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Seat Belt Usage and Benefits in North Carolina Accidents

Forrest M. Council

William W. Hunter

University of North Carolina
Highway Safety Research Center
Chapel Hill, North Carolina

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ATTENTION

The enclosed report is a reprint of the original technical report which has recently gone out of print. Its content does not differ in any way from the original report. The format differs slightly due to time restrictions in the reprinting process.

We hope that this report will fulfill your interests. We appreciate your continued concern in highway safety.

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ABSTRACT

This report is an evaluation of restraint system benefits based on lap belt and shoulder harness usage rates and injury reduction benefits for all seating positions in North Carolina accident-involved vehicles. The restraint system data were collected in addition to the accident information normally collected by the North Carolina State Highway Patrol in the summer of 1970. Detailed analyses were conducted based on accident type, impact site, estimated speed just prior to contact, and non-belted and belted frequencies for both serious and minor injuries. Depending on the available sample sizes, chi-square, Poisson, or binomial tests were employed to detect significant differences between the belted and unbelted groups. Some major findings included the following:

Lap Belt Effects

1. For single vehicle crashes with unspecified points of impact (including rollovers), lap belted drivers experienced 66 percent fewer serious and fatal (A+K) injuries than expected in medium-speed collisions, and 53 percent fewer serious and fatal injuries in high-speed collisions.

2. Lap belted drivers experienced 43 percent fewer serious and fatal injuries than their unbelted counterparts in frontal impacts when all accident types and speeds were combined.

3. Lap belted right front seat passengers also experienced a 37 percent reduction in serious and fatal injuries for frontal collisions with all accident types and speeds combined.

Shoulder Harness Effects

1. For frontal impacts, none of the 29 drivers and right front seat passengers wearing a shoulder harness experienced a serious or fatal (A or K) injury. This is significantly lower than both the lap belted and the unbelted groups in comparable accidents ($p < .05$).

Lap Belt Usage

1. Based on a total of approximately 10,600 observations of occupants in crashes who had a lap belt available, 19.4 percent of the drivers used lap belts, while only 12.3 percent of the center front seat, 14.9 percent of the right-front seat, and 11.0 percent of the rear seat occupants used lap belts.

2. Differences were found in usage frequencies between sexes, but these differences were not consistent over all seating positions. For example, male drivers were more likely to be users than female drivers, but the reverse was generally true for other occupant positions.

3. Lap belt usage tended to increase with increasing age.

Shoulder Harness Usage

1. Shoulder harnesses are available for only the driver and right front seat positions, with the overall usage rate being 5.1 percent for occupants who had the system available.

2. The overall usage rate for male occupants (6.2 percent) was significantly different from the 3.2 percent usage rate for females ($p < .001$).

3. Shoulder harness usage tended to decrease with increasing age, which is the opposite of the lap belt effect.

4. Occupant usage of both the lap belt and shoulder harness appear to be affected by the use or non-use of other occupants in the vehicle, suggesting the possibility of an "influence effect."

These results further document previous findings which show the effectiveness of lap belts and shoulder harnesses and point out the continuing need for programs aimed at increasing restraint system usage rates.

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the North Carolina State Highway Patrol for its efforts in collecting these data. Without its cooperation, this study would not have been possible.

Special thanks are expressed to Kathryn F. Garren for her efforts in the computer programming required for the analysis.

I. INTRODUCTION

Because of the great amount of capital that is invested yearly in various automobile safety innovations, there is a continuing need for relevant evaluation of the injury reduction capabilities of these items. The restraint systems that are now installed in all new vehicles, and in particular the lap belt, are felt to be the most important. Because of the ever changing nature of the interior of automobiles, it is important to ascertain the continuing benefits of the system in order to insure proper expenditure of safety funds.

This study is an attempt to evaluate restraint system benefits for the purpose of providing more useful information to the motoring public. It is also an update of a previous HSRC study concerning belt use in 1967 automobile accidents. In addition to previously collected data, information on usage and injury patterns for all seating positions in N.C. accident vehicles has been compiled and analyzed. In the past, these data have only been available on the vehicle driver.

The format of this evaluation is similar to previous work: the data are supplied by the investigating officer -- a member of the North Carolina State Highway Patrol. The Highway Patrol investigates approximately 50 percent of all North Carolina accidents and over 99 percent of accidents occurring outside municipalities. Thus, the data represent a fairly extensive sample of the accident conditions and resulting injuries which are occurring on the highways across the state.

II. REVIEW OF THE LITERATURE

Lap Belt Studies

During the past decade, many studies have been conducted concerning restraint systems, and information has accumulated on design specifications, usage patterns, injury reduction, and injury causation.

In order to present background information related to this evaluation, pertinent studies have been reviewed. Topics investigated include restraint system usage patterns and related injury in real world accidents. Thus, studies of controlled crash tests have been deleted. In addition, the works reviewed are limited by the requirement that the data be reported by the vehicle owner or the investigating police officer rather than by an in-depth accident investigation team. While this approach may not produce the same level of accuracy or detail as a team approach, a large sample of data may be collected in a relatively short period of time.

Tourin and Garrett (1960) reported on injury sustained by 933 lap belt users and 8794 non-users in rural California accidents. Data were collected on all accidents investigated by the California Highway Patrol during specific periods in 1958 whether injury producing or not. Preliminary analysis indicated that the comparison between belted and unbelted drivers and right front seat occupants had to control for accident conditions because the belted group in the sample tended to be involved in more serious accidents. Therefore, comparisons were made under similar conditions for speed, accident type (point of impact), and seating position. The authors concluded that:

1. Belt users sustained 35.06 percent fewer major and fatal injuries than non-users. For drivers only, the figure was 37.06 percent fewer.

2. Under the given controlled situations, a total of 8.10 fatal injuries were expected, but only 4 fatalities were observed in the belted group. (These numbers were too small for significance testing).

3. No belt benefit was seen in accidents where the force was directly forward or rearward.

4. Most of the benefit attributable to belt use appeared to result from prevention of ejection.

It was interesting to note that the chances of injury were about equal for the two groups. Belt use seemed to shift the degree of injury toward the lower end of the scale. However, no significant differences were found in the proportions of injury in the two groups.

Garrett (1963) reported on lap belt usage in injury-producing accidents. The installation of seat belts was made mandatory by law in Wisconsin in the 1962-1963 model year. Analysis of the relatively small sample of accident-involved occupants indicated that 35.1 percent of all the occupants to whom belts were made available by law were using them. Not surprisingly, of the 7.3 percent of older Wisconsin vehicles in which belts had been voluntarily installed, 65.0 percent of the occupants were using them. While 57.8 percent of the males were lap belt users, only 43.8 percent of the corresponding female populations were users. This sex difference has also been noted in other work.

The earlier Tourin and Garrett (1960) study had indicated that the benefit of the lap belt seemed to result from prevention of ejection. Campbell and Kihlberg (1965) looked at the injury reducing potential of the belt by examining rural injury-producing accident data in which there had been no occupant ejection. The report considered the possibility that the belt could provide additional protection (beyond ejection control) inside the car through reducing or preventing contact with interior objects.

Because of the subtle nature of the injuries to be examined, it was felt necessary to provide highly controlled comparisons between the belted and non-belted groups. Thus, 232 matched pairs of occupants were formed from the existing data files. In each pair one occupant was belted and one not belted. The pair were matched on a number of variables including:(1) accident severity; (2) direction of impact; (3) seating position; (4) year of car; (5) make of car; (6) whether driver had a passenger or not; (7) occupant height; (8) occupant weight; (9) occupant sex; (10) occupant age; and wherever possible (in cases of duplicate matches),(11) impact type and (12) car body type. Analyses were conducted on both overall injury and injury to six body areas. Each pair was classified according to whether the belted occupant was (1) less severly injured, (2) more severely injured, or (3) not different from the unbelted occupants in regard to injury.

The results of this study indicated that there was <u>no</u> significant difference between the belted-unbelted overall or serious injury configuration except in the cases of thorax injuries to right front seat occupants. The authors raised a caution concerning the small sample size, and concluded that the benefit of the belt results primarily from ejection control. They suggested that other injury reduction would result from the use of chest restraints.

Garrett and Braunstein (1962) came to a different conclusion concerning injury in side impact situations (where ejection might not be expected). The authors examined a special class of data in which belts were worn by at least one accident-involved occupant in order to gather information on injuries caused by the seat belt itself. They, like others, concluded that an occupant wearing a belt was less likely to be seriously injured than his unbelted counterpart. More specifically, "when the impact was on the opposite side of the car, or on front or rear fenders on the same side as the occupant, injury was markedly reduced."

Kihlberg and Robinson (1967) later published an in-depth study based on updated Cornell Aeronautical Laboratory data files in an attempt to increase knowledge of the seat belt's relationship to injury reduction and injury patterns. This study involved 651 belted occupants (drivers and right front seat passengers) who had been involved in injury producing accidents. Just as in the earlier Campbell and Kihlberg (1965) study, each belted occupant was matched on nine variables with an unbelted occupant. Appropriate statistical analyses of these matched pairs revealed the following results:

1. Frequency of injury generally was higher for unbelted occupants than for their belted counterparts, ranging from 30 percent higher for thorax injuries to lesser elevations for other areas. This was true for all cases except abdominal injury for the right front seat passengers. Here the authors concluded that the belt may have increased the probability of injury.

2. In general, the frequency of serious injury was also higher for the unbelted group. Severe injuries occurred to 6.7 percent of the belted drivers versus 11.4 percent of the unbelted drivers, representing a 41.3 percent reduction. For right front seat passengers, the corresponding figures were 9.6 percent for the belted versus 11.1 percent for the unbelted, a 13.5 percent reduction.

3. The use of a seat belt tended to change the nature and source of an injury resulting in "injury exchange" to a more desirable type injury by limiting the range of contact available to the

occupant.

4. In the case where overall injury was higher for the belted occupant (that of abdominal injury to the right front seat passenger), most of the increase in injury was on the minor or less severe end of the scale.

5. The use of the belt prevented ejection from the vehicle in all but one case. The percentage of ejection was 7.3 percent for the unbelted group and 0.2 percent for the belted group.

6. The beneficial effect of the seat belt was more pronounced in rollover accidents where risk of ejection is greatest.

One of the more recent studies of seat belt effectiveness has been published by the Highway Safety Foundation (1970). The authors reported on 4571 accidents investigated by the Ohio State Highway Patrol and one local police department in Ohio. Most of the accidents were rural in nature. Of the 12,797 occupants, 65 percent had some type of restraint available and 31 percent of those with a lap belt available were using it at the time of the accident. For the passenger cars in the sample, 68 percent of the occupants had lap belts available and of these, 32 percent were using them. Only 4 percent of those with a shoulder harness available were using the device. This small sample of shoulder restraint users precluded this restraint system from injury related analysis. Of interest was the fact that while 26 percent of all right front seat passengers having belts used them, 66 percent of the same passengers buckled up when the driver used his belt. This "follow the leader" effect also carried over into the center front and rear seat positions where 45 percent of the occupants used the available belts when the driver used his.

The results of the injury analysis were presented in the form of ratios of unrestrained injury probability to restrained probability. This analysis indicated that the relative risk of a fatal injury for a non-belted passenger car occupant (including drivers) was 4.06 times the risk for a belted occupant. For non-belted drivers, the risk was 5.63 times as great. For serious and fatal injuries combined, the risk for all non-belted occupants was 1.95 times as great as the risk for belted occupants and the risk for unbelted drivers was 2.45 times as great as the risk for the belted driver. The results of seating position analysis showed far greater benefits for front seat occupants than for those in the rear seat. The main advantage occurred in the 41-60 mph speed range (as opposed to 20-41 mph and 60+ mph ranges).

The study which serves as the basis for the current work is entitled, Seat Belt and Injury Reduction in 1967 North Carolina Automobile Accidents (Campbell, 1968). The report was based on data collected by the North Carolina State Highway Patrol on accident-involved drivers. This research effort was an approximate replication of the Tourin and Garrett (1960) study on 1958 California accidents.

Comparisons of the belted and unbelted groups were controlled by three variables: (1) speed prior to the accident, (2) part of the car impacted, and (3) accident type. Because of the few fatalities in the sample, the fatal and serious injury groupings were combined for analysis purposes.

The expected injury frequencies for the analysis of the belted population were determined by applying the proportions associated with the unbelted drivers exposed to the same accident conditions (i.e., the three variables previously stated). Statistical tests employed included the use of the chi-square (based on a normal approximation for large samples) and the binomial or Poisson for large samples. Fisher's Exact Test was employed when the samples were small.

The analysis indicated a 36 percent reduction in serious plus fatal injuries for the belted group (68 observed versus 106 expected injuries), a highly significant result ($p < .005$). The unspecified impact type (containing rollovers) accounts for almost all of the difference in injury with the major benefits noted in the higher speed category (50+ mph).This finding again points out the beneficial effect of the belt through ejection control. In this sample, the belted group was shown to have been exposed to about the same accident conditions as the unbelted drivers, differing slightly from the Tourin and Garrett results, where the belted group were involved in more serious accidents. In addition, no beneficial effect was indicated in examination of frontal impacts.

Levine and Campbell (1971) published a recent study of lap belts and energy-absorbing steering systems. Data from 1966 and 1968 North Carolina accidents were divided into four mututally exclusive groups based on the presence of the energy-absorbing (EA) steering system and lap belt usage. The effects of the two systems were examined by fitting linear models to the categorical data.

The analyses indicated that the lap belt effectiveness was independent of the presence of the EA system. Serious and fatal injuries (A+K) were reduced by 32.5 percent in frontal impacts and by 39.6 percent in high speed frontal impacts. (Both reductions significant at α = .01 level.) These results are in contrast to those of previous studies which indicated no effect in frontal impacts. In addition, serious injuries were reduced by 58 percent (α = .05) in rear impacts. Again a major benefit was found in the car-ran-off-road category where the majority of rollovers would be expected. Here, an overall reduction of 49.5 percent was noted. For all points of impact, speed, and accident types combined, the lap belts were found to reduce serious and fatal injury frequency by 43 percent (α = .01).

Only one report reviewed presented an analysis of injury severity risk by seating position in the vehicle. O'Day and Darby (1970) presented limited information on this topic in a report on "The Highway Safety Research Institute Accident Data Banks." The percentages of occupants sustaining varying degrees of injury in each seating position were presented in tabular form. Examination of the table indicates that the highest percentage of fatal injuries was, suprisingly, in the right rear seating position. It should be noted here that no frequencies or significance levels were presented and that no partitioning by accident variables or seat belt usage were given, although it is possible that analyses of these variables were conducted and not presented in this brief summary.

Shoulder Harness Studies

Several of the researchers previously cited indicated that use of an upper torso restraint could greatly reduce injury to occupants by preventing injury caused by striking interior structures and by spreading the deceleration forces over a larger area of the body. However, because of the very low usage levels of these restraints in U.S. cars, little meaningful research on the injury-reducing potential of these devices has been possible. However, because shoulder harnesses have been in use in Europe for a much longer period of time, some very relevant work has been conducted.

In the study, A Statistical Analysis of 28,000 Accident Cases with Emphasis on Occupant Restraint Value, Bohlin (1967) reported on the three-point safety harness found in two models of Volvos. In this three-point system the shoulder and lap belts are interconnected so that one may not be worn independently of the other. The data were drawn from accident reports filled out by vehicle owners and included injury information on 37,511 front seat occupants. In comparisons that controlled for accident speed (limited inherently by vehicle make), analysis indicated that there were no fatal injuries for the belted group in accidents occurring below 60 mph. For the unbelted group, fatal injuries were found at speeds from 12 mph and upward. Reduction in non-fatal driver injury was 57 percent at the lower speeds and 48 percent at higher speeds. For front seat passengers, the corresponding reductions in injury were 63 percent and 55 percent. There were 159 cases of ejection in the non-belted sample but only one case in the belted group (and this case was not completely substantiated). The data also indicated that 25 percent of the drivers who had the three-point system available were using it at the time of their accidents. This is much higher than the reported shoulder harness usage percentages for U.S. drivers.

A report with a somewhat wider scope was prepared by Lister and Neilson (1966). Again, this report dealt with upper torso restraints but here three different systems were investigated: (1) full harness with a double shoulder strap, (2) diagonal belt alone, (3) diagonal plus lap belt. The data were retrieved from accident reports completed by owners of accident involved vehicles. The final sample consisted of 2068 drivers and front seat passengers (1994 belted, 74 unbelted). Since there were no fatal injuries in any belted group, serious injuries were examined. Analysis indicated 22 percent serious injury in the small non-belted sample group and 6.5 percent serious injury in the belted group, representing a 70 percent reduction for the belted sample.

As noted, the relative effectiveness of various upper torso systems was examined. The full harness group (double shoulder straps) had the lowest serious injury rate of 3.5 percent. The diagonal belt alone had a serious injury percentage of 5.5 percent and the diagonal plus lap belt had a corresponding percentage of 8 percent. This final layout is very similar to the one now being installed in most U.S. manufactured vehicles. The lower percentage of the diagonal belt alone is suprising to some who have predicted the occurance of submarining for this particular layout. It must be noted, however, that the vehicles under study are the smaller European cars and that the knees of an occupant are only a few inches from the shelf. Therefore, in a collision, submarining may be partially controlled by contact with this structure. This is supported by the fact that the highest percentage of injury to legs and feet is in this diagonal-only category.

Anderson (1971) attempted to estimate the percentage of drivers using an available shoulder belt for a number of parameters. Field observations of 1707 drivers moving in traffic were collected across North Carolina, and an overall utilization rate of 8.26 percent was calculated. Other results included the following:

1. Male drivers (9.51 percent) used the shoulder harness more than female drivers (4.82 percent).

2. Drivers of foreign vehicles (19.86 percent) used the shoulder belt more than drivers of U.S. manufactured vehicles (5.96

percent).

3. Young drivers (11.15 percent) were observed to be using the shoulder harness more than either mature (7.16 percent) or older drivers (5.32 percent).

4. Drivers of out-of-state vehicles (12.19 percent) had a higher utilization rate than their in-state counterparts (7.19 percent), perhaps as a result of trip length.

These studies indicate the tremendous injury reduction potential of the upper torso restraint systems. However, these and other studies also document the extremely low usage levels for these devices and indicate an area requiring a great deal of persuasive effort or measures leading to mandatory usage.

Summary

A review of the research on lap and shoulder belt usage and injury reduction in accidents indicates the following major findings:

1. Lap belt users sustain less serious injuries than do non-users. The reduction of driver injury is approximately 30 to 40 percent.

2. Most of the benefit of the lap belt has been attributable to ejection control. Until very recently, little effect has been noted in frontal or rearward impacts.

3. Usage levels for lap belts in accidents are low, ranging from approximately 10 percent to 30 percent for occupants with belts available to them.

4. Shoulder harness systems exhibit enormous benefits for those who wear them, in that related injuries are reduced approximately 50 to 60 percent.

5. Shoulder harness usage rates are extremely low (<10 percent), indicating a need for widespread efforts to publicize their general utility.

III. METHODOLOGY

The purpose of this study was to determine the effects of restraint systems, especially the lap belt, in terms of injury reduction and prevention. In addition to information on belt usage and benefits for the driver station, the data provide similar information for all other seating positions. In conjunction with this usage and injury information, related data on the source of the information and the data collector's confidence in its reliability have been gathered.[1]

For this study, information was collected by North Carolina State Highway Patrol personnel in three of six troops during the summer period between May 1 and August 3, 1970. While some few urban accidents are in the sample, the accidents were predominantly rural in nature and occurred in the Piedmont area of the state. The officers were instructed to complete the supplementary form on any passenger car involved in an accident. Thus, by definition, occupants of trucks, buses, motorcycles, and other miscellaneous vehicles were omitted from the supplementary study sample. Because of this data restriction and the rural nature of the accidents, the injury severity levels of the sample are slightly higher than those for the population at large.

In addition to the information normally collected for the basic accident form, supplementary data were collected on the following variables for the sample (see Appendix A):

1. "Seating Position" - six possible positions, three front seat and three rear seat positions.

   A = driver
   B = center front seat
   C = right front seat

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[1]*The basic data were collected through a process established in an ongoing Traffic Records Project funded through the Office of the Governor's Highway Safety Program. One phase of upgrading North Carolina's Traffic Records system is the collection of previously unsampled data. This is being done through the use of supplementary forms which are linked with the basic accident report (i.e., a bi-level report filed on all normally reportable accidents---those which involve personal injury or more than $200 property damage). The supplementary form used in collection of restraint system data is shown in Appendix A.*

D = left rear seat
E = center rear seat
F = right rear seat

2. "Age" - age of occupant.

3. "Sex" - male or female.

4. "Injury" - injury severity to each occupant based on standard scale used by North Carolina State Highway Patrol.

   K = killed
   A = visible sign of injury such as bleeding wound or distorted member, or had to be carried from scene.
   B = other visible injury or bruises, abrasions, swelling, limping
   C = no visible sign of injury but complaint of pain or momentary unconsciousness
   N = no injury

5. "Restraint Installed" - type of restraint installed at given position. These include:

   A. Lap belts.
   B. Shoulder harnesses or belts.
   C. Both lap and shoulder belts.
   D. No belts.
   E. Specially designed child restraint system.

6. "Restraint Used" - which of the available restraints systems was in use by the occupant at the time of the accident.

7. "Information" - the source of the information on belt usage, including:

   A. "I" - The officer himself observed the usage or non-usage.
   B. "Him" - The occupant in question provided the information.
   C. "Occ" - Another vehicle occupant provided the information.
   D. "Wit" - A witness outside the vehicle provided the information.
   E. "Other" - Some other person provided information. Example, wrecker driver or ambulance attendant.

8. "Confidence" - the officer's confidence in the usage information, a subjective measure of data reliability.

   A. ++ Positive.
   B. + No reason to doubt.
   C. - Some doubt.
   D. -- Unsure.

The supplementary information was punched onto computer cards and later linked with the appropriate accident information for analysis.

IV. ANALYSIS AND RESULTS

The format for the analysis of the injury data is very similar to that employed in the HSRC study, Driver Injury in Automobile Accidents Involving Certain Car Models (1970). A matrix is constructed containing rows based on accident type, impact site, and estimated speed just prior to impact and columns containing belted and non-belted occupant injury frequencies for both serious (A+K) and minor (B+C) injuries.

The tables that are included in this report are taken directly from the matrix. For example Table 1, page 15, deals with serious and fatal (A+K) injuries suffered by drivers in single vehicle crashes. The expected frequencies of serious and fatal (A+K) injuries to belted occupants for each row were determined by applying to the belted group the injury proportions associated with unbelted drivers exposed the the same accident conditions. Thus, in the first row, for medium speed impacts, the expected number of A and K injuries (11.736) is determined by multiplying the proportion of unbelted A and K injuries (13.05 percent) times the total number of belted drivers (90). Comparisons can then be made concerning the observed and expected numbers of A and K injuries for the belted occupants, the last two columns in the table.

The unbelted occupants are thus used throughout as a standard population against which to contrast the injury experience of belted occupants in the same classes of accidents. This is reasonable because of the predominance of unbelted occupants over the frequency of belted ones. In other words, the unbelted group more nearly represents the standard population than does the belted sample.

The analyses conducted concerned two hypotheses.

First, the one-sided hypothesis that restraint system usage results in a beneficial effect on injury. Depending on available sample sizes, either Binomial or Poisson tests were employed to detect significant differences between the belted and unbelted groups. Binomial tests were used in all instances except where otherwise noted.

Second, two-sided hypotheses concerning the effects of various parameters such as occupant age on restraint system usage rates, using tests concerning differences between Binomial productions. (See Appendix B for more detail.) The reader should note that significance levels of

$\alpha \leq .10$ are reported in the first section of the paper concerning injury reduction.

The first part of the following section will concern the effect of the lap belt use on injuries for the driver, the center front seat passenger, the right front seat passenger, and rear seat occupants. Occupant injury in terms of points of impact is discussed for the different seating positions. Next, a similar analysis will be made of the effect of the shoulder harness restraint on injuries. This analysis includes two seating positions: the driver station and the driver and right front seat passenger combined. Finally, the effects of various parameters on restraint system usage will be studied.[1]

Injury Reduction Associated with Lap Belt Use

The effects of lap belt and chest restraint usage on injury were examined for all seating positions. The following discussion concerns results based on the analysis of the previously mentioned matrix for lap belt usage only. The important results are categorized by seating position.

The driver.

Because of the number of drivers in the sample it was possible to examine each accident type, impact site and speed range separately.

Unspecified point of impact.

In the previously noted study of 1967 accident data (Campbell, 1968) the most significant benefit attributed to lap belt usage was found in the single vehicle, unspecified impact site category, a group which is composed largely of vehicles involved in rollovers. A parallel effect is noted in the current research. As can be seen from Table 1, for the medium speed category, four of the 90 belted drivers (4.4 percent) sustained serious or fatal (A+K) injuries, while 11.74 such injuries would have been expected, based on the experience of the unbelted sample where 51 of the

[1]*Most of the following discussion will concern detailed analyses. For the reader who wishes to study the analyses and results in less detail, summary sections are incorporated into the paper. The summary of restraint system effects on injuries can be found on page 41, and the summary of usage results begins on page 59.*

391 drivers (13.0 percent) sustained similar injuries (i.e., 90 x 13.0 percent = 11.74). Thus, by comparing the expected number (11.74) of serious injuries with the observed number (4), it can be shown that drivers using lap belts experienced 66 percent fewer A+K injuries than would be expected ($p = .01$). Similarly, in the high speed category, drivers using lap belts experienced 53 percent fewer serious injuries than the corresponding unbelted group ($p < .001$). This reduction in injury in the unspecified impact site (including rollovers) has also been substantiated by other studies (Tourin and Garret, 1960; Kihlberg and Robinson, 1967; Campbell, 1968).

Table 1. Serious and Fatal Driver Injuries in Single Vehicle Crashes, Unspecified Point of Impact.

Driver not Wearing Belt			
	Total	Observed No. with A or K Injury	Percentage with A or K Injury
Medium Speed (30-40 mph)	391	51	13.0
High Speed (50+mph)	945	217	23.0
Driver Wearing Belt			
		Observed No. with A or K Injury	Expected No. with A or K Injury
Medium Speed 30-40 mph)	90	4 (4.4%)*	11.739
High Speed (50+ mph)	186	20 (10.8%)**	42.711

* $\alpha \leq .05$

** $\alpha \leq .01$

Frontal impacts.

In addition to the previously noted "rollover" benefits, these current data have indicated significant benefits in frontal impacts. In order to understand this result, it is necessary to understand the definition of "frontal" impact sites. The figure presented below is present on the standard accident report form from which information concerning impact site was taken.

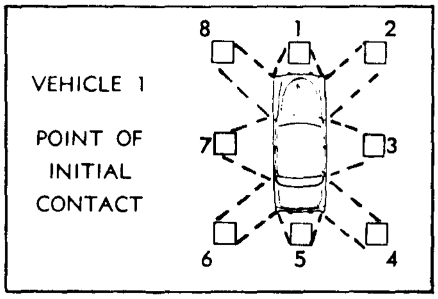

Figure 1. "Point of Initial Contact" drawing taken from North Carolina Standard Accident Report Form.

As can be seen from the figure, areas shown on the drawing refer to "point of initial contact" rather than direction of impact force. However, other research involving the same group of officers making an independent rating of area impact (i.e., a damage severity rating using the TAD scale[1]) has indicated that the investigators are using this figure to indicate direction of impact in some cases. Thus, an impact force striking the vehicle at or near the left front corner would be classified as an "8" even though the major resultant force vector would be in a "frontal" direction. Because TAD readings were unavailable on the data to be analyzed, it was decided to classify "frontal impacts" as those crashes in which the initial point of impact was entered as a "1". Because this reduces the sample sizes, some cell collapsing was necessary for analysis. It is also realized that some crashes which should be classified as frontals

[1]*The Vehicle Damage Scale for Traffic Accident Investigators (TAD Scale) is a pictorial guide used by investigators to assess vehicle damage. A series of photographs and a seven-point scale are used to portray the most common types of impacts. The investigator compares the actual damage with the photographs and then rates the damage with a code that indicates the area involved and the severity of the crash, e.g., FD-3 refers to a front-distributed crash with a severity level of three.*

are deleted. However, significant results were still indicated (see Table 2).

Table 2. Driver Injury (serious or fatal) for Frontal Impacts in Car Versus Car Collisions.

Unbelted Drivers		
Speed (mph)	Total	Observed No. with A or K Injury
Low (0-29)	241	8 (3.3%)
Medium (30-49)	323	28 (8.7%)
High (50+)	190	48 (25.3%)
Total	754	84 (11.1%)

Belted Drivers			
Speed (mph)	Total	Observed No. with A or K Injury	Expected No. with A or K Injury
Low (0-29)	82	1 (1.2%)	2.722
Medium (30-49)	81	5 (6.2%)	7.022
High (50+)	47	11 (23.4%)	11.874
Total	210	17 (8.1%)†	23.395

† $\alpha \leq .10$

For car versus car crashes when all speed categories are summed, belted drivers experienced approximately 27 percent fewer serious injuries than would be expected from the experience of the unbelted group (17 versus 23.395, respectively) ($p = .10$).

Similar results are indicated by the data concerning car versus truck collisions (with frontal impact to the car). Again note that in a car versus truck accident, only injury information on the passenger car occupants is analyzed. The occupants of the truck (or bus, motorcycle, etc.) are not included in the sample. Here the results are significant within some individual speed ranges.

Table 3. Frontal Impacts in Car Versus Truck Collisions.

Unbelted Drivers		
Speed (mph)	Total	Observed No. with A or K Injury
Low (0-29)	59	3 (5.1%)
Medium (30-49)	64	12 (18.8%)
High (50+)	32	9 (28.1%)
Total	155	24 (15.5%)

Belted Drivers			
Speed (mph)	Total	Observed No. with A or K Injury	Expected No. with A or K Injury
Low (0-29)	13	0	0.661
Medium (30-49)	16	0*	3.000
High (50+)	14	1 (7.1%)†	3.938
Total	43	1 (2.3%)*	6.658

† $\alpha \leq .10$
* $\alpha \leq .05$

For both medium speed collisions (p=.04) and high speed collisions (p=.06), the belted drivers sustained fewer A and K injuries than were expected. Over all speed ranges, the belted drivers experienced 85 percent fewerserious injuries than would be expected from the experience of the unbelted group (p=.01).

Thus, for the driver station, the data indicate a reduction in serious injuries in frontal collisions. The question arises concerning the nature of this reduction in terms of the overall injury picture. Specifically, has the reduction of serious and fatal injuries been accompanied by an increase in minor injuries, or is there a significant reduction in total injuries?

Analysis of the data indicated no significant increase in minor injuries in any of the individual accident-type speed categories. Further, when the frequency of all injuries was examined, significant belt benefits were indicated in some instances. Specifically, in car versus car collisions with all speeds combined, the belted group of drivers experienced 24 percent fewer total injuries than expected (p=.06). In this classification 29 (or 13.8 percent) of the 210 belted drivers were injured to some extent, while 137 (or 18.17 percent) of the 754 unbelted drivers sustained some injury. When "all injuries" were examined in the car versus truck frontal collisions, significant benefits occurred in some individual speed groups (see Table 4). Here, in both the medium and high speed groups, the belted drivers experienced significantly fewer injuries than would be expected from the experience of the unbelted group (p=.005, and p=.05, respectively). As a result, when all speeds were combined, the belted group experienced 71 percent fewer injuries than were expected (p=.01).

Even in the multivehicle accidents, the trend continued. While no individual speed group showed a significant difference, the belted drivers experienced significantly fewer total injuries than would be expected based on the experience of the unbelted group (p=.01). Here, one of the 21 belted drivers was injured (4.8 percent), while 32 of the 121 unbelted drivers sustained some degree of injury (26.4 percent).

In most cases, it would be feasible on a cost basis to accept an increase in the number of minor injuries for a corresponding decrease in the frequency of serious and fatal injuries. Such a tradeoff might be expected in the effects of many safety devices, the lap belt included. These data indicate, however, than an even more beneficial situation is resulting in frontal crashes: not only are serious and fatal injuries being significantly reduced, but, in addition, so is the frequency of any injury in some cases.

Table 4. Driver Injury in Car Versus Truck Frontal Collisions.

Unbelted Drivers		
Speed (mph)	Total	Observed No. Injured
Low (0-29)	59	4 (6.8%)
Medium (30-49)	64	18 (28.1%)
High (50+)	32	15 (46.9%)
Total	155	37 (23.9%)

Belted Drivers			
Speed (mph)	Total	Observed No. Injured	Expected No. Injured
Low (0-29)	13	0	0.881
Medium (30-49)	16	0**	4.500
High (50+)	14	3(21.4%)*	6.563
Total	43	3 (7.0%)**	10.265

* $\alpha \leq .05$
** $\alpha \leq .01$

Side impacts.

Driver injury was also analyzed for impacts resulting from "side" collisions. Again, a rather limited definition of impact site was used. Only those passenger vehicles for which the initial point of impact was in the passenger compartment area were included in the analysis (i.e. only those vehicles whose "point of initial contact" was entered as "3" or "7" - see Figure 1, page 16).

In high speed car versus car collisions with point of impact on the opposite side (i.e., the right side or passenger side), belted drivers experienced fewer serious injuries than were expected (p = .05). Here none of the 18 belted drivers were seriously injured while 8 of the 53 unbelted drivers sustained an A or K injury (15.1 percent). Because of the small sample of belted drivers involved, an additional analysis was performed on these opposite side impacts summed over all speeds. The belted driver again experienced fewer serious injuries than expected (p = .03). In this group, none of the 38 belted drivers were seriously injured, while 12 of the 133 unbelted drivers were (9.0 percent).

The matrix was examined to determine if there was the aforementioned "trade-off" to the minor injury category for these opposite side, car versus car collisions, and again the results indicated the opposite to be true. No significant differences were indicated in the minor injury groups. There were, however, notable differences in the "all injury" classifications. In the high speed group, the belted drivers sustained fewer injuries than expected (p = .05). One (or 5.5 percent) of the 18 belted drivers was injured, while 13 (or 24.5 percent) of the 53 unbelted drivers sustained some injury. When all speed groups were combined, 2 of the 38 unbelted drivers, (15.0 percent) sustained injury. (p = .07).

Because this beneficial belt effect was indicated for opposite side impacts, a reverse effect might be hypothesized for "same side" impacts. This hypothesis was tested for serious, minor, and all injuries within each speed group and over combined speed groups. While the observed injuries for the belted drivers were higher than the expected frequencies for many of the situations, there was no case in which there were significant differences. In other words, the overall injury pattern was not significantly affected.

It would appear that any slight increase in injuries to belted drivers in "same side" impacts is more than compensated for by the beneficial effects of the belt in other impacts. (See Overall Driver Injury section, below)

Rear impacts.

The rear impacts analyzed in the basic matrix were defined as those in which the point of initial impact was entered as either a "4", "5", or "6" (see Figure 1, p. 16). Here it should be noted that this definition is less stringent than the definition used for frontal impact. Thus, there is the possibility of some error in the data due to collisions which might better be classified "side" collisions in terms of their force vector. However, the limited amount of data and the fact that the impacts studies were all behind the passenger compartment led to the definition used.

No significant differences in serious or minor injuries were noted in any speed group or in combined speed groups for any accident type. However, in the car versus car accidents, when all speeds were combined and total injuries examined, the observed number of injuries was less than the expected frequency ($p = .06$, Poisson). In this grouped classification, nine of the 180 belted drivers (5.0 percent) sustained some injury compared to 71 of the 807 unbelted drivers (8.8 percent).

Overall driver injury.

In order to summarize driver injury by impact point, the matrix was summed to form table number 5, Driver Injury Frequency by Point of Contact. Analysis of this table indicates significant beneficial results in many cases. As might be expected from the previously discussed frontal benefits for individual speed groups and accident types, belted drivers involved in all frontal accidents experience significantly fewer serious, minor, and total injuries than expected ($p = .005$, $p = .08$, and $p = .001$, respectively). There was a 42.7 percent reduction in serious and fatal injuries, and a 38.4 percent reduction in all injuries.

"Right" or "opposite" side impacts followed a similar trend. The difference between the 4.547 expected serious and fatal injuries and the zero observed is significant at the $p = .009$ level. When minor and serious injuries were combined, the total observed frequency was significantly less than expected at the $p = .06$ level. Caution must be observed in expressing percentages

Table 5. Driver Injury Frequency by Point of Contact.

Unbelted Drivers				
Impact Site	Total	Observed No. with B or C Injuries	Observed No. with A or K Injuries	Total No. Injured
Front	1086	83 (7.6%)	132 (12.2%)	215 (19.8%)
Right Side	190	10 (5.3%)	16 (8.4%)	26 (13.7%)
Left Side	230	20 (8.7%)	16 (7.0%)	36 (15.7%)
Rear	1189	84 (7.1%)	22 (1.9%)	106 (8.9%)
Unspecified	1379	178 (12.9%)	274 (19.9%)	452 (32.8%)
Total	4074	375 (9.2%)	460 (11.3%)	835 (20.5%)

Belted Drivers									
Impact Site	Total	Observed No. with B or C Injuries	Expected No. with B or C Injuries	Observed No. with A and K Injuries	Expected No. with A and K Injuries	% Diff. A or K Injuries	Observed No. Total Injuries	Expected No. Total Injuries	Total Injuries
Front	287	15 (5.2%)†	21.935	20 (7.0%)**	34.884	-42.7%	35 (12.2%)**	56.819	-38.4%
Right Side	54	3 (5.6%)	2.842	0**	4.547	-100.0%	3 (5.6%)†	7.389	-59.4%
Left Side	62	5 (8.1%)	5.391	5 (8.1%)	4.313	+15.9%	10 (16.1%)	9.704	+ 3.1%
Rear	289	16 (5.5%)	20.417	2 (0.7%)†	5.347	-62.6%	18 (6.2%)†	25.765	-30.1%
Unspecified	283	30 (10.6%)	36.529	25 (8.8%)**	56.231	-55.5%	55 (19.4%)**	92.760	-40.7%
Total	975	69 (7.1%)**	89.746	52 (5.3%)**	110.088	-55.8%	121 (12.4%)**	199.834	-39.4%

† $\alpha \leq .10$
* $\alpha \leq .05$
** $\alpha \leq .01$

of reduction because of the small sample sizes. Left or "same side accidents" showed no significant differences in serious, minor, or all injury classification.

As noted previously, there was only one situation in which the basic matrix revealed a significant benefit in rear impacts, and this was in the combined injury and speed classification for car versus car impacts. When all rear impacts are combined in the summary table, the level of significance for belt benefits is slightly less than before, although the belted drivers still experienced fewer serious and fatal injuries than would be expected ($p = .10$, Poisson). When all injuries in these rear impacts were combined, the belted group sustained fewer injuries than expected ($p = .07$). Here 8.9 percent of the unbelted group were injured while 6.2 percent of the belted group sustained either a minor or serious injury.

As in previous studies, the most significant lap belt effect is found in the unspecified impact site, both in terms of significance levels and, perhaps more importantly, in terms of percent injury reduction. As can be seen in Table 5, belted drivers experienced significantly fewer serious injuries and total injuries than expected ($p < .01$ in both cases). In the serious injury group for unspecified impacts, 8.8 percent of the belted drivers sustained injury as compared to 19.9 percent of the unbelted group. Correspondingly, 19.4 percent of the belted group sustained some degree of injury while 32.8 percent of the unbelted sample of drivers were injured.

In order to examine the overall benefits of lap belts for drivers, the points of impact frequencies were summed to give the 'total' row. Here, significant decreases are noted in minor, serious and all injuries ($p < .01$ in all cases). The data indicate that belted drivers sustained 39.4 percent fewer injuries of any type than would be expected from the experience of the unbelted group. This figure can be compared to the 30 percent which can be calculated from the report by Levine and Campbell (1971). In terms of serious or fatal injury, the most important category on a cost-to-society basis, the data indicate a 52.8 percent reduction in driver injuries from the expected frequency. This benefit is somewhat higher than the 43 percent found by Levine and Campbell (1971) on comparable data with much larger sample sizes. These percentages support the statement made on page 22 concerning any slight increase in injury for "same side" impacts. The overall data indicate that any increase in injury frequency in these impacts has been more than compensated for by the beneficial effects of the belts in other accident situations. Such a potential savings in injury again stresses the need for some workable program to increase lap belt usage.

The center front seat passenger.

Because of the small sample of occupants (belted = 31) in the center front seat, position B, little meaningful analysis could be conducted. No significant differences were found in any individual speed or accident type classification. When the data were summed over all speed groups and accident types the following overall frequencies resulted.

Table 6. Center Front Passenger Injury Frequencies Over All Speeds and Accident Types.

Unbelted Passengers		
Total	Observed No. with B and C Injuries	Observed No. with A or K Injuries
242	41 (16.9%)	34 (14.0%)

Belted Passengers				
Total	Observed No. with B&C Inj.	Expected No. with B&C Inj.	Observed No. with A&K Inj.	Expected No. with A&K Inj.
31	2 (6.5%)†	5.252	3 (9.7%)	4.355

† $\alpha \leq .10$

The number of minor injuries observed in the belted group is less than expected (p = .05). No significant differences were found between observed and expected serious injuries. When both minor and serious injuries were combined to give an all injury class, the observed injury frequency in the belted group was significantly less than would be expected from the experience of the unbelted passengers (p = .05). Here, there were 9.61 injuries expected and 5 observed. Again, while these differences must be viewed with some reservation because of the small sample size, it is important to note that every difference favors the belted occupant.

The right front seat passenger.

The analysis of injuries sustained by right front seat occupants, position C, was conducted in the same manner as the analysis of injuries to drivers. There were 1680 unbelted occupants and 297 belted occupants in the sample.

Unspecified point of impact.

As in the driver matrix, there were significant reductions in the number of serious injuries sustained in the single vehicle unspecified point of impact collisions (which include rollovers). As shown in Table 7, the right front passengers sustained fewer serious injuries than expected in both the medium and high speed situations ($p = .02$ and $p = .004$, respectively). When the injury frequencies were summed over all speed groups, the belted passengers experienced 68 percent fewer A and K injuries than would be expected from the experience of the unbelted passenger group. The minor injury and all injury groupings were examined to test for the "trade off" effect, i.e. a change in the injury severity distribution. There were no significant differences between observed and expected minor injury frequencies in any individual speed group or when all groups were combined. When serious and minor injury frequencies were combined, there were significant reductions in all injuries for the belted group in both the medium and high speed classes ($p = .01$ in both cases). In the medium speed class, there was one injury of some degree observed and 5.58 expected. In the high speed class, while 26.61 injuries were expected only 18 were observed. As expected from these results, when all speeds were evaluated, there was a significant reduction in the overall frequency of injury (24.7 percent for belted group, 41.8 percent for unbelted group, $p = .002$).

Frontal impacts.

Injury to right front passengers was examined in frontal impacts in each accident group. Sample sizes for belted occupants were usually small, ranging from 1 to 29. In car versus car frontal collisions, while observed frequency of serious and fatal injury for the belted group was less than the expected frequency in each speed group and, thus, in the total group with all speeds combined, none of these differences were significant at the p < .10 level. Examination of minor injuries for the belted group indicated a higher observed frequency in low speed crashes (p=.08, n=24) and a lower observed frequency in medium speed frontal impacts (p=.06, n=27). Just as in previous cases, when the total number of injuries were examined in each speed category and over all speed categories, no significant differences were found.

Table 7. Right Front Passenger Injury in Single Vehicle Unspecified Point of Impact Collisions.

Unbelted Passengers			
Speed	Total	Observed No. with B or C Inj.	Observed No. with A or K Inj.
Low (0-29)	9	1 (11.1%)	0
Medium (30-49)	129	14 (10.9%)	22 (17.1%)
High (50+)	362	73 (20.2%)	99 (27.3%)
Total	500	88 (17.6%)	121 (24.2%)

Belted Passengers				
Speed	Total	Observed No. with B or C Inj.	Observed No. with A or K Inj.	Expected No. with A or K Inj.
Low (0-29)	1	0	0	0
Medium (30-49)	20	1 (5.0%)	0*	3.411
High (50+)	56	12 (21.4%)	6 (10.7%)**	15.315
Total	77	13 (16.9%)	6 (7.8%)**	18.634

* $\alpha \leq .05$
** $\alpha \leq .01$

Further analysis of frontal impacts indicated no significant differences in any speed classification, injury grouping, or combined groups for either car versus truck or multiple vehicle frontal impacts. As indicated above, these situations were characterized by very small sample sizes of belted right front passengers.

Other impacts

Same side, opposite side, and rear impacts were examined for reductions or increases in injury for the belted right front seat passenger in individual speed groups, individual accident types and combined groups and types. No significant differences were found in any situations. Again, many of the sample sizes were very small.

Overall injury for right front seat passengers

Table 8 provides a summary of injury to right front passengers by point of impact. Each impact site row represents a summation of injury over all speeds and accident types. In frontal impacts, the belted occupants experienced fewer A or K injuries than expected ($p = .07$). There were no significant increases in minor injury or in all injury in these frontal collisions. Thus, the previously mentioned slight increase in minor injuries is more than balanced by the reduction in serious injuries in this total row. In the rear impact situations, the minor injuries observed in the belted group were fewer than expected ($p = .09$). Here, while the serious injury frequency was less than expected, the difference was not significant. However, when serious and minor injuries were summed to give an all injury category, the belted right front seat occupants did experience fewer injuries than expected ($p = .04$). Because of the highly significant reduction in the unspecified point of impact classification for single vehicle collisions (see page 24), one might expect to find significant reductions when these collisions involving unspecified points of impact are summed over all accident types and speeds, and in fact, this is the case. Here, both serious injury frequencies and all injury frequencies are much less than expected from the unbelted experience ($p < .001$, $p = .002$, respectively). However, this summary row provides no new information over that presented in Table 7, since 500 of these 505 unbelted occupants and 77 of the 78 belted occupants were in the single vehicle unspecified point of impact classification discussed earlier. As with the driver

Table 8. Right Front Passenger Injury by Point of Impact.

Unbelted Passengers

Impact Site	Total	Observed No. with B or C Injuries	Observed No. with A and K Injuries	Total No. Injured
Front	457	40 (8.8%)	89 (19.5%)	129 (28.2%)
Right Side	96	10 (10.4%)	13 (13.5%)	23 (24.0%)
Left Side	106	12 (11.3%)	13 (12.3%)	25 (23.6%)
Rear	516	53 (10.3%)	30 (5.8%)	83 (16.1%)
Unspecified	505	89 (17.6%)	122 (24.2%)	211 (41.8%)
Total	1680	204 (12.0%)	267 (15.9%)	471 (28.0%)

Belted Passengers

Impact Site	Total	Observed No. with B or C Injuries	Expected No. with B or C Injuries	Observed No. with A and K Injuries	Expected No. with A or K Injuries	% Diff. A or K Injuries	Observed No. Total Injuries	Expected No. Total Injuries	% Diff. Total Injuries
Front	89	10 (11.2%)	7.790	11 (12.4%)†	17.333	-36.5%	21 (23.6%)	25.123	-16.4%
Right Side	19	4 (21.1%)	1.979	0	2.573	-100.0%	4 (21.1%)	4.552	-12.1%
Left Side	21	1 (4.8%)	2.377	3 (14.3%)	2.575	+16.5%	4 (19.0%)	4.953	-19.2%
Rear	90	5 (5.6%)†	9.244	3 (3.3%)	5.233	-42.7%	8 (8.9%)*	14.477	-44.7%
Unspecified	78	13 (16.7%)	13.747	6 (7.7%)**	18.844	-68.2%	19 (24.4%)**	32.590	-41.7%
Total	297	33 (11.1%)	36.064	23 (7.7%)**	47.202	-51.3%	56 (18.9%)**	83.266	-32.7%

† $\alpha \leq .10$
* $\alpha \leq .05$
** $\alpha \leq .01$

matrix, all points of impact frequencies were summed to provide information concerning the overall benefits of the lap belts for the right front passengers. Here, both the observed serious injury and all injury frequencies were less than the expected values ($p < .001$ in both cases). The results indicate the lap belted right front passengers experienced 32.7 percent fewer total injuries than expected and, even more important, 51.3 percent less serious and fatal injuries. This last figure is comparable to the 52.8 percent reduction noted on page 24 for drivers. Again, the driver sample is approximately three times as large as the right front passenger sample.

Rear seat occupants.

As expected, injury data on rear seat occupants were limited by the relatively small samples of occupants exposed to crash situations. Table 9 presents the frequencies of lap belted and unbelted rear seat occupants by position. It should be restated that all the occupants in this study had a lap belt available for use. This further reduces the sample size since many manufacturers did not install any rear seat lap belts until the 1966 model year (as compared to 1964 model year for the two outboard front seat positions). Injury data for each seating position were analyzed whenever possible and then combined with other rear seat data for further analysis (see Table 10). The information obtained on injuries sustained by occupants in the left rear seat, position D, indicated that when all accident types, points of impacts, and speeds were combined, there were fewer serious and fatal injuries than expected, but the difference was not significant at the $p = .10$ level. A more beneficial effect was found through analysis of the minor injury group. While two of the 53 belted group sustained injuries, 6.43 injuries were expected ($p = .05$). When serious and minor injuries for the left rear seat position were combined to give an all-injury classification, the difference between observed and expected injuries was even more impressive, as expected. While 13.92 of the 53 occupants would be expected to sustain some injury based on the experience of the unbelted sample, only six occupants actually sustained injury ($p = .01$). This difference represents a 57 percent reduction in all injuries for the belted left rear seat occupant.

Analysis of the injury data for the center rear seat occupant, position E, indicated no significant differences in any impact site, speed, or accident type category, or in the combined totals. Again the small sample of only 13 belted occupants should be noted.

Table 9. Sample Sizes for Rear Seat Occupants.

	Unbelted	Belted	Total
Left Rear Seat	354	53	407
Center Rear Seat	170	13	183
Right Rear Seat	362	50	412
Total	886	116	1002

Table 10. Injury Experience of Lap Belted and Unbelted Rear Seat Occupants.

Unbelted	Total	Observed No. with B or C Inj.	Observed No. with A or K Inj.
Left Rear Seat	354	43 (12.1%)	50 (14.1%)
Center Rear Seat	170	21 (12.4%)	20 (11.8%)
Right Rear Seat	362	28 (7.7%)	48 (13.3%)
Total	886	92 (10.4%)	118 (13.3%)

Lap Belted Occupants: Total	Observed No. with B or C Inj.	Expected No. with B or C Inj.	Observed No. with A or K Inj.	Expected No. with A or K Inj.
53	2 (3.8%)*	6.438	4 (7.5%)†	7.486
13	0	1.606	2 (15.4%)	1.529
50	1 (2.0%)	3.867	5 (10.0%)	6.630
116	3 (2.6%)	12.045	11 (9.5%)	15.449

† $\alpha \leq .10$ * $\alpha \leq .05$

When the injuries sustained by the 50 lap belted right rear seat occupants, position F, were compared to expected values based on the injury experience of the 362 unbelted occupants, no significant differences were indicated in any speed, accident type, point of impact, or individual injury group. When all injuries were combined, six injuries were observed for the belted group while 10.50 were expected (p=.08). While this represented a 43 percent reduction in total injuries, the small sample size must again be noted.

In order to examine specific points of impact, it was necessary to combine injury data from all three rear seat positions. Thus, the implied assumption being made is that occupants in any of the rear seat positions fare equally well in accidents involving frontal, rear, and unspecified points of impact. This assumption may be compromised by the presence or absence of front seat passengers, the predominate direction of roll in a rollover, etc.

When seating positions were combined, data analysis indicated several interesting results (see Table 11). No significant differences were found in frontal or side impacts. For rear impacts, the total number of observed injuries (serious and minor) in the belted groups was less than the expected number (p=.09). While 5.31 injuries of some type were expected based on the experience of the unbelted group, only two injuries were observed.

When collisions involving unspecified points of impact were examined, although there were fewer serious injuries than expected (3 vs. 5.6), the difference was not statistically significant. When all injuries were combined, the number of belted rear seat occupants who were injured was again smaller than expected (p=.04). Here, five (or 20 percent) of the belted occupants sustained some degree of injury while 97 (or 38.1 percent) of the unbelted occupants were injured.

When all impact types were combined to obtain an overview of rear seat occupant injury, significant differences were again indicated. Here, 12.1 percent of the belted group sustained some injury compared to 23.7 percent of the unbelted group (p=.002). While the number of belted occupants sustaining <u>serious</u> injury was less than expected, the difference was not significant. However, if the frontal impacts are deleted from the combined total, there is a significant difference in serious and fatal experience between the two comparison populations (p=.03), indicating a benefit in the remaining three impact types. While 5 of the 74 (6.75 percent) belted occupants sustained serious or fatal injury, 95 of the 634 (15.0 percent) of the unbelted rear seat occupants were seriously injured.

Table 11. Injury Experience of Combined Rear Seat Occupants.

Unbelted Occupants				
Impact Site	Total		Observed No. with B or C Inj.	Observed No. with A or K Inj.
Front	252		24 (9.5%)	23 (9.1%)
Side	101		5 (5.0%)	23 (22.8%)
Rear	279		23 (8.2%)	15 (5.4%)
Unspecified	254		40 (15.7%)	57 (22.4%)
Total	886		92 (10.4%)	118 (13.3%)

Lap Belted Occupants					
Impact Site	Total	Observed No. with B or C Inj.	Expected No. with B or C Inj.	Observed No. with A or K Inj.	Expected No. with A or K Inj.
Front	42	0	4.000	6 (14.3%)	3.833
Side	10	0	0.495	1 (10.0%)	2.277
Rear	39	1 (2.6%)	3.215	1 (2.6%)	2.097
Unspecified	25	2 (8.0%)	3.937	3 (12.0%)	5.610
Total	116	3 (2.6%)	12.045	11 (9.5%)	15.449

Injury Reduction Associated with Shoulder Harness Use

The second major group of analyses involved the hypothesized benefits of shoulder harness usage in passenger vehicles. The analysis involved two comparisons, the first involving shoulder harness and lap belt versus no restraint and the second involving shoulder harness and lap belts versus lap belts only. The second of these was conducted to test for additional benefit provided by the shoulder harness over that provided by lap belt usage. In all ensuing discussion, "shoulder harness" will actually refer to the restraint system in which both a shoulder harness and a lap belt were used.

In order to insure comparability of data, the analysis is concerned with three restraint groups (none, lap belt, and shoulder harness) for only those vehicles in which a shoulder harness was installed. By screening out vehicles which did not have a shoulder harness installed, it was hoped that a more homogeneous data pool in terms of the presence of other safety devices (such as head restraints, extensive padding, energy absorbing steering columns, etc.) had been identified. In addition, only the driving station and right front seat position could be analyzed (based on normal shoulder harness location). While this process reduced the size of the data pool for the "none" and "lap belt" groups, more meaningful comparisons could be made with the remaining sample.

Analyses of the data followed the same patterns used with the lap belt data. The same matrix format was used, including groupings by accident type, point of impact, and speed.

The driver.

The only group at the most detailed level of analysis in which there was a significant difference between the observed and expected proportion of injury was composed of drivers involved in single vehicle, high-speed crashes with an unspecified point of impact. In this group, the shoulder harness users experienced fewer serious injuries than expected when compared with the unbelted group (p=.03). Here, 92 of the 302 (24.1 percent) unbelted drivers experienced A or K injuries, and 1 of the 20 (5.0 percent) drivers wearing shoulder harnesses experienced similar injuries. The difference between the shoulder harness group and the lap belt group was not statistically significant.

In no other group at this level of analysis were there significant differences between observed and expected injury for driver or right front seat occupants. In many cases, the percentage of injury for the shoulder harness group was lower than the other two groups, but small sample sizes precluded meaningful analysis. Because of this, the driver data were grouped into two larger categories: (1) drivers involved in frontal impacts, and (2) drivers involved in all other impacts. The distinction was made because the major design purpose of the shoulder harness was to reduce the number and severity of injuries in frontal collisions. Again, the sample sizes remained very small, with only 22 shoulder belted drivers involved in frontal collisions at all speeds, and only 72 involved in the other types of collisions. Significant results included the following (see Table 12).

In high speed frontal impacts, drivers wearing a shoulder harness experienced fewer serious injuries (A or K) than were expected from the experience of the unbelted group (p=.04). While 28 of the 103 unbelted drivers were seriously injured, none of the ten drivers wearing a shoulder harness was seriously injured. When this same shoulder harness group is compared to the drivers wearing lap belts only, the harnessed drivers again seem to experience fewer serious injuries than expected, but at a marginal level of significance (p=.10). The trade-off" effect in injury severity was again noted, with the shoulder harness group sustaining more minor injuries than either of the other groups. However, when all injuries were compared in this high speed frontal impact group, the shoulder harness group was not significantly different from the lap belted group or the unbelted group.

In the "other impacts" classification, compared to unbelted drivers the drivers wearing shoulder harnesses experienced significantly fewer serious injuries than expected in high speed collisions (p=.02), and in all collisions regardless of speed (p=.005). In addition, when all injuries were examined, this shoulder harness group again sustained fewer injuries than the unbelted group in high speed crashes (p=.08), 18.5 percent versus 32.6 percent) and in all crashes regardless of speed (p=.05, 12.5 percent versus 21.1 percent). However, as can be observed from table 12, there were no cases in which the shoulder harness users experienced significantly fewer total injuries than the lap belted group even though the percentages of injury were somewhat lower.

Table 12. Injury Experience for Unbelted, Lap Belted, and Shoulder Belted Drivers.

	Unbelted Drivers			Lap Belted Drivers			Shoulder Belted Drivers		
Frontal Impacts	Total	Observed B or C Inj.	Observed A or K Inj.	Total	Observed B or C Inj.	Observed A or K Inj.	Total	Observed B or C Inj.	Observed A or K Inj.
Low Speed (0-29 mph)	136	9 (6.6%)	4 (2.9%)	47	1 (2.1%)	0 (0%)	6	0 (0%)	0 (0%)
Medium Speed (30-49 mph)	167	9 (5.4%)	13 (7.8%)	42	1 (2.4%)	1 (2.4%)	6	1 (16.7%)	0 (0%)
High Speed (50+ mph)	103	15 (14.6%)	28 (27.2%)	44	3 (6.8%)	9 (20.5%)	10	3 (30.0%)	0 (0%)
Total	406	33 (8.1%)	45 (11.1%)	133	5 (3.8%)	10 (7.5%)	22	4 (18.2%)	0 (0%)
Other Impacts									
Low Speed (0-29 mph)	253	15 (5.9%)	3 (1.2%)	70	4 (5.7%)	1 (1.4%)	31	2 (6.5%)	0 (0%)
Medium Speed (30-49 mph)	357	27 (7.6%)	28 (7.8%)	82	5 (6.1%)	2 (2.4%)	14	2 (14.3%)	0 (0%)
High Speed 50+ mph)	481	59 (12.3%)	98 (20.4%)	92	20 (21.7%)	7 (7.6%)	27	4 (14.8%)	1 (3.7%)
Total	1091	101 (9.3%)	129 (11.8%)	244	29 (11.9%)	10 (4.1%)	72	8 (11.1%)	1 (1.4%)

Note: All drivers in the above table were in vehicles which had shoulder belts installed.

The driver and right front seat passenger combined.

In order to further examine the hypothesized benefits of the shoulder harness in accidents involving different impact sites, (front, side, rear, unspecified), the data on drivers and right front seat occupants were combined to provide a larger sample (these being the only two positions where shoulder harnesses are available). While safety devices such as the padded headers, pillars, and head restraints should operate equally well for both positions, it must be noted that there are differences in the "potential" for injury between the two positions due to the presence of the steering wheel. However, it is not felt that this potential difference biases the combined data to an appreciable extent. The resulting matrix is presented in Table 13.

Analysis of these data revealed the significant benefits of the shoulder harness system in individual speed, point-of-impact cells. Again, the sample sizes were small (see Table 13). In high speed frontal collisions, the occupants wearing a shoulder harness experienced fewer serious injuries than the unbelted group ($p=.005$). In this cell, while 30.0 percent of the unbelted occupants experienced A or K injuries, none of the 15 occupants wearing shoulder harnesses was seriously injured. In addition, when the serious injury experience of this group wearing a shoulder harness is compared to the lap belted occupants, another significant difference is indicated. Here, 20.6 percent of the lap belted group sustained an A or K injury compared to none of the 15 shoulder harness group ($p=.03$). The injury severity "trade off" effect mentioned earlier was again apparent. The frequency of minor injuries (B and C) sustained by the shoulder harness wearers (33.3 percent) was higher than expected from the injury experience of both the lap belted group (11.1 percent, $p=.02$) and the unbelted group (13.3 percent, $p=.04$). However, when the total number of injuries was examined for each of the three groups, no differences were noted.

When all speeds in the frontal impact group were combined, similar differences were indicated. Again, the shoulder harness group experienced fewer A or K injuries than would be expected from the experience of both the lap belted group ($p=.06$) and the "no belt" group ($p=.02$). While 9.4 percent of the lap belted occupants and 13.1 percent of the unbelted occupants were seriously injured, none of the 29 drivers and right front passengers wearing a shoulder harness sustained an A or K injury. Further analysis indicated that the injury "trade off" effect was again present, with the occupants who wore a shoulder harness experiencing more minor injuries than either of the other groups. However, there was no difference

Table 13. Combined Injury Experience of Drivers and Right Front Passengers while Unbelted, Wearing Lap Belts only, or Wearing Lap and Shoulder Belts.

		Unbelted Drivers			Lap Belted Drivers			Lap and Shoulder Belted		
Impact Site	Speed	Total	Observed No. with B or C Inj.	Observed No. with A or K Inj.	Total	Observed No. with B or C Inj.	Observed No. with A or K Inj.	Total	Observed No. with B or C Inj.	Observed No. with A or K Inj.
Front	Low	196	9 (4.6%)	12 (6.1%)	62	2 (3.2%)	1 (1.6%)	7	0 (0.0%)	0 (0.0%)
	Med.	234	17 (7.3%)	19 (8.1%)	56	2 (3.6%)	3 (5.4%)	7	1 (14.3%)	0 (0.0%)
	High	150	20 (13.3%)	45 (30.0%)	63	7 (11.1%)	13 (20.6%)	15	5 (33.3%)	0 (0.0%)
	Total	580	46 (7.9%)	76 (13.1%)	181	11 (6.1%)	17 (9.4%)	29	6 (20.7%)	0 (0.0%)
Side	Low	34	0 (0.0%)	0 (0.0%)	16	3 (18.8%)	0 (0.0%)	2	0 (0.0%)	0 (0.0%)
	Med.	90	9 (10.0%)	8 (8. %)	21	2 (9.5%)	1 (4.8%)	3	1 (33.3%)	0 (0.0%)
	High	76	10 (13.2%)	6 (8.0%)	29	2 (6.9%)	1 (3.4%)	8	0 (0.0%)	0 (0.0%)
	Total	200	19 (9.5%)	14 (7.0%)	66	7 (10.6%)	2 (3.0%)	13	1 (7.7%)	0 (0.0%)
Rear	Low	334	22 (6.6%)	6 (1.8%)	82	2 (2.4%)	1 (1.2%)	36	2 (5.6%)	0 (0.0%)
	Med.	216	18 (8.3%)	5 (2.3%)	55	1 (1.8%)	0 (0.0%)	8	1 (12.5%)	0 (0.0%)
	High	76	7 (9.2%)	2 (2.6%)	28	4 (14.3%)	0 (0.0%)	2	0 (0.0%)	0 (0.0%)
	Total	626	47 (7.5%)	13 (2.1%)	165	7 (4.2%)	1 (0.6%)	46	3 (6.5%)	0 (0.0%)
Unspecified	Low	9	2 (22.2%)	1 (11.1%)	0	0 (0.0%)	0 (0.0%)	3	0 (0.0%)	0 (0.0%)
	Med.	181	16 (8.8%)	29 (16.0%)	31	3 (9.7%)	2 (6.5%)	8	0 (0.0%)	0 (0.0%)
	High	528	75 (14.2%)	132 (25.0%)	100	19 (19.0%)	11 (11.0%)	27	5 (18.5%)	3 (11.1%)
	Total	718	93 (13.0%)	162 (22.6%)	131	22 (16.8%)	13 (9.9%)	38	5 (13.2%)	3 (7.9%)

in the number of total injuries sustained by the three groups. Thus, the data indicated that front seat occupants involved in frontal impacts experienced fewer serious injuries when wearing shoulder harness systems than when wearing a lap belt or no restraint.

The only other individual speed-impact site cell in which the shoulder harness group experienced significantly fewer injuries was in the high speed crashes with unspecified point of impact. Here, 11.1 percent of the occupants wearing the shoulder harness experienced serious injury while 25.0 percent of the unbelted group were injured to the same degree (p=.07). No difference was seen between the injury experience of the shoulder harness wearers and the lap belt wearers. This was not unexpected since the lap belt by itself was shown earlier to have a very significant effect on injury in crashes with an unspecified point of impact.

Table 14 was formulated to further examine the hypothesized benefit of the shoulder harness system in frontal impacts versus its benefit in other crashes. When the number of serious injuries sustained in non-frontal impacts by the shoulder harness group and the number of serious injuries sustained by the lap belted group were each compared separately to the expected number based on the experience of the unbelted group, large differences were found (p=.005, p<.001, respectively). However, when the shoulder harness serious injury frequency was compared to that of the lap belted group in the non-frontal crashes, no significant differences existed.

In frontal impacts, both the lap belted and shoulder harness groups experienced fewer serious injuries than the unbelted group (p=.08, p=.02, respectively). However, in contrast to the non-frontal collisions, the shoulder harness group experienced fewer serious injuries than the lap belted group in these frontal impacts (p=.06), again indicating the additional benefit of the shoulder harness in these crashes over the one provided by the lap belt alone.

Again, the "trade off" effect was noted. While the shoulder harness group experienced more minor injuries than both the lap belted group and the unbelted group (p=.007, p=.02, respectively), there was no difference in the frequency of all injury between the three groups. This again supports the hypothesis that the use of the shoulder harness results in a shift from serious to minor injury.

Table 14. Combined Injury Experience of Drivers and Right Front Passengers in Frontal Collisions and All Other Collisions.

	Total	Observed No. with B or C inj.	Observed No. with A or K inj.
Unbelted			
Frontal Impacts	580	46(7.9%)	76(13.1%)
Other Impacts	1544	159(10.3%)	189(12.2%)
Lap Belts Only			
Frontal Impacts	181	11(6.1%)	17(9.4%)
Other Impacts	362	36(9.9%)	16(4.4%)
Shoulder Belts			
Frontal Impacts	29	6(20.7%)	0(0.0%)
Other Impacts	97	9(9.3%)	3(3.1%)

Summary of Restraint System Effects on Injuries

This section will recapitulate the major findings noted for wearers of: (1) lap belts only, and (2) lap and shoulder belts. Just as in the preceding sections of the paper, detailed analyses will be treated first (based on individual impact sites, accident types, and speeds by seating position), followed by results of the categories formed by aggregating or collapsing individual cells.

Overall, restraint system wearers experience fewer serious and minor injuries than their unbelted counterparts, leaving no doubt as to the general utility of these devices.

Lap belt effects.

The driver.

For single vehicle crashes with unspecified points of impact (the category including rollovers), lap belted drivers experienced 66 percent fewer serious and fatal (A and K) injuries than expected in medium speed collisions, and 53 percent fewer serious and fatal injuries in high speed collisions.

For frontal impacts, car versus car crashes with all speed categories aggregated, belted drivers experienced 27 percent fewer serious and fatal injuries than their unbelted counterparts. Similar results were indicated for car versus truck frontal collisions. Analysis also indicated that these reductions in serious and fatal injuries were not accompanied by significant increases in minor (B and C) injuries for any of the individual categories, resulting in a decrease in the overall frequency of injury.

Driver injury was examined for side impacts, i.e. those occurring in the passenger compartment area. In high speed car versus car collisions with impact site on the "opposite" side (away from the driver), belted drivers experienced fewer A and K injuries than expected. Again, no significant differences were indicated for the minor injury groups. "Same" side impacts were also examined to test for a reverse or non-beneficial belt effect. While the observed number of injuries for the belted drivers did exceed the expected number for various speed groups, there were no significant differences.

For rear impacts, no significant differences in serious or minor injuries were noted in any speed group or in combined speed groups for any accident type. However, collapsing across all speeds for car versus car accidents revealed that the total number of observed injuries for belted drivers was significantly less than expected.

Following the above mentioned detailed analyses, overall driver injury was viewed by combining accident types and speeds in a matrix of driver injury by impact site (frontal side, rear, unspecified). Belted drivers involved in all frontal accidents experienced significantly fewer serious, minor, and total injuries than expected. The results were similar for "opposite" (right) side impacts. No significant differences were noted in any injury classification for "same" side impacts. For rear impacts, this summary revealed that belted drivers experienced significantly fewer serious and total injuries than their unbelted counterparts.

Paralleling prior research, the most important lap belt effects in regard to overall driver injury were noted in the unspecified impact site (which contains rollovers). The belted driver experienced a 56 percent decrease in serious injury frequency and a 41 percent decrease in all injuries.

Finally when all impact points were combined, belted drivers sustained 53 percent fewer serious injuries and 39 percent fewer injuries of any type than expected, based on the experience of the unbelted group. Any increase in minor injury frequency was more than compensated for by the beneficial effects of the lap belt.

The center front seat passenger.

Based on a very small sample of belted occupants (N = 31), no significant differences were found for any individual speed or accident type classification. This is not to imply that lap belts are not beneficial to center front seat passengers, but that the sample was too small for meaningful analysis.

The right front seat passenger.

While the frequency of serious or fatal injury was less than expected in car versus car crashes none of these reductions was significant at the $\alpha < .10$ level.

For single vehicle, unspecified point of impact collisions (including rollovers), the right front seat passenger sustained fewer serious injuries than expected in both medium and high speed collisions. As would be expected, when the injury frequencies were combined for all speed groups, belted passengers experienced 68 percent fewer serious injuries than expected. There was also a significant reduction in the frequency of any injury.

No significant differences were found in any injury situation for individual accident types of speed groups in same side, opposite side, or rear impacts.

To further examine the injury experience of these right front seat occupants, speeds and accident types were combined in a matrix of injury by impact site. For frontal collisions, the belted occupants experienced significantly fewer serious injuries than expected. In rear impacts, belted right front seat passengers sustained significantly fewer total injuries than expected.

Finally, when all points of impact were combined to investigate the overall lap belt benefit, there were significant reductions for both serious injury frequency and total injury frequency. The lap belted occupant experienced 33 percent fewer total injuries and 51 percent fewer serious injuries than his unbelted counterpart (comparable to the corresponding 39 percent and 53 percent reductions for belted drivers).

The rear seat occupants.

Small samples made analysis difficult, with only 116 of the 1002 rear seat occupants being belted. However, when all impact points, accident types, and speeds were combined, there were significantly fewer observed serious injuries than expected for the belted left rear seat occupant. When all injuries were combined for these occupants, the belted group sustained 57 percent fewer injuries than expected, based on their unbelted counterparts.

There were only 13 belted occupants in the center rear seat position, and no significant differences were noted for any impact site, speed, or accident type, or in the combined totals.

For the belted right rear seat occupant, no significant differences were noted for any individual category. A 43 percent reduction in total injuries was noted when all injury types were combined.

When the data from all three rear seat positions were combined, no significant differences were noted for frontal or side impacts. However, for rear impacts, the total number of injuries in the belted group was significantly less than expected.

Combining all the speed groups and injury classes indicated a significantly smaller number of injured belted rear seat occupants than expected for the unspecified point of impact category.

Finally, when all impact sites and speed categories were combined, the total number of observed injuries in the rear seat belted group was significantly less than the expected number.

Shoulder harness effects.

Comparisons were made for two groups: (1) shoulder harness and lap belt versus no restraint, and (2) shoulder harness and lap belt versus lap belts only. All vehicles in these samples were equipped with a shoulder harness (this produced smaller samples than those in the previous section).

Drivers using the shoulder harness experienced significantly fewer A and K injuries than expected when compared with both the unbelted group and the lap belted group for single vehicle, high-speed crashes with unspecified point of impact. The sample size was small: only 20 drivers wore the harness.

When cells were collapsed to form the category containing drivers in frontal impacts, no significant differences were noted except in the high speed group, where drivers wearing a shoulder harness sustained fewer serious injuries than the unbelted group.

For the category containing drivers involved in crash situations other than frontal impacts, drivers wearing shoulder harnesses experienced significantly fewer serious injuries than expected when compared with the unbelted group in both high speed collisions and all collisions regardless of speed. The results were similar when total injuries were examined. There were no cases in which the shoulder harness users experienced significantly fewer total injuries than the lap belted group, although their percentages were lower.

When drivers and right front passengers were combined, in high speed frontal collisions, harness users experienced significantly fewer A and K injuries than both the comparable unbelted and lap belted groups. The results were similar when all speeds in the frontal impacts were combined.

The data indicated that front seat occupants involved in frontal impacts experienced significantly fewer serious injuries when wearing shoulder harness systems than when wearing either a lap belt only or no restraint. Benefits were also apparent in high speed crashes with unspecified point of impact, a result consistent with the lap belt data presented earlier.

While both the shoulder harness group and the lap belted group experienced significantly fewer serious injuries than the unbelted group in non-fatal impacts, no significant differences were noted when there two groups were compared to each other.

Restraint System Usage

From the preceding discussion, it is evident that lap belts and shoulder harness systems are beneficial as injury reducing agents. However, in order for them to be effective, these restraints obviously must be worn. Usage rates were examined for both lap belt and shoulder harness wearers involved in accidents. Only those vehicles in which the lap belt or shoulder harness were available were included in the analysis.

Users of belt systems were categorized by seating position, sex, and age, as indicated in the following sections. Because there is little previous information concerning the occupant sex, age, and position effects on usage rates, all hypotheses involved two-sided tests of significance. All tests involved the difference in two proportions from binomial populations (see Appendix B). Results of analyses in which $p < .05$ are presented.

Lap belt usage.

Preliminary analyses of occupant data in which lap belts were available were based on approximately 10,600 observations. (The differences in totals in the following tables arise because of lack of information on the one variable under consideration. For example, analysis of the effect of occupant sex on lap belt usage was conducted on all data except that in which sex was unknown. Analysis of the effect of occupant age included data with unknown sex.) Because of the small sample of occupants in each of the three rear seat positions, the data for all three positions were combined for analysis.

Overall differences in the occupant usage rates were found to be significantly affected by seating position, sex, and age. When all sex and age groups were combined within seating position, drivers were found to wear available lap belts more frequently than occupants of other positions (See Table 15). While 19.4 percent of the drivers were users, only 12.3 percent of center front seat occupants, 14.9 percent of right front seat occupants, and 11.0 percent of rear seat occupants were belt wearers. When individual pairs of positions were compared, significant differences were indicated. Driver usage rates were different for positions B, C, and D + E + F ($p < .001$). No differences were found between usage proportions of the center and right front seat, but right front seat occupants were found to wear belts more often than rear seat occupants (14.9 percent versus 11.0 percent, $p < .001$).

Table 15. Frequency of Lap Belt Usage by Occupant Seating Position.

POSITION	BELT USE		
	Yes	No	Total
A	1268 (19.4%)	5264	6532
B	42 (12.3%)	300	342
C	382 (14.9%)	2189	2571
D + E + F	137 (11.0%)	1114	1251

The data shown in Table 15 were further categorized by occupant sex to examine the question of whether or not the positional differences were actually the result of sex effects (see Table 16).

Table 16. Frequency of Lap Belt Usage by Sex and Seating Position.

POSITION	SEX	BELT USE		
		Yes	No	Total
A	M	994 (21.5%)	3637	4631
	F	274 (14.4%)	1627	1901
B	M	10 (7.7%)	120	130
	F	32 (15.1%)	180	212
C	M	161 (13.1%)	1069	1230
	F	221 (16.5%)	1120	1341
D + E + F	M	75 (11.0%)	606	681
	F	62 (10.9%)	508	570
Total	M	1240 (18.6%)	5432	6672
	F	589 (14.6%)	3435	4024

Examination of the table shows that there were indeed differences in usage frequencies between sexes but that these differences were not consistent over all seating positions. For example, male drivers were more likely to be lap belt users than female drivers (21.5 percent versus 14.4 percent, $p < .001$). However, when the right front seat occupant is male, he is less likely to be a lap belt user than his female counterpart (13.1 percent versus 16.5 percent, $p = .02$). No differences were indicated for rear seat positions.

Analysis of seating position differences within sexes indicated that male drivers use the available lap belt more often than do male occupants in any other position (21.5 percent versus 7.7 percent, 13.1 percent, 11.0 percent for B, C, D + E + F, respectively). These differences had corresponding p values of less than .001 for all three pairs of comparisons. No differences were indicated between the usage rates of male passengers regardless of position.

In contrast, usage rates for females were similar across the front seat positions. No differences were noted between female drivers and center or right front seat female occupants. Differences were noted between female occupants in front and rear seat positions with each outboard front seat position (A and C) being characterized by a higher usage rate than the combined rear seat positions ($p = .04$, $p = .002$, respectively).

As indicated earlier, the data were also categorized according to age of occupant. In all discussions of occupant age, the following definitions will apply: (1) Young, "Y" = 1-35 years of age; (2) Mature, "M" = 36-55 years of age; and (3) Older, "O" = over 55 years of age. In order to ascertain overall usage differences between age groups, the following table was formulated.

Table 17. Frequencies of Lap Belt Usage by Age and Seating Position.

POSITION	AGE	BELT USAGE		
		Yes	No	Total
A	Y	802 (18.4%)	3560	4362
	M	326 (21.3%)	1206	1532
	O	134 (23.6%)	433	567
B	Y	31 (10.9%)	253	284
	M	5 (12.8%)	34	39
	O	4 (28.6%)	10	14
C	Y	239 (13.3%)	1564	1803
	M	84 (16.9%)	413	497
	O	55 (24.0%)	174	229
D + E + F	Y	111 (10.3%)	970	1081
	M	17 (19.1%)	72	89
	O	9 (13.4%)	58	67
Total	Y	1183 (15.7%)	6347	7530
	M	432 (20.0%)	1725	2157
	O	202 (23.0%)	675	877

The analysis indicated a large difference ($p < .001$) between the usage proportion of the young occupant and the older groups (see "Total" cells).

The trend of lower usage for the younger occupants and increasing usage with age was also noted within occupant positions. Young drivers were users fewer times than mature and older drivers (18.4 percent versus 21.3 percent and 23.6 percent, $p = .02$, $p = .003$, respectively). In position C, the right front seat, the oldest occupants used the lap belts more than the mature occupants ($p = .03$), and the mature occupant used the belts more often than the young occupant ($p = .04$). A slightly different trend was indicated by the rear seat data, where the highest usage rate belonged to the mature group. Here, the mature occupant used the belt more than the young occupant ($p = .02$), but no significant difference in proportions was found when the mature group was compared to the older group.

Because these "age-related" differences in usage could be the result of differences in the proportions of occupant sexes in the age categories (i.e., really a sex effect), the data were further subdivided into cells by seating position, sex, and age for more detailed analysis. This subdivision results in small cell sizes in the center front seat position (Position B), so that this position was not examined further. However, meaningful analyses of positions A, C, and D + E + F, can be accomplished (see Table 18).

The proportions of lap belt usage indicated above support the trends indicated by the less detailed previous categorizations. There appears to be a trend toward increasing usage with increasing age within sex and seating position for front seat occupants. Younger male drivers used the lap belts less than mature male drivers (20.5 percent versus 23.7 percent, $p = .03$). Younger female drivers also showed less frequent usage than their older counterparts and a significant difference was indicated between the young and older groups (12.0 percent versus 22.4 percent, $p = .002$).

Similar age trends were found in position C. Here younger males wore the lap belt less than older males (12.7 percent versus 23.0 percent, $p = .02$), and younger females had lower usage frequency than the mature and older females (14.0 percent versus 19.3 percent and 24.5 percent, $p = .03$, $p < .001$).

Rear seat trends were based on relatively small sample sizes and were not as clear. However, the younger males' usage frequency was lower than that of the mature male (10.11 percent versus 21.62 percent, $p = .05$).

Table 18. Frequency of Lap Belt Usage by Age, Sex, and Seating Position.

Position	Sex	Age	Belt Use		
			Yes	No	Total
A	M	Y	635 (20.5%)	2467	3102
		M	246 (23.7%)	793	1039
		O	100 (24.0%)	317	417
	F	Y	158 (12.8%)	1074	1232
		M	77 (15.8%)	409	486
		O	33 (22.4%)	114	147
C	M	Y	122 (12.7%)	837	959
		M	22 (12.9%)	149	171
		O	15 (23.8%)	48	63
	F	Y	116 (14.0%)	714	830
		M	62 (19.3%)	260	322
		O	40 (24.5%)	123	163
D+E+F	M	Y	62 (10.1%)	551	613
		M	8 (21.6%)	29	37
		O	1 (8.3%)	11	12
	F	Y	46 (10.1%)	408	454
		M	8 (15.7%)	43	51
		O	8 (14.8%)	46	54

When the same detailed breakdown is examined for differences between sexes within age groups and positions, the earlier trends toward higher male usage in the driver seat and higher female usage in other seats appear to be replicated. For the driver station (position A) both young males (20.5 percent) and mature males (23.7 percent) presented higher usage rates than did young (12.0 percent) and mature (15.0 percent)females ($p < .001$, $p = .003$, respectively). In position C, the right front seat, the female usage rates were slightly higher in all age categories, but none of the differences were significant at the $\alpha \leq .05$ level)

Driver usage of the lap belt can be compared to the results presented by Campbell (1969). While these earlier data, based on accidents occurring in the summer of 1967, were not categorized by occupant age, comparisons involving driver sex and the availability of belts were possible. Campbell found that 668 of 3577 (18.7 percent) male drivers were users of the available lap belt system. The current 1970 data indicates 994 of the 4631 male drivers (21.5 percent) were users.

Female drivers in the 1967 study were users in 172 of the 1215 cases (14.2 percent). Their counterparts in the summer of 1970 data were users of available systems in 274 of 1627 cases (14.4 percent).

The Highway Safety Foundation study (1970), based on passenger car occupants involved in Ohio accidents occurring in August, 1969, presented a limited amount of information on usage by seated position. The data were not categorized by sex or age of the occupant. For the accidents studied, 2461 of 7813 (31.5 percent) occupants used available lap belts, a significantly higher usage proportion than the 17.1 percent indicated for occupants in the current study. The only other comparable figure presented involved right front seat passengers. In the Ohio study, approximately 26 percent of these occupants were users of available lap belts. As noted earlier, the right front seat passengers in the current data were users in only 14.9 percent of the cases. While it is not possible to determine whether the age and sex characteristics of the two samples are similar, the differences appear large enough to represent real differences in usage between the sample locations.

Shoulder harness usage.

The data concerning usage of the shoulder harness were only available for the driver and right front seat positions (A and C). Analysis of the data summed over all ages and both sexes indicated no significant difference between the usage proportions for the two positions (5.4 percent versus 4.4 percent).

Further analysis, however, did indicate differences in usage rates as a function of accupant sex. As indicated in Table 19, the overall usage rate for male occupants (6.2 percent) was higher than the 3.2 percent usage rate for females ($p < .001$). When the data were categorized by sex and position, the analysis indicated a highly significant difference between the shoulder harness usage rates for male and female drivers (6.5 percent versus 2.9 percent, $p < .001$). However, for the right front seat position, even though the male usage rate was higher, the difference was not significant.

Table 19. Shoulder Harness Usage Rates by Occupant Seating Position and Sex.

Position	Sex	Harness Use		
		Yes	No	Total
A	M	117 (6.5%)	1694	1811
	F	22 (2.9%)	745	767
C	M	24 (5.2%)	435	459
	F	21 (3.7%)	543	564
Total	M	141 (6.2%)	2129	2270
	F	43 (3.2%)	1288	1331

When the data were categorized according to age and sex of occupant, differences were noted between age groups, but the differences were not consistent with trends indicated by lap belt data.

Table 20. Shoulder Harness Usage by Occupant Sex and Age.

Sex	Age	Belt Usage		
		Yes	No	Total
M	Y	99 (6.2%)	1493	1592
	M	35 (7.7%)	418	453
	O	6 (3.5%)	165	171
F	Y	28 (3.2%)	835	863
	M	12 (3.7%)	313	325
	O	3 (2.5%)	119	122
Total	Y	127 (5.2%)	2328	2455
	M	47 (6.0%)	731	778
	O	9 (3.1%)	284	293

Whereas in the lap belt data, older occupants showed higher usage rates, in this table it appears that, even though all groups have low usage rates, the younger and middle age occupants used available shoulder harnesses in greater proportions of the case than did the older occupants. However, the differences between the usage rates shown in this table were not significant at the $\alpha \leq .05$ level.

A similar age effect was noted in the Anderson study (1971), which indicated that younger drivers (11.15 percent) were significantly more likely to be wearing the harness than either the mature (7.16 percent) or older (5.33 percent) drivers. Sex differences were also similar, where male drivers had a utilization rate of 9.51 percent, compared to 4.02 percent for female drivers, a statistically significant difference.

"Follow the leader" effect.

As noted by the Highway Safety Foundation (1970), there is some indication that restraint system usage increases dramatically for any given passenger position, if the driver is using his system. In order to further study this effect, the driver and passenger usage rates in the current North Carolina data were examined under various conditions of occupancy. The 2592 cases in which both a driver and right front seat occupant were present and had a lap belt available are categorized in Table 21.

Table 21. Right Front Seat Passenger (C) Usage by Driver (A) Usage.

Lap Belt Usage for Position A.	Lap Belt Usage for Position C.		
	Yes	No	Total
Yes	343 (63.3%)	199	542
No	76 (3.7%)	1974	2050
Total	419 (16.2%)	2713	2592

The data indicate some striking differences. While only 3.7 percent of the occupants of position C used the available lap belt when the driver was a non-user, 63.3 percent of these occupants wore the belt in cases where the driver was also a user, a large increase ($p <.001$).

These data, and additional data on driver usage when alone, are re-organized and presented in Table 22 in order to study the effect of passenger usage on driver usage.

Data in Table 22 indicate that in accidents in which the driver was the sole occupant of the vehicle, i.e., when no other occupants could have affected his lap belt usage, the drive wore available lap belts in 21.2 percent of the cases. When a right front passenger, position C was present (either with the driver only or with the driver and rear seat occupants), the driver used the available lap belt in 20.9 percent of the cases, regardless of passenger usage (i.e., when right front seat passenger usage is summed over). The difference in these two figures does not approach significance. However, when the data were categorized according to the usage of the right front seat passenger, significant differences did result.

When the right front seat passenger was not wearing a lap belt, the driver usage rate was 9.2 percent. However, when the right front seat passenger was a belt user, the driver usage rate increased to 81.9 percent, again a large increase ($p < .001$).

Table 22. Driver Lap Belt Usage by Occupancy Condition and Passenger Usage.

Occupancy Condition	Driver Lap Belt Usage		
	Yes	No	Total
No passengers present	830(21.2%)	3081	3911
Right front seat passenger (C) present	542(20.9%)	2050	2592
Right front seat passenger (C) not using lap belt	199(9.2%)	1974	2173
Right front seat passenger (C) using lap belt	343(81.9%)	76	419

The same trend is noticeable in accidents in which rear seat occupants were present. Position D occupants used available lap belts 37.9 percent of the time when a driver was a user and 4.7 percent of the time when he was not (N = 510 cases). Occupants of position F, the right rear seat, were users 37.6 percent of the time when drivers were also users and 3.8 percent of the time when drivers did not wear the available lap belt (N = 520). Both of these increases had corresponding p values of less than .001. It must be noted that these rear seat usage rates might just as possibly have been affected by right front seat usage practices since the presence of a rear seat occupant often implies presence of a right front seat occupant. In addition, the previous data on position A and C usage rates did not delete cases in which the rear seats were also occupied.

The use of a shoulder harness was also examined for similar "follow the leader" trends. Again, only those occupants in positions A and C, the outboard front seat positions, which are equipped with shoulder harnesses, were included in the analysis. Table 23 indicates driver harness usage based on passenger presence and usage.

Table 23. Driver Shoulder Harness Usage by Occupancy Condition and Passenger Usage.

Occupancy Condition	Driver Shoulder Harness Usage		
	Yes	No	Total
No passengers present	87 (7.2%)	1127	1214
Passenger C present	39 (5.1%)	719	758
Passenger C present and not using shoulder harness	9 (1.2%)	716	725
Passenger C present and using shoulder harness	30 (90.9%)	3	33

It was first noted that the overall usage rate for drivers seemed higher when the driver was alone than when the right front seat occupant was present, but the difference was not significant ($p = .09$). Also of interest are the trends noted when the data are categorized by position C usage. When the right front seat passenger was wearing a shoulder harness, the driver was also wearing the harness in 90.9 percent of the cases. When the right front seat passenger was not a user, the driver was wearing his harness in only 1.2 percent of the cases ($p < .001$).

Because the above noted difference in driver usage rates when alone (7.2 percent) and when with other passengers (5.1 percent) could have been related to driver sex (i.e., the difference in these two rates could have been the result of the earlier sex effect if a disproportionate number of female drivers were in the "passenger present" group), the usage data were categorized by sex of driver and passenger in Table 24.

Table 24. Driver Shoulder Harness Usage by Sex of All Occupants.

	Shoulder Harness Usage		
	Yes	No	Total
Male driver usage with no passenger present	80 (9.6%)	753	833
Overall male driver usage with passenger present	27 (5.4%)	476	503
Male driver usage with male passenger present	13 (5.3%)	230	243
Male driver usage with female passenger present	14 (5.4%)	246	260
Female driver usage with no passenger present	6 (1.6%)	367	373
Overall female driver usage with passenger present	12 (4.9%)	231	243
Female driver usage with female passenger present	2 (1.4%)	142	144
Female driver usage with male passenger present.	10 (10.1%)	89	99

Analysis of this table indicated that male drivers were users of available shoulder harness systems more often when alone in the vehicle than when with another passenger, regardless of the sex of the occupant. The corresponding usage rates were 9.6 percent and 5.4 percent ($p = .008$).

The corresponding comparisons for female drivers led to somewhat different results. Here, female driver usage rates were quite low when the driver was alone or when there was a female passenger in the right front seat (1.6 percent and 1.4 percent, respectively).

However, when a male passenger was present, the female driver was a user in 10.1 percent of the cases. This rate is different than both the rate with female passengers (p=.006) and the rate with no passengers (p < .001). This highly significant difference with a male passenger heavily influenced the overall rate for female drivers with passengers present (4.9 percent).

As expected, trends for occupant C usage rates were similar to those indicated above (see Table 25).

Table 25. Right Front Passenger Shoulder Harness Usage by Driver Usage.

Position A Shoulder Harness Usage	Position C Shoulder Harness Usage		
	Yes	No	Total
Yes-driver using	30 (76.9%)	9	39
No-driver not using	3 (0.4%)	716	719
Total	33 (4.4%)	725	758

Again, right front seat passengers used the available shoulder harness much more frequently when the driver was a user than when he was a non-user (76.9 percent versus 0.4 percent, p < .001).

These data were also categorized by occupant sex, and the results are shown in Table 26.

Analysis indicated no significant difference in the usage rates of female right front seat occupants regardless of whether the driver was male or female. However, male passengers were observed to be users more often with a female driver than with a male driver (p = .04), a surprising fact in view of the previously mentioned "influence" effect and the higher male driver usage rate.

Thus, analysis indicates that the usage rates of an occupant may affect and be affected by the usage rates of other occupants. The "follow the leader" effect might better be termed an "influence" effect since the data do not make it possible to determine who influenced whom, (i.e., who was the "leader" and who the "follower"). The promise of this information lies in the fact that if this "influence" effect continues, the usage rates of all occupant positions might be affected by actual increases in an individual position. In addition, if this "influence" effect holds, "confirmed" belt users may influence the usage habits of others in their vehicle.

Table 26. Occupant C Usage by Sex of All Occupants.

	Shoulder Harness Usage		
	Yes	No	Total
Male occupant C with male driver	9 (3.7%)	234	243
Male occupant C with female driver	10 (10.1%)	89	99
Female occupant C with female driver	3 (2.1%)	141	144
Female occupant C with male driver	11 (4.2%)	249	260

Summary of usage results.

The data on 1970 automobile accidents in North Carolina indicate that a relatively small proportion of accident-involved occupants who have restraint systems available use them. Only 17.1 percent of all accident-involved occupants were lap belt users; only 5.2 percent of accident-involved occupants having available shoulder belts used them. The lap belt proportion is heavily weighted by drivers who wore available belts in 19.4 percent of the cases.

Occupant age, sex, and seated position appear to affect restraint system usage rates to varying degrees. Drivers used lap belts more often than occupants of other positions. Although the shoulder harness usage rate for drivers was slightly higher than that of right front seat occupants, the difference was not significant. Male drivers used available lap belts and shoulder harness more often than did female drivers. On the other hand, female front seat passengers more often used lap belts than did their male counterparts. Analysis also indicated that occupant age was an important variable, but its effect was different on usage of lap belts and shoulder harnesses. Mature and older occupants consistantly used lap belts more often than did the younger occupant, and the trend remained within sex categorization. On the other hand, the younger occupants appeared to use available shoulder harnesses more often than their mature and older counterparts.

Lap and shoulder belt usage also tended to increase whenever one occupant in the car, whether driver or passenger, used his restraint system. In other words, an "influence effect" was noted whereby usage in an individual seating position affected usage in other seating positions.

V. DISCUSSION

This study has further documented the case for restraint systems presented in many previous works. Analysis of the data indicates the significant benefits afforded by both lap belts and shoulder harnesses in terms of injury reduction capability. Belt wearers fare much better than their unbelted counterparts in most types of traffic crashes. The restraint systems tend to modify the overall injury distribution by reducing the seriousness of the injury, and by reducing the total number of injuries. Thus, an accident that might produce a serious injury for an unbelted occupant could very likely result in only a minor injury for a lap belted occupant under the same crash circumstances; a potential minor injury may be completely avoided with belt use. Analysis of the shoulder harness data has indicated that even greater significant benefits can be realized by using this device in conjunction with the lap belt.

The data also further document the low usage rates for these restraint systems. Given that the benefits do exist, the relatively low usage rates for lap belts and even lower usage rates for shoulder harnesses are both disappointing and puzzling. National estimates indicate that lap belts are used approximately 30 to 35 percent of the time in the population at risk. The data from this current study indicate even lower usage in accidents (15-20 percent). It should be remembered that lap belts have been available to front seat occupants since 1964. Many different efforts have been aimed at increasing belt usage in this nine year period. Most of these have been in the form of mass media public education programs. These campaigns were designed to bring about large increases in public usage rates; yet two of every three drivers on the road do not wear available lap belts. Even more disturbing than this figure, however, is the very low usage rate for the shoulder harness. Here, the current data indicate that only three to five percent of people who have the shoulder harness available for use are actually using this device, a distressingly low figure. Thus, 11 of 12 people on the road who have a shoulder harness available are not using the device. While the 30 to 35 percent usage rate for lap belts is low, it is at least ten times the usage rate for shoulder harness systems. Considering this large difference, it would appear that educational programs designed to convince the driving public to use the shoulder harness have largely failed.

Some surveys have indicated that the non-usage may result from discomfort caused by the design of the belt system itself. A more basic reason for the low rate may be the general feeling among drivers that the accident will happen to the "other guy", and that it is therefore not necessary to use any restraint system especially one that may be uncomfortable. Thus, it would appear that there is quite definitely a failure in our educational programs to get the message to the public that not only do the upper torso restraints prevent significantly more injuries, but that these injuries are the result of crashes which do involve "good" drivers.

Of great interest will be usage changes resulting from the required starter interlock systems now placed on all 1974 model vehicles. With this system, the driver will not be able to start the vehicle unless he wears the lap and shoulder harness system. However, even if this system were to be one hundred percent effective, it must be remembered that new cars will constitute only a very small part of the vehicles which are on the road and which become involved in crashes. The need for increased usage among drivers of older vehicles is still distressingly apparent.

The current study indicates usage differences among groups. In general, accident-involved females use lap and shoulder belts less than males. Also, lap belt usage tends to increase with increasing age, while shoulder belt usage tends to decrease with increasing age. Again it must be noted that the shoulder harness usage is very low regardless of what age group we are talking about. Perhaps more educational efforts should be aimed at these special groups. For example, articles in popular magazines aimed at the female readership might prove to be an effective means of information dissemination.

Another method which to some researchers appears even more promising in terms of possible effects is the use of grammar schools and high schools as forums for seat belt information. Because it has been shown that the belts could save many of the lives of the younger people in the U.S. today, it appears important that the information concerning restraint systems be disseminated to these people at a young age. The most obvious place to encounter large groups of young people is in the school system. Of course, some work in this area has been conducted in driver education courses taught in school systems, and some emphasis is placed on the effects of restraint systems and restraint system usage. However, it also appears that there is a need to incorporate this information into curricula at an earlier point in a child's education. There is no reason why restraint system usage could not be taught in kindergarten - and during all the subsequent years.

The National Highway Traffic Safety Administration has funded the preparation of a supplementary curriculum text called Physics and Automobile Seat Belts which is directly aimed at this problem. The text itself is a workbook of physics problems all of which refer to accident forces and restraint systems and how restraint systems can help drivers. It is designed for use in a standard high school physics course. Other material for students in lower age groups concerning restraint systems and their benefits has also been published.

The "influence effect" concept whereby usage by one occupant appears to influence the usage rates of other occupants also appears promising. If effective programs such as those outlined above can be implemented, the increased usage of one occupant might in turn result in increased usage by other occupants and a snowballing effect might occur.

To summarize, the general usefulness of lap and shoulder belts is widely documented in research studies. Such safety devices result in injury reducing benefits that far exceed their costs. In the past, efforts at increasing belt usage have failed to some degree. The need for increased usage is still present even though the newer cars will be equipped with either passive systems or an interlock system. Thus, it is the conclusion of the authors that effective programs and legislative action should be designed to increase the usage rate of these restraint systems, and that efforts toward this end must assume a position of high priority among highway safety programs.

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APPENDIX A

North Carolina Department of Motor Vehicles
Supplementary Report on Seat Belts

Form SR-004

NORTH CAROLINA
DEPARTMENT OF MOTOR VEHICLES
SUPPLEMENTARY REPORT ON SEAT BELTS

Occupant Position:

Front of Car

Driver -A-	-B-	-C-
-D-	-E-	-F-

CODE

Injury:
Same as on accident report
No = no injury

Restraint System:
Lap: Lap belt
Shld: Shoulder belt
Both: Combination of lap and shoulder belt
no: no restraint
Child: Child restraint

Source of Information:
I: Direct observation
Him(Her): Subject
Occ: Vehicle Occupant
Wit: Witness
Other: Please specify in comments

Confidence in Information:
++ Positive
\+ No reason to doubt
\- Some doubt
-- Unsure

Name:

Troop-District:

Registry number:

Date of Accident:

Vehicle number:_____ (Same as number on accident report) Number of Occupants:_____

(For each occupant, circle the information according to the code)

Occu-pant	Age	Sex	Injury	Restraint Installed	Restraint Used	Infor-mation	Confi-dence
Driver -A-		M F	K A B C No	Lap Shld Both no	Lap Shld Both no	I Him Occ Wit Other	++ + - --
-B-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-C-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-D-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-E-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-F-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --

Comments:

Vehicle number:_____ (Same as number on accident report) Number of Occupants:_____

(For each occupant, circle the information according to the code)

Occu-pant	Age	Sex	Injury	Restraint Installed	Restraint Used	Infor-mation	Confi-dence
Driver -A-		M F	K A B C No	Lap Shld Both no	Lap Shld Both no	I Him Occ Wit Other	++ + - --
-B-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-C-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-D-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-E-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --
-F-		M F	K A B C No	Lap Shld Both no Child	Lap Shld Both no Child	I Him Occ Wit Other	++ + - --

Comments:

APPENDIX B

Discussion of Statistical Tests Used

In the statistical tests used in this paper, the following definitions and assumptions apply:

Let

u_{iI} = number of unbelted occupants in the i^{th} row of the data matrix who were injured,

u_i = total number of unbelted occupants in the i^{th} row,

and similarly let b_{iI} and b_i represent the belted occupants. Let

$e_{iI} = b_i \left(\frac{u_{iI}}{u_i}\right)$ = expected number (based on the unbelted population) of injured belted occupants in the i^{th} row.

Assume that u_{iI} is binomial (u_i, p_{uiI}), b_{iI} is binomial (b_i, p_{biI}), and u_{iI} and b_{iI} are independent.

Then, under the one-sided null hypothesis that the belted occupants are not injured less frequently than their belted counterparts (i.e., H_o: $p_{biI} \geq p_{uiI}$), it is necessary to calculate the one-sided probabilities of observed belted-occupant injury frequencies as extreme or more extreme in the direction away from the expected number of injuries. To do this, binomial (b_i, $\hat{p}_{biI}$) probabilities were calculated when

$$\hat{p}_{biI} \overset{H_o}{=} p_{uiI} = \frac{u_{iI}}{u_i}$$

was not too small nor b_i too large.

Here,

$$\text{Prob } (X \leq b_{iI}) = \sum_{x_i = o}^{b_{iI}} \binom{b_i}{x_i} \hat{p}_{biI}^{\ x_i} (1 - \hat{p}_{biI})^{b_i - x_i}$$

When $b_i \geq 30$ and when $(b_{iI})\ (\hat{p}_{biI}) > 5$ and $b_i\ (1 - \hat{p}_{biI}) > 5$ this can be approximated by the normal distribution where

$$\hat{\mu} = b_i\ \hat{p}_{biI} \text{ and } \hat{\sigma} = \sqrt{b_i\ \hat{p}_{biI}\ (1 - \hat{p}_{biI})}$$

Thus

$$\text{Prob } (X \leq b_{iI}) = \text{Prob}\left(z \leq \frac{b_{iI} - b_i\ \hat{p}_{biI}}{\sqrt{b_i\ \hat{p}_{biI}\ (1 - \hat{p}_{biI})}}\right)$$

Applying the continuity correction

$$\text{Prob } (X \leq b_{iI}) = \text{Prob}\left(z \leq \frac{(b_{iI} + \frac{1}{2}) - b_i\ \hat{p}_{biI}}{\sqrt{b_i\ \hat{p}_{biI}\ (1 - \hat{p}_{biI})}}\right)$$

When b_i is large and $\hat{p}_{biI}$ is small, the Poisson distribution was used as a better approximation of the binomial distribution

where

$$\lambda = b_i\ \hat{p}_{biI}$$

then

$$\text{Prob } (X \leq b_{iI}) = \sum_{x_i = o}^{b_{iI}} \frac{e^{-\lambda}\ \lambda^{x_i}}{x_i!}$$

In the section concerning differences in usage rates, tests of the null hypothesis of no difference between usage proportions of two populations were conducted.

Let

b_a = number of belted occupants in group A (e.g., group A = males)

n_a = total number of occupants in group A

b_b = number of belted occupants in group B (e.g., group B = females)

n_b = total number of occupants in group B

Assuming underlying binomial distributions, Bi $(n_a, \frac{b_a}{n})$ and Bi $(n_b, \frac{b_b}{n_b})$, two-sided tests were run on the difference between proportions using the following test statistic:

$$z = \frac{\left|\frac{b_a}{n_a} - \frac{b_b}{n_b}\right| - \frac{1}{2}\left(\frac{1}{n_a} + \frac{1}{n_b}\right)}{\sqrt{\left(\frac{b_a + b_b}{n_a + n_b}\right)\left(1 - \frac{b_a + b_b}{n_a + n_b}\right)\left(\frac{1}{n_a} + \frac{1}{n_b}\right)}}$$

Under the null hypothesis of no difference in belt wearing rates between the two groups, z is approximately normally distributed N(0,1).