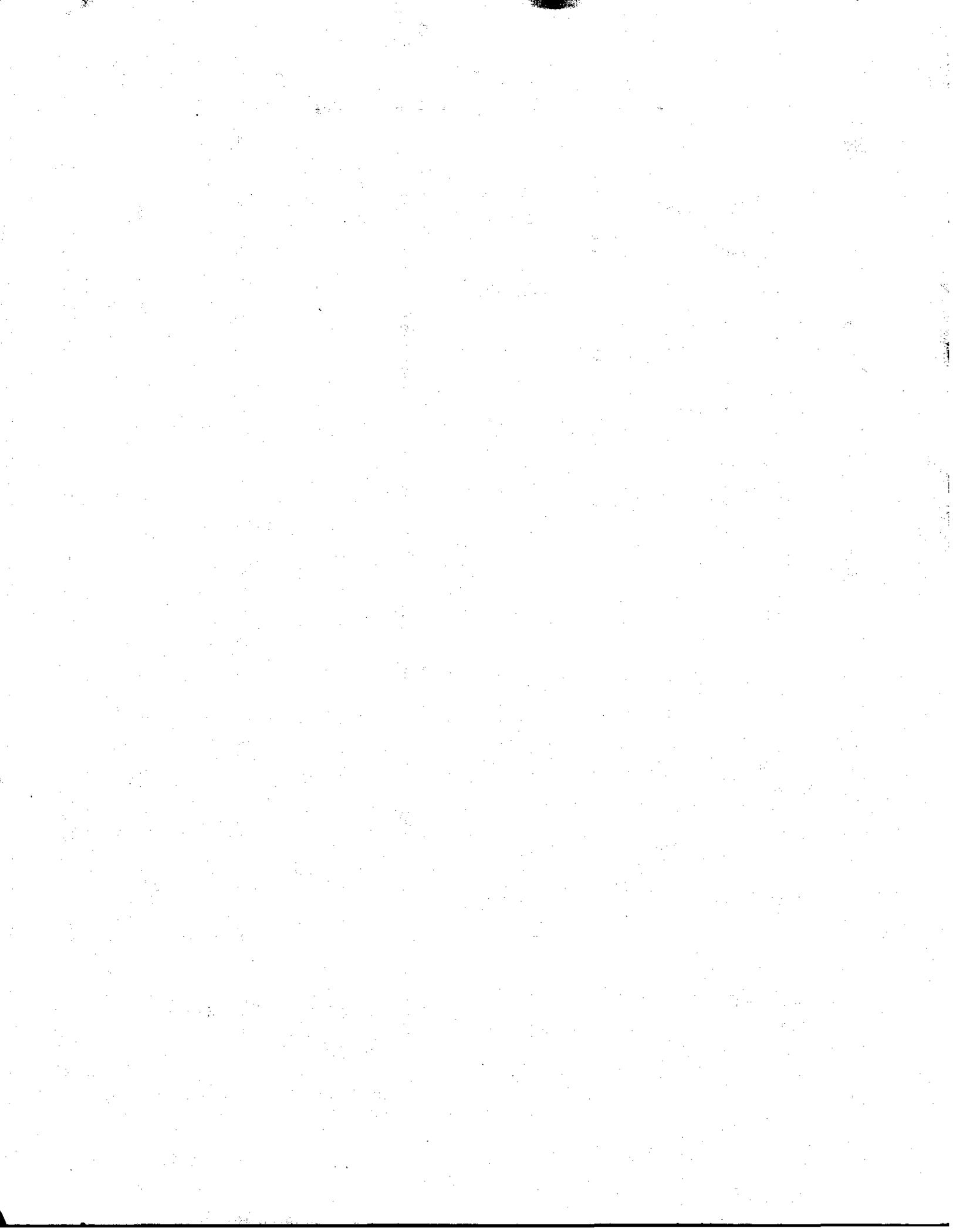
### PERFORMANCE OF LAP BELTS IN 26 FRONTAL CRASHES

NTSB/SS-86/03

July 28, 1986

UNITED STATES GOVERNMENT





TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB/SS-86/03		2. Government Accession No. PB86-917006		3. Recipient's Catalog No.	
4. Title and Subtitle Safety Study— Performance of Lap Belts in 26 Frontal Crashes				5. Report Date July 28, 1986	
				6. Performing Organization Code	
7. Author(s)				8. Performing Organization Report No.	
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Safety Programs Washington, D.C. 20594				10. Work Unit No. 4378A	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address  NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594				13. Type of Report and Period Covered  Safety Study 1984-1986	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract This study reports on the performance of lap belts in 26 frontal crashes of passenger vehicles investigated by the Safety Board. The report discusses the Board's findings, selected lap belt cases, statistical estimates of seat belt effectiveness, related research on lap belt performance, and Federal regulations and manufacturers' practices on motor vehicle seat belts. The report concludes with recommendations to U.S. and foreign manufacturers of passenger vehicles, to the National Highway Traffic Safety Administration, to the International Chiefs of Police, and to associations and groups concerned with emergency medicine.					
17. Key Words  lap belt; lap/shoulder belt; seat belt; restraint systems; injury; medical treatment; motor vehicle;				18. Distribution Statement  This document is available to the public through the National Technical Information Service Springfield, Virginia 22161	
19. Security Classification (of this report) UNCLASSIFIED		20. Security Classification (of this page) UNCLASSIFIED		21. No. of Pages 236	22. Price

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**NATIONAL TRANSPORTATION SAFETY BOARD  
WASHINGTON, D.C.**

**SAFETY STUDY**

**Adopted: July 28, 1986**

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**PERFORMANCE OF LAP BELTS  
IN 26 FRONTAL CRASHES**

**INTRODUCTION**

For many years, the National Transportation Safety Board has supported efforts to increase the use of seat belts to protect motorists from severe injury or death in crashes. More recently, however, the Safety Board has felt that it would be useful to undertake a special crash investigation program focused on accidents involving the use of seat belts to learn more about their performance. This view was based on a number of facts. First, the manual belt systems in motor vehicles today are not required to be dynamically tested for crash protection performance (those requirements are limited to passive systems, such as passive belts or airbags). Second, data on real-world performance of belt systems are limited. Furthermore, there have been basic changes in vehicle designs over the years that could affect the performance of belt systems designed for vehicles of the 1970's. For example, there was concern that, with the "downsizing" of automobiles, the ability of seat belts to provide crash protection might be diminished. In vehicles with less distance between front seat occupants and frontal interior surfaces, for instance, such problems as excessive spool-out of the upper torso restraint in lap/shoulder belts might permit injurious contact between the occupant and the interior surfaces, despite use of the belt.

Therefore, in the fall of 1984, the Safety Board embarked on a program to investigate approximately 200 crashes in which the crash performance of seat belts would be thoroughly examined. The criteria for investigating a crash were:

- Case vehicle must be post-1974 model car, light truck, or van;
- At least one occupant in the case vehicle must have been using a seat belt 1/;
- The crash must have been of sufficient severity to require that the case vehicle be towed from the scene 2/; and
- The crash must not have been so severe for the case vehicle as to be deemed unsurvivable for its belted occupant(s). 3/

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1/ Before the program was completed, it was decided to investigate a few cases in which no occupants were restrained, for comparison purposes.

2/ 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 seat belts could not be expected to affect the outcome, these particular towaway cases were not followed up.

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

The Safety Board's investigators were alerted to potential cases for the study in a number of ways. The Board's highway field investigators, trained in the techniques of investigating crashes involving restrained occupants, are located in eight cities: Atlanta, Chicago, Denver, Fort Worth, Kansas City (Missouri), Los Angeles, New York, and Seattle. At the beginning of the program, each of these field offices arranged an accident notification scheme, involving a network of law enforcement and medical authorities in the multistate region surrounding the Board field office. These authorities agreed to notify the Board investigators of any crash meeting the Board's criteria as soon as they became aware of it. Upon notification, Board investigators would go to the accident location, explore the facts sufficiently to determine that the crash in fact met the selection criteria, and if so, begin a detailed examination to establish all the relevant facts.

A careful examination of the case vehicle was carried out in each crash investigation, documenting its "vital statistics" and information about the restraint system available to each occupant. The size, weight, and seating location of each occupant was determined. For each occupant, the investigator determined whether the available seat belt was used, whether it was used correctly, the nature and severity of each injury sustained (expressed in terms of the Abbreviated Injury Scale (AIS)), and the probable source of each injury. Necessary measurements were made that permitted the Safety Board to estimate the collision severity in terms of the velocity change ("Delta V") experienced by the case vehicle. Based on these data, an analysis could be made of the performance of each belt system in use during the crash, and some overall conclusions drawn about the role of belt restraint systems in the crashes studied.

After about a quarter of the investigations had been initiated, several cases involving lap belted rear seat occupants began to draw the Safety Board's attention to these belt systems in particular. For example, in one case involving a rather moderate collision (Delta V 25.7 mph), the lap/shoulder belted front seat occupants sustained no injuries, while the lap belted left rear seat occupant sustained three critical intra-abdominal injuries, two severe intra-abdominal injuries, five serious intra-abdominal injuries, one serious hip injury, one moderate intra-abdominal injury, and three moderate hip injuries--all induced by the lap belt itself. This man died after 39 hours in the intensive care unit.

Despite the concern about the apparent poor performance of the lap-only belt in several early cases, the accident notification criteria were not changed. However, after several more cases turned up involving rear seat lap belts, it was decided to alert the field investigators to look especially carefully at potential cases involving occupants restrained in the rear seat (as distinct from the earlier, more general criterion of "at least one occupant in the vehicle using a seat belt").

In all, the Safety Board was notified of 26 accident cases involving lap belt restrained occupants that also met the other notification criteria established for the program. This report presents findings on the performance of the seat belts used in these 26 cases--50 lap-only belts, 32 lap/shoulder belts--and on the experience of the 57 unrestrained occupants in these cases and in 3 other cases involving only unrestrained occupants, studied for comparison purposes. In addition, one case involving front and rear seat occupants, all using lap/shoulder belts, was studied, again for purposes of comparison.

It is important to remember that this study is limited in two important respects. First, the crashes examined here (with one exception) are all frontal crashes. Results derived from analysis of frontal collisions cannot be applied to other crash configurations.

The benefits that may be derived from lap belt use (compared to no restraint) in minimizing the possibility of ejection during rollover or side impact cannot be discovered through analyzing frontal collisions. Second, the small size of the sample in this study means that no statistically valid conclusions can be drawn from it. The Safety Board's study is a case study which emphasizes the collection of accurate, complete data on a number of specific points relevant to the question of belt performance.

The report begins with an overview of the findings of the lap belt crash investigation program. This overview is followed by brief summaries of several illustrative cases and discussion of their significance. The next section discusses the reasons why large-scale databases have been inappropriate for assessing seat belt effectiveness. A chapter describing what has been known about lap belts and lap/shoulder belts since their use began in the 1960's is next, including knowledge of the special problems in diagnosing and treating lap belt injured persons. The relationship of the Federal Motor Vehicle Safety Standards to lap belt and lap/shoulder belt installation is covered in the next section. The final section presents several recommendations for improving occupant restraint systems and recommendations for improving the handling of persons injured in motor vehicle crashes while wearing a seat belt.

Several appendices follow the report, the first being a presentation, in brief format, of all the study cases, describing the facts of each case and discussing the Safety Board's interpretation of these facts. Other appendices present additional cases from other sources of lap belt injured persons; a glossary; discussions of "Delta V" and the use of the AIS; anatomical drawings to assist in understanding the nature of the injuries described in this report; a chronology of selected events related to seat belts since their early development; and a number of tables depicting various findings from the Board's lap belt case investigations.

### OVERVIEW OF FINDINGS FROM SAFETY BOARD CRASH INVESTIGATIONS

The Safety Board investigated 26 crashes involving at least one lap belted person and concluded that, overall, the crash performance of the lap belts in these cases was very poor. Among the 50 persons using a lap-only belt, the Board determined that at least 32 of them would have fared substantially better if they had been wearing a lap/shoulder belt. In many cases, the lap belts induced severe to fatal injuries that probably would not have occurred if the lap belts had not been worn. The occurrence of lap belt induced severe to fatal injuries was not limited to severe crashes: 14 lap belted occupants sustained belt induced injuries of AIS 3 or greater severity (including 6 fatally injured) in crashes of Delta V 28 mph or lower. Even correctly <sup>4/</sup> worn lap belts induced severe injury: 24 occupants who received AIS 3 or greater injuries from the belt itself are believed to have been wearing it correctly. Twenty-six of the lap belted occupants sustained serious to fatal injuries in crashes in which other occupants--either unrestrained or lap/shoulder belted, and often seated in the more vulnerable front seating locations--were less seriously injured or not injured at all. The injuries characteristically induced by the lap belt were among the most dangerous types of injuries: those to the head, spine, <sup>5/</sup> and abdomen. The ages of lap belt injured persons ranged from 4 to

<sup>4/</sup> There is no officially agreed-upon definition of "correct" lap belt use, but the Safety Board has used the term to mean snugly crossing the lower abdomen between the pubis and the umbilicus, with the belt low on the hips below the crest of the ilium. This appears to be the generally accepted meaning.

<sup>5/</sup> In this study, lap belt induced head and spine injuries are those brought about by the violent jackknifing motion over the lap belt--injuries that would not have occurred but for the use of the lap belt.

82 years (more than half were younger than 15 years, however) and included both males and females. Finally, the postcrash medical handling of several of the lap belt injury victims demonstrated the need for improved understanding by medical personnel of the possibility and gravity of seat belt induced injuries in motor vehicle crashes.

**Injuries to Case Vehicle Occupants**

Thirty-one vehicles (passenger cars or vans), occupied by 139 persons ranging in age from 10 months to 82 years, were involved in this lap belt study. 6/ The crash forces involved in these primarily frontal crashes ranged from Delta V 9.8 mph to Delta V 43 mph. Fifty-seven of the occupants were unrestrained, 27 of them in a front seat location, 30 in some other seating location. Thirty-two were wearing a lap/shoulder belt, all but 1 in a front seat. Fifty were wearing a lap belt, all but 3 in a rear seating location.

Only 7 of the 139 occupants were uninjured. Five of them were in crashes of low Delta V (10-13 mph)--4 of them unrestrained, 1 lap belted, all in the rear seat. The other 2 were in the front seat wearing lap/shoulder belts in a moderately severe crash (Delta V 25 mph).

Another 48 occupants received AIS 1 (minor) injuries as their most severe injury (MAIS); 32 received AIS 2 (moderate) injuries as most severe; 21 received AIS 3 (serious) injuries as most severe; 31 received AIS 4 (severe), AIS 5 (critical), or AIS 6 (maximum) injuries. Eighteen persons died of their crash induced injuries: 1 with AIS 2 injuries, 1 with AIS 3, 1 with AIS 4, 11 with AIS 5, and 4 with AIS 6.

	<u>Uninjured</u>	<u>MAIS 1</u>	<u>MAIS 2</u>	<u>MAIS 3</u>	<u>MAIS 4</u>	<u>MAIS 5</u>	<u>MAIS 6</u>	<u>(Fatal)</u>
Unrestrained (57)	4	20	17	11	1	2	2	(4)
Lap belted (50)	1	16	5	7	6	13	2	(13)
Lap/shoulder belted (32)	2	12	10	3	4	1	-	(1)

**Restraint Use, Injuries, Delta V**

AIS 2 As Most Severe Injury (MAIS 2). Of the 139 occupants, 32 received MAIS 2 (moderate) injuries; 17 of them were not restrained, 5 were wearing lap belts, and 10 were wearing lap/shoulder belts.

Persons With MAIS 2 Injury,  
by Case Vehicle Delta V and Restraint Use

	<u>&lt;15 mph</u>	<u>15-25 mph</u>	<u>26-35 mph</u>	<u>36-45 mph</u>
Unrestrained (17)	-	4	2	11
Lap belted (5)	-	3	1	1
Lap/shoulder belted (10)	1	3	4	2

6/ A 5-month-old boy, using an improperly installed child restraint device, sustained AIS 3 head injuries in a crash of Delta V 33.6 mph; this occupant will not be included in the discussion and tables that follow.

Most of the unrestrained persons at the moderate injury level were in severe crashes (11 of the 17 in crashes of Delta V greater than 35 mph); the lowest case vehicle Delta V for these occupants was 23 mph. There were only 5 lap belted persons at the moderate injury level; 1 was in a crash at Delta V 38.5 mph, 1 at Delta V 35.7 mph, and 3 at Delta V 15-25 mph. The lap/shoulder belted persons with moderate injuries were in moderate to severe crashes (6 of 10 in crashes at Delta V 26-45 mph).

AIS 3 As Most Severe Injury (MAIS 3). Of the 139 occupants, 21 received MAIS 3 (serious) injuries; 11 of them were not restrained, 7 were wearing lap belts, and 3 were wearing lap/shoulder belts.

**Persons With MAIS 3 Injury,  
by Case Vehicle Delta V and Restraint Use**

	<u>&lt;15 mph</u>	<u>15-25 mph</u>	<u>26-35 mph</u>	<u>36-45 mph</u>
Unrestrained (11)	-	1	4	6
Lap belted (7)	-	1	6	-
Lap/shoulder belted (3)	-	1	2	-

Most of the unrestrained persons with MAIS 3 injuries were in severe to very severe crashes (6 of 11 at Delta V greater than 35 mph, 3 more at Delta V 33-35.5 mph). Most of the lap belted persons with MAIS 3 injuries were in moderately severe crashes (6 of 7 at Delta V less than 35 mph, 4 of these at Delta V less than 30 mph). All three lap/shoulder belted persons with MAIS 3 injuries were in moderately severe or severe crashes (Delta V 33.6 mph, 32 mph, and 22.5 mph).

MAIS 4, 5, or 6, or Fatal Injuries. Of the 139 occupants, 33 received MAIS 4, 5, or 6 injuries, or were killed. Only 5 of these occupants were not restrained; 5 of them were wearing lap/shoulder belts. The remainder, 23 of the 33, were wearing lap belts.

Of the 33 occupants in this category, 18 were killed; 4 of them were not restrained and were in higher Delta V collisions (43 mph and 35.5 mph); 1 was wearing a lap/shoulder belt (a driver in a Delta V 36 mph crash); 13 were wearing lap-only belts (6 at Delta V less than 30 mph, 7 at Delta V 30-40 mph).

**Persons With MAIS 4, 5, or 6 Injuries or Killed, 7/  
by Case Vehicle Delta V and Restraint Use**

	<u>&lt;15 mph</u>	<u>15-25 mph</u>	<u>26-35 mph</u>	<u>36-45 mph</u>
Unrestrained (5)	-	-	1	4
Lap belted (23)	-	5	12	6
Lap/shoulder belted (5)	-	-	3	2

Only 5 of the 57 unrestrained persons sustained these level injuries; 4 were in vehicles that underwent Delta V of greater than 35 mph; 1 was in a crash of Delta V 25-28 mph. Four of the 5 were in a front seat in these severe frontal collisions.

7/ Of the 31 persons who sustained MAIS 4, 5, or 6 injuries, 16 were killed. In addition, 2 other persons were killed, 1 with MAIS 2 injuries, and 1 with MAIS 3 injuries.

The 5 lap/shoulder belted persons who suffered these levels of injuries also were involved in severe crashes (3 at Delta V 32 mph, 1 at Delta V 36 mph, and 1 at Delta V 38.5 mph). Four of the 5 were drivers.

There were 23 lap belted persons in this category. Six were in crashes involving Delta V 36-40 mph, 12 were in crashes of Delta V 26-35 mph, and 5 were in crashes of Delta V 20-25 mph. One of the 23 persons was a driver, 1 was seated center front, and 2 were seated right front. The remaining 19 were all seated in rear locations.

Thirteen of the 23 lap belted persons in this category were killed, all by lap belt induced injuries. Five more sustained MAIS 4 injuries but were not killed, and another 5 sustained MAIS 5 injuries but were not killed.

Sixteen of the 23 lap belted persons who sustained MAIS 4, 5, or 6 injuries or were killed were judged to have been wearing the belt correctly and also did not slide downward under the belt or have the belt slide up over the iliac crests ("submarining"). Four were judged to have been wearing the belt correctly but possibly to have submarined. One was judged to have been wearing the belt incorrectly (loose or too high).

Twenty-one of the 23 lap belted persons in this category were in vehicles in which at least one other person, unrestrained or lap/shoulder belted, was either uninjured or had MAIS 1, 2, or 3 level injuries. In all but one of these cases, there was more than one non-lap belted person who survived the crash with less than AIS 3 injuries, often in a front seat position.

Seven of the 23 lap belted persons in this category were younger than 10 years; 8 were aged 10-20; 4 were aged 21-50; 4 were older than 51. Fifteen were male, 8 were female.

#### Additional Information on Persons Wearing Lap-Only Belts

The Safety Board's investigators concluded that 37 of the 50 lap belted occupants were wearing the belt correctly and also did not submarine. Four other lap belt wearers were judged to have been wearing the belt correctly but to have experienced, or possibly experienced, submarining. Five of the lap belt wearers were judged to have worn the belt incorrectly or probably incorrectly. For four of the lap belt wearers, there was insufficient evidence to determine whether it was being worn correctly and whether it rode up during the impact.

#### Correct/Incorrect Use, Submarining

Wore lap belt correctly, no submarining	37
Wore lap belt correctly, but possible submarining	4
Wore lap belt incorrectly	5
Correctness of use and occurrence of submarining unknown	4

Of the 50 persons wearing a lap belt in these crashes, 49 were injured:

Outcomes for 50 Lap Belt Users

<u>Survivors</u>	MAIS 1:	16
	MAIS 2:	4
	MAIS 3:	6
	MAIS 4:	5
	MAIS 5:	5
<u>Killed</u>		13

There was little or no intrusion or compression of the occupant space in the areas surrounding the 13 fatally injured lap belt wearers. They all received their fatal injuries as a result of wearing the lap belt. Eleven of these 13 were wearing the lap belt correctly; there was possible submarining in 3 of the 13 lap belt induced fatalities, all involving proper use of the belt.

Of the 33 lap belted persons who received AIS 2 or greater injuries, 30 received one or more of these injuries as a direct result of the lap belt. One other person received an intra-abdominal injury as a result of lap belt use, but its severity was undocumented.

Of the 29 persons with AIS 3 or greater (or fatal) lap belt induced injuries, 21 sustained more than one injury at this level (induced by the lap belt itself):

Distribution of AIS 3 or Greater Lap Belt Induced Injuries

Persons with 2 such injuries:	4
Persons with 3 such injuries:	3
Persons with 4 such injuries:	4
Persons with 5 such injuries:	5
Persons with 6 such injuries:	1
Persons with 7 such injuries:	1
Persons with 10 such injuries:	3

**SELECTED LAP BELT CASES**

Detailed factual and analytical summaries of each case in this study are presented in appendix A. Several cases are presented here to illustrate many of the findings set out in the previous section.

In Case 1, a 15-year-old female driver lost control of the 1983 Pontiac Phoenix she was driving and crashed head-on into a tree. The Delta V was calculated to be 37 mph. The girl driving and the 12-year-old boy in the right front seat sustained only minor to moderate injuries, despite the fact that they were not using the available lap/shoulder belts and despite the fact that they were in the most vulnerable seating location for a frontal collision. The two 13-year-old boys wearing lap belts in the rear seat, however, both sustained violent injuries to the intra-abdominal organs and connecting tissue; one boy was pronounced dead less than 1 hour after the crash, and the other boy died 5 days later (he had shown no brain activity from the time of the crash). The Safety Board concluded that both boys probably were wearing the lap belt in the proper pelvic area, though it is possible that one boy's belt "rode up" over the iliac crests during the crash.

In Case 4, a 1983 Dodge 15-passenger van was struck by a 1970 Chevrolet Chevelle, with the van undergoing an estimated Delta V 38.5 mph. The van driver, a 36-year-old man, was using his 3-point lap/shoulder belt; however, since he was seated directly behind the area of major crash induced vehicle collapse, he sustained moderate to severe injuries, primarily to his head, face, and legs. The unrestrained right front passenger, a 17-year-old boy, sustained only minor injuries. Eight other unrestrained young people sustained only minor or moderate injuries; all were treated and released the same day.

The remaining four young men in the van were wearing lap belts. One sustained serious lap belt induced injuries to the head, spine, and iliac crest and severe lap belt induced intra-abdominal injuries (in addition to numerous other minor to moderate lap belt induced injuries); he was hospitalized for an extended period and continued under out-patient care after hospitalization. When last contacted by the Safety Board, 7 months after the crash, he was still unable to work.

A second lap belted passenger received moderate, serious, and severe lap belt induced head injuries and spent 4 months in a hospital before being transferred to another facility for long-term care. Seven months after the crash, he was still under extended care and on full disability.

A third lap belted passenger received fractures of his left leg due to an unsecured spare tire under his seat moving forward and compressing his leg against the forward seat framework. His head struck the seatback in front of him, as those of the first two lap belted passengers did, but with reduced severity, probably due to the lesser rigidity of the seat framework immediately in front of him. He also received an injury to his urinary tract, probably lap belt induced, of unknown severity. He was in a hospital for a week, and could not return to work for 4 months.

The fourth lap belted passenger sustained critical and severe lap belt induced intra-abdominal injuries and serious lap belt induced spine injuries. He spent 2 months in a hospital and had to return for out-patient care once a month after that. Seven months after the accident he had not returned to work and was on disability.

In Case 6, a 1983 Chevrolet Malibu was struck in the front by a 1980 Ford Mustang, with a resulting Delta V for the Chevrolet of 23 mph. The lap/shoulder belted Chevrolet driver, a 58-year-old man, received only minor injuries; the unrestrained right front passenger, a 55-year-old woman, received a moderate level injury to her head, in the form of a 2-inch temple laceration when she struck the rearview mirror; her other injuries were minor. However, the lap belted rear seat passenger, a 56-year-old woman, received fatal lap belt induced intra-abdominal injuries and died within minutes of reaching the hospital.

In Case 23, 12 small children (aged 6-7 years) were being transported in a day care van. The Ford van struck a 1984 Lincoln Town Car, resulting in a Delta V of 25-28 mph for the van. The unrestrained 24-year-old woman driver of the van received severe injuries. The five unrestrained small child occupants received only minor injuries and were either treated and released or did not receive medical treatment at all. The seven children wearing lap belts, however, all received serious to critical injuries including head, pelvic, intra-abdominal, and spinal injuries, all induced by the lap belt. One of these children was killed due to her massive head, spine, and intra-abdominal injuries; the others spent considerable time in a hospital, two being transferred later to extended-care facilities.

In Case 24, six young men (21-25 years old) were crowded into a 1979 VW Rabbit when it struck a 1977 Chevrolet Impala. The VW underwent a Delta V of 35.5 mph, while the Chevrolet underwent a Delta V of 23 mph. The four unrestrained men in the Chevrolet, all aged 22, sustained only minor to moderate injuries; all were treated and released immediately. The unrestrained driver of the VW Rabbit sustained critical injuries and died instantly. The lap/shoulder belted right front passenger sustained only moderate injuries, as did two of the unrestrained rear seat passengers. A third unrestrained rear seat passenger, sitting on the lap of the man in the center position, sustained serious injuries, due to being compressed between the center occupant and front seat. The remaining rear seat occupant, wearing a lap belt, sustained critical lap belt induced head and intra-abdominal injuries, serious lap belt induced spinal injuries, and moderate lap belt induced injuries to the abdomen.

In Case 26, a 1985 Ford Escort struck a 1974 International Harvester tractor-trailer, with a resulting Delta V of 33.5 mph for the Ford. The most serious injury sustained by the unrestrained 16-year-old girl driving the Ford was a fractured left femur (AIS 3); the same was true for the unrestrained 15-year-old girl in the right front seat. A 14-year-old boy in the rear, wearing a lap belt, sustained severe to critical lap belt induced intra-abdominal injuries and died 5 hours later. An 11-year-old boy wearing a lap belt in the rear seat sustained 4 severe intra-abdominal injuries, 4 critical intra-abdominal injuries, 1 critical spinal injury, 1 serious abdominal injury, and 1 moderate abdominal injury (in addition to other minor lap belt induced injuries). All his moderate to critical injuries were lap belt induced. He spent 2 months in a hospital before being transferred to an extended-care facility, due to paraplegia from his spinal column injury.

In Case 27, a 1980 Dodge Colt struck a tree head-on, with a resulting Delta V of 28 mph for the Dodge. The lap/shoulder belted front seat occupants sustained only minor injuries; however, the lap belted 15-year-old boy in the rear seat sustained severe intra-abdominal and spinal injuries due to the lap belt.

These cases illustrate why the Safety Board is concerned about the poor performance of lap belts in many crashes. Although virtually all of the lap belted persons were seated in rear seats (less vulnerable in a frontal crash), they often sustained serious to fatal injuries while front seat occupants received lesser or no injuries. Often the lesser injured occupants were unrestrained, while the more seriously or even fatally injured were lap belted. The unrestrained or lap/shoulder belted occupants tended to sustain only AIS 1-3 level injuries, even in severe to very severe crashes (only 5 of the 57 unrestrained occupants sustained higher level injuries, although 43 of these occupants were in severe to very severe crashes; only 5 of the 32 lap/shoulder belted occupants sustained higher level injuries, although 15 of these occupants were in severe to very severe crashes). At the same time, the lap belted occupants tended to receive AIS 4, 5, 6, and fatal injuries (21 of the 50 lap belted occupants, 11 of whom died, received AIS 4-6 level injuries; 2 of the 28 lap belted occupants whose highest documented injury was AIS 1-3 also died). The majority (23 of 29) of seriously to fatally injured lap belt wearers were believed to have been using the lap belt correctly--snug and low on the hips.

It is also important to understand that even in the cases in which lap belted persons did not sustain serious belt induced injuries, the lack of injury could not be attributed to effective crash protection performance by the lap belt. In Case 5, for instance, a 14-year-old lap belted boy sustained only AIS 1 injuries. However, the Delta V involved in this crash was only 9.8 mph; three unrestrained persons sustained no injuries, and the highest injury among all six occupants was AIS 2 (the lap/shoulder belted driver). Significantly, it was found that the buckle of the lap belt did not hold at impact; either the buckle failed (the evidence was against this) or the boy had not latched it properly in

the first place (most likely). Thus, little or no restraint was provided by the lap belt in this low Delta V crash. In three other crashes (Cases 14, 15, and 16), the Delta V was quite low and no occupants (even unrestrained) sustained other than minor injuries.

In four crashes (Cases 8, 11, 12, and 21), the Delta V was moderate (around 20 mph). In one, a lap belted 5-year-old girl in the rear of a 1977 Chevette sustained only AIS 1 injuries. However, another 5-year-old girl seated next to her, of identical size and weight, was also lap belted; she sustained maximum level injuries (AIS 6) to her head and cervical spine, plus other injuries. She died of her lap belt induced head/spine injuries. The Safety Board concluded that the radical difference in these children's experiences was probably due to slight differences in the attitude of their heads as their upper bodies flexed violently downward--a matter of chance.

In Case 11, all four lap belted children received only AIS 1 level injuries. Two toddler boys were belted together in the front seat using the lap portion of a 3-point lap/shoulder belt; the Safety Board concluded that little restraint was provided by the belt, however, since much of the crash energy acting on them was dissipated by the contact between their bodies and their head strikes into the well-padded instrument panel. The outboard seated child also avoided belt induced abdominal bruising, the Board concluded, because he loaded the inboard seated child into the belt; that child received belt bruising on both the left and right sides. The lap belted 5-year-old girl in the left rear seat probably avoided more serious lap belt injuries because she flexed over the belt in a leftward direction, thus bringing her upper body and head down onto her left upper leg; this prevented the serious head and neck injuries sustained by children wearing lap belts who flex downward between the legs. The same was true for the lap belted 4-year-old girl in the right rear seat.

In Case 12, a woman was lap belted in the left rear seat position. She sustained three moderate (AIS 2) injuries to her head and face, resulting from violent jackknifing induced by the lap belt, and an AIS 2 hip injury (plus several other injuries). She sustained the most serious injuries of the three occupants.

In the final example of a quite moderate crash, Case 21, the two lap belted rear seat occupants sustained only minor injuries. The Safety Board concluded that they had decelerated mainly into the front seatback, not into the lap belt. The two lap/shoulder belted front seat occupants also sustained only minor injuries.

There were three cases involving moderately severe to severe crashes in which lap belted occupants sustained only minor to moderate injuries. However, even in these cases the Safety Board concluded that this was not due to safe and effective restraint provided by the lap belt. In Case 3, the lap belted 6-year-old boy in the center rear seat of the 1984 Chevrolet Impala involved in a head-on crash at Delta V 28.6 mph sustained only minor injuries. However, the Board found that 1) the lap belt was not in fact "snugged up" around him at the time of the crash; 2) when his body slid forward and finally made contact with the belt webbing, the latchplate did not lock the webbing in place but allowed it to slip through for several inches before it finally jammed on a folded-over section; and 3) a large plastic box on the boy's lap was shattered between the boy and the front seatback, thus accounting for much of the boy's deceleration. Thus, this boy was not restrained to any significant degree by the lap belt.

In Case 7, a 1983 Chevrolet Celebrity was involved in a severe crash (Delta V 38 mph). The most severe injury sustained by the lap belted left rear seat occupant was AIS 2. However, the Safety Board investigation showed that he decelerated primarily into the left interior side wall and B pillar, not into the lap belt, so that his lack of lap belt induced internal or spinal injuries is not surprising. The belt was not effective in preventing head injuries; he sustained five AIS 2 injuries to his head and face, necessitating more than 8 weeks in a hospital and 2 months' loss of work.

Finally, in Case 13, three children were lap belted: one at center front seat, two in the rear seat. The child at center front sustained AIS 2, 3, and 4 (two) injuries to her head and face, resulting from the violent jackknifing over the lap belt. 8/ Fortunately, the two children in the rear seat benefited from the wide, firm seats provided in this 1978 Buick station wagon; because of the wideness and firmness of the seats, these children were not able to be injured through either jackknifing or submarining, as children on narrower, softer seats were (see Cases 8 and 10, for example).

In sum, the cases investigated during the Safety Board's project do not support the view that lap-only belts are effective countermeasures against crash injury in frontal collisions. In most of the Board cases, the lap belt itself induced serious to fatal injuries. However, in those cases in which the lap belt did not induce injuries, it does not appear that the lack of induced injuries could be attributed to effective lap belt performance. Furthermore, in these latter cases, either the lap belt failed to prevent other (nonbelt-related) crash injuries or the crash was so mild that few or no injuries were sustained by any occupant, regardless of their seating location or restraint system use. The evidence of these cases however, strongly supports the effective performance of lap/shoulder belts.

### STATISTICAL ESTIMATES OF SEAT BELT EFFECTIVENESS

#### Databases

The Safety Board is aware that the cases investigated in its project are not representative of the range of real-world accidents and, therefore, the findings are not necessarily representative of overall lap belt performance. That is, it may be that if sufficient, accurate data were available on lap belt performance in crashes, it would be shown that lap belts reduce crash losses to a greater extent than they increase them. Unfortunately, the data needed to make such a showing are not available.

As part of this study, the Safety Board examined many studies that have been used in attempts to determine seat belt effectiveness. The types of work done in this area fall into three general categories: observational surveys of restraint use, laboratory tests, and analysis of large databases, most of which are derived from police accident records. Observational surveys, while useful in providing estimates of belt use rates by nonaccident-involved occupants, provide no information on accidents and injuries.

8/ It is useful to compare the types and severity of head and face injuries sustained by this child with those of a girl of similar size seated center front, unrestrained, in a car of similar size and loaded weight, involved in a frontal collision of almost identical Delta V, in Case 34. In that case, the child's most serious head injury was a moderate contusion on her forehead; her most serious injury of any sort was a fractured left leg.