A Study of Restraint System Use and Effectiveness

by
Fred L. Preston and Ray M. Shortridge

June 14, 1973

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UM-HSRI-SA-73-10		

4. Title and Subtitle A Study of Restraint Use and Effectiveness	5. Report Date July, 1973
	6. Performing Organization Code
7. Author(s) Fred L. Preston and Ray M. Shortridge	8. Performing Organization Report No.
9. Performing Organization Name and Address Highway Safety Research Institute Huron Parkway & Baxter Road Ann Arbor, Michigan 48105	10. Work Unit No.
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Motor Vehicle Manufacturers Assn., Inc. 320 New Center Building Detroit, Michigan 48202	13. Type of Report and Period Covered Special Report 1973
	14. Sponsoring Agency Code

15. Supplementary Notes The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Motor Vehicle Manufacturers Assn., Inc.

16. Abstract

The report contains three related investigations: (1) a determination of the demography of restraint system use; (2) a comparison of the incidence and severity of injuries for restraint system users and nonusers; and (3) a comparison of the incidence and severity of injury from those various areas in the vehicle that were contacted by the occupants.

For the first part of the study, restraint usage rates were compared for age groups, seat locations, and sex for selected mass accident files maintained by HSRI. Further comparisons were made for different values of speed, type of highway, and driver's physiological condition, using the CPIR file. The results of these comparisons reveal that 16 to 22 year old drivers, drivers not using limited-access roads and drivers who had been drinking are the least likely users of seat belts.

Another aspect of this investigation was an evaluation of the methods of circumventing the seat-belt buzzer system. A survey reveals that the most prevalent method is to keep the seat belt permanently buckled.

The contact-point comparisons for part three of the study were conducted in much the same was as for the comparison in part two, only each possible contact point was treated separately. The results of these comparisons, revealing how the pattern of injuries changes with different values of the controlled factors, and how restraint usage affects these changes, are presented in the body of the paper.

17. Key Words	18. Distribution Statement
restraint system use, effectiveness, injury reduction, contact point.	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
none	none	205	

Form DOT F 1700.7 (8-69)

TABLE OF CONTENTS

List of Tables

List of Figures

ACKNOWLEDGEMENTS

The investigators are indebted to several organizations and individuals. The data used in the study are drawn from the large accident files maintained by the staff of the Highway Safety Research Institute. The Motor Vehicle Manufacturers Association provides the financial support for processing the Dade County, Florida, Denver County, Colorado, Cornell Level I, and King County, Washington data sets used in the study. The Motor Vehicle Manufacturers Association and the National Highway Traffic Safety Administration provide the financial support for maintaining the Collision Performance and Injury Report, Revision 3, Occupant file accessed for this study.

The direct funding for the costs associated with this investigation was derived from gifts donated by the Motor Vehicle Manufacturers Association to The University of Michigan.

We also wish to thank Robert Scott and John Green of the Highway Safety Research Institute for their assistance in the course of this investigation.

INTRODUCTION

This report presents the findings of three separate but not unrelated investigations regarding restraint usage and injury. The study addresses the general issue whether active restraints, such as lap belts or shoulder harnesses, fulfill the need for effective countermeasures for automobile accident injury. There are important policy implications involved with this issue. A number of state legislatures are considering laws which require the use of restraint devices by the motoring public. Moreover, the automobile manufacturers are moving to install expensive passive restraint systems, such as airbags, into future models. Before these serious policy steps are implemented, it seems prudent to examine the available empirical evidence about the use of restraint devices and the effects which restraint system use has on injury. If active restraints are sufficient countermeasures to injury, then additional equipment may not be necessary. On the other hand, if active restraints are by themselves inadequate, then legislators should consider policy which does not rely exclusively on them. Moreover, this type of study presents policy implications regarding the design of the restraint systems and of the vehicle. The restraint device itself may produce certain types of injuries which can be counteracted by alterations in its design. Perhaps more important, is the possibility that restraint system users may be particularly vulnerable to contact with certain parts of the vehicle--a situation which could be mitigated by changes in the design of the passenger car itself.

The point of departure for the first part of the study is that restraint devices have been shown to be generally effective in reducing the degree of injury sustained by a person in an automobile accident (1,2). One problem facing those interested in highway safety lies in increasing the usage rate (16). For some time, the public has been encouraged to use their restraints whenever they ride in a car. However, aside from a surge in usage rates associated with the factory installation of seat belts in the mid-1960's (3), the literature presents little evidence that the public has increased the level at which it uses active restraints (11). Perhaps inducements to use a restraint device designed to influence specific groups within the population might be more effective. We felt that those groups which were less likely to use a restraint could be the ones to receive focused attention. Accordingly, we sought to determine which groups were significant underusers of restraints by drawing upon the relevant information contained in the mass accident data files maintained by the Highway Safety Research Institute. Moreover, we conducted a survey aimed at identifying the means by which drivers circumvented the buzzer reminder system installed in cars built after calendar year 1971.

The next phase of our investigation stemmed from the evidence in the literature indicating that the effect of using restraint systems might be different for different areas of the body (4,5). We conducted a systematic analysis of the variations occurring in the effect which using a restraint device had on injury to selected body regions. For restrained and unrestrained occupants, we examined the incidence and severity of injury to the head, brain, neck, shoulder, chest, back, abdomen and pelvis and for overall injury severity. In addition, the literature also suggest that the incidence and severity of injury differs for various accident situations (6,7,8). Accordingly, we controlled upon the estimated speed at impact, seating location, accident configuration, vehicle deformation, and rollover versus non-rollover. This analysis utilized data contained in the Collision Performance and Injury Report file.

The third section identified the objects in the car which the occupant contacted in producing injuries to the selected body regions. By comparing the different frequencies and severity of contacts between restrained and unrestrained occupants and among the various circumstances pertaining to the accident, such as configuration or speed, we can specify the injury producing mechanisms at work in each accident situation and also the effect which the use of restraint systems has on the types of injury produced by the mechanisms. Moreover, the relative frequencies among the objects contacted by the occupants indicates the areas in which interior design improvements could reduce injury. Finally, controlled comparison between the effects which the circumstances pertaining to the accident have on which objects are contacted is of importance for frame and interior design.

Section IV contains a condensed version of the entire report. In addition, Sections I and II contain separate statements of conclusions. Section 1.6 summarizes the analyses performed in Sections 1.2 to 1.5. Section 2.6 summarizes the analyses found in Sections 2.4 and 2.5.

SECTION I: SOME DEMOGRAPHICS OF SEAT BELT USE

1.1 The Data

We examined the patterns in the use of seat belts by drawing upon the mass accident data files maintained by the HSRI. Five of these data files contain information concerning the use of restraint systems. These include the Calspan Level I for eight counties of western New York, and police accident record files for Denver County, Colorado; King County (Seattle), Washington; and Dade County (Miami), Florida. We accessed the 1970 and 1971 files for the Dade County, Florida data.

Marked differences exist between the sort of seat belt information which is recorded in the data files. The Dade County, Seattle, and the New York data sets indicate whether the vehicle was equipped with seat belts -- hence, the usage information reflects the choice of the occupant. However, in the Denver data file we cannot distinguish between vehicles which were equipped from those which were not equipped with seat belts.

Moreover, the proportion of drivers who reportedly used seat belts varies across the files. Table 1 contains proportions which exemplify these variations.

In order to determine possible causes for the regional differences in the seat belt usage rates, we contacted the agencies which collected the data. Summaries of their reports regarding possible error in the collection of seat belt usage data follow.

In Denver County, the police officer investigating the accident records the statement of the occupant regarding seat belt usage. Some over-reporting of seat belt usage is considered likely. For the Calspan Level I information, approximately 90 police jurisdictions contribute accident data to the file. However, some of the police agencies do not report seat belt usage and cases from these jurisdictions were deleted from the file during this study. It is thought the reporting was

Table 1

Seat Belt Usage Rates Among Drivers in the Five Mass Accident Data Files

	Percent	Number of Users
Dade County, Florida (1970)[a]	48.3	17,923
Dade County, Florida (1971)[a]	45.3	19,064
Western New York[a]	41.0	5,183
King County, Washington[a]	41.3	5,856
Denver County, Colorado[b]	20.0	5,633

[a] Calculated by dividing the number of drivers of the case vehicle (#1) who were using seat belts by the total number of drivers in those case vehicles (#1) which reportedly were equipped with belts.

[b] Calculated by dividing the number of vehicle #1 drivers using seat belts by the number of drivers about whom usage information is recorded. This divisor includes drivers of vehicles unequipped with seat belts.

relatively accurate with no unusual biases. In Seattle, police officers record the occupants' own statements regarding the use of seat belts. Perhaps some over-reporting of usage is due to this method. For Dade County, the police feel that because motorists believe they might incur insurance penalties for non-usage, the drivers probably over-report usage of seat belts.

The data collection agencies generally believe that they report a higher proportion of seat belt users than might actually be the case. Indeed, the percentages obtained for Dade County, Western New York, and King County exceed that found in other surveys of driver populations (11,12). Although regional bias in usage rates is possible, we are inclined to believe that the proportions calculated from the mass accident data sets do over-estimate usage rates. However, the agencies do not report any additional systematic error being introduced into the records. For example, there is no indication that only males or young people over-reported using their seat belts.

Further examinations of seat belt usage were performed using the Collision Performance and Injury Report, Revision 3, Occupant file. This file contains information for more than 4,000 occupants of vehicles which were involved in accidents. Because this is an accident data file, it does not represent the total occupant population. Seat belt usage was examined for the driver's physiological condition and for the type of road he was using and the speed at which he was travelling. In general, 21.4% of the CPIR file occupants used seat belts when riding in vehicles equipped with them.

1.2 Seat Belt Usage by Age

Because the possible benefits derived from using a seat belt are not immediate or tangible, one might postulate that a greater degree of maturity or foresight is required for their use. If such a postulate were true, then we would expect that there are differences in the proportions of people who use a seat belt across various age categories.

This question of seat belt usage for different age groups was investigated by drawing upon the mass accident date files discussed above. Table 2 contains the percentage of the drivers in each age group which used their seat belts.

All five data files indicate that fewer drivers from 16 to about 21 years of age reportedly use their seat belts than drivers over 22 years old. Generally, the seat belt usage rate reported for drivers over about 22 years of age is perhaps 5% greater than that reported for 16 to 21 year old drivers.

The New York and Seattle data show a decline in seat belt usage rates for drivers above 65 years old. However, the other data sets do not evidence this pattern. Because the number of cases is rather small in the 65+ age group, we cannot say with any confidence whether there are regional differences in the seat belt usage patterns of older drivers.

The lower restraint use rates for the younger drivers, coupled with the observation that younger drivers comprise a large proportion of the cases in the accident files, depresses the mean age for the non-users of restraints in these files. Table 3 contains the mean ages for the users and non-users of restraints. The calculations were not based upon the actual age of the Denver, Seattle, and Dade drivers but upon the numerical value ascribed to their age categories. Hence, a 16 year old Denver driver, for example, being grouped in the first category, is given an age value of 1, while a 27 year old Denver driver, being grouped in the sixth category, is given an age value of 6. Drivers 65 and older were excluded from the computations because these few cases contribute disproportionately to the dispersion about the mean.

If one wishes to assume that a given file is in some sense a sample of a larger accident population, then an analysis of the variance around the means indicates whether it is likely that the observable differences would be found in the larger population. (For a discussion of analysis of variance, see Section 2.5, A.) The analysis examines for the significance of the differences within the age categories for restrained and unrestrained drivers for each county and does not compare across counties.

Table 2
Proportion of Drivers of Various Age Groups Who Wore Seat Belts

Dade County 1970 [a]

Age Bracket	%
16	45.1
17	43.7
18-19	44.9
20-24	47.9
25-34	49.8
35-44	49.2
45-54	50.2
55-64	49.3
65-74	47.2
75+	53.8

Dade County 1971 [a]

Age Bracket	%
16	41.8
17	40.6
18-19	42.0
20-24	44.7
25-34	46.3
35-44	45.2
45-54	47.5
55-64	47.2
65-74	47.6
75+	47.1

Denver County 1970 [b]

Age Bracket	%
16	12.5
17	16.4
18-19	16.4
20-21	16.8
22-24	22.1
25-29	22.1
30-34	23.5
35-44	21.6
45-54	25.0
55-64	23.7
65+	24.5

New York Counties [a]

Age Bracket	%
16	32.4
17	41.0
18-19	33.0
20-21	36.0
22-24	42.0
25-29	42.4
30-34	43.5
35-44	42.8
45-54	45.5
55-64	44.0
65+	35.6

King County 1970 [a]

Age Bracket	%	Age Bracket	%
15-19	39.2	50-54	39.0
20-24	39.5	55-59	42.8
25-29	41.6	60-64	40.0
30-34	42.3	65-69	42.3
35-39	41.3	70-74	40.6
40-44	39.9	75+	37.3
45-49	41.7		

[a] Calculations do not include vehicles equipped with seat belts

[b] Calculations do include vehicles unequipped with seat belts

Table 3

Statistical Significance of Age Variations Between
Belted and Unbelted Drivers Aged 16-65

Data Base	Mean Age Bracket (Belted)	(Unbelted)	N	F-Stat	Sig. Level
Denver 1970	6.667	6.327	24,217	88.851	.00
Seattle 1970	7.162	7.110	13,239	1.221	.--
Dade 1970	6.378	6.284	34,268	26.308	.00
Dade 1971	6.410	6.306	38,937	37.446	.00
	Mean Age				
Western New York	34.36	32.80	11,966	40.295	.00

With the exception of the Seattle area, these results reveal that age produces statistically significant variations between the populations of belted and unbelted drivers. The observation that seat belt users tend to be older than non-users (Based on the Dade County, New York, and Denver data files) attains a significance level equal to 0.00.

The percentages presented in Table 2 show that the seat belt usage-age relationship is not a linear one (9,13). That is, the usage rate tends to stabilize for all age groups between about 24 and 65 in the five data sets. The finding present in Table 3 that users tend to be older than non-users reflects two points; (1) the markedly lower seat belt usage rate for 16-22 year old drivers and (2) the disproportionately large number of drivers of this lower age category who are involved in the accidents recorded in the data files.

Thus, the findings indicate that a relatively large proportion of the drivers involved in accidents who neglect to wear their seat belts can be specified in terms of their age. Consequently, we suspect that a potentially large increase in seat belt usage observable within the accident population can perhaps be obtained by focusing the efforts to encourage the use of restraints upon the 16-22 age group.

1.3 Seat Belt Usage by Sex

We drew upon the five mass data files to examine for variations in the use of a seat belt according to sex. Previous studies found that men were more likely to use restraints than women (9,12). Table 4 contains the data for the drivers recorded in the data sets.

A noticeable variation in seat belt usage emerges between the regions. However, the reports of the data collection agencies indicate that there ought not to be a sex bias in the recording of the accident information. Consequently, we are inclined to view the differences between the proportions of

Table 4
Drivers, by Sex and Seat Belt Usage

New York Drivers (Veh 1)[a]

	M	F		M	F
Belted	3647	1281	Belted	42.8%	37.7%
Unbelted	4878	2119	Unbelted	57.2%	62.3%
				100.0%	100.0%

Denver Drivers (Veh 1 & 2)[b]

	M	F		M	F
Belted	8538	3602	Belted	24.9%	26.3%
Unbelted	25767	10091	Unbelted	75.1%	73.7%
				100.0%	100.0%

Dade 1970 Drivers (Veh 1&2)[a]

	M	F		M	F
Belted	20055	9699	Belted	49.2%	47.7%
Unbelted	20538	10653	Unbelted	50.6%	52.3%
				100.0%	100.0%

Dade 1971 Drivers (Veh 1 - 3)[a]

	M	F		M	F
Belted	23613	10397	Belted	46.0%	44.7%
Unbelted	27705	12875	Unbelted	54.0%	55.3%
				100.0%	100.0%

Seattle Drivers (Veh 1 & 2)[a]

	M	F		M	F
Belted	7569	2965	Belted	44.4%	40.8%
Unbelted	9496	4309	Unbelted	55.6%	59.2%
				100.0%	100.0%

[a] The denominator includes only vehicles equipped with seat belts.

[b] The denominator includes vehicles unequipped with belts.

males and females using seat belts as reflecting the actual variations in usage by sex.

These differences are not the same across the five data sets -- among Denver drivers, women are more likely to have worn their seat belts than were men (26.3% to 24.9%). However, the men drivers recorded in the New York, Seattle and Dade 1970 and 1971 data sets were more likely to have worn their seat belts than were the women drivers.

Table 5 contains the comparable data for the passengers in the vehicles. Only the New York and Seattle files record this information.

Among passengers in these files, New York males and again more likely to have worn their seat belts, but, unlike Seattle male drivers, Seattle male occupants are less likely than women to use seat belts.

These percentages could be interpreted in a number of ways. One might argue that there are regional differences in the seat belt usage patterns for males and females. That is, in some regions men are more likely to use seat belts but elsewhere women tend to use them more frequently. The comparison between the percent of drivers by sex supports this proposition.

Moreover, one might contend that the seat location importantly influences whether a person of a given sex decides to use the seat belt (10). The shift observable in the Seattle data where men are more likely to use belts as drivers than women, but are less likely to do so as passengers supports this contention.

Finally, the change noticeable between 1970 and 1971 in Dade County suggests the possibility that trends or cycles might occur in the frequency with which a given sex uses the seat belt.

To some degree, these speculations, however attractive, explain only rather small variations in the seat belt usage rate. At most, one sex exceeds the other by about 5%. The low level of the extent of correlation could be shown a number of ways. The following, drawing upon chi-square and phi-square, assumes that these data sets are samples of some larger accident population. First, we calculated the chi-square variates for the actual frequencies contained in Tables 4 and 5. The chi-square significance level indicates the degree of confidence one may have that the

Table 5

Passenger Seat Belt Usage by Sex

New York Passengers (Veh 1 & 2)[a]

	M	F		M	F
Belted	955	606	Belted	21.6%	18.1%
Unbelted	3469	2748	Unbelted	78.4%	81.9%
				100.0%	100.0%

Seattle Passengers (Veh 1 & 2)[b]

	M	F		M	F
Belted	1015	1497	Belted	24.4%	28.3%
Unbelted	3146	3796	Unbelted	75.6%	71.7%
				100.0%	100.0%

[a] The denominator includes vehicles unequipped with belts.

[b] The denominator includes only vehicles equipped with belts.

distribution observable in the sample data did not occur by chance. If the chi-square suggests non-random differences in seat belt usage by sex, then it is useful to know whether the sex variable is an important predictor of seat belt use. In order to see the strength of the association between sex and seat belt use, we computed the phi-square predictive measure for the same data. Table 6 presents these summary statistics.

The chi-square variates calculated for the tables are all statistically significant to the .00 level. That is, we can confidently conclude that within each data set males and females do manifest different seat belt usage rates. However, the phi-square variates which measure the strength of the differences are trivial for each of the tables. That is, although there are differences between men and women in their reported seat belt usage rates, the differences are not very important. It is apparent that sex is not a useful predictor of seat belt usage for the drivers or for the occupants recorded in the five mass accident data files.

1.4 Seat Belt Usage, Type of Road and Speed

Other studies have shown that occupants are more likely to use their restraint devices when traveling on expressways than on unlimited access roads (13,14). When CPIR file occupants were involved in accidents on limited access highways, they used their seat belts 25.6% of the time as compared with 18.5% of the time for those involved in accidents not on limited access highways. This result is statistically significant to the .01 level of confidence.

However, this may only reflect a tendency for greater usage at higher speeds because drivers can maintain a higher average speed on expressways than on other types of roads. Consequently, we examined seat belt usage as a function of impact speed. Table 7 contains the results.

The small variation in usage rates observable in the table for different rates of speed is statistically insignificant. Hence, the relationship between speed and limited access highway

Table 6
Measures of Association, Sex and Seat Belt Usage

	Chi-Square	DF	Phi-Square
New York Drivers	26.110	1	+ .002
Denver Drivers	10.398	1	.000
Dade 1970 Drivers	20.098	1	.000
Dade 1971 Drivers	11.539	1	.000
Seattle Drivers	26.810	1	+ .001
New York Occupants	14.725	1	+ .002
Seattle Occupants	18.063	1	+ .002

Table 7

Proportion of Drivers Using their Seat Belt at Various Rates of Speed

Speed (mph)	Usage (%)
1-10	22.2
11-20	20.1
21-30	19.7
31-40	18.4
41-50	18.7
51-60	19.5
61-70	20.7
71-80	12.9

Table 8

Drivers, by Physiological State and Seat Belt Use

Condition	Number of Cases	% Using Seat Belt
None	1443	21.2
Fatigue	39	20.0
Blackout	15	20.0
Dozing	21	16.1
Drinking	303	11.2
Drunk	131	9.9
Drugs	15	5.0

Table 9

Seat Belt Usage and Drinking

	Using Seat Belt	Not Using Seat Belt
Drinking	47	387
Not Drinking	306	1137

Chi-Square (df=1) = 23.526
Phi-Square = .013

travel is not what explains the increased usage found for driving on an expressway. Unfortunately, the data at hand do not permit pursuing an explanation for why seat belt usage is greater for driving on expressways than on other roads.

1.5 Seat Belt Usage and the Driver's Physiological Condition

The CPIR file contains information regarding transient physiological conditions which could affect the driver's judgment and coordination. However, because the number of cases recorded for some of the conditions is not large , firm conclusions regarding their effects on the driver's decision to use the seat belt cannot be made. Table 8 presents the percent of the drivers within certain physiological states who used their seat belts.

The marked pattern of lower seat belt usage among drinking or drunk drivers led us to group these together to see whether the association is statistically significant. Table 9 contains the results.

The chi-square variate testing whether drinking drivers are less likely to use their seat belts is significant to the .01 level. However, the predictive power of the drinking factor is not great -- the phi-square variate is relatively trivial.

1.6 Conclusions to Sections 1.2-1.5

The data at hand suggest that drivers within the 16 to 21 age group, drivers not using limited access roads, and drivers who have been drinking are less likely users of their seat belts. There is no consistent correlation between the occupant's sex or the speed of the vehicle and probability of wearing a seat belt. However, the strength of the associations found between age, road type and drinking with seat belt usage is not overwhelming. The fact of the matter is that none of the sizeable groups identifiable with the data have a recorded seat belt usage rate exceeding 50% in the mass accident data files or 30% in the CPIR file. Some increases in the overall seat belt usage rate can be made if the 16 to 21 year olds, the drinking driver, and drivers on ordinary roads and highways can be induced to used their seat belts at rates comparable to their counterparts. However, the usage rates for those groups which are more prone to wear a restraint device -- non-drinking drivers, 22 to 65 years olds, and drivers on expressways -- are themselves not very great.

1.7 A Report on a Survey to Determine the Methods of Circumvention of the Buzzer-Reminder System for Seat Belt Use.

Another important question refers to the buzzer reminder system for seat belts. Of primary interest is how it is being circumvented. A secondary question is its effectiveness in increasing seat belt use.

The seat belt buzzer is a system that emits a loud buzzing noise if it detects the seat belts of either the driver or right front passenger not being used, and it is intended to remind and indeed force the occupants to wear their seat belts. Unfortunately it does not always do this, because the occupants are defeating the system by such methods as disconnecting it, keeping the seat belt permanently buckled, etc. To help design a system that eliminates this circumvention, it is desirable to know the distribution of methods of foiling the buzzer as installed in American-made cars. This is the purpose of this part of the study. The reader is cautioned that the additional results concerning the effectiveness of the buzzer system are not based on a random sample of the entire driving population and one should be careful not to make inferences to the entire driving population from them.

The main result of this part of the study, then, is found in Table 15. Although most of the commentary concerns the secondary question of buzzer system effectiveness, this does not indicate the relative importance of the two questions.

Our approach was first to determine how other investigators had proceeded. A previous study by Robertson and Haddon attempted to determine if the buzzer had affected seat belt wearing habits by comparing the proportions of seat belt wearers in cars where the buzzer was installed with those in cars where it was not installed, the proportions being found by observing cars in the traffic stream (17). While this sampling method has many advantages, it was impossible for our purposes since we also had to ask the occupants how they foiled the system. Thus, we resorted to direct questioning of selected drivers, which may have introduced a bias towards over-reporting usage since some drivers are reluctant to admit that they do not wear seat belts, especially to interviewers whom they perceive to be interested in highway safety. We attempted to minimize this bias by not having the interviewers identify themselves unless specifically asked, and by designing questions that required clear, precise answers, thus making it difficult for the driver to "hedge" his answers without outright lying. We will discuss the questionnaire in detail later.

Having decided on a survey as our research technique, it was obvious that the subjects would have to be operators of American-made cars in which the buzzer system was installed. This meant cars produced after January 1972. But since the interviewers could not differentiate between pre- and post-January 1972 models, we decided the pre-January cars could be used as a control group to help determine the effectiveness of buzzers over and above such other factors as seat belt advertizing campaigns. It would have been better had we obtained a completely random sample of the traffic stream, but many factors precluded this approach. For one, it was impossible to ask questions of drivers unless they had stopped the engine, thus we had to contact them as they were entering or leaving their cars. Second, the subjects would have to have enough time to answer the questions -- this eliminated such places as factory parking lots, where the rush to and from cars is well known. Third, there had to be enough subjects to interview, which meant the survey would have to be conducted somewhere with a high turnover of cars. Fourth, we wanted to confront the subjects personally so as to help increase the reliability of their answers. Finally, we had to get permission for interviewing, and unfortunately several otherwise excellent locations were denied us because their owners were reluctant to have their customers questioned. All these restrictions narrowed our survey to direct interviews at two locations: Arborland Shopping Center on the east side of Ann Arbor, and Topps Discount Store parking lot southeast of Ann Arbor.

There remained the question of when the survey should be conducted. The best procedure would have been to survey drivers during both day and night in order to obtain a more random sample of the population, but approaching people in a parking lot at night had its drawbacks and we decided against it. However, we did select both weekends and week days for our interviews, and this tended to give us a more inclusive sample. The days we chose were Friday Nov. 17, Saturday Dec. 2, Sunday Dec. 3, and Tuesday Dec. 5, 1972.

Before the questionnaire could be designed it was necessary to decide exactly what we wanted to find out. We selected four specifics: (1) How is the buzzer bypassed?, (2) Does the buzzer affect seat belt use?, (3) If it does, what is the magnitude of this effect?, and (4) What are the ages and sexes of those surveyed? The problem then was to translate these four into concise, unambiguous questions which would elicit the information desired as reliably as possible. Question number one was straightforward enough to be posed directly. Secondly, it was felt that the answer to question number three would imply an answer to question two, since any magnitude other than zero means some sort of effect. But how does an individual perceive that the buzzer system has affected his use of seat belts, and how can he express the magnitude of this effect? Ideally, a driver would be able to determine precisely what proportion of his desire to use his seat belt comes from the buzzing in his ear, and what proportion comes from some innate yearning that would be there even if the buzzer were not installed. But people cannot do this, and the best that can be done is to compare their performance in buzzer installed cars with their pre-buzzer driving and riding habits. For this reason, the third issue was posed as a pair of questions: "How often did you wear your seat belt before you had the buzzer?", and "How often do you wear it now?" Fortunately there was virtually no one who did not have the opportunity of at least riding in a car equipped with seat belts before he had the buzzer. (Those few that did not were not questioned further).

Unfortunately, even these simple questions are not easy to answer, because it is hard for most people to pin down the exact proportion of time they use their seat belt. Any attempt to get people to come up with some number would not yield very satisfactory results. Therefore, we decided to divide the scale into four degrees of seat belt use: "none of the time", less than half", "more than half", and "all the time" (it is probable that when a driver responds "all the time" he often does not actually wear it 100% of the time, so this category might more properly be interpreted as something like "more than 90% of the time"). Thus the presence and magnitude of a buzzer effect on seat belt use is indicated by the responses to the pair of questions stated above. For those who drove pre-January '72 cars and did not have a buzzer system, the pair of questions became "How often did you wear your seat belt a year ago", and "How often do you wear it now". The responses to this pair of questions is a measure of the effect of factors other than the buzzer, such as TV advertising. One can point out that a respondent may indicate an effect which is insufficient to cause his wearing habits to go from one category to another, and thus would be classified as "no effect" by his responses to the two questions. For example, he may actually wear his seat belt 10% of the time before the buzzer, and 40% of the time after the buzzer, and yet his answers would indicate no effect, since both would be "less than half the time". We agree that this is possible but most people are not able to specify two levels of use that are within one category. If they do perceive an effect, it is because it is large enough to cause their use to jump from one category to another. Question 4 could be determined by direct observation of the respondent. One more question was inserted in the questionnaire because it was recognized that there is probably a high correlation between the seat belt wearing habits of family members. Moreover, many of the methods of circumventing the buzzer system, such as disconnecting it under the hood, disable the system for all users of the car. If the buzzer did not affect the respondent because of something another family member did, we wanted to know this. The entire questionnaire is presented in Figure 1.

Before we present the results of the survey it is necessary to discuss how we expected to analyze these results. The secondary purpose of this study was to determine the magnitude of the effect of the seat belt buzzer system. This was measured by the difference in the percentage of seat belt use before and after the buzzer. One test of whether the buzzer is effective was a comparison of these average differences for those with a buzzer and those without. If the average difference was significantly greater for buzzer users, this would indicate that it does help, and the magnitude of the effect would be given by the average difference figure. Further tests were made to determine whether the distributions of the differences in these two cases were the same. However, by just looking at

Figure 1

THE UNIVERSITY OF MICHIGAN
HIGHWAY SAFETY RESEARCH INSTITUTE
SEAT BELT BUZZER EFFECTIVENESS STUDY

1. Do you have a seat belt buzzer system in your car?

   Yes ____ No ____

2. How often did you wear your seat belt before you had the buzzer?

   Never ____ Less than 50% ____ More than 50% ____ Always ___

3. How often do you wear it now?

   Never ____ Less than 50% ____ More than 50% ____ Always ___

4. How much has the buzzer affected the seat belt use of other members of your family?

   a) Husband/father ___ Wife/mother ___ Son/daughter/sister/brother ____
   b) Seat belt use before the buzzer
   Never ____ Less than 50% ____ More than 50% ____ Always ____
   c) Seat belt use now
   Never ____ Less than 50% ____ More than 50% ____ Always ____

   d) Husband/father ___ Wife/mother ___ Son/daughter/sister/brother ___
   e) Seat belt use before the buzzer
   Never ____ Less than 50% ____ More than 50% ____ Always ____
   f) Seat belt use now
   Never ____ Less than 50% ____ More than 50% ____ Always ____

5. How do you beat the buzzer?

   ____

   ____

6. Why do you not wear your seat belt?

   ____

   ____

   ____

7. Sex _____

8. Estimated age ______

these differences for the entire sample, we were missing something, for it was obvious that the degree by which the buzzer increases the use of seat belts depends considerably on how much the belts are being used in the first place. The more one uses his seat belt the less the buzzer could possibly change his habits, and certainly someone who uses his seat belt all the time would not be affected at all. Thus we divided the sample into four categories, depending on their percentage of seat belt use before the buzzer, and performed a similar analysis on all categories. The four classes of percentage seat belt use were: (1) no use, (2) less than half the time, (3) more than half the time, and (4) all the time. We arbitrarily mapped the per cent of restraint use onto a continuous scale, where "no use" corresponded to the value 1.00, "less than half the time" to 2.00, "more than half the time" to 3.00, and "all the time" to 4.00. All statistical analyses were done using this new variable. Finally, we obtained a distribution of the methods of beating the system, as well as peripheral statistics such as the correlation of the increase in seat belt use between family members, the average age of the subjects, and their sex distribution.

The first task, then, was to determine the amount of prior usage of seat belts for both the buzzer and non-buzzer groups. It turned out that the average seat belt usage in pre-buzzer cars was not significantly different for those that subsequently bought buzzer installed cars than from those that continued driving non-buzzer-installed cars. Moreover, a test of the distribution of usage showed that they are not significantly different either, as can be seen from Figure 2 and Table 10.

However, when we compared the present usage of the seat belt with the prior use for both the buzzer users and non-users, both the average and the overall distribution of usage were shifted significantly for those with the buzzer, while

Figure 2

Distribution of Prior Percentages for Use of Seat Belt

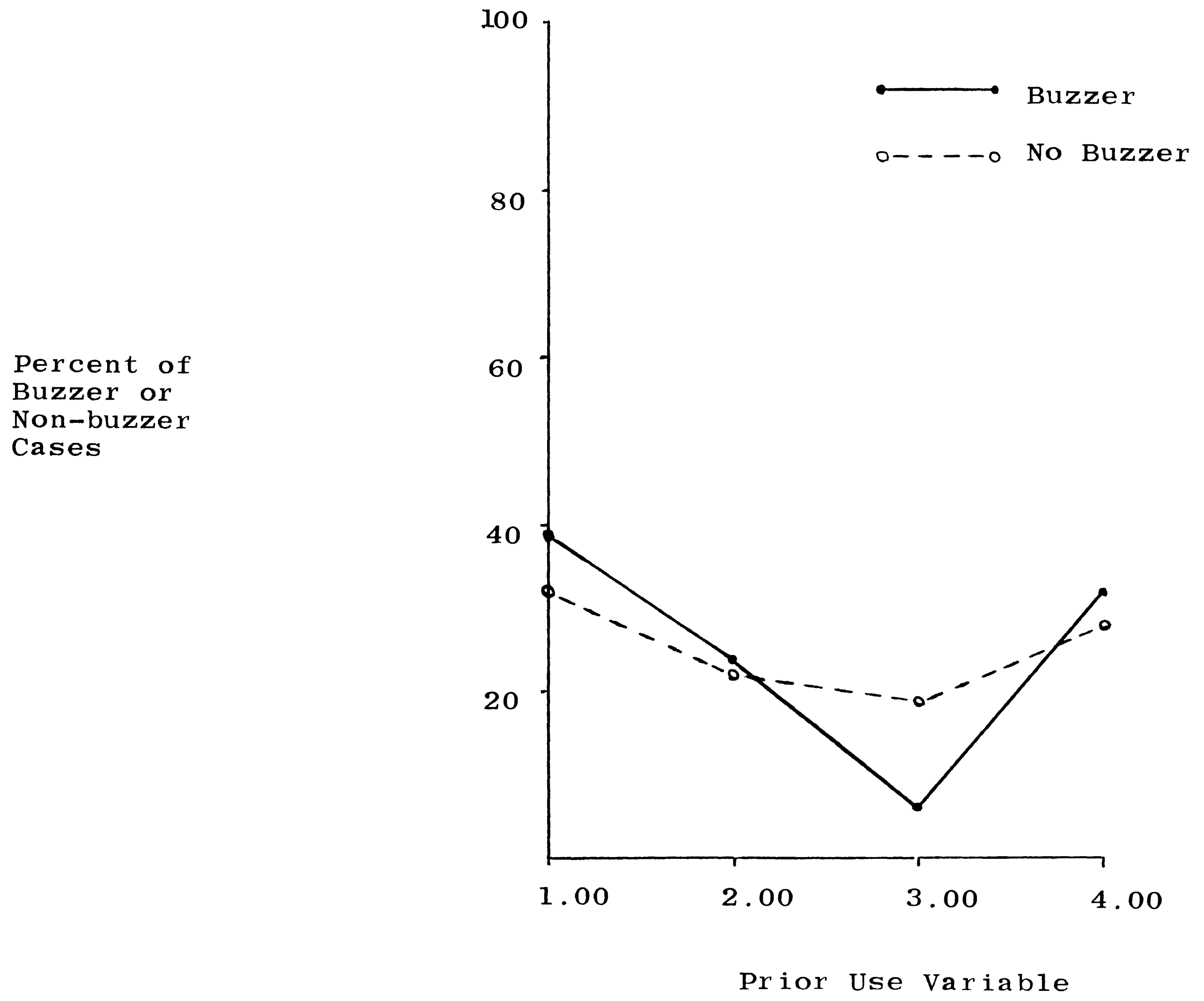


Table 10
Distributions of Prior Percentages for Use of Seat Belt

Buzzer

Prior Use Variable

	1.00	2.00	3.00	4.00	Total	Average
Number	72	44	11	59	186	2.31
Percentage	39%	24%	6%	32%	100%	

No Buzzer

Number	22	15	13	19	69	2.42
Percentage	32%	22%	19%	28%	100%	

the non-buzzer drivers continued their same pattern of usage. Figure 3 and Table 11 show this.

This result was substantiated when we looked at the distributions of each individual's difference between prior and present seat belt usage for both the buzzer and the non-buzzer groups. Again the average difference is significantly greater for drivers of buzzer-equipped cars, as is the overall distribution, shown in Figure 4 and Table 12.

Categorizing the subjects by per cent of prior usage, and performing analyses similar to the one above, we saw that for all categories except category 4, the 100% seat belt wearers, there was a significantly greater difference between prior and present seat belt use for those with buzzers over those without the buzzer. Figure 5 and Table 13 illustrate this. The averages of the differences in prior to present usage for each prior use category, and for those with buzzers, and those without, are given in Figure 6 and Table 14. As can be seen, the increase in seat belt usage generally drops off for those with more pre-buzzer use of the seat belt. Usage generally dropped off for those with more prior use of the seat belt. For both the buzzer and non-buzzer samples the increases for both the first two categories were significant, while for those with a buzzer the increase for the third category was significant at the .06 level.

Other analyses show that the correlation of usage between family members is .7317, that there are 53% women in the survey, rather more than the driving population as a whole, and the average age of the respondents is 31.4, which is close to the overall average of drivers.

The main purpose of the project was to obtain a distribution of the methods of foiling the buzzer, and this is presented in Table 15.

Before drawing any conclusions from these results, it is necessary to mention again the limitations of the data. For one thing, the sample is not a random sample of the entire

Figure 3

Distributions of Present Percentages for Use of Seat Belt

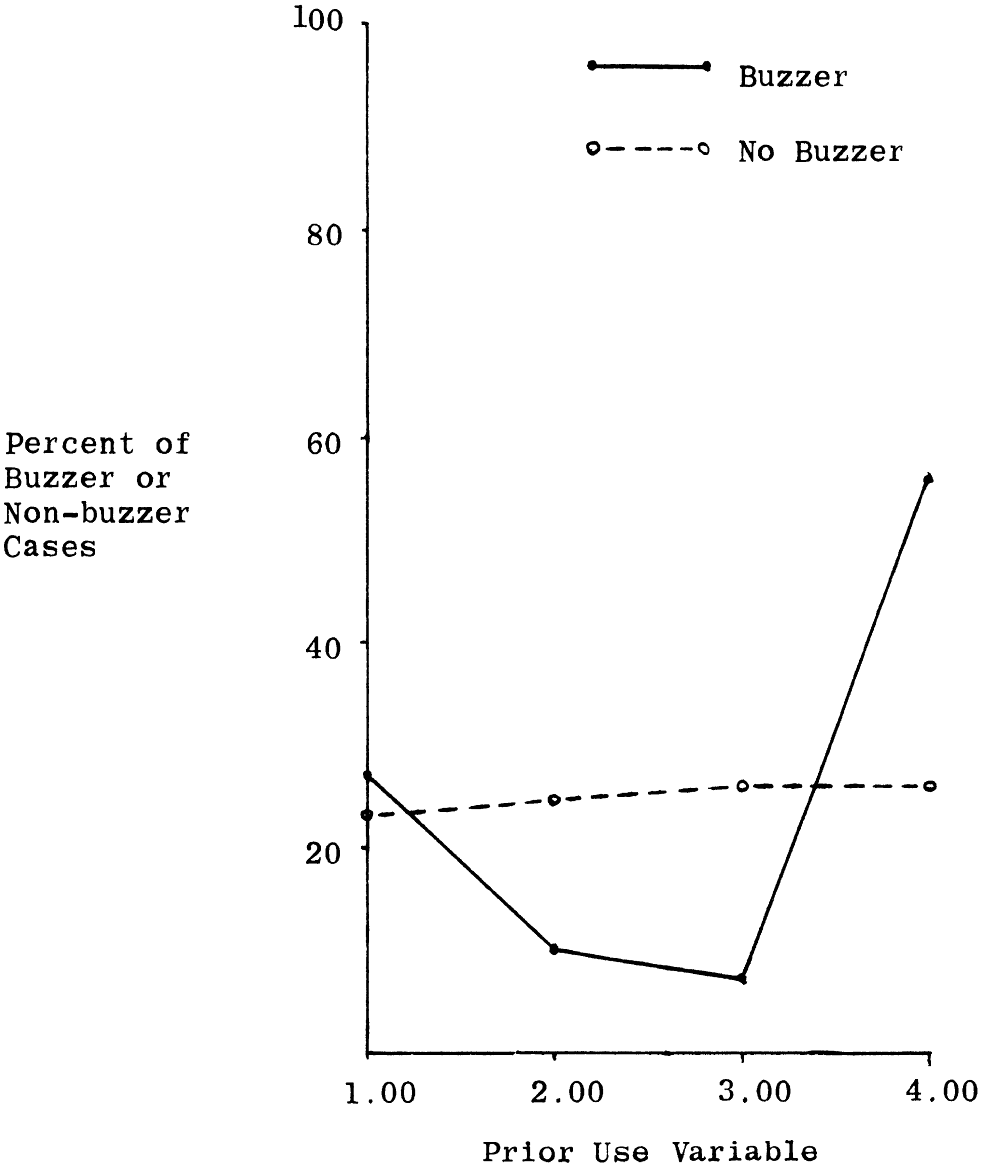


Table 11
Distributions of Present Percentages for Use of Seat Belt

Buzzer

Post-Buzzer Use Variable

	1.00	2.00	3.00	4.00	Total	Average
Number	50	18	13	105	186	2.93
Percentage	27%	10%	7%	56%	100%	

No Buzzer

Number	16	17	18	18	69	2.55
Percentage	23%	25%	26%	26%	100%	

Figure 4

Distribution of Differences in Percent Use of Seat Belt

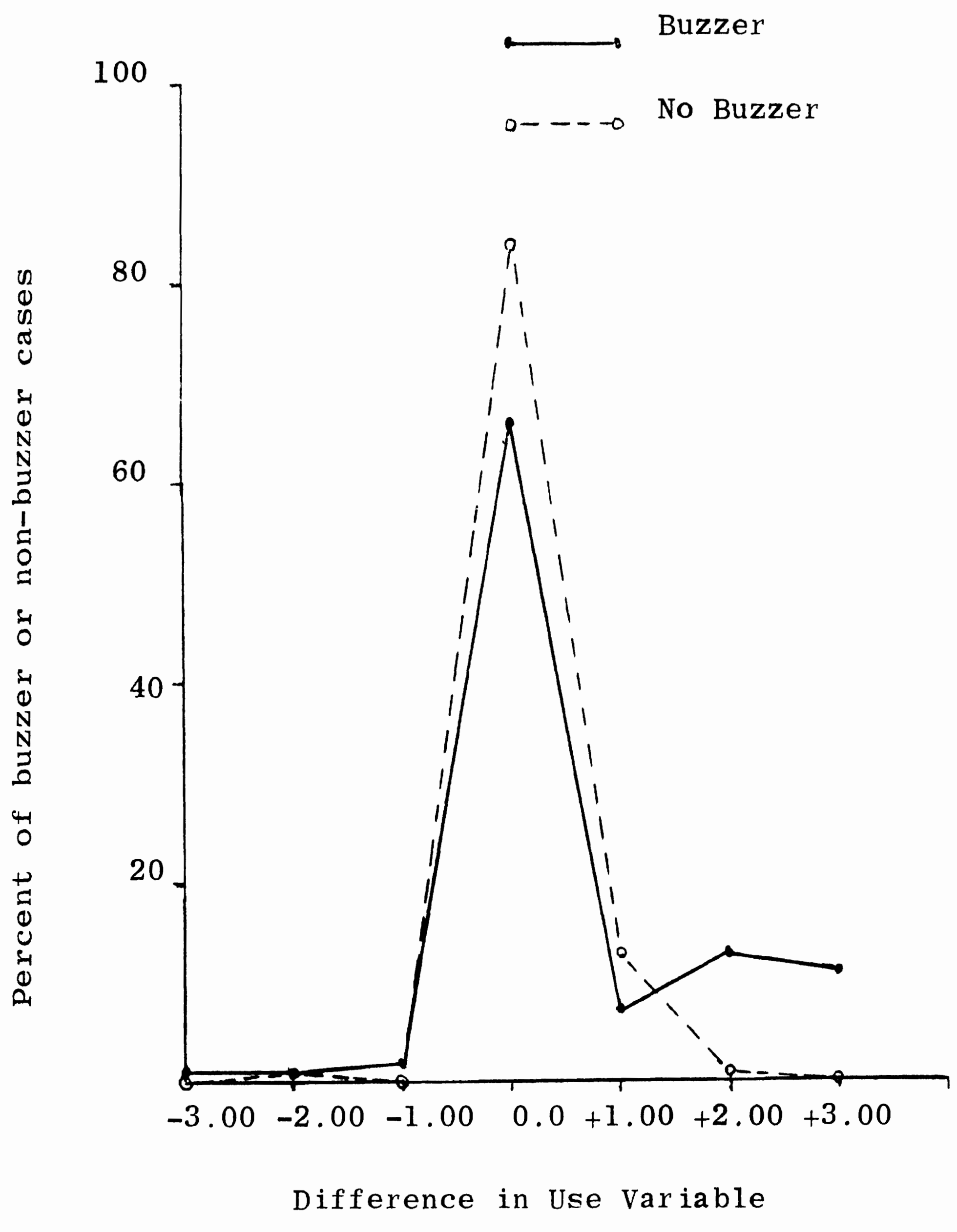


Table 12

Distribution of Differences in Percent Use of Seat Belt

Differences Between Prior and Present Use of Seat Belt Variables

	-3.00	-2.00	-1.00	0.00	+1.00	+2.00	+3.00	Average
Number	11	1	3	123	13	24	21	+.623
Buzzer								
Percentage	10%	1%	2%	66%	7%	13%	11%	-
Number	0	1	0	58	9	1	0	+.13
No Buzzer								
Percentage	0%	1%	0%	84%	13%	1%	0%	-

Probability that averages are equal .0016.

Figure 5

Distribution of Differences in Percent Use of Seat Belt by Rate of Use Categories

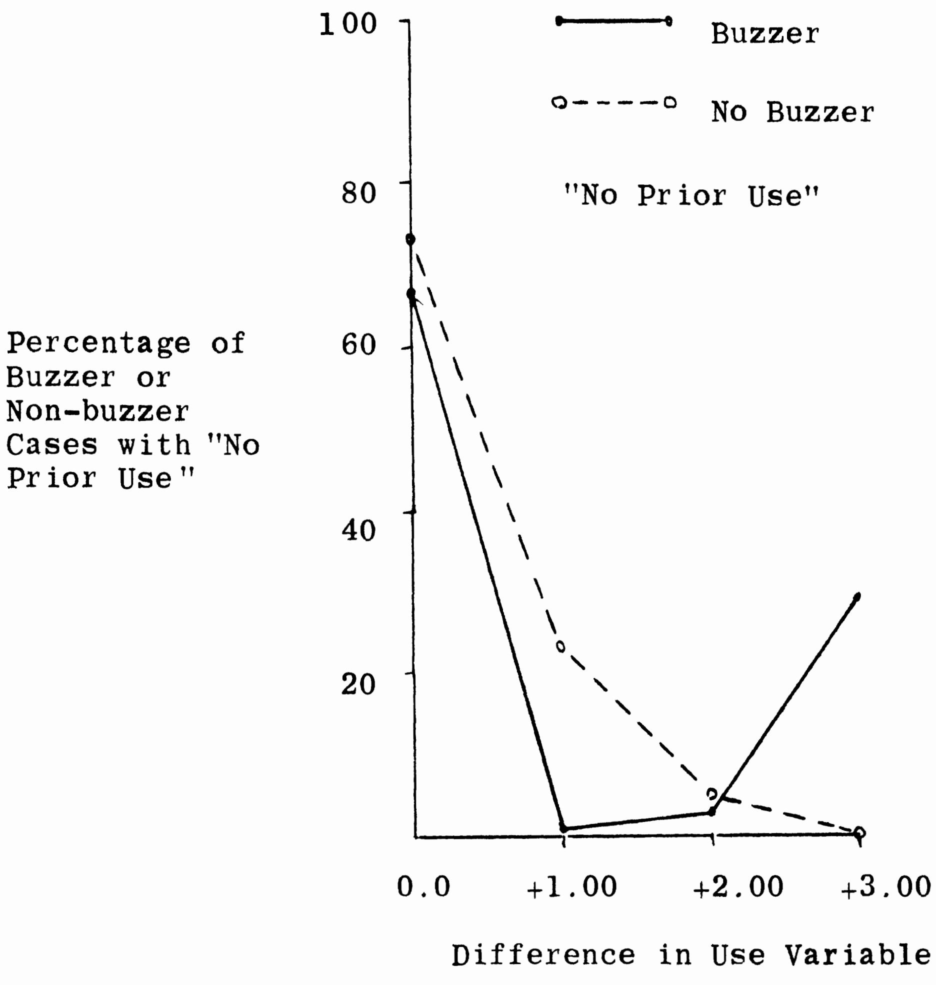


Figure 5 (continued)

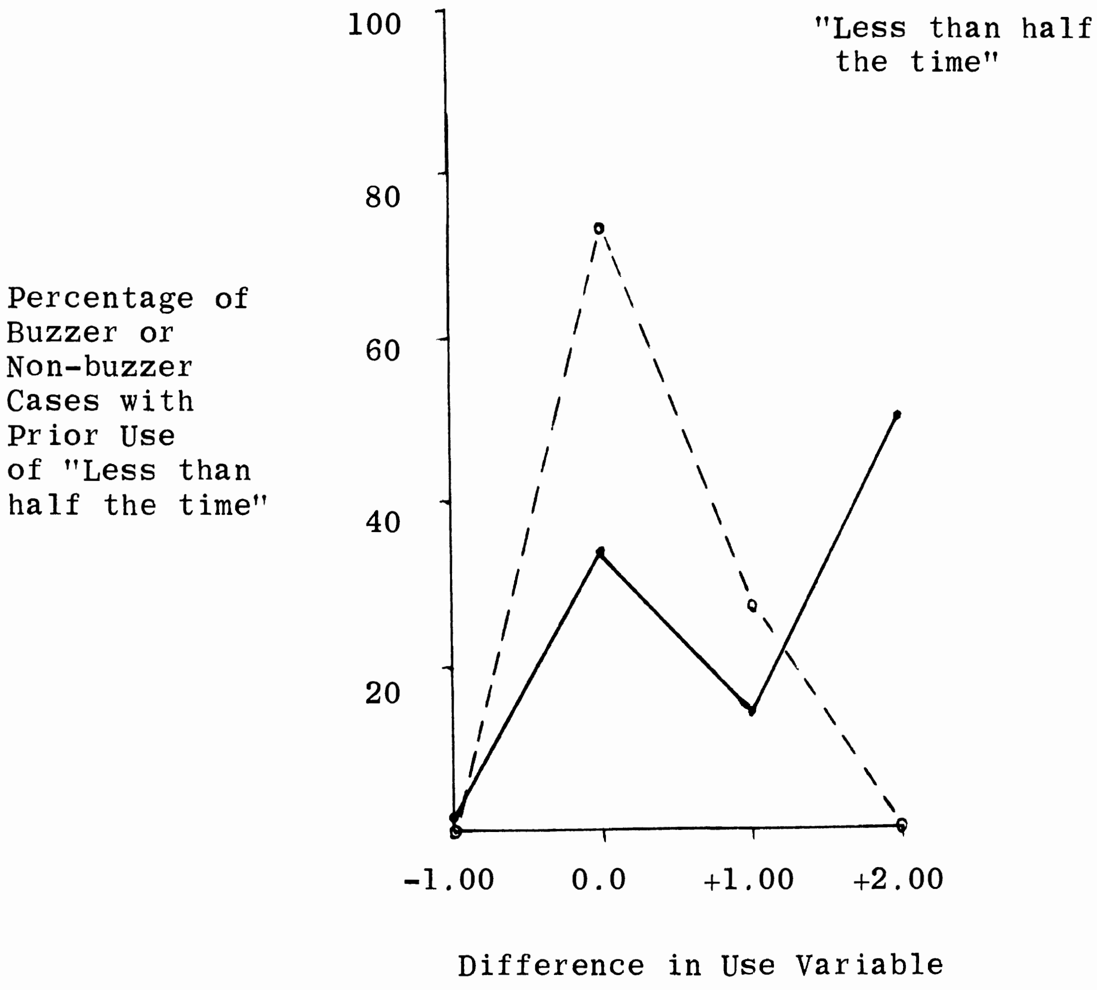


Figure 5 (continued)

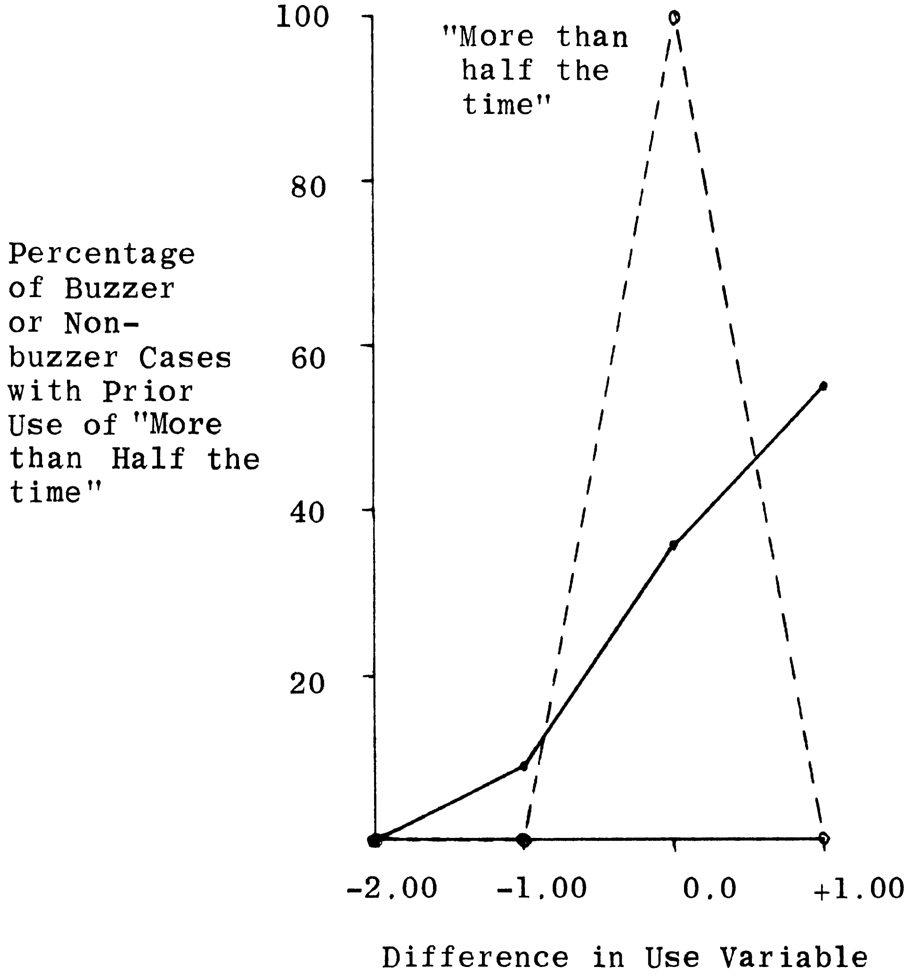


Figure 5 (continued)

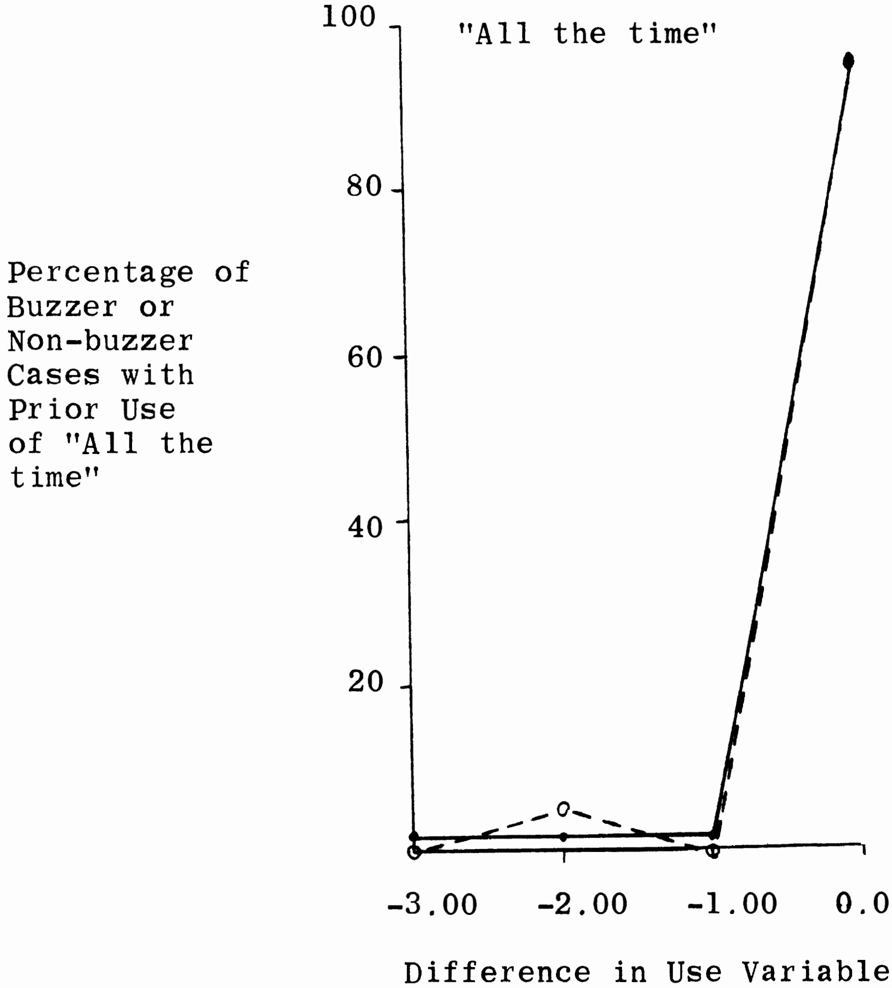


Table 13
Distribution of Differences in Percentage Use
of Seat Belt by Rate of Use Category

Buzzer

Differences in Use of Seat Belt

Prior Use Variable		-3.00	-2.00	-1.00	0.0	+1.00	+2.00	+3.00	Average	Prob Aver=0
1.00	Number	-	-	-	48	1	2	21	+94	.0000
	Percentage	-	-	-	67%	1%	1%	29%		
2.00	Number	-	-	1	15	6	22	-	+1.11	.0000
	Percentage	-	-	2%	34%	14%	50%	-		
3.00	Number	-	0	1	4	6	-	-	+.45	.0531
	Percentage	-	0%	9%	36%	55%	-	-		
4.00	Number	1	1	1	56	-	-	-	-.10	.1094
	Percentage	2%	2%	2%	95%	-	-	-		

Table 13 (continued)

No Buzzer

Differences in Use of Seat Belt

Prior Use Variable		-3.00	-2.00	-1.00	0.0	+1.00	+2.00	+3.00	Average	Prob Aver=0
1.00	Number	-	-	-	16	5	1	0	+.32	.0157
	Percentage	-	-	-	73%	23%	5%	0%		
2.00	Number	-	-	0	11	4	0	-	+.27	.0406
	Percentage	-	-	0%	73%	27%	0%	-		
3.00	Number	-	0	0	13	0	-	-	0.0	1.00
	Percentage	-	0%	0%	100%	0%	-	-		
4.00	Number	0	1	0	18	-	-	-	-.11	.3306
	Percentage	0%	5%	0%	95%	-	-	-		

Figure 6

Differences in Prior to Present Percent
of Seat Belt Use For
Each Usage Category

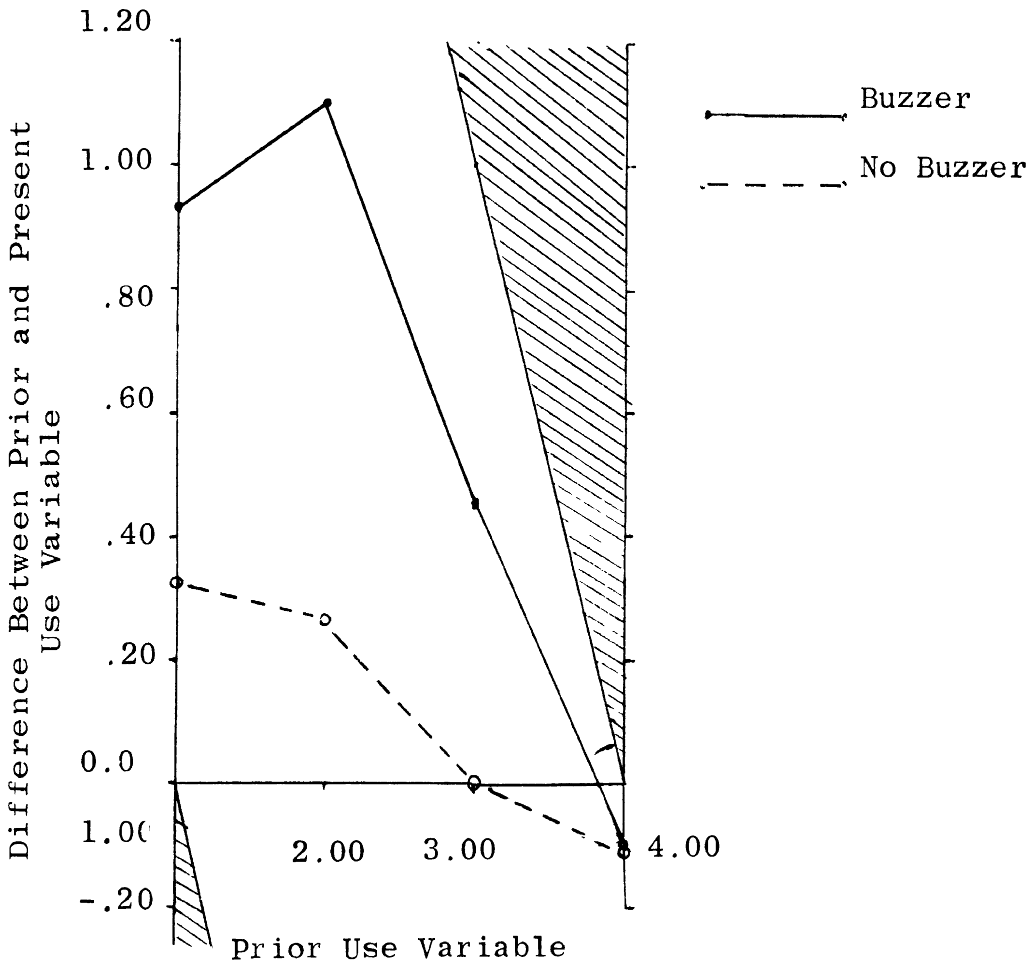


Table 14
Differences in Prior to Present Percent of Seat Belt Use for Each Usage Category

	Buzzer prior to present use diff (d_1)	No buzzer prior to present use diff (d_2)	d_1-d_2	Pr $(d_1-d_2)=0$
1.00	+.94	+.32	+.63	.0003
2.00	+1.11	+.27	+.85	.0000
3.00	+.45	+.00	+.45	.0271
4.00	-.10	-.11	+.01	.50
Total	+.62	+.13	+.49	.0026

Table 15
Distribution of Methods of Circumventing the Buzzer

Method	Number	Percent
Buckle seat belt but not around occupant	56	59.6%
Deform seat belt so it cannot retract	5	5.3%
Disconnect or tear out mechanism	10	10.6%
Let it buzz	1	1.1%
Fasten seat belt to some object to keep it from retracting	18	19.1%
Buzzer self-failure	4	4.3%

driving population. The percentage of females shows that they are over-represented -- there are probably other biases inherent in the sample of those customers that visited our two locations on the days specified. A second problem is the honesty of the answers. Did the drivers of buzzer-equipped cars answer the way they did because they felt some sort of guilt for not using their seat belts even though they had the buzzer? As was mentioned before, attempts were made to minimize this, but there still may have been some false answers. We can feel confident in the distribution of ways of circumventing the buzzer, because there seems to be no reason for lying on this question.

The strongest conclusion, therefore, is the distribution of methods of beating the buzzer -- especially the finding that the predominant method is to keep the seat belt permanently buckled. We can also conclude, albeit not as strongly, that for the population represented by the sample as is indicated by all the above analysis, the seat belt buzzer system is effective in increasing seat belt usage over and above other factors such as advertizing.

SECTION II: RESTRAINT SYSTEM USE AND OCCUPANT INJURY PATTERNS

2.1 The Data

The source for the data used in these analyses is the CPIR Revision 3 Occupant File compiled at the HSRI, University of Michigan (18). This source contains information on more than four thousand occupants of vehicles involved in traffic accidents. This data file does not consistute a random sample of motor vehicle accidents which have occurred in the United States or even within those areas from which the data were collected. As a consequence, the precise dimensions of the accident population of which the CPIR file comprises a useful sample is unknown.

Perhaps the most significant bias within the data in regards to this project is the over-representation of cases in which occupants of vehicles involved in accidents are injured. About 75% of the occupants contained in the file sustained injuries. This compares to about 22% derived from a comprehensive census of tow-away accidents occurring in Washtenaw County, Michigan, from January 1968 through 1971. This bias in the data towards over-representing the properties of occupants who incurred injury leads to inflated estimates pertaining to the likelihood of sustaining an injury. However, there seems no reason to believe that the distribution of injuries is otherwise biased as a result of selection criteria involving the use of restraints, conditions surrounding the accident, or the areas of the body sustaining the injury. The desirability of employing these factors in understanding the effect of using a restraint leads us to use the CPIR file which contains rich information about the accident situation and specific information about the level and location of the injuries. The cases included in this analysis stem from only those vehicles equipped with both lap belts and torso restraints (number of occupants = 2676).

We examined the CPIR file in order to determine the frequency of injury at various levels of severity for occupants who used and for those who did not use a restraint device. The injury severity variable accessed from the file ranges from 0, no injury, to 9, three or more fatal injuries, for overall injury severity, and from 0 to 6, no injury to fatal, for the specific body regions. We examined the injury pattern for overall injury severity (v600 in the CPIR file), and for injury to the organs, brain, head, neck, shoulder, back, abdomen, and pelvic regions. Moreover, in an effort to see whether the effect of restraint system usage on injury differed according to the situation, the injury patterns for the body regions were calculated for various accident configurations, occupant seating locations, speed levels, vehicle deformation extents, and rollover versus non-rollover cases. "Accident configuration" derives from variable 59 in the CPIR file and records whether the accident was a head-on, rear-end, side-swipe, T or L type intersection collision, or a single vehicle crash. "Vehicle deformation" refers to the extent to which the sheet metal was crushed by the accident and, hence, is one index to the severity of the accident.

Initially, we were hopeful that the full range of restraint systems and the various combinations involved with their usage (such as 3 point or 4 point shoulder harness) could be analyzed. Unfortunately, incorporating this extensive array of restraint system usage data contained in the CPIR file quickly exhausts the limited number of cases available for some of the cells. For example, only 2% of the occupants wore upper torso equipment. Consequently, for the purposes of this study, we grouped upper torso belts and lap belts into one category. With the exception of Section 2.2, the effects of different types of restraints are not compared.

An important point is that injuries which occur when an occupant is wearing a restraint do not necessarily result from the restraint device itself. Throughout this study, we examine for the levels of injury severity or the frequency of injury which are associated with the use (and non-use) of restraint systems, but only in the final section do we discuss which objects produce the injury. Within the context of the present analysis, any number of objects can injure those occupants who wear restraints and hence are correlated with restraint system usage.

2.2 A Comparison of Injury Patterns for Torso-Restrained, Lap Belted and Unrestrained Occupants

This section explicitly examines the comparative injury severity rates for the occupants according to their restraint status. The following table contains the frequencies and row percentages for the occupants in the three restraint categories of torso restraint, lap belt with or without shoulder harness, and no restraint.

Regarding the incidence of injury, the percentages suggest that CPIR occupants wearing either lap belts or torso restraints had about the same likelihood of escaping injury (32% to 36%, respectively). Moreover, those using any restraint were less likely to have been injured than occupants who did not wear restraints. On the other end of the injury severity scale, CPIR occupants who wore torso restraints or lap belts were less likely to have been killed than those who did not wear restraints (3%-4% to 7%, respectively).

2.3 An Overview of the Effect of Restraint System Usage and Occupant Injury

The data describing the effects which restraint system use has on overall injury when controlling on the various factors pertaining to an accident discussed above and the effects which using a restraint have on injury to the selected body regions have been plotted in a series of graphs. For the purposes of comparison, the graphs for the users and non-users of restraints

Table 16
Absolute and Relative Frequencies of Injury
at Various AIS Levels

	0	1	2	3	4	5	6	Mean Injury
Unrestrained								
Frequency	476	963	263	132	47	23	132	1.91
Percent	23.4	47.3	12.9	6.5	2.3	1.1	6.5	
Lap Restrained								
Frequency	190	289	44	26	8	9	22	1.67
Percent	32.2	49.0	7.5	4.4	1.4	1.5	3.7	
Full Restrained								
Frequency	33	45	6	1	2	2	3	1.63
Percent	35.9	48.9	6.6	1.1	2.2	2.2	3.3	

have been superimposed. Because there are more restraint non-users than users, the proportion of injuries at each severity level is presented rather than the actual number. This allows a direct comparison of the proportions of injuries at each level.

A pair of graphs can suggest several things. The relative positions of the two curves at the 0 injury level indicate whether a larger or smaller proportion of injuries result to users of restraints, and their relative positions at the higher severity levels indicate the proportions of serious injuries and fatalities. By comparing the shapes of the curves, one can determine if the injury pattern is the same for both groups. For example, if the nonuser's curve slopes up at the more severe injury levels and the users' curve slopes downward, this would suggest that restraint use tends to mitigate the injury mechanisms that cause serious injury to non-users of restraints. If the two curves have the same basic shape, but one is skewed more to the left than is the other, then this indicates that the skewed curve enjoys a similar reduction of injury severity at all injury levels.

The data from which the graphs are plotted exhibit a notable feature: almost all injury variables in the graphs show either no injury or injury at level one (slight). For this reason, it is often impossible to present the proportions of injuries at all levels using only one scale. Consequently two scales are often used -- one for the more frequent injury severity levels and one for the less frequent levels. Unfortunately, it is sometimes difficult to meaningfully compare the curves at the less frequent injury levels due to the paucity of cases.

The following points summarize the statistical analyses performed on the data contained in the graphs. First, for each graph, tests were performed to determine the statistical significance of the differences observable in the frequency of injury for restrained and unrestrained occupants. Second, the differences between the distribution of injury severity for restrained and unrestrained occupants given that they are injured (that is, analysis of the 1-6+ AIS values) are systematically examined.

Hence, the mean injury levels in the following discussion exclude occupants who were uninjured. The data presented are obtained from Tables 17 and 31-36 found in the analysis sections. The reader is urged to read the discussion of the statistical models employed and the criterion for "statistical significance" found in Section 2.3. These two operations are intended to answer the following two questions: does the use of a restraint significantly affect the likelihood of injury, and are there significant differences observable between the mean injury level reported for users and non-users of restraints?

1. Overall Injury:

Regarding overall injury severity (v600), 68% of the users of torso or lap belts sustained an injury versus 77% for non-users. This difference is significant to the .00 level and warrants concluding that restraints do indeed reduce the incidence of injury. The mean severity level for those injured is 1.65 for users and 1.91 for non-users. This difference, too, is significant to the .00 level indicating that restraints exercise a demonstrable effect in reducing the severity of injury. (See Figure 7; Tables 17,31)

2. Accident Configuration:

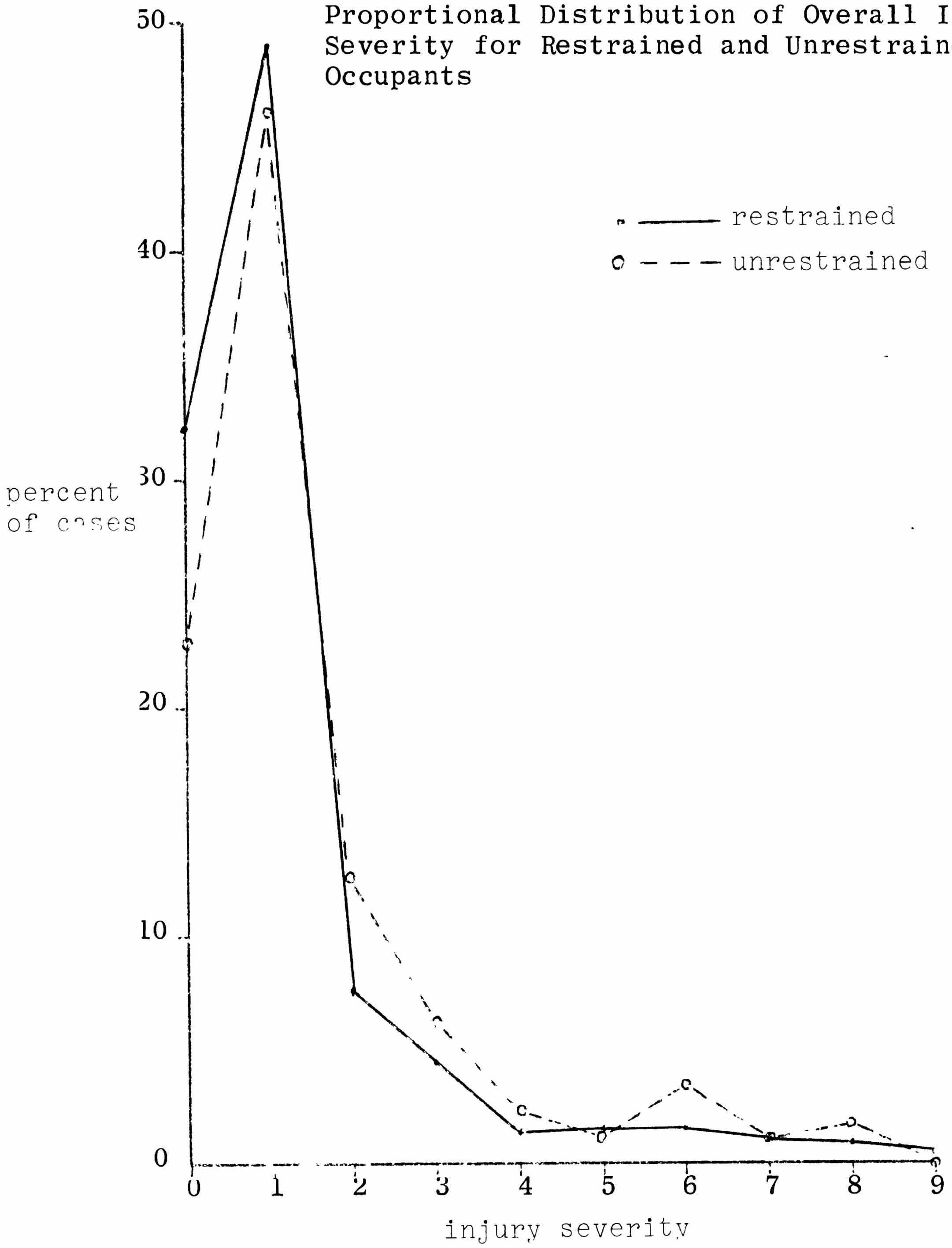
Differences across the accident configurations in the extent of the reduction in the incidence of overall injury associated with restraint use are not statistically significant. That is, the effect of restraints in reducing the incidence of overall injury (by 9%) is about the same for single vehicle collisions, T/L intersections, head-on, sideswipe, and rear-end accidents. However, the reduction in the severity of the injury is significant only in the case of single vehicle accidents. In single vehicle collisions, the mean injury level is 1.80 for restrained occupants and 2.23 for the unrestrained occupants. (See Figures 8-12; Tables 18,32)

3. Seating Location:

The reduction in the incidence of overall injury severity of 9%

Figure 7

Proportional Distribution of Overall Injury Severity for Restrained and Unrestrained Occupants



OVERALL INJURY

Table 17
Incidence of Injury and Restraint System Use

Proportion of Occupants Receiving an Injury to:	Restraint System Users	Non-Users	Sig
Overall Injury	68%	77%	.0000
Organs	2%	5%	.0050
Brain	8%	13%	.0005
Head	20%	28%	.0002
Chest	21%	25%	.0247
Neck	15%	15%	.9587
Shoulders	10%	10%	.9033
Back	7%	6%	.2594
Abdomen	9%	5%	.0001
Pelvic Region	9%	7%	.1259

Table 31
Anova of Injury Severity, Controlling
on Restraint System Use

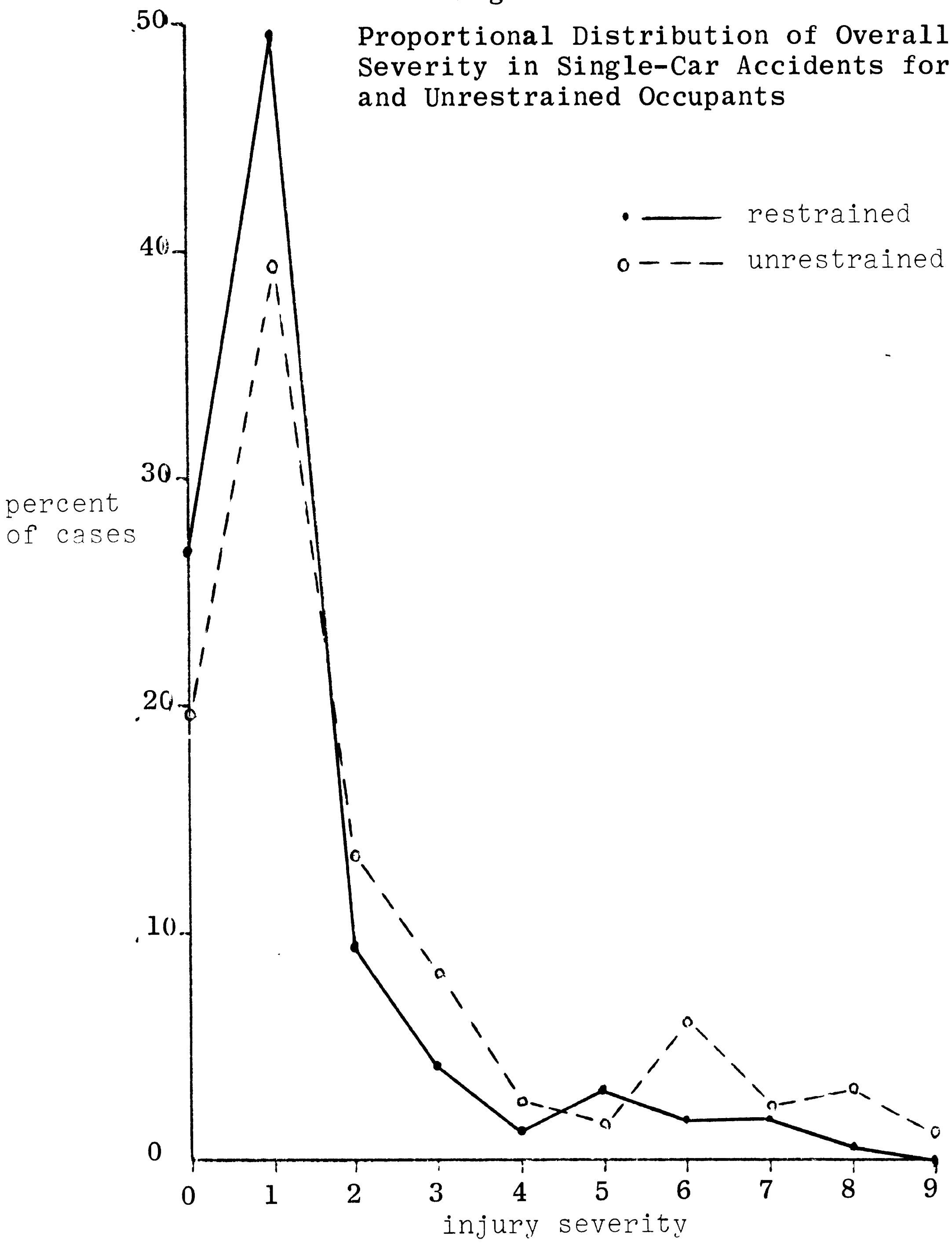
	Overall Injury			Organs			Brain		
	Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
$\overline{RSU}$	1.91	.0016	1560	5.03	.34	120	3.22	.93	267
RSU	1.65		396	4.59		17	3.24		45

	Head			Neck			Shoulder		
	Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
$\overline{RSU}$	1.69	.34	590	1.64	.01	321	1.33	.03	212
RSU	1.55		122	1.18		89	1.16		58

	Chest			Abdomen			Pelvis		
	Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
$\overline{RSU}$	1.97	.32	518	2.07	.21	113	1.71	.02	160
RSU	1.82		121	1.75		59	1.37		57

Figure 8

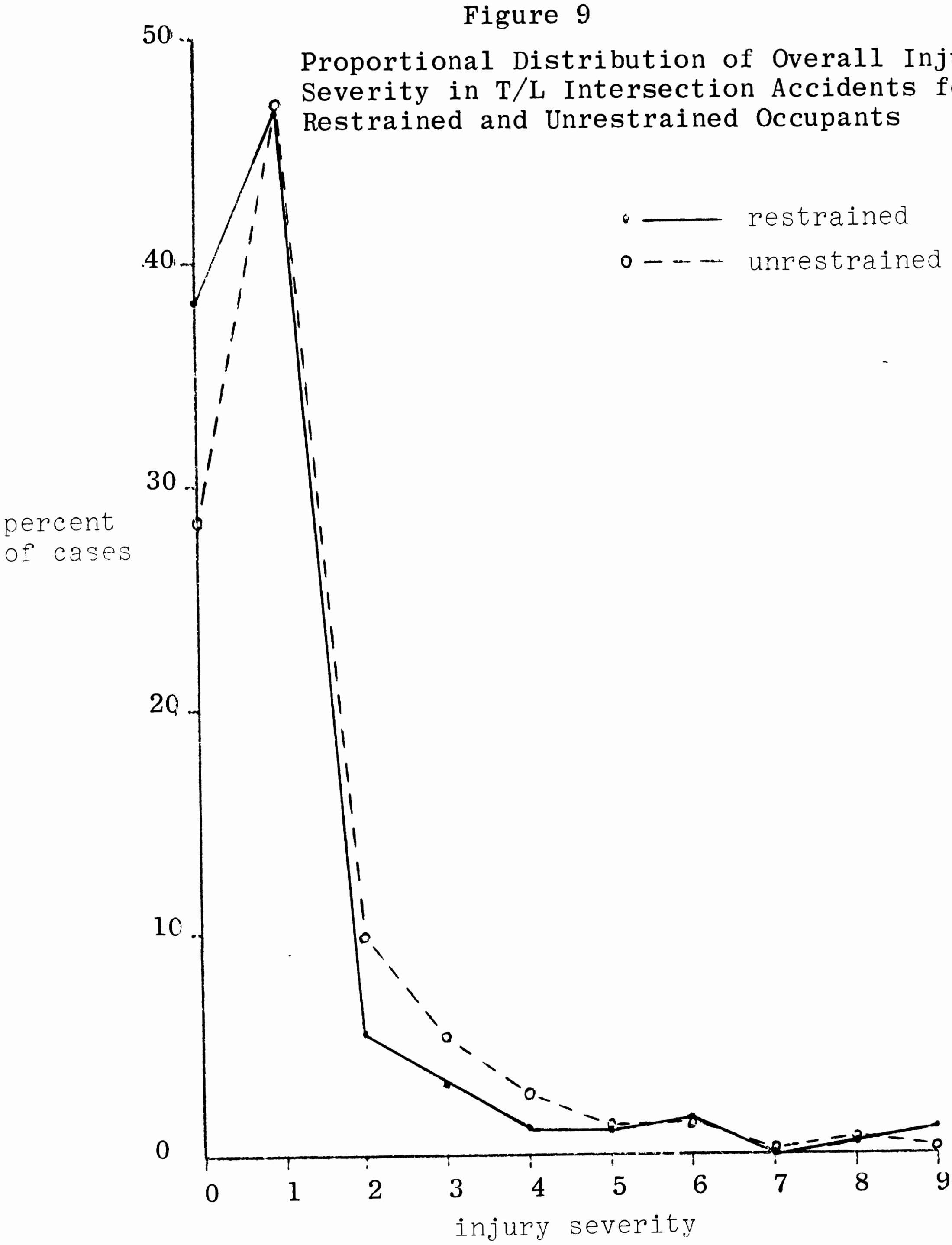
Proportional Distribution of Overall Injury Severity in Single-Car Accidents for Restrained and Unrestrained Occupants



INJURIES IN SINGLE CAR ACCIDENTS

Figure 9

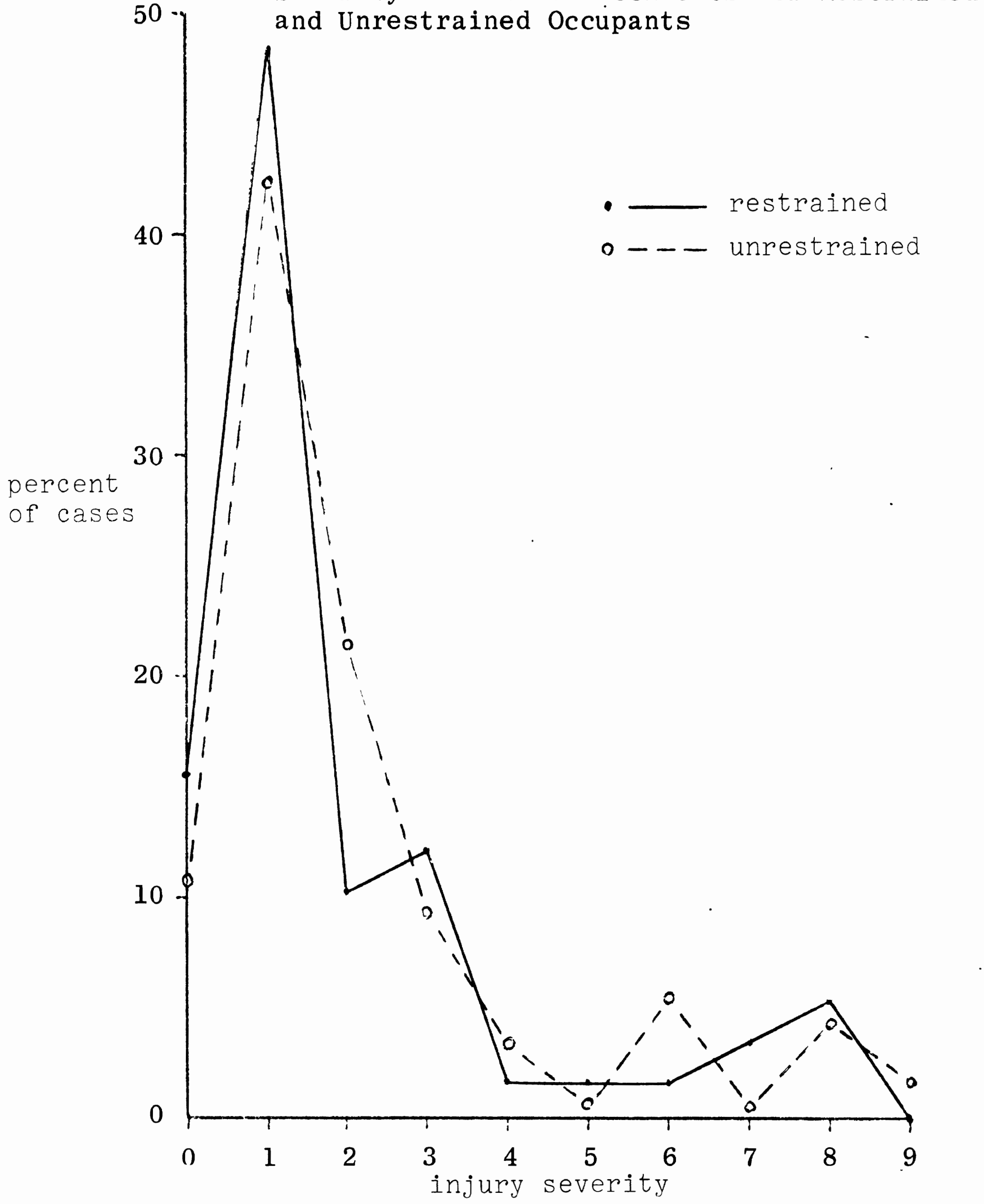
Proportional Distribution of Overall Injury Severity in T/L Intersection Accidents for Restrained and Unrestrained Occupants



INJURIES IN T/L INTERSECTION ACCIDENTS

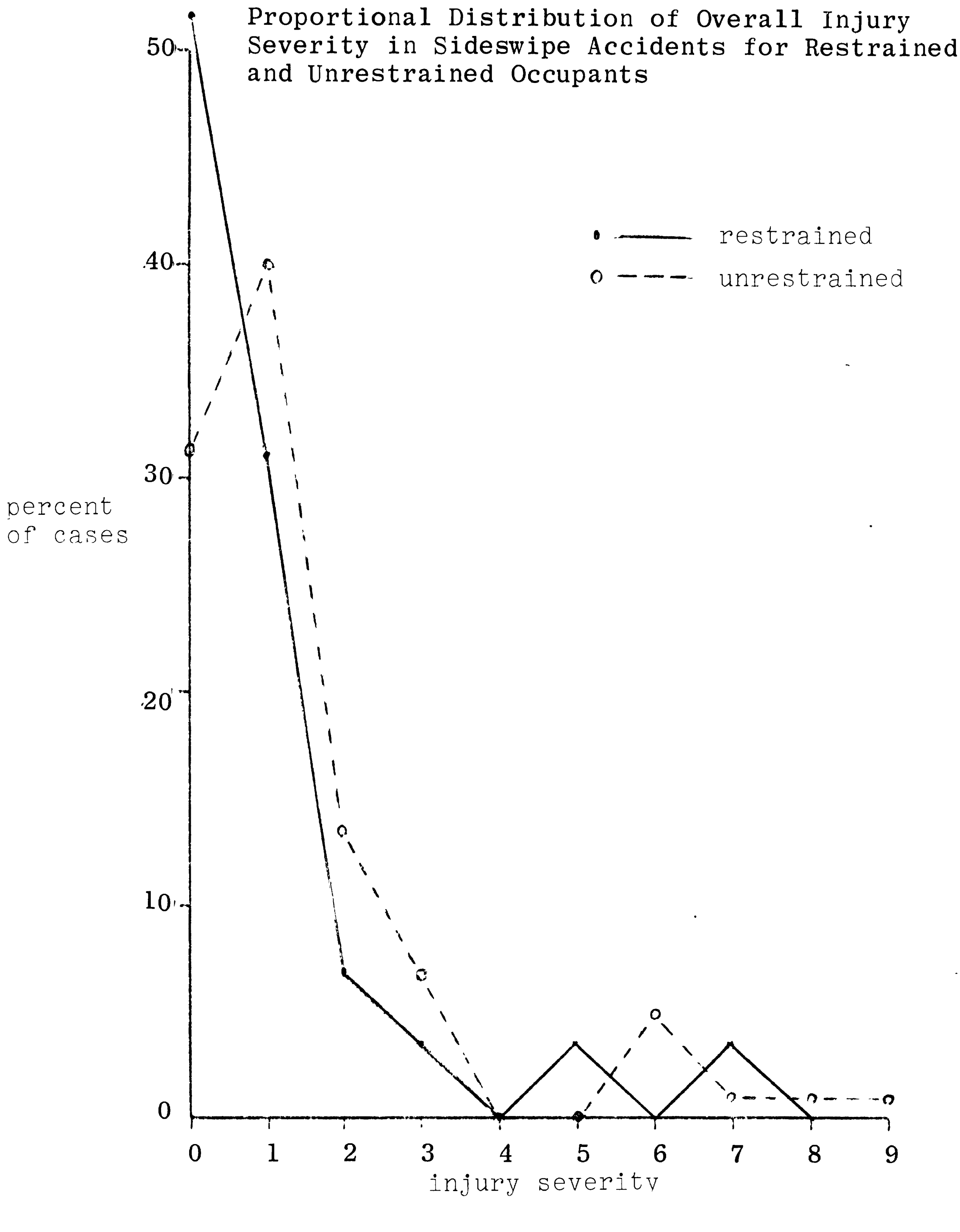
Figure 10

Proportional Distribution of Overall Injury Severity in Head-on Accidents for Restrained and Unrestrained Occupants



INJURIES IN HEADON ACCIDENTS

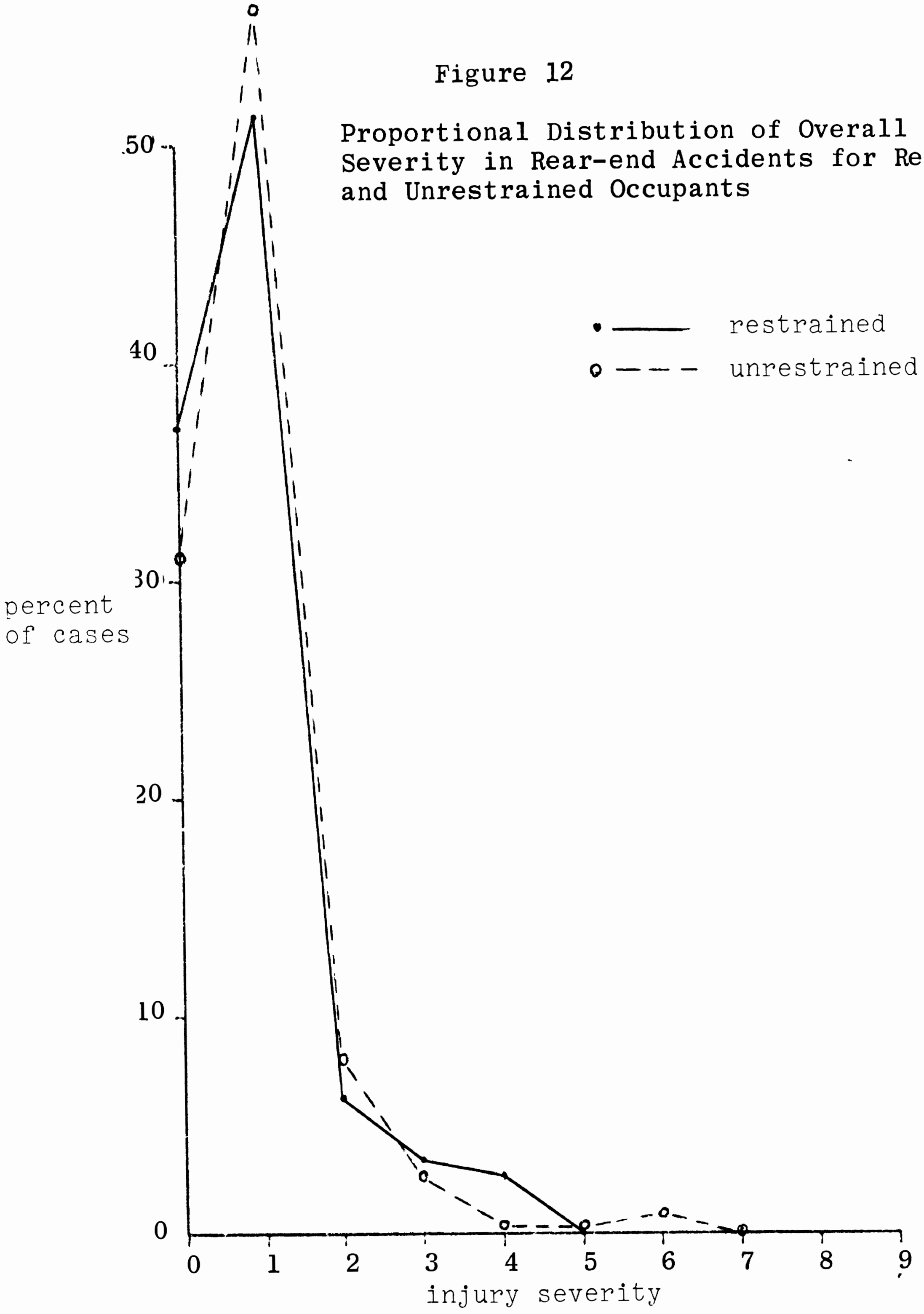
Figure 11



INJURIES IN SIDESWIPE ACCIDENTS

Figure 12

Proportional Distribution of Overall Injury Severity in Rear-end Accidents for Restrained and Unrestrained Occupants



INJURIES IN REAREND ACCIDENTS

Table 18
Equality of Slopes Test--Incidence of Injury and Restraint System Use Within Accident Configurations

Region of Body Sustaining Injury:	F-Statistic Significance Level
Overall Injury	.63
Organs	.36
Brain	.34
Head	.88
Neck	.02
Shoulder	.21
Chest	.20
Back	.04
Abdomen	.02
Pelvic Girdle	.33

Table 32
Anova of Injury Severity, Controlling on Restraint System Use by Accident Configuration[1]

		Overall Injury			Organs			Brain		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
SVC	$\overline{RSU}$	2.34	.00	508	5.30	.70	54	3.55	.40	119
	RSU	1.80		112	5.60		5	3.07		14
H-O	$\overline{RSU}$	2.18	.94	206	5.67	.33	18	3.12	.38	34
	RSU	2.16		49	4.75		4	3.23		13
T/L	$\overline{RSU}$	1.68	.30	403	4.39	.91	23	3.03	.75	63
	RSU	1.52		108	4.50		4	3.23		13
SS	$\overline{RSU}$	1.91	.97	69	4.60	.15	5	3.38	.21	13
	RSU	1.93		14	2.50		2	6.00		1
R	$\overline{RSU}$	1.30	1.00	213	4.25	.90	4	1.81	.71	16
	RSU	1.30		71	4.00		1	2.20		5

		Head			Neck			Shoulder		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
SVC	$\overline{RSU}$	2.06	.01	203	2.31	.05	86	1.42	.05	83
	RSU	1.39		38	1.54		13	1.08		12
H-O	$\overline{RSU}$	1.92	.61	75	2.00	.03	32	1.21	.47	24
	RSU	2.12		16	1.12		16	1.37		8
T/L	$\overline{RSU}$	1.37	.43	169	1.20	.96	83	1.27	.66	55
	RSU	1.57		42	1.19		16	1.20		15
SS	$\overline{RSU}$	1.52	.07	23	2.06	.15	18	1.64	.15	11
	RSU	3.50		2	1.00		4	1.00		2
R	$\overline{RSU}$	1.15	.89	53	1.15	.99	75	1.12	.90	17
	RSU	1.21		14	1.14		28	1.09		11

[1]SVC = Single Vehicle Collision; H-O = Head-on; T/L = T/L Intersection Collision; SS = Sideswipe; R = Rear-end.

Table 32 (continued)

		Chest			Abdomen			Pelvis		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
SVC	$\overline{RSU}$	2.30	.27	188	2.42	.43	45	1.91	.98	65
	RSU	1.97		31	2.83		12	1.69		13
H-O	$\overline{RSU}$	2.11	.88	80	1.93	.34	14	1.75	.41	12
	RSU	2.17		24	1.33		12	1.33		6
T/L	$\overline{RSU}$	1.83	.99	117	1.97	.55	29	1.60	.38	45
	RSU	1.82		34	1.68		19	1.37		24
SS	$\overline{RSU}$	1.73	.66	22	1.00	.72	4	2.50	.09	4
	RSU	1.43		7	1.50		2	1.00		2
R	$\overline{RSU}$	1.24	.91	51	1.80	.63	10	1.29	.63	7
	RSU	1.29		14	1.44		9	1.00		5

is common to both drivers and right front passengers. The difference in the incidence rate by seated location is statistically insignificant. The difference between the mean injury level found for restrained and unrestrained drivers is statistically significant. The mean injury severity is 1.61 for restrained drivers and 1.89 for unrestrained drivers. However, the difference in the mean injury severity for right front passengers is not statistically significant. The mean values are 1.81 and 1.94 for restrained and unrestrained right front passengers, respectively. (See Figures 13,14; Tables 22,36)

4. Speed:

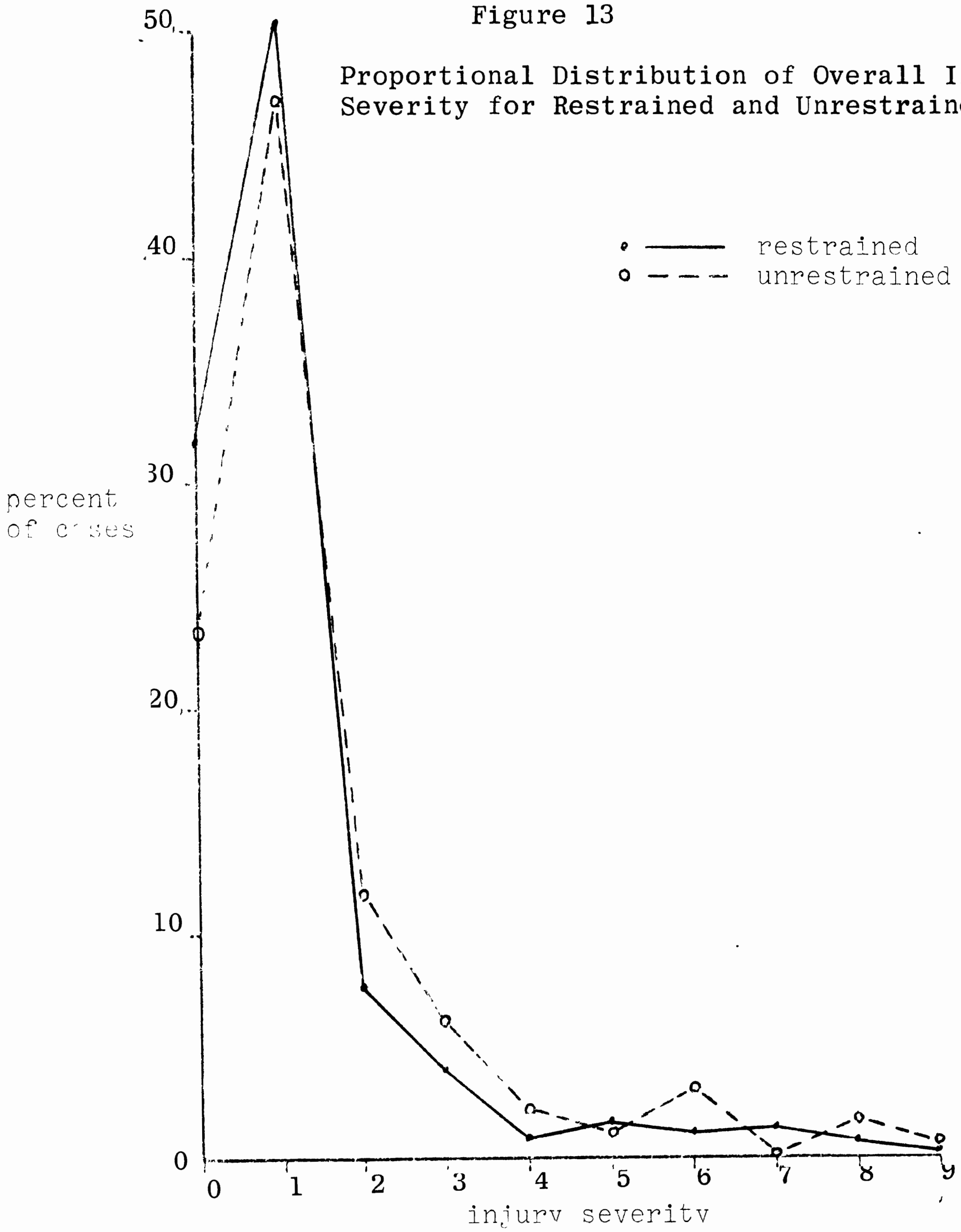
The effect of restraint use in reducing the incidence of overall injury is the same across the three speed ranges. The differences were statistically insignificant. However, the effect of restraints in reducing the severity of injury differed according to bracketed speed. At 0-30, the mean overall injury severity is 1.33 for restrained occupants and 1.51 for unrestrained occupants. This difference is not statistically significant. At speeds 31-60, the mean overall injury severity is 2.19 for restrained and 2.29 for unrestrained occupants. This difference attains statistical significance. (See Figures 15,16; Tables 25, 34)

5. Vehicle Deformation:

The reduction of the overall injury incidence rate is about the same across ranges of VDI levels. The difference in the effect are statistically insignificant. The mean injury severity for restrained and unrestrained occupants at VDI 1,2 is 1.14 and 1.32 respectively. The difference is not statistically significant. For VDI 3-5, the mean values are 1.81 and 2.08 for restrained and unrestrained occupants. This difference is statistically significant. At the higher VDI levels, 6-9, the means are 3.50 and 3.71 for restrained and unrestrained. Only at VDI levels 3-5 does restraint usage correlate with a reduction in overall injury severity to a significant degree. (See Figure 17-19; Tables 27,35)

Figure 13

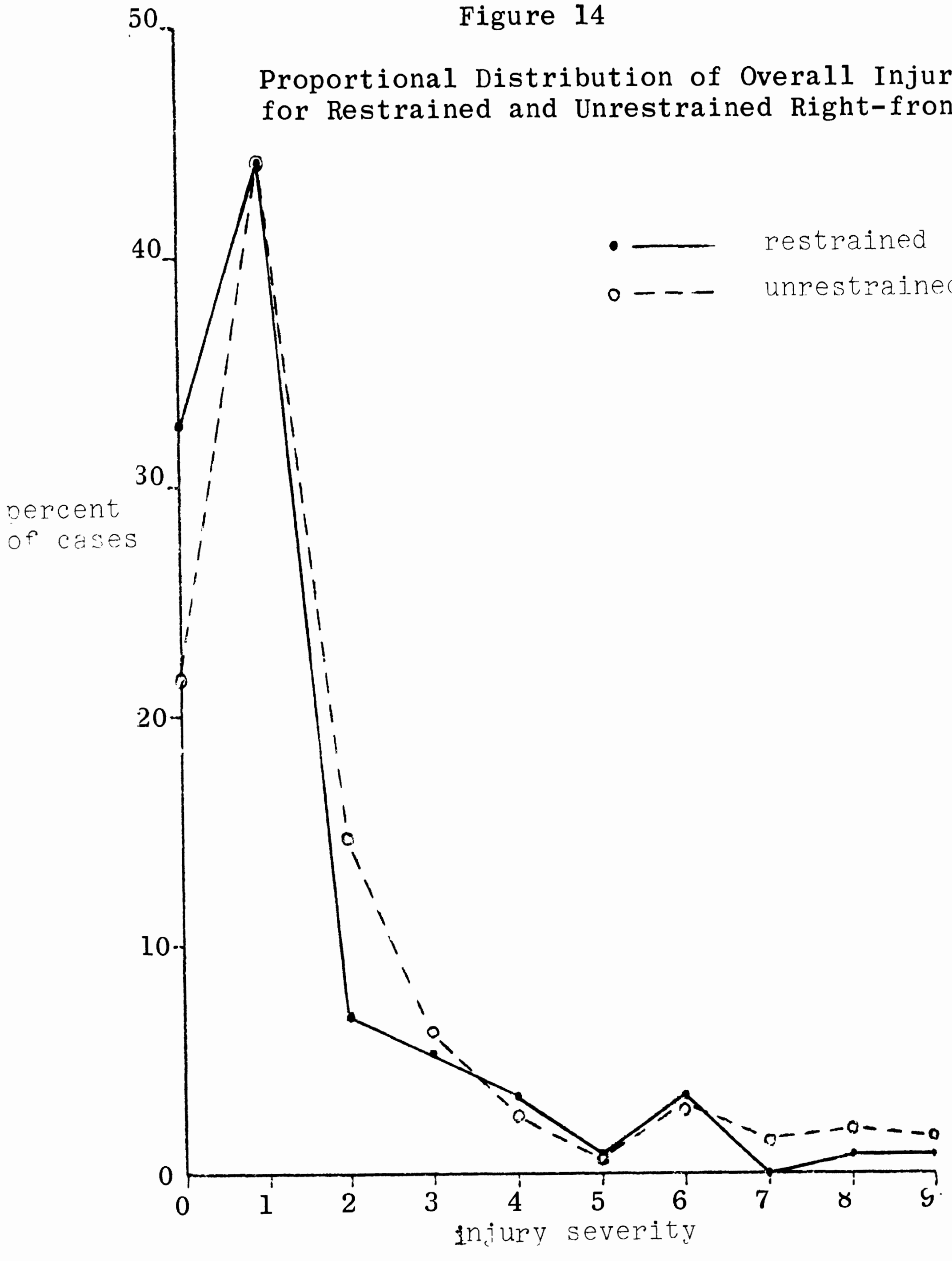
Proportional Distribution of Overall Injury Severity for Restrained and Unrestrained Drivers



DRIVER

Figure 14

Proportional Distribution of Overall Injury Severity for Restrained and Unrestrained Right-front Passengers



RIGHT FRONT PASSENGER

Table 22

Equality of Slopes Test--Incidence of Injury and Restraint System Use Within Seating Location Categories

Region of the Body Sustaining the Injury:	F-Statistic Significance Level
Overall Injury	.09
Organs	.84
Brain	.99
Head	.90
Neck	.18
Shoulder	.55
Chest	.88
Back	.87
Abdomen	.02
Pelvic Girdle	.84

Table 36
Anova of Injury Severity, Controlling on
Restraint System Use by Seating Location

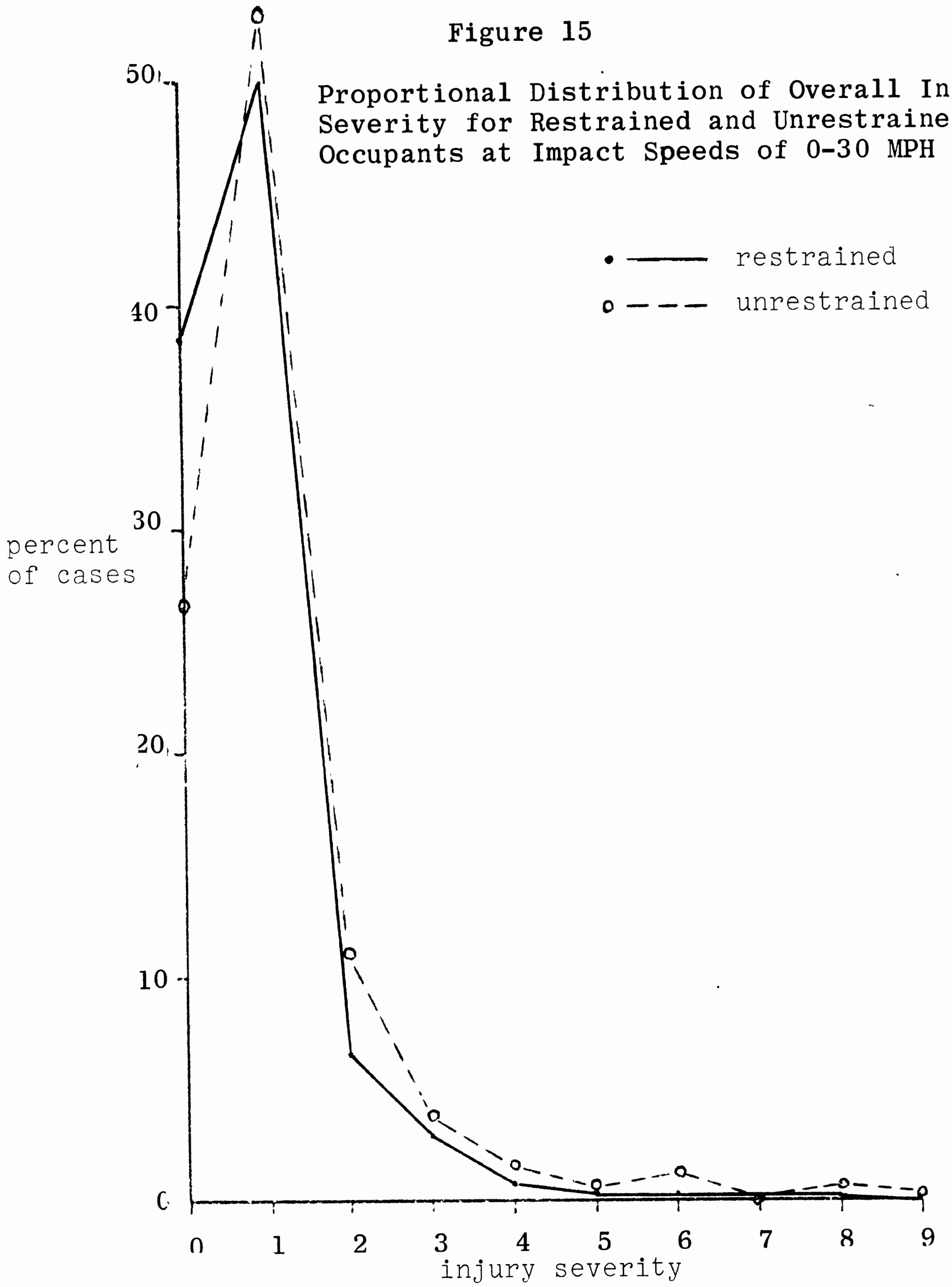
		Overall Injury			Organs			Brain		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
Driver	$\overline{RSU}$	1.89	.00	1093	5.00	.37	85	3.13	.91	185
	RSU	1.61		319	4.50		12	3.09		35
Right Front	$\overline{RSU}$	1.94	.48	416	5.12	.71	33	3.35	.51	75
	RSU	1.81		75	4.80		5	3.80		10

		Head			Neck			Shoulder		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
Driver	$\overline{RSU}$	1.65	.37	418	1.60	.03	227	1.33	.08	141
	RSU	1.49		99	1.18		67	1.17		48
Right Front	$\overline{RSU}$	1.78	.99	156	1.75	.09	80	1.31	.26	64
	RSU	1.78		23	1.18		22	1.10		10

		Chest			Abdomen			Pelvis		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
Driver	$\overline{RSU}$	1.88	.83	379	2.00	.46	79	1.72	.01	107
	RSU	1.84		101	1.76		38	1.28		43
Right Front	$\overline{RSU}$	2.20	.18	125	2.31	.18	32	1.72	.80	46
	RSU	1.70		20	1.68		19	1.64		14

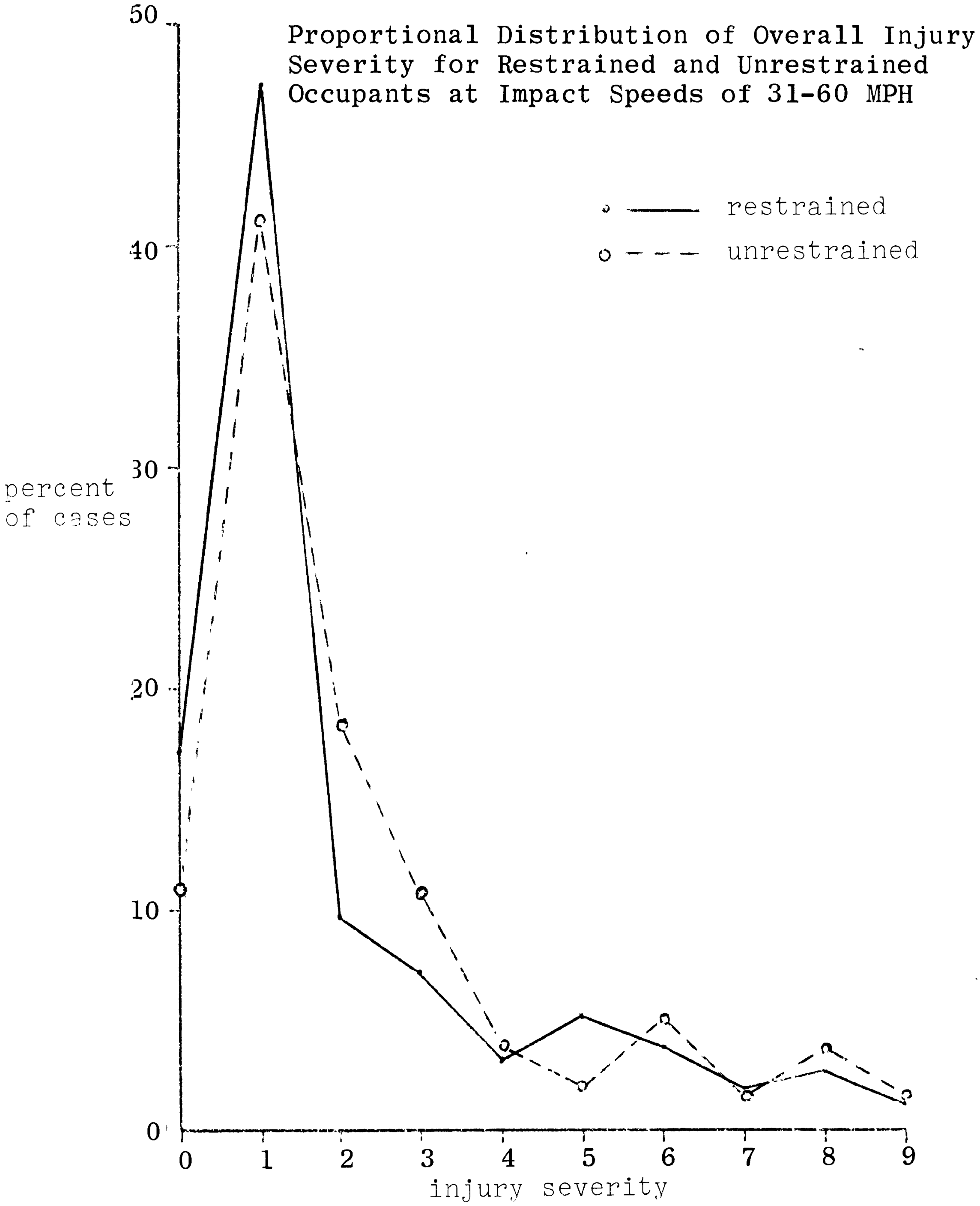
Figure 15

Proportional Distribution of Overall Injury Severity for Restrained and Unrestrained Occupants at Impact Speeds of 0-30 MPH



INJURIES AT 0 - 30 MPH

Figure 16



INJURIES AT 31 - 60 MPH

Table 25
Equality of Slopes Test--Incidence of Injury and Restraint System Use Within Velocity Brackets

Region of the Body Sustaining the Injury:	F-Statistic Significance Level
Overall Injury	.46
Organs	.02
Brain	.30
Head	.68
Neck	.95
Shoulder	.59
Chest	.78
Back	.31
Abdomen	.36
Pelvic Girdle	.52

Table 34
Anova of Injury Severity, Controlling on
Restraint System Use by Velocity

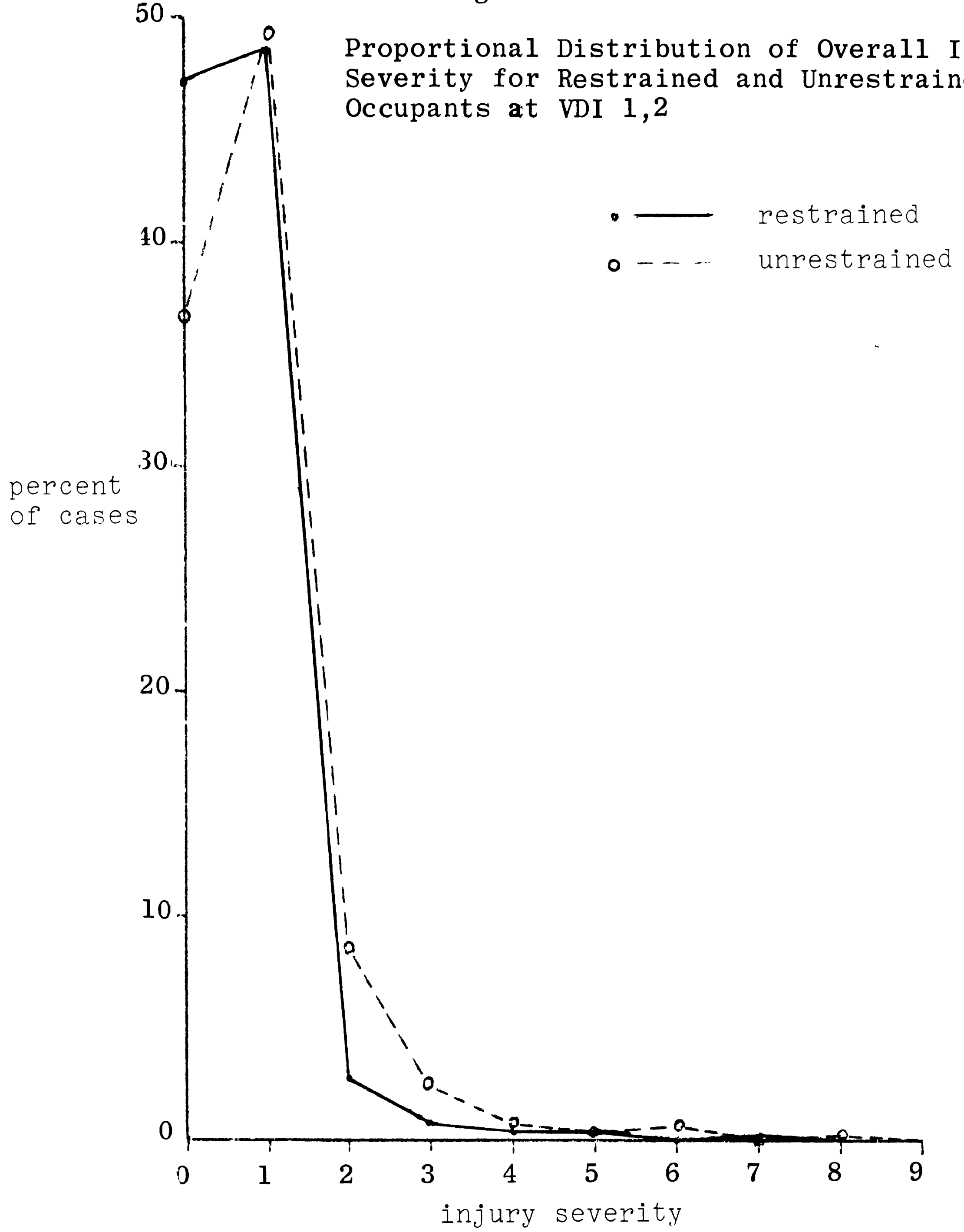
		Overall Injury			Organs			Brain		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
0-30	$\overline{RSU}$	1.51	.08	853	4.71	.43	34	2.40	.77	93
	RSU	1.33		221	4.00		4	2.25		16
31-60	$\overline{RSU}$	2.29	.46	467	4.82	.78	50	3.45	.45	115
	RSU	2.19		123	4.67		12	3.80		20
60+	$\overline{RSU}$	3.27	.02	81	6.10	.96	21	4.72	.65	25
	RSU	2.37		16	6.00		1	4.25		4

		Head			Neck			Shoulder		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
0-30	$\overline{RSU}$	1.29	.64	297	1.32	.23	185	1.26	.67	96
	RSU	1.19		57	1.09		55	1.21		33
31-60	$\overline{RSU}$	2.07	.12	182	2.00	.06	82	1.35	.13	66
	RSU	1.95		44	1.43		23	1.12		17
60+	$\overline{RSU}$	2.54	.50	35	2.36	.37	14	1.67	.25	12
	RSU	3.00		5	1.50		2	1.00		1

		Chest			Abdomen			Pelvis		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
0-30	$\overline{RSU}$	1.57	.60	227	1.50	.43	44	1.32	.57	68
	RSU	1.45		55	1.21		29	1.20		25
31-60	$\overline{RSU}$	2.20	.56	197	2.53	.89	43	2.12	.03	51
	RSU	2.33		48	2.59		22	1.59		22
60+	$\overline{RSU}$	2.89	.01	35	2.71	.16	14	2.60	.01	15
	RSU	1.56		9	1.33		3	1.25		4

Figure 17

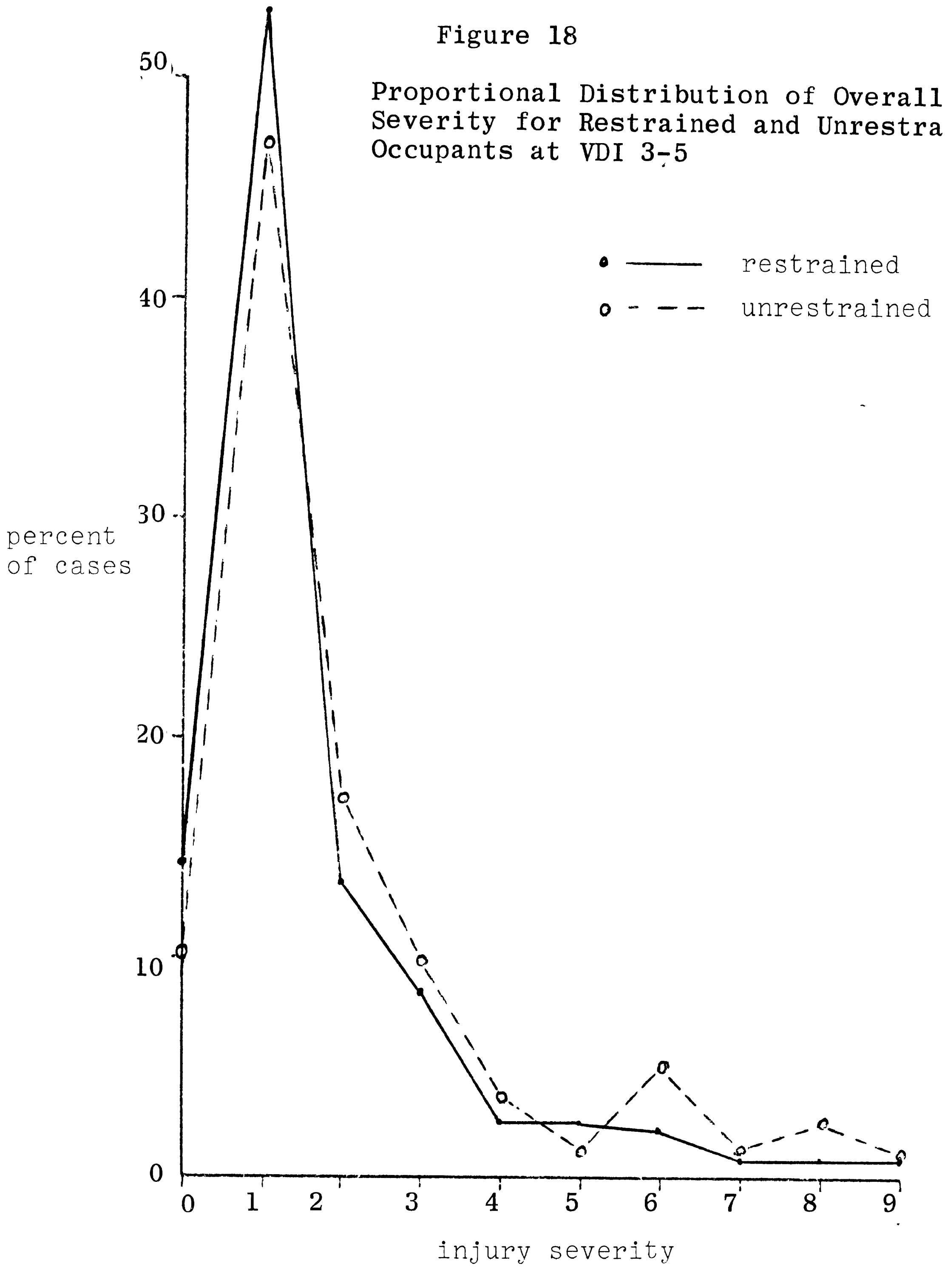
Proportional Distribution of Overall Injury Severity for Restrained and Unrestrained Occupants at VDI 1,2



INJURIES AT VDI = 1,2

Figure 18

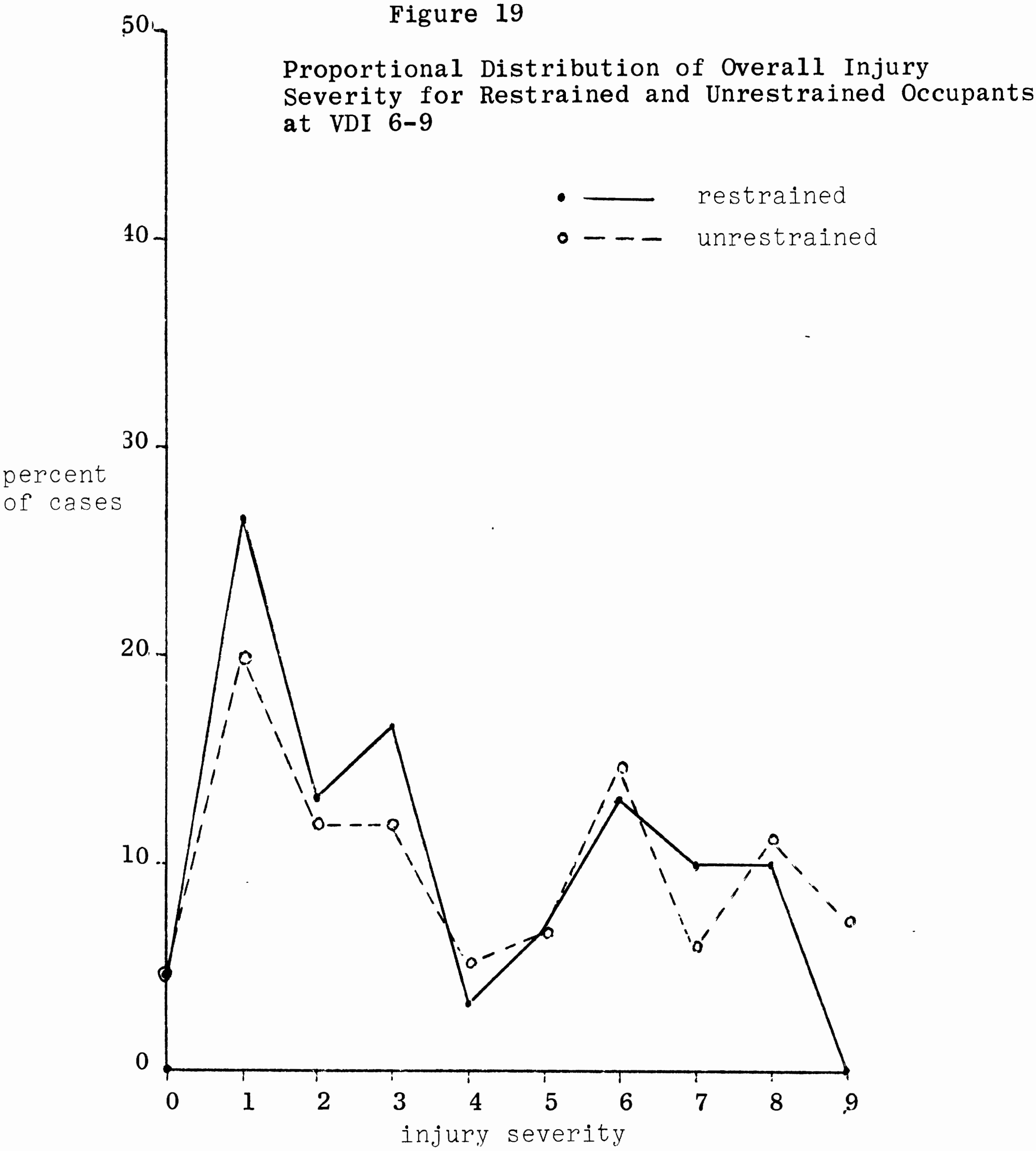
Proportional Distribution of Overall Injury Severity for Restrained and Unrestrained Occupants at VDI 3-5



INJURIES AT VDI = 3 - 5

Figure 19

Proportional Distribution of Overall Injury Severity for Restrained and Unrestrained Occupants at VDI 6-9



INJURIES AT VDI = 6 - 9

Table 27

Equality of Slopes Test--Incidence of Injury and Restraint System Usage Within Vehicle Deformation Categories

Region of the Body Sustaining Injury:	F-Statistic Significance Level
Overall Injury	.13
Organs	.03
Brain	.18
Head	.59
Neck	.94
Shoulder	.27
Chest	.02
Back	.00
Abdomen	.04
Pelvis	.30

Table 35
Anova of Injury Severity, Controlling on
Restraint System Use by Vehicle Deformation

		Overall Injury			Organs			Brain		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
1,2	$\overline{RSU}$	1.32	.13	635	3.62	.55	8	2.13	.70	54
	RSU	1.14		173	4.33		3	1.75		4
3-5	$\overline{RSU}$	2.08	.01	789	4.92	.26	73	3.24	.49	156
	RSU	1.81		193	4.22		9	2.96		28
6-9	$\overline{RSU}$	3.71	.43	132	5.54	.87	39	4.19	.85	57
	RSU	3.50		30	5.40		5	4.31		13

		Head			Neck			Shoulder		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
1,2	$\overline{RSU}$	1.11	.71	214	1.16	.56	122	1.08	.81	50
	RSU	1.02		45	1.03		39	1.05		21
3-5	$\overline{RSU}$	1.78	.74	305	1.78	.00	174	1.34	.27	140
	RSU	1.71		63	1.16		45	1.23		31
6-9	$\overline{RSU}$	3.11	.13	70	3.04	.49	25	1.82	.01	22
	RSU	2.50		14	2.60		5	1.17		6

		Chest			Abdomen			Pelvis		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
1,2	$\overline{RSU}$	1.32	.77	142	1.30	.82	20	1.19	.71	32
	RSU	1.24		33	1.41		17	1.08		13
3-5	$\overline{RSU}$	1.96	.40	311	1.93	.73	76	1.68	.14	103
	RSU	1.80		70	1.83		35	1.42		38
6-9	$\overline{RSU}$	3.48	.16	65	3.59	.03	17	2.52	.04	25
	RSU	2.94		18	2.14		7	1.67		6

6. Rollover/Non-Rollover:

The reduction in the incidence of overall injury associated with restraint use is about the same for rollover and non-rollover accidents. Differences in the effect of using a restraint for these two situations are statistically insignificant. For non-rollovers, the mean overall injury severity is 1.68 for restrained occupants and 1.82 for the unrestrained. The difference is not statistically significant. For rollovers, the mean values are 1.38 and 2.43 for restrained and unrestrained. This difference is statistically significant. (See Figure 20; Tables 20,33)

7. Organ Injury:

Focusing specifically on injury to the organs, the likelihood of a CPIR file occupant sustaining an organ injury is 2% for users and 5% for non-users. This difference is significant to the .00 level. The mean severity level for organ injury is reduced from 5.03 to 4.59 by using restraints. However, because this reduction is not statistically significant one has little confidence that this difference reflects an actual effect in the larger population represented by the CPIR sample. (See Figure 21; Tables 17,31)

8. Brain Injury:

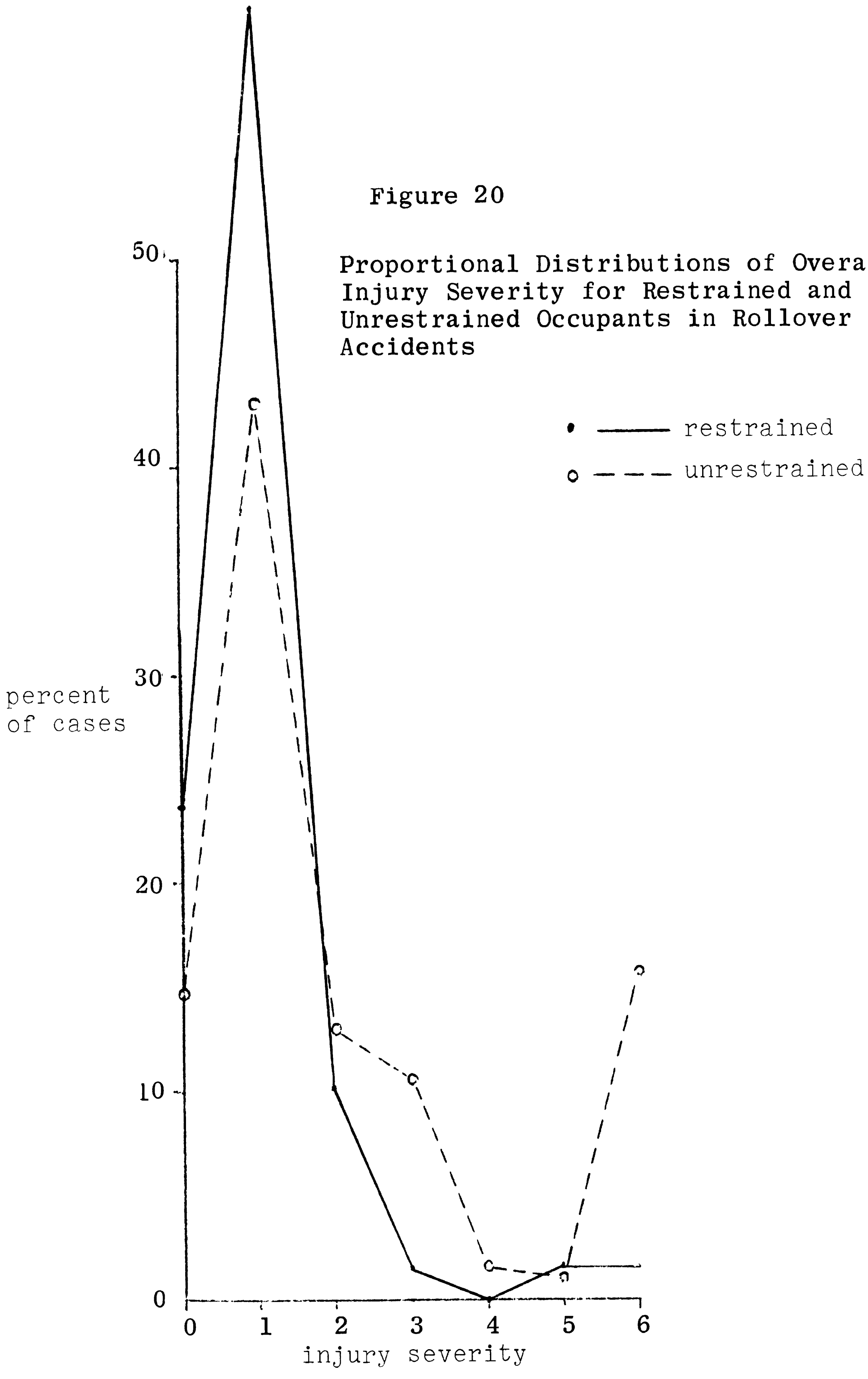
The effect of using restraints upon the incidence of brain injury is to reduce the likelihood of their occurring from 13% to 8%. This result is significant to the .00 level. The mean injury level for injured restrained occupants in the CPIR file is 3.24 as compared with 3.22 for the unrestrained. This difference in the several levels is not statistically significant. (See Figure 22; Tables 17,31)

9. Head Injury:

20% of the users of restraints incurred head injuries versus 28% for non-users. This reduction in the incidence of head injury is significant to the .00 level. However, the difference in the severity of injury associated with restraint use is not statistically significant. The mean injury severity level for users is 1.55 and for non-users is 1.69. (See Figure 23; Tables 17,31)

Figure 20

Proportional Distributions of Overall Injury Severity for Restrained and Unrestrained Occupants in Rollover Accidents



ROLLOVER INJURIES

Table 20
Equality of Slopes Test--Incidence of Injury and Restraint System Use Within Rollover and Non-Rollover Situations

Region of the body sustaining the injury:	F-Statistic Significance Level
Overall Injury	.65
Organs	.07
Brain	.24
Head	.29
Neck	.14
Shoulder	.35
Chest	.02
Back	.84
Abdomen	.00
Pelvic Girdle	.14

Table 33
Anova of Injury Severity, Controlling on
Restraint System Use by Rollover and Non-Rollover Situations

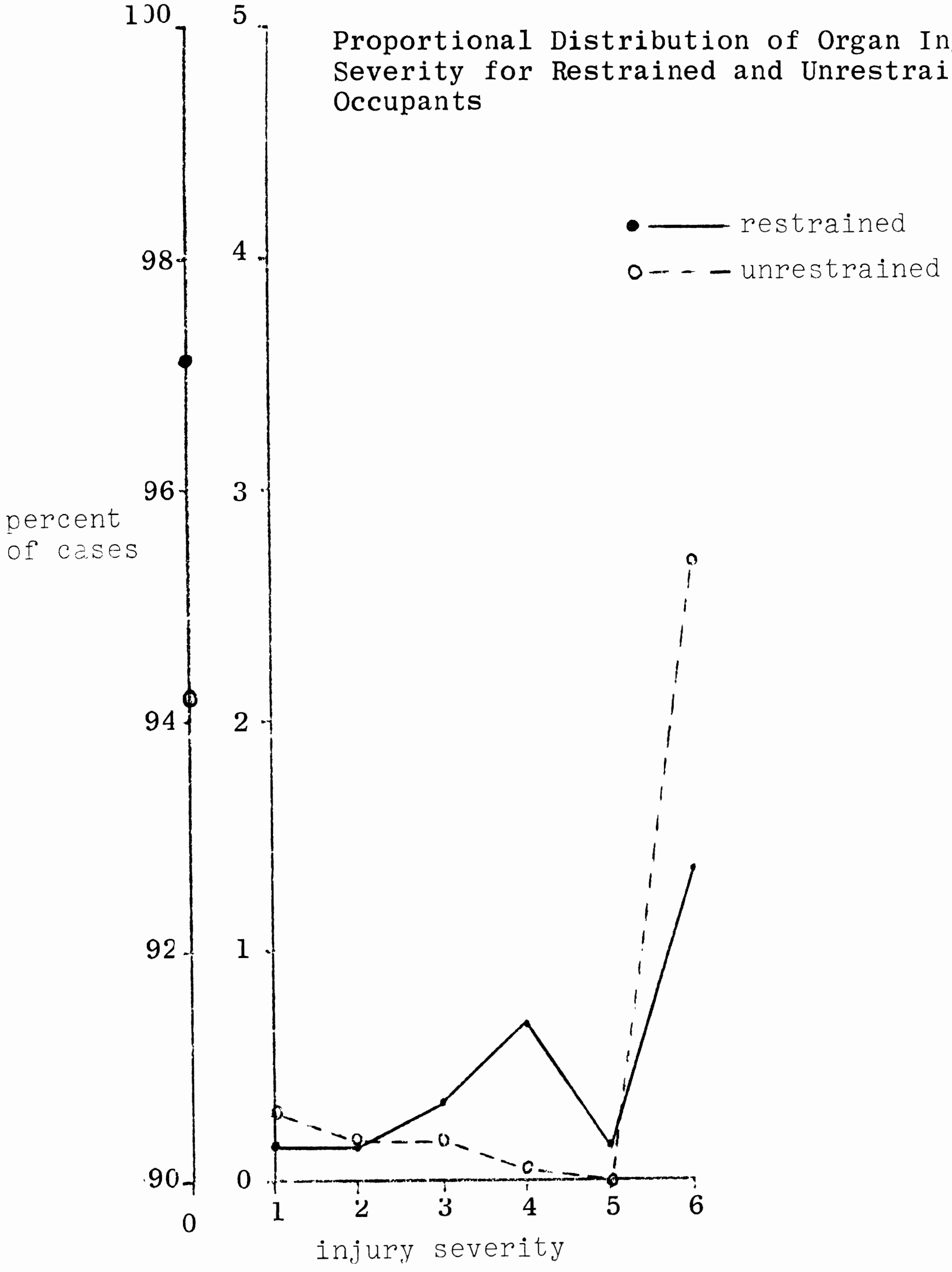
		Overall Injury			Organs			Brain		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
Roll-over	$\overline{RSU}$	2.43	.00	221	5.00	.10	25	3.70	.12	47
	RSU	1.38		45	2.00		1	2.20		5
Non-Roll-over	$\overline{RSU}$	1.82	.11	1338	5.03	.56	94	3.11	.45	220
	RSU	1.68		351	4.75		16	3.37		40

		Head			Neck			Shoulder		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
Roll-over	$\overline{RSU}$	2.02	.05	90	2.66	.00	47	1.44	.03	50
	RSU	1.30		20	1.00		6	1.00		9
Non-Roll-over	$\overline{RSU}$	1.63	.83	500	1.47	.10	273	1.30	.21	162
	RSU	1.60		102	1.19		83	1.18		49

		Chest			Abdomen			Pelvis		
		Mean	Sig	N	Mean	Sig	N	Mean	Sig	N
Roll-over	$\overline{RSU}$	2.10	.09	82	2.14	.93	21	1.66	.16	32
	RSU	1.12		8	2.00		1	1.00		5
Non-Roll-over	$\overline{RSU}$	1.95	.60	436	2.05	.25	92	1.73	.04	128
	RSU	1.87		113	1.74		58	1.40		52

Figure 21

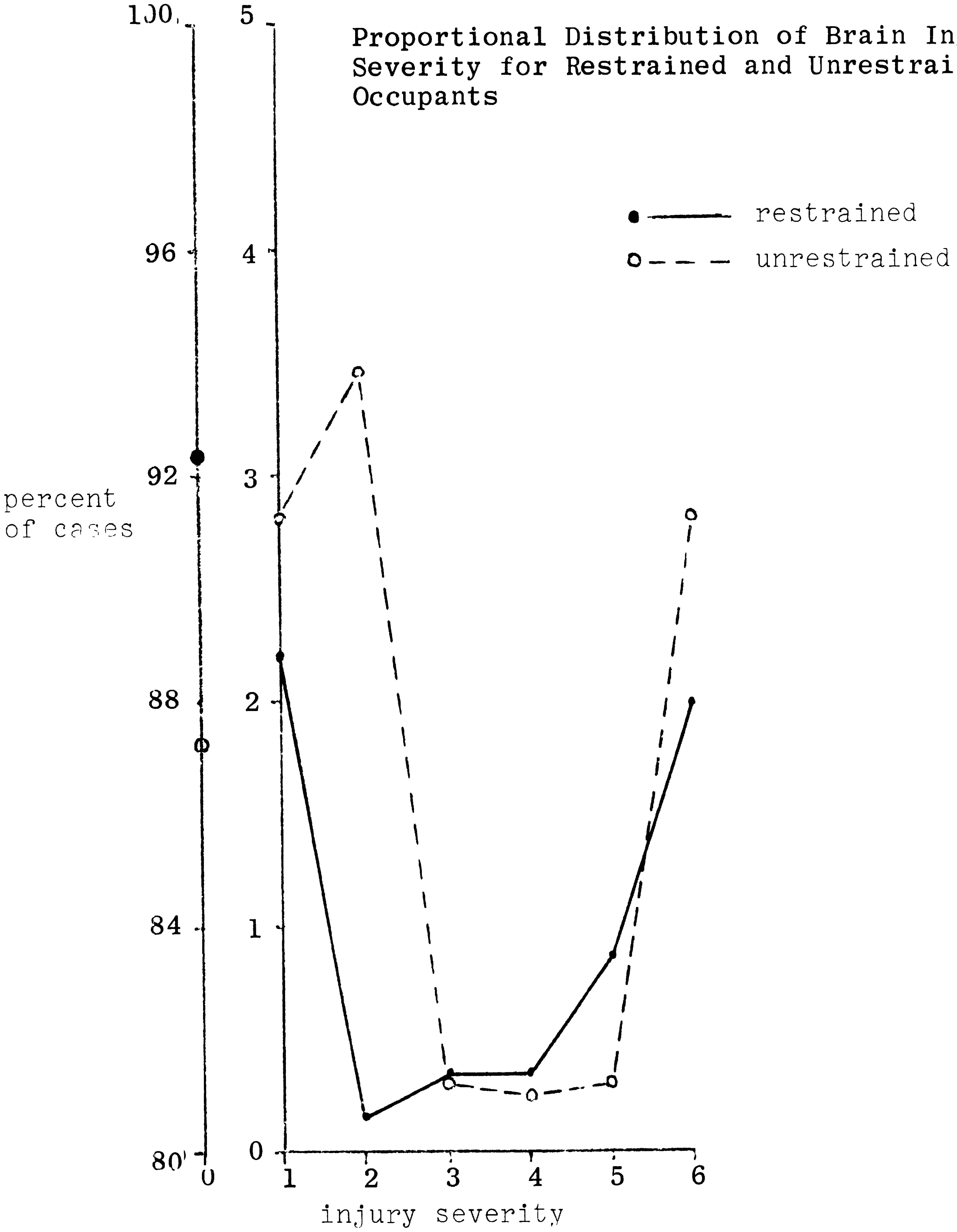
Proportional Distribution of Organ Injury Severity for Restrained and Unrestrained Occupants



ORGAN INJURY

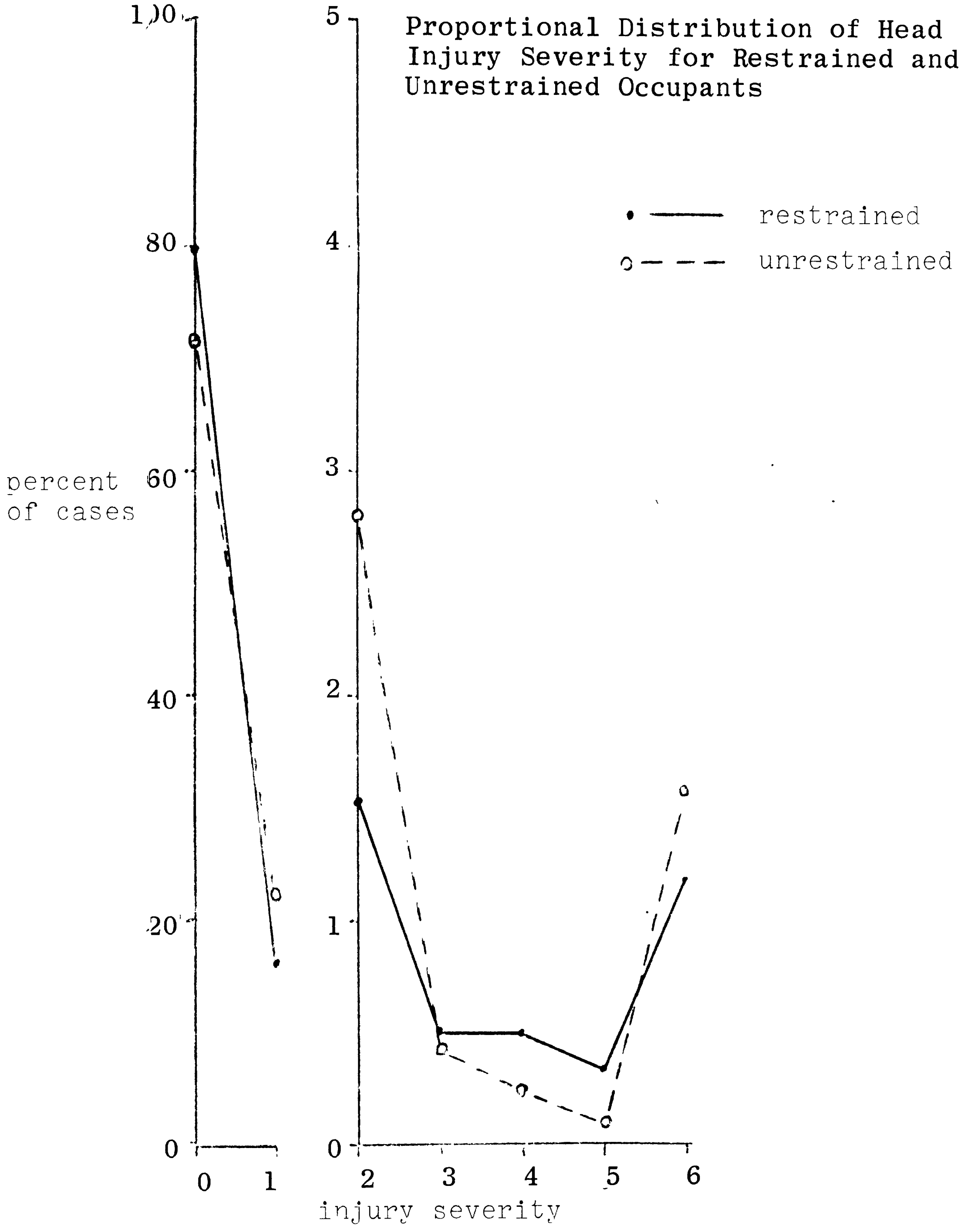
Figure 22

Proportional Distribution of Brain Injury Severity for Restrained and Unrestrained Occupants



BRAIN INJURY

Figure 23



HEAD INJURY

10. Neck Injury:

The 15% incidence rate of neck injury to CPIR file occupants is the same for both users and non-users of restraints. However, restraint use is associated with a significant reduction in the level of injuries. The mean injury severity for users is 1.18 as compared with 1.64 for non-users. (See Figure 24; Tables 17,31)

11. Abdominal Injury:

Using a restraint increases the likelihood of injury to the abdomen from 5% to 9%. This increase is statistically significant. The effect of restraint use on the severity of abdominal injury (a mean of 1.75 for users versus 2.07 for non-users) is not statistically significant. (See Figure 25; Tables 17,31)

12. Pelvic Injury:

9% of the restraint users in the CPIR file sustained pelvic injuries as opposed to 7% of the non-users. This difference does not attain statistical significance. However, the reduction in the severity of injury from a mean of 1.37 for users as compared with 1.71 for non-users is statistically significant. (See Figure 26; Tables 17,31)

13. Back Injury:

The incidence of injury to the back is 7% for users and 6% for non-users of restraints. This difference in these rates is not statistically significant. There were too few back injury cases for meaningful analysis comparing the mean severity levels for users and non-users. (See Figure 27; Tables 17,31)

14. Chest Injury:

The chest of 21% of the restraint users in the CPIR file was injured as compared with 25% of the non-users. This reduction is statistically significant. However, the difference in the mean injury level for users (1.82) and non-users (1.97) does not attain significance. (See Figure 28; Tables 17,31)

Figure 24

Proportional Distribution of Neck Injury Severity for Restrained and Unrestrained Occupants

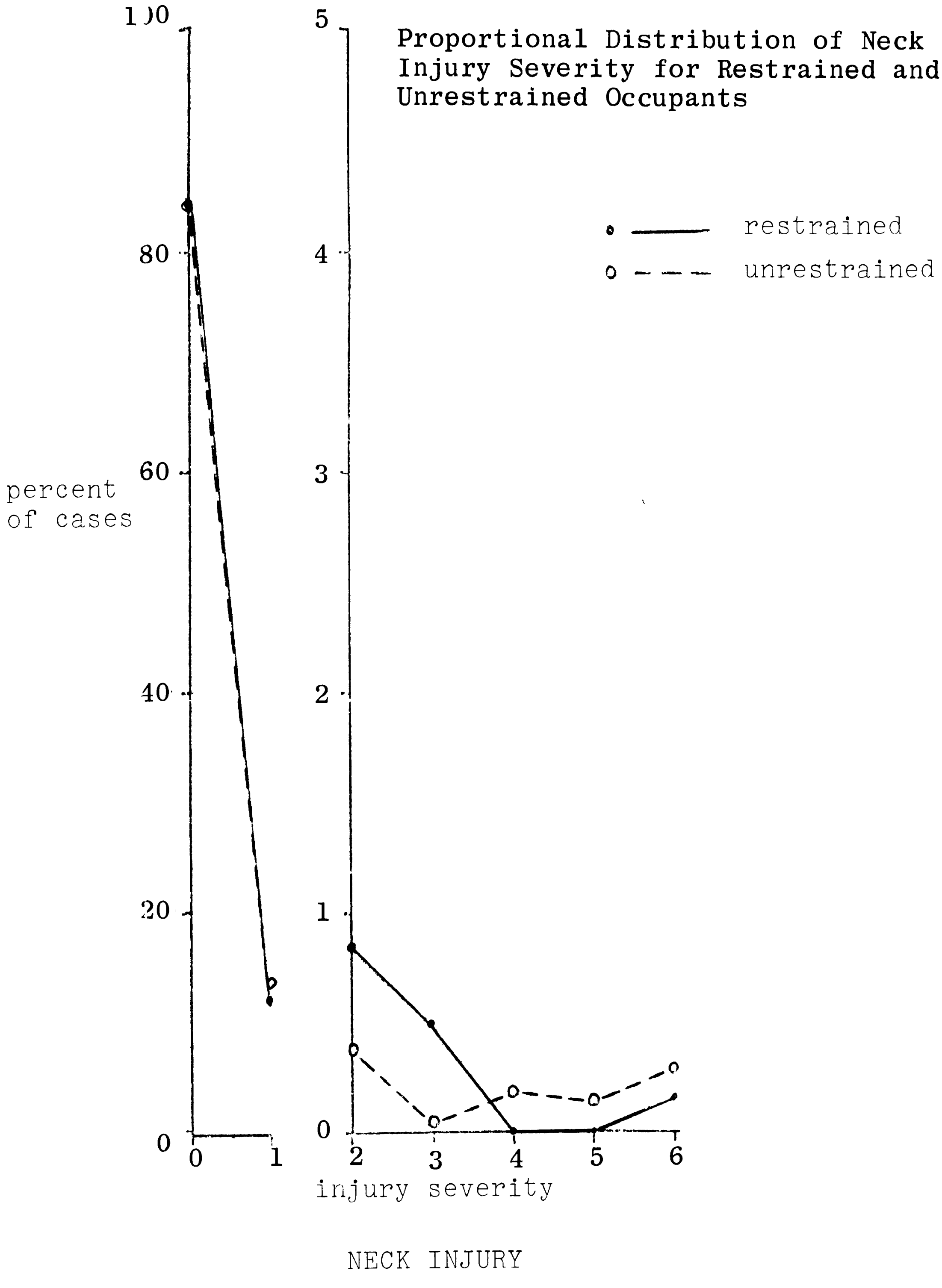
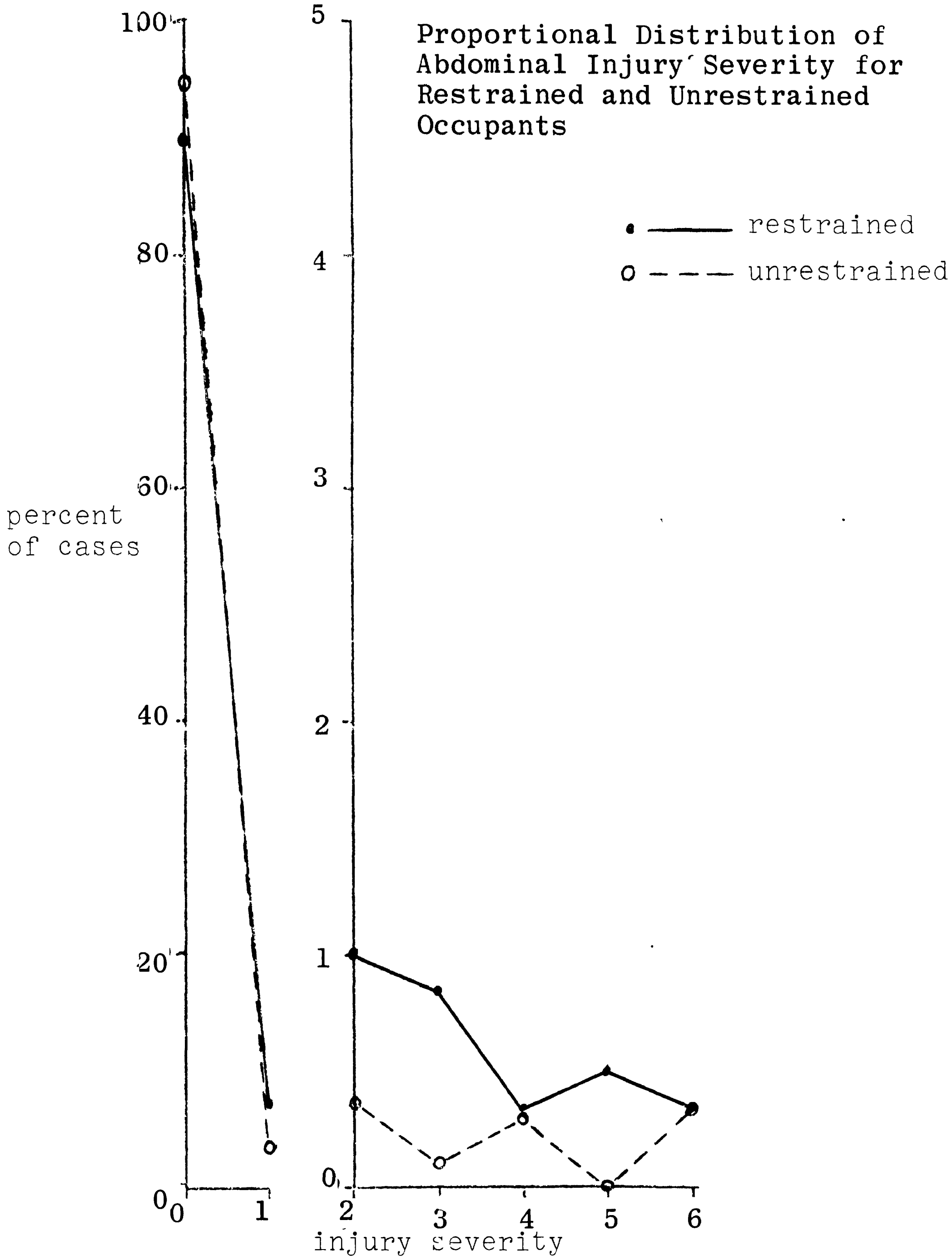


Figure 25

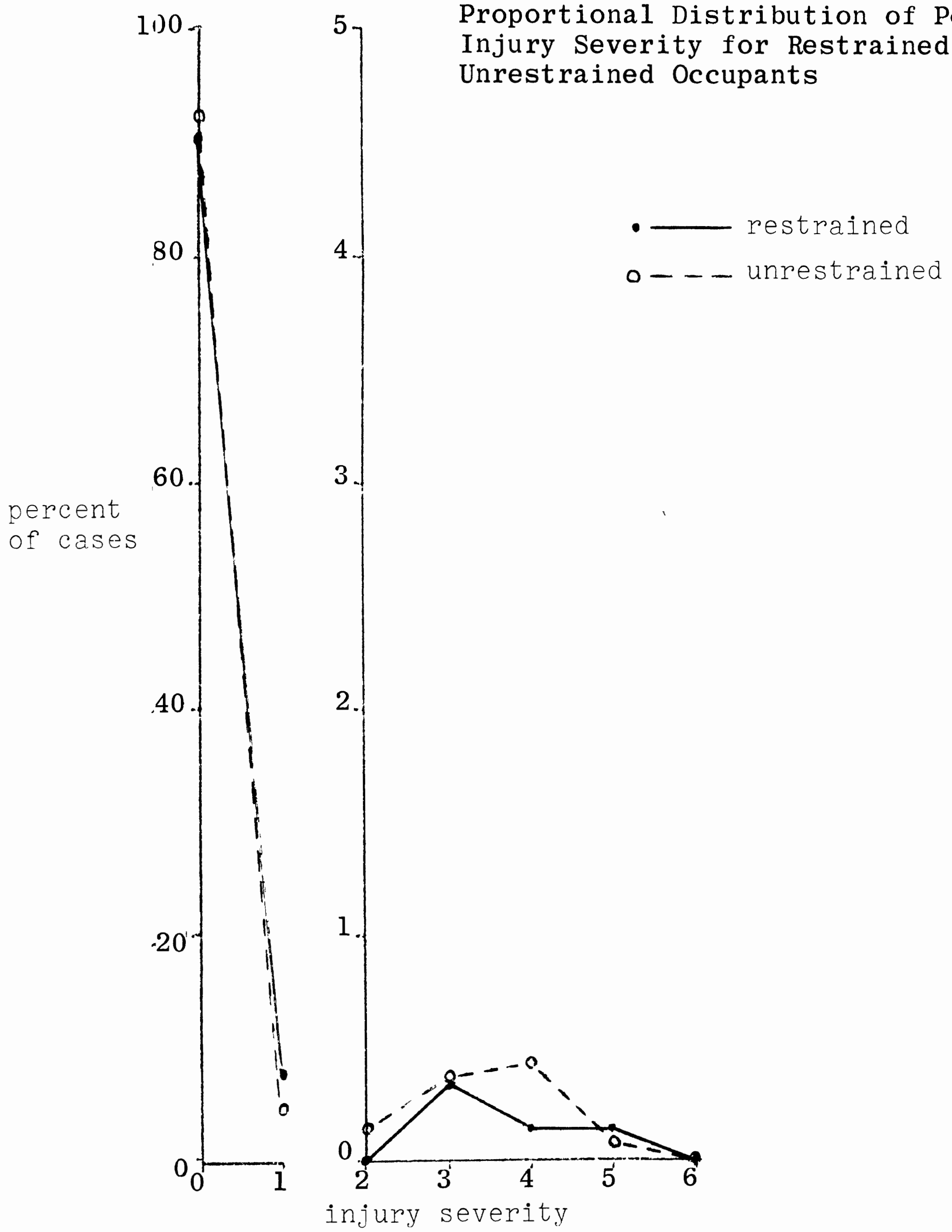
Proportional Distribution of Abdominal Injury Severity for Restrained and Unrestrained Occupants



ABDOMINAL INJURY

Figure 26

Proportional Distribution of Pelvic Injury Severity for Restrained and Unrestrained Occupants



PELVIC INJURY

Figure 27

Proportional Distribution of Back Injury Severity for Restrained and Unrestrained Occupants

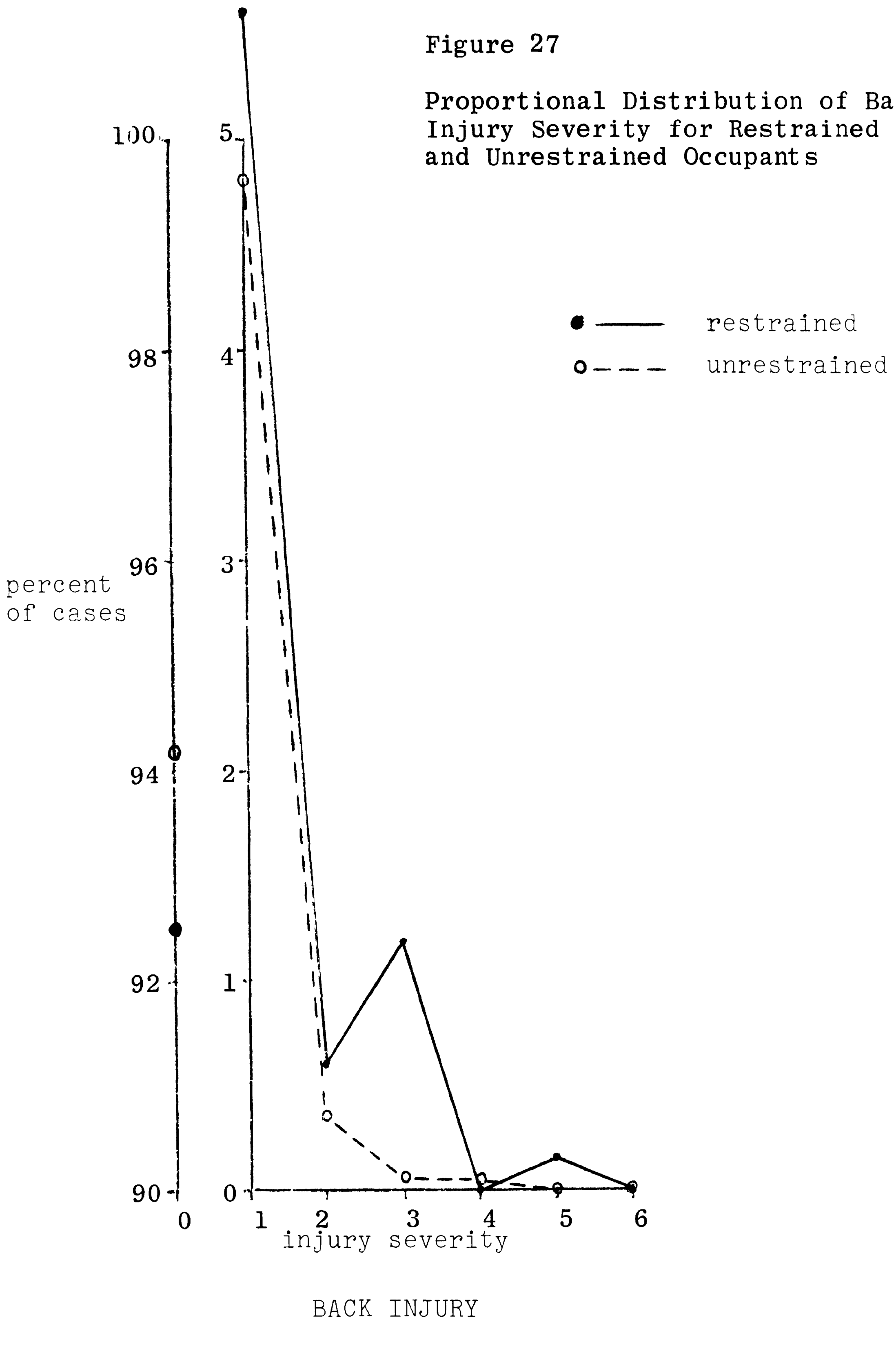
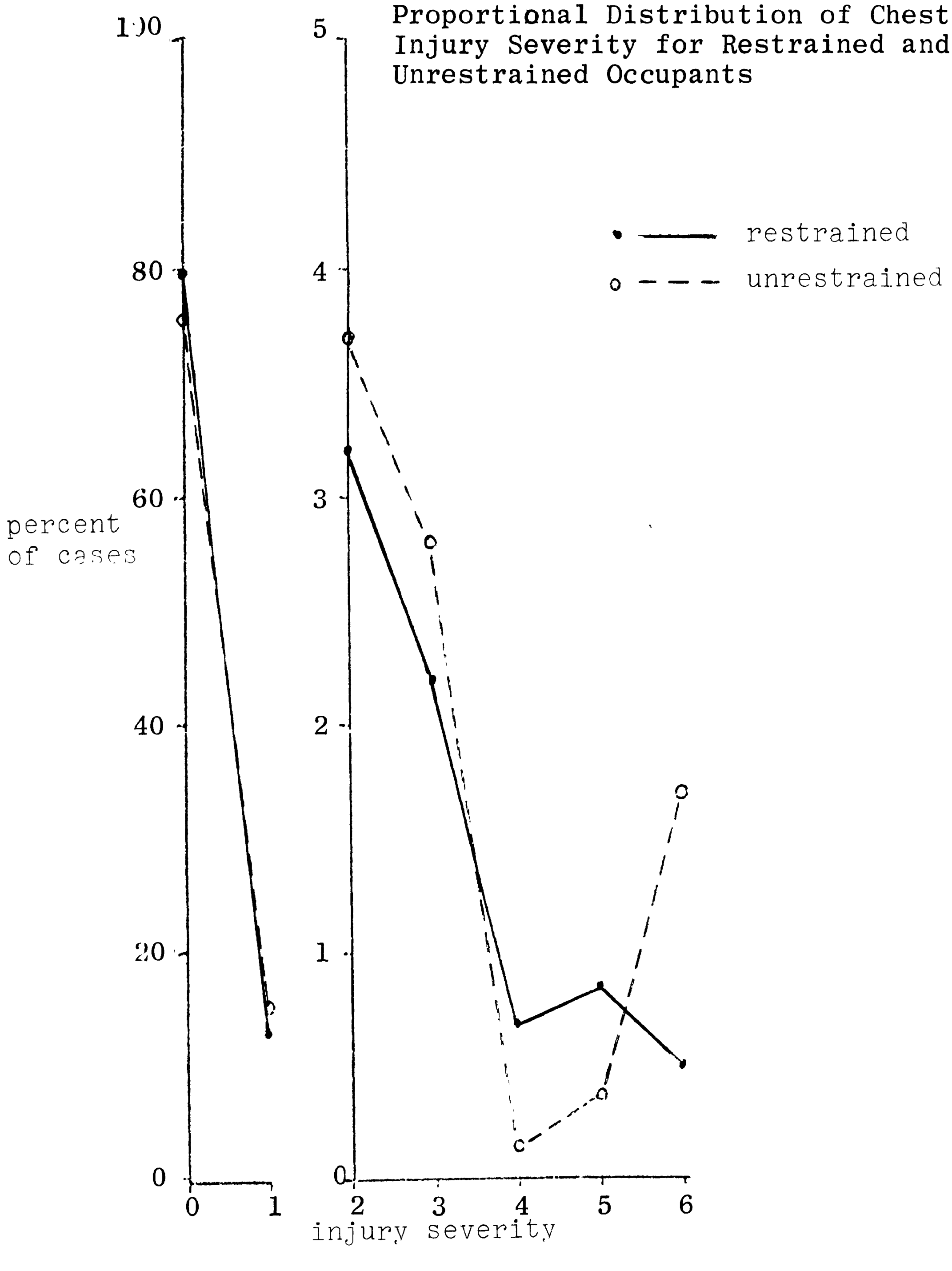


Figure 28

Proportional Distribution of Chest Injury Severity for Restrained and Unrestrained Occupants



CHEST INJURY

15. Shoulder Injury:

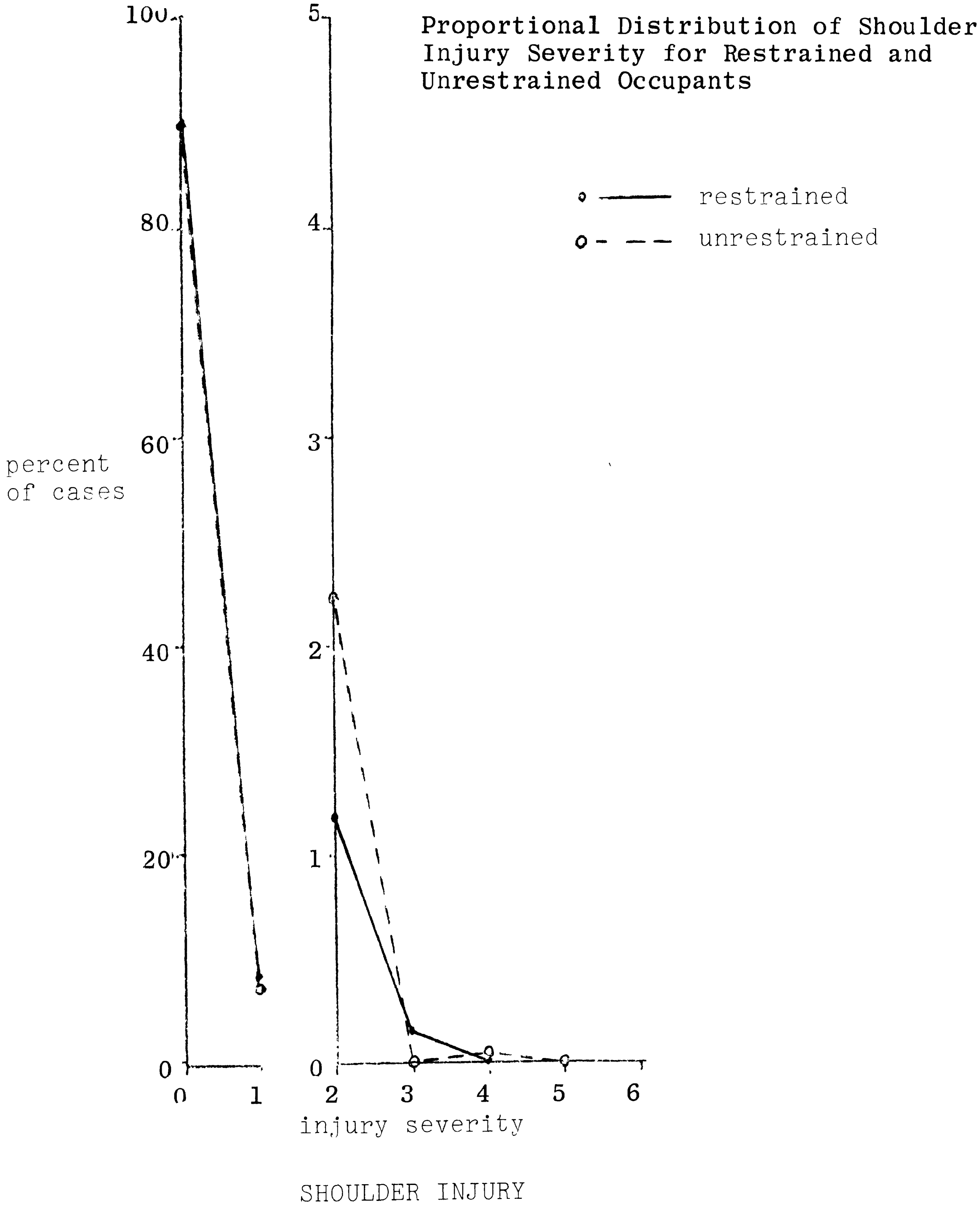
Both users and non-users of restraints evidence a 10% incidence of injury rate to the shoulders. However, the mean injury level for users is significantly lower than that for non-users (1.16 to 1.33). (See Figure 29; Tables 17,31)

2.4 Statistical Analysis of the Effects of Restraints on the Incidence of Injury

A. The previous section discussed in general terms the effect which using a restraint system had on the incidence of injury under specified conditions. The graphs indicated that this effect for a given body region frequently was not constant as factors such as speed or seating location in the vehicle varied. This section attempts to determine the statistical significance of these differences in the effect which using a restraint system has on increasing or decreasing the likelihood of sustaining an injury.

Throughout the following sections, we use "significant" and "statistically significant" synonymously. Statistical significance levels provide a standardized way of indicating the degree of confidence one can have that observed differences in frequencies or averages did not happen by chance. The analysis always tests the null hypothesis that there is no difference. Significant to the .05 (or 5%) level, for example, means that one could expect a difference in the total population (see Section 2.1) as large as the one found in the sample data file, given the number of cases in the analysis, no more than five times out of one hundred (15). If the significance attains the 0.05 level, then the null hypothesis is rejected. That is, we have arbitrarily set this as the point at which we can no longer believe that the observed differences arose from purely random error. Thus, in the following discussion, we will maintain the assumption of no effect until an observed difference is "statistically significant." If the differences attain the significance

Figure 29



Proportional Distribution of Shoulder Injury Severity for Restrained and Unrestrained Occupants
restrained
unrestrained
percent of cases
100
80
60
40
20
0
5
4
3
2
1
0
0
1
2
3
4
5
6
injury severity
SHOULDER INJURY

level of .05, then we reject the hypothesis that the difference occurred by chance.

The initial analysis entails regressing the dichotomized injury-no injury variable on the restrained-unrestrained dichotomy. The regression coefficient can be interpreted as the effect of restraint use on the likelihood of sustaining an injury. The intercept value derived from the analysis can be interpreted as the likelihood of unrestrained drivers sustaining an injury. Adding the two results gives one the likelihood of restrained drivers sustaining an injury.

The second step in the analysis compares the effects which the use of restraints have on the incidence of injury. The technique used to make the comparison is the analysis of covariance; a statistical model which compares the regression coefficients and tests the null hypothesis that the coefficients (or slopes) are equal. If the coefficients markedly differ in magnitude or direction across a category such as speed ranges or seating location, then we know that the effect of using a restraint on the incidence of injury is affected by that particular factor pertaining to the accident. Again, we arbitrarily select the .05 level of statistical significance as the criterion upon which we choose to accept or reject the hypothesis that the slopes are equal.

B. The initial analysis was to measure the effect of RSU on the incidence of injury, and the incidence of injury to specific body regions. Following the method outlined above, we calculated the per cent of restraint system users and non-users who sustained injuries to various regions of the body. Table 17 contains these percentages.

The results show that the likelihood of an occupant in the CPIR file being injured is reduced by using a restraint system from 77% to 68%. This result is significant to the .0000 level. (See row one, Table 16). However, examining the relationship within particular body regions reveals that the effect of RSU varies markedly. For example, using a restraint system reduces the probability of an organ injury by 60% (from 5% to 2%). The comparable reduction for chest region, as another example, is 16% (from 25% to 21%). In general, what the graphs in the previous section suggested, is that there is a definite decrease in the incidence of overall injury to the body, and specifically to the organs, brain, head and chest.

On the other hand, the table shows that using a restraint device evidently has no effect for the neck and shoulder regions. Finally, CPIR file occupants who used restraining equipment evidenced an increased likelihood of injury to the back, abdomen and pelvic areas. For example, the probability of injury to the abdomen is increased by 80% by wearing a restraint (from 5% to 9%).

C. We thought that the effect of restraint system usage (RSU) upon the incidence of injury might be a function of the configuration of the accident. The configuration variable has been discussed in Section I. That is, a restraint system might reduce the likelihood of an injury to a greater degree in some types of accidents than in others.

Table 18 contains the results of the tests for equality of regression coefficients across the configuration groups. If the test statistic is significant to the .05 level, we rejected the hypothesis that the coefficients were equal.

The results of the covariance analysis reveal that for most regions of the body the effect of using a restraint does not vary significantly among different accident configurations. That is, the effect of using a restraint system in preventing or not preventing overall injury to the organs, brain, head, shoulder, chest and pelvic girdle is not affected by the type of accident in which the occupant's vehicle was involved.

However, restraint systems do have a differential effect on the incidence of injury in the neck, back and abdomen regions which is statistically significant to the .05 level. Consequently, we rejected the equal coefficients hypothesis, and looked at the slopes within the groups of accident configuration for these three body regions to ascertain which configuration(s) is interacting with RSU in predicting injury. Table 19 contains the coefficients across the five configurations for the three body regions, and the significances of the differences.

The data for the neck region indicate that using a restraint device reduces the likelihood of a neck injury for all accident situations except for rear-end and, significantly, head-on. In the head-on collisions recorded in the CPIR file, using a restraint system increased the likelihood of a neck injury by 115% (from 13% to 28%). Comparably significant increases in the probability of sustaining an injury to the back and abdomen while using a restraint system also resulted from head-on collisions. The likelihood for a back injury increased from 2% to 12%, and that for an abdominal injury increased from 5% to 20%. In addition, both T/L and rear-end collisions also show significant increases in abdominal injury.

The evidence indicates that although RSU generally reduces the likelihood of sustaining an injury to most regions of the body, using a restraint device seems to increase the probability of injury to the neck, back and abdomen regions in head-on collisions, and for the abdomen in T/L rear-end crashes also.

Other significant findings were that there were decreases in organ, brain, and chest injuries in single vehicle crashes, and an increase in pelvic injuries in T/L crashes. In addition, overall injuries were decreased significantly in T/L and sideswipe configurations as the graphs in Section I imply. Because of the smaller number of cases for some configurations, however, the assumption of equal effect in all configurations could not be rejected in rollover and non-rollover situations.

D. A characteristic of accident situations which frequently leads to injury is the rollover. We grouped the occupants into

Table 19
Probability of Injury Associated with Restraint System Usage, Controlling on Accident Configuration

	Single Vehicle	Head-on	T/L Type	Sideswipe	Rear-end
Neck					
No Restraint	13%	13%	14%	17%	24%
Restraint	9%	28%	9%	14%	25%
Sig	.1354	.0005	.0648	.6978	.9015
Back					
No Restraint	7%	2%	4%	7%	9%
Restraint	6%	12%	6%	4%	6%
Sig	.7671	.007	.2267	.4954	.3498
Abdomen					
No Restraint	7%	5%	5%	3%	3%
Restraint	8%	20%	9%	7%	8%
Sig	.5828	.0001	.0323	.3363	.0374

two sets--one consisted of those riding in vehicles which rolled over and the second consisted of those riding in vehicles which did not roll over. Table 20 contains the results of the covariance analysis testing for the equality of the regression coefficients between injury and seat belt usage in rollover and non-rollover situations.

The table indicates that for overall injury and for the brain, head, neck, shoulder, back pelvic regions the use of a restraint device has about the same effect on the incidence of injury in the rollover as it does in the non-rollover situation. Generally, using a restraint system reduces the likelihood of an injury occurring to these regions.

However, the table shows that the effect of a restraint system in rollover accidents is significantly different from its effect in non-rollover situations for the incidence of injury to the chest and abdomen and,less significantly, to the internal organs. The following table presents the probability of sustaining an injury to these regions when using and not using a restraint device in rollover and non-rollover situations.

Table 21 shows that using a restraint system only slightly reduces the likelihood of sustaining an injury to the organs and chest when the vehicle does not rollover. However,in rollover situations, the use of a restraint system has a marked effect in reducing the probability of an injury occurring to the organs and chest regions. Using a restraintsystem reduces the likelihood of sustaining an injury to the abdomen from .08 to .02 when the vehicle rolls over; this compares with an increase in the probability of injury to the abdomen in roll-over situations when wearing a restraint system.

In sum, with a few exceptions, using a restraint system tends to reduce the likelihood of injury to the various body regions about equally in rollover and non-rollover accidents. However, with regard to sustaining an injury to the organs, chest and abdomen, using a restraint system has a much greater effect in reducing the likelihood of being injured in a rollover accident than in a non-rollover situation.

Table 21
Probability of Injury Associated with Restraint System Use, Controlling for Rollover Accidents

	Rollover	Non-Rollover
Organs		
No Restraint	.10	.05
Restraint	.02	.03
Sig	.0467	.0398
Chest		
No Restraint	.32	.24
Restraint	.14	.21
Sig	.0051	.1894
Abdomen		
No Restraint	.08	.05
Restraint	.02	.11
Sig	.1001	.0000

E. We next examined whether the likelihood of sustaining an injury varied significantly among the seating locations within the vehicle. We categorized location into three groups: driver seat, front right seat, and rear seat. Throughout the study we have included only those occupants who were humanoid and sitting in an upright position. Table 22 contains the results of the covariance analysis testing for the equality of the regressions (Injury/No-injury on RSU) among the three seating locations. The data indicate that with one exception, the abdomen region, the effect of using a restraint device does not vary significantly among the seat locations. That is, location within the vehicle does not interact with restraint system usage to produce significant variation in the likelihood of sustaining an injury.

However, abdominal area injuries depart from this pattern. Table 23 contains the injury--RSU relationship for the occupant's location in the vehicle. Restraint system use increases the likelihood of injury to the abdomen, but the increment is significantly greater for right front passengers than for drivers (10% to 3%).

We suspected that the tendency for women to sit in the right front location, coupled with the observation that using a restraint system produces a greater increase in the incidence of abdominal injuries for women than for men, might explain this finding. The following table presents the percentage of men and women users and non-users of a restraint device who were injured in the abdomen.

The evidence shows that seat location interacts with the occupant's sex to increase the abdominal injuries sustained by right front passengers. Seat belted male right front passengers are only slightly more likely to sustain an abdominal injury than are male drivers who are seat belt users. However, women right front passengers using a seat belt are much more likely to be injured in the abdomen when sitting in the right front position than when driving.

Table 23
Probability of Abdominal Injury
Associated with Restraint System Use,
Controlling on Seating Location

	Driver	Front Right	Rear
No Restraint	5%	5%	*
Restraint	8%	15%	
Sig	.03	.00	

* Too few cases for meaningful anlysis

Table 24
Probability of Injury to the Abdomen Associated With Restraint System Use and Controlling on Sex and Seating Location

	% Injured to the Abdomen
Male Drivers	
Belted	8.3
Unbelted	6.3
Male Right Front	
Belted	9.3
Unbelted	6.3
Female Drivers	
Belted	11.1
Unbelted	5.5
Female Right Front	
Belted	19.8
Unbelted	6.6

F. We then tested for differential effects of RSU on the incidence of injury among different speed ranges. We bracketed the velocity of the case vehicle in several ways and ran the analysis on each of them. The results did not differ markedly, so for convenience, we include only the following bracketed groups: 0-30 mph, 31-60 mph, 60+ mph. Again, the technique tested whether the Injury-RSU slopes varied significantly among the three velocity categories. Table 25 contains the results.

The analysis revealed no significant interaction among the categories, except for injury to the occupant's organs. That is, the efficacy of using a restraint system was not significantly altered by the velocity of the vehicle in which the occupant was riding. There were several instances of significant effects at some speed brackets but not at others. However, for none of these cases were we able to reject the assumption of equal effects and so these significant effects will not be mentioned. The data on the one exception, organ injury, is contained in Table 26. These data indicate that using a restraint device reduces the likelihood of an injury to the organs from 0 through 60 miles per hour by 2%. However, at speeds in excess of 60, the probability of an organ injury is reduced by 17% by using a restraint system. Although the equal effects assumption was rejected, either because of small differences or small numbers of cases, none of the differences in per cent usage attains a high level of significance.

This section examines for interaction between restraint system usage and incidence of injury across categories measuring the overall severity of the accident. Although not a perfect surrogate, we operationalized the severity factor by drawing upon the Vehicle Deformation Index from the CPIR file. This variable records the amount of sheet metal crush produced by the accident. We placed Vehicle Deformation Index codes one and two into the first category, three through five

Table 26

Probability of Organ Injury
Associated with Restraint System Use,
Controlling for Velocity

		0-30	30-60	60+
No Restraint		3%	8%	21%
Restraint		1%	6%	4%
	Sig	.0641	.5083	.0775

into the second, and six through nine into the third. The analysis determines whether the associations between restraint system usage and incidence of injury differ significantly across the three vehicle deformation categories. Table 27 presents the results. The table indicates that the effect of using a restraint system upon the incidence of overall injury and for injury to the brain, head, neck, shoulder, and pelvic regions is about the same for all three categories of vehicle deformation. However, the analysis shows that the effect of restraint system usage is significantly different among the vehicle deformation groups for the incidence of injury to the organs, chest, back, and abdomen. Table 28 contains the injury-restraint usage associations found in the vehicle deformation categories for these four regions.

The data reveal that the effect of using a restraint system in reducing the incidence of injury to the organs increases as the vehicle deformation increases. A similar pattern emerges for the abdominal region where the effect of using a restraint system is to increase the likelihood of injury--this effect of restraint system usage increases with an increase in vehicle deformation. The patterns for the chest and back are more complicated. Restraint system usage reduces the probability of sustaining a chest injury for low and medium vehicle deformation codes 6-9. Using a restraint system slightly reduces the incidence of back injuries at low vehicle deformation, sharply increases the incidence at medium crush, and also increases the probability of back injury at VDI 6-9, although at a somewhat lower rate.

G. We then looked to see whether the incidence of injury-restraint system usage patterns are different for men than for women. The test determines whether the coefficient obtained by regressing the injury variable on restraint system usage differs significantly for men and women. Table 29 contains the results.

Table 28

Probability of Injury Associated with Restraint System Usage,
Controlling for Vehicle Deformation

Organs	VDI 1-2	VDI 3-5	VDI 6-9
No Restraint	.01	.08	.24
Restraint	.01	.03	.16
Significance	.82	.02	.36
Chest			
No Restraint	.14	.34	.41
Restraint	.10	.29	.60
Significance	.0670	.1843	.0581
Back			
No Restraint	.05	.07	.04
Restraint	.03	.14	.07
Significance	.0545	.0013	.4471
Abdomen			
No Restraint	.02	.08	.08
Restraint	.05	.14	.23
Significance	.0020	.0060	.0129

Table 29

Equality of Slopes Test--Incidence of Injury and Restraint System Use, Controlling on Sex

Region of the body sustaining the injury:	F-Statistic Significance Level
Overall Injury	.62
Organs	.25
Brain	.06
Head	.74
Neck	.52
Shoulder	.74
Chest	.10
Back	.18
Abdomen	.00
Pelvis	.90

The data indicate that the incidence of injury / RSU correlations are not statistically different for men and women for overall injury or for injury to the organs, brain, head, neck, shoulder, chest, back and pelvic regions. However, restraint system usage does have differential impact on men and women in the incidence of injury to the abdomen. Men who use a restraint device are slightly more likely to sustain an injury to the abdomen than are men who do not use one. However, women who use a restraint system are much more likely to be injured in the abdomen than those who do not wear a restraint system. This difference is significant to the .00 level.

H. This section partitions the data by both seat position and accident configuration. We examined for differences in the effect of restraint system usage for each seat location within each accident configuration. For all regions of the body, the equality of slopes tested indicated differences which were significant to the .00 level. Table 30 presents the difference in the probability of injury associated with wearing a seat belt.

With the table so extensive, we will discuss only the salient features. Brain injuries for drivers in single car accidents are significantly reduced. For neck injuries there is a significant increase with restraints for drivers in head-on collisions. This is greater than the increase for the right front passenger and suggests that the observed increase in neck injuries in head-on crashes is mainly due to the driver. As with the neck, shoulder injuries for drivers in head-on crashes show an increase (significant to the .08 level) and this is contrasted with a decrease in shoulder injuries for the right front passenger. This suggests that there are differences in the effect of restraints on shoulder injury in head-on crashes for the two seat positions. There are significant and equal increases in injuries to the back in head-on crashes

Table 30

Differences in the Probability of Injury
Between Restrained and Unrestrained Occupants
Controlling on Location and Accident Configuration

Region of the Body:	SVC	H-O	T/L	SDSWP	Rear
Overall Injury					
Driver	-.06	0.01	0.07	-.18	-.06
Right Front	-.08	-.16	-.17	-.41	.02
Organs					
Driver	-.04	-.03	-.03	-.01	.00
Right Front	-.07	.09	-.03	-.03	-.02
Brain					
Driver	-.09	.01	-.05	-.08	.01
Right Front	-.11	-.07	-.02	-.14	-.06
Head					
Driver	-.08	.01	-.06	-.15	-.07
Right Front	-.05	-.15	-.11	-.21	.06
Neck					
Driver	-.05	.18	-.05	-.04	-.03
Right Front	-.01	.06	-.03	.08	.15
Shoulder					
Driver	-.04	.09	-.01	-.01	.05
Right Front	-.06	-.10	-.02	-.14	.03
Chest					
Driver	-.09	-.09	-.01	.04	-.03
Right front	-.09	.05	.08	.01	.09
Back					
Driver	-.01	.10	.04	-.02	-.05
Right Front	.04	.11	-.06	-.10	.01
Abdomen					
Driver	.01	.12	.00	.04	.03
Right Front	.03	.23	.18	*	.08
Pelvis					
Driver	.00	.01	.04	.04	.04
Right Front	-.05	.17	.12	*	-.04

* number of cases too few for analysis

so the detrimental effect of restraints in this configuration is the same for both seat positions. We also see a significant increase in back injuries for drivers in T/L intersection crashes. This is interesting, for when both seat positions were considered together, there was no apparent increase-- it was offset by the insignificant decrease in injuries to the right front passenger. We can conclude that the use of restraints is associated with back injuries only for drivers in T/L crashes. Abdominal injuries also exhibit significant increases in head-on crashes for both driver and passenger, but the increase is greater for the passenger. There is also a substantial increase in abdomen injuries for the right front passenger in T/L intersection crashes that is not apparent for drivers. This suggests that the increase in abdominal injuries that was observed in T/L crashes is primarily inflicted upon the right front passengers and not the drivers. It also suggests that the previously observed difference in effects of restraints on these two seat positions observed previously is only in head-on and T/L intersection crashes. Similar disparities occur to the pelvic region where there is a significant increase in the incidence of injury to the right front passengers using restraints who are involved in head-on crashes--these disparities were completely masked by the very slight increase for drivers involved in that situation. By contrast, there is a significant increase in pelvic injuries to drivers involved with rear-end crashes that was masked by a slight reduction in pelvic injuries for right front passengers.

2.5. Statistical Analysis of the Effect of Restraint Usage on the Severity of Injury

A. The previous section examined the incidence of injury; this section considers the situation in which the occupant was injured and determines the statistical significance of the effect which restraint system usage has on the severity of the injury.

The approach is to analyze the difference in the mean injury severity sustained by users of restraint systems as compared with non-users, while controlling on various factors pertaining to the accident.

In all of the analyses, the dependent variable is an injury severity index coded in the CPIR data file for injury to the entire body, and to the head, brain, organs, neck, shoulder, chest, abdomen, and pelvic regions of the body. (See variables 600, 608, 610, 614, 616, 618, 624, 628, and 630.)

We altered these variables somewhat from their form in the CPIR file. Variable 600 in the file contains nine injury severity categories ranging from minor to fatal injuries in three or more body regions. We collapsed the four categories indicating fatality into just one fatal group. Hence, this and the other injury severity variables contain values for the severity of the injury ranging from minor to fatal.

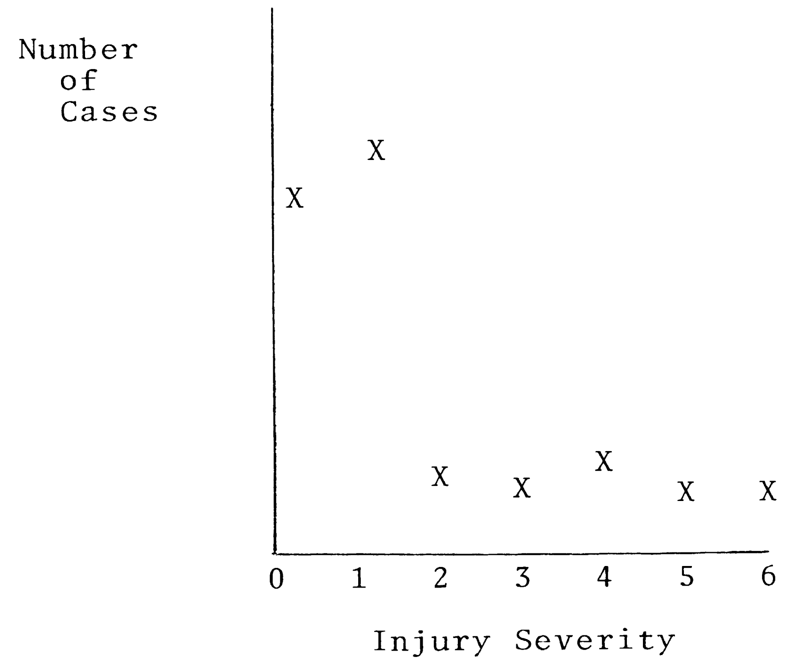
The distribution of these variables each resembles the pattern contained in Figure 30.

This distribution introduces complications in the analysis of the variables. The obvious over-representation of injury values coded 1 and 2 violates the assumption of homoscedasticity underlying many parametric analytical techniques. We believe that the analysis of variance statistical model (Anova) results are not seriously compromised by this distribution. The focus is upon the difference in group means, that is, the mean injury for RSU versus the mean injury sustained by non-users. The central limit theorem indicates that although the values of a variable may not be normally distributed, the assumption that there is no difference between group means using non-normally distributed variables does not seriously compromise the Anova technique.

Also, although the differences in the means can be discerned by the Anova, we believe that the distribution causes the actual effect to be underestimated by this technique. That is, with so many cases assuming a value of 1 or 2, the significant injury

Figure 30

Hypothetical Distribution of Injury Severity Code Values



reduction or production effect of RSU can easily be lost when only a few cases have values larger than 2. Thus, the results of the Anova analysis probably understate the real effect. Perhaps this conservatism in inference is more desired given the tentative nature of the inquiry reported upon here, and the preliminary nature of the empirical investigation of RSU and injury in general.

The Anova calculates the mean injury severity for the two RSU categories, and then tests to see if the two means are significantly different. The logic behind this operation is that if using a restraint system does reduce injury severity, then the mean injury sustained by users should be lower than that sustained by non-users. If restraint systems do not reduce injury, then the mean injury sustained by those who use a restraint device should be the same as that coded for non-users. We performed the analysis of variance upon the injury severity obtained by user and non-users of restraint systems to the entire body and to the selected regions of the body used throughout this study.

B. The first analysis provides a general overview of the effect which using a restraint system has upon the severity of the injury to the body and to various regions of the body. We tested to see whether the mean injury level was the same for users of a restraint device as compared to non-users. Table 31 contains the means, the statistical significance level of the difference in means, and the number of cases within the groups.

The table indicates that using a restraint system tends to reduce the severity of the injury sustained by the CPIR file occupants. The mean injury level found for users of restraint systems was lower than that for non-users in overall injury and to all selected regions of the body except the brain, where the severity level was very nearly the same for users and non-users.

The reduction in severity associated with using a restraint device is statistically significant to the .05 level for overall injury and specifically for injury to the neck, shoulder, and pelvic regions. However, an examination of the significance levels of the differences in the mean injury severity for other regions reveals that they are not statistically significant.

Thus we can state that severity of overall injury and of injuries to the neck, shoulder, and pelvic regions is reduced by using a restraint system. Although it appears from the data that using a restraint system also reduces the severity of injury to the occupants' organs, head, chest, and abdomen, we cannot confidently conclude that this is the case, (because of the lack of statistical significance).

C. We then sought to determine whether the type of accident made any difference in the observed effects which restraint devices have on injury level. The type of accident factor was operationalized by using the accident configuration variable discussed earlier, which categorized five types of accidents: single vehicle, head-on, T/L intersection, sideswipe, and rear-end. The tests were similar to those discussed above in that they used the Anova technique to determine if the observed differences in mean injury levels between users and non-users would have happened by chance. The analysis was performed for injury to the body and to selected regions of the body.

Table 32 reveals some variation in the effectiveness of restraint devices on the mean injury severity sustained by the areas of the body among the several accident configurations. Looking at each configuration in turn, we see that in single vehicle accidents, overall injury severity and head injury severity are reduced significantly while neck and shoulder injury severity reductions are close to being significant at the .05 level. Head-on crashes are associated with a significant decrease in neck injury severity. In no other configurations do we find any significant differences in injury severity to any body region. Looking at the data from the viewpoint of body regions, overall injury severity is decreased significantly only in the single vehicle configuration, head injury severity is reduced in single car accidents, neck injury severity is decreased in both single car and head-on crashes, and shoulder injury severity is reduced in single car accidents. The general lack of statistical significance in the data is in large measure due to the small number of injuries recorded for some areas of the body. This is especially true for organ, neck, shoulder, abdomen and pelvic regions.

D. We next examined whether restraint systems affect the injury severity sustained in rollover and non-rollover accidents. The analysis of variance technique was used for rollover cases and for non-rollovers, testing whether the mean injury severity recorded for restraint system users was significantly different from the average injury severity recorded for non-users of a restraint device. Again, the Anova's were run for overall body injury and for injury to each body region.

The data in Table 33 indicate that the use of a restraint system markedly reduces the injury level sustained by an occupant in a vehicle which has rolled over. This reduction of injury severity is significant to the .05 level in rollover accidents regarding overall injury and injury specifically to the head, the neck, and the shoulder regions. The mean severity of all injuries is reduced from 2.43 to 1.38, from 2.66 to 1.00 for the neck region, from 2.02 to 1.30 for the head, and from 1.44 to 1.00 for the shoulder region. Also, of slightly less statistical significance is the reduction of injury to the organs, brain, and pelvic areas of the body. In these regions, the mean injury severity is reduced from 5.00 to 2.00 for the organs, from 3.70 to 2.20 for the brain, and from 1.66 to 1.00 for the pelvic region. Clearly, those occupants recorded in the CPIR file who used a restraint system tended to sustain less severe injuries when their vehicle rolled over than did non-users of a restraint device.

The table also reveals that the reduction of injury generally associated with the use of a restraint system is much greater in the rollover situation than in non-rollover accidents. For example, the use of a restraint device reduces injury severity by about 1.05 for overall injury in rollover accidents, but only by about .14 in non-rollovers. Similarly, the reduction of injury to the head associated with a restraint system is .72 for rollovers versus .03 for non-rollovers. This pattern holds for all body regions except for injury to the abdomen. In general, however, the differences in mean injury severity between users and non-users of restraint systems are too small to attain statistical significance at the .05 level.

In short, the CPIR data strongly suggest (1) that the use of a restraint system reduces the severity of the injury sustained in a rollover accident especially for head, neck, and shoulder injuries, and (2) the efficacy of a restraint system is greater in a rollover versus a non-rollover situation.

E. This section controls on the velocity of the occupant's vehicle at impact. We felt that it was important to determine whether using a restraint system seemed effective in reducing injuries at various rates of speed. The CPIR file contains estimates for the velocity of the occupant's vehicle. (See variables 74,75,78,79.) We operationalized this factor by bracketing the velocity variable in several ways -- for example: 0-20, 20-40, 40-60, 60+; and 0-30, 30-70, 70+. We then tested whether the mean injury severity level was equal for users and non-users of restraint systems within the various velocity ranges. For example, did using a restraint device tend to reduce the degree of injuries in accidents in which the vehicle was traveling at about 25 mph and also those at about 50 mph? This analysis was performed with the Anova technique for injuries to the total body and to the selected body regions.

The pattern of the association between the severity of the injury and restraint system use was quite similar for the various ways in which we bracketed velocity. Consequently, we present in Table 34 the results for only one: 0-30, 31-60, 60+. The data reveal that using a restraint device seems effective at all speed ranges in reducing the seriousness of overall body injury, but significantly so at velocities over 60 mph and less significantly at speeds under 30 (significance level of .0772). There is no proportionate decrease in severity with increasing speed, however. For most body regions there is a lack of significance due either to small differences in mean injuries or small numbers of injuries, but for chest injuries over 60 mph and for pelvic injuries over 30 there are marked reductions in severity. Interestingly, the mean chest injury level is slightly increased at speeds of 30-60 mph with restraints while the pelvic injury severity decreases more with greater speeds. Thus we can firmly conclude that restraints are effective in reducing injury severity, especially to the chest, at very high speeds (over 60). However, the reduction in injury obtained by using a restraint device does not increase proportionally with the speed, except with pelvic injuries.

F. This section also approaches the problem of whether a restraint device is effective in reducing the occupant's injury level in accidents of varying degree of severity. We selected the extent of the crush sustained by the occupant's vehicle as an index of the accident's severity.

The Vehicle Deformation Index (VDI), contained in the CPIR file, contains a measure of the amount of crush. The VDI damage extent variable is an ordinal scale which assumes values from 1 to 9. We categorized this scale into three groups: 1-2, 3-5, 6-9. The analytical technique, analysis of variance, again tests for whether the mean injury level for users of restraint systems was the same as for the non-users within a given damage extent category. This test was performed on the extent of injury to the total body and to certain areas of the body. Table 35 contains the data.

The data indicate that overall injury severity and neck injury severity are significantly reduced by using a restraint device only for VDI extents of 3 to 5. Shoulder, abdomen, and pelvic injury severity are reduced significantly for VDI extents of 6 to 9. There seems to be a general tendency toward reduced severity of injuries by using restraints, but only in the cases mentioned above do the associations attain statistical significance. Further, the effect of restraint systems in reducing injury levels does not appear to be proportional to the VDI extent.

G. This analysis of the effect which the use of a restraint system has on the severity of the injury controls on the occupant's seat location within the vehicle. We examined the injury patterns only for drivers and right front seat passengers because the number of occupants recorded in the CPIR file using a restraint device in the rear seat was too few for meaningful analysis to be performed.

The analysis technique was again to test whether the mean injury severity for users of a restraint device was the same as that for non-users. We examined this relationship for the injury to the total body and to selected regions of the body. Table 36 contains the results.

The table reveals that, for drivers, using a restraint system significantly reduces the overall injury severity and the injury severity to the neck and pelvic regions. Although there is a general tendency for a reduction of injury severity sustained by other body regions for both drivers and right front passengers, there are too few cases for the reduction to attain statistical significance. The injury severity to the neck for the right front passengers are markedly reduced, but again, due to the paucity of cases, the significance level is .09. Similarly, the drivers' shoulder injury severity is reduced at a significance level of .08.

We conclude that overall injury severity to the driver is reduced by using a restraint device, and that this is particularly significant for the neck and pelvic areas. However, it cannot be concluded from these results that there is a difference in the effect of restraints on injury severity between the two seat positions for overall injury or for injury to any specific body region.

H. This section tests whether the effect of restraint system usage upon the injury level is common to men and women alike. We divided the occupants into two groups by sex, and then looked at each group separately for the effect of using a restraint device on injury severity. Table 37 contains the results.

The table shows that the effect of using a restraint system attains a statistical significance level of .05 for both men and women only for overall injury severity. In this case, using a restraint device significantly reduces the injury level for both men and women. For head injuries, restraint system usage reduces injury severity to a significant degree for men, but for women, there is not a statistically significant difference between the injury level sustained by users versus that recorded for non-users. The same pattern holds for neck and chest injuries--significant reduction for men restraint users, but no statistically significant difference between women users and non-users. The reverse situation occurs for abdominal injuries. The reduction in the abdominal injury sustained by women users of restraints as opposed to non-users is statistically significant while the reduction observed for men wearers is not statistically significant to the .05 level.

2.6 Concluding Observations on Sections 2.4 and 2.5

Overall injury is shown to be reduced in both incidence and severity with restraints. The incidence of overall injury is decreased at all speeds, but only at VDI levels of 1 to 5.

TABLE 37

ANOVA OF INJURY SEVERITY,CONTROLLING ON
RESTRAINT SYSTEM USE BY SEX

		Overall Injury			Organs		
		Mean	Sig	N	Mean	Sig	N
Men	$\overline{RSU}$	1.689	.00	1851	5.369	.29	141
	RSU	1.158		506	4.875		16
Women	$\overline{RSU}$	1.509	.01	1218	4.539	.69	65
	RSU	1.192		292	4.300		10

		Brain			Head		
		Mean	Sig	N	Mean	Sig	N
Men	$\overline{RSU}$	3.404	.71	270	1.912	.02	522
	RSU	3.541		37	1.500		102
Women	$\overline{RSU}$	3.313	.27	134	1.576	.19	347
	RSU	3.826		23	1.864		59

		Neck			Shoulder		
		Mean	Sig	N	Mean	Sig	N
Men	$\overline{RSU}$	1.747	.00	245	1.132	.08	189
	RSU	1.159		63	1.222		45
Women	$\overline{RSU}$	1.591	.25	215	1.263	.80	133
	RSU	1.333		51	1.233		30

		Chest			Abdomen		
		Mean	Sig	N	Mean	Sig	N
Men	$\overline{RSU}$	2.161	.02	447	2.230	.12	113
	RSU	1.784		111	1.781		41
Women	$\overline{RSU}$	1.883	.79	281	2.131	.02	61
	RSU	1.952		42	1.386		44

However, the severity of overall injury is reduced more at higher speeds and VDI extents of 3 to 5. Both seat positions exhibit a decrease in the incidence of overall injury, but only for the driver is the severity reduced. Similarly, in both rollover and non-rollover accidents, there are reductions of overall injuries, but only in the rollover is there also a reduction in the severity of overall injuries with the use of a restraint device. Restraint systems are particularly effective in reducing both the incidence and severity of overall injury in single vehicle accidents. In addition, T/L and sideswipe configurations both show restraint induced reductions in the incidence of overall injury.

Regarding the internal organs, we find no significant reduction in the severity of injury, but we observe a general reduction in the incidence of injuries with restraint use at higher speeds and greater VDI extents. They are also more prevalent for the driver than for the right front passenger. Furthermore, a marked reduction in the incidence of organ injury is associated with single car accidents. The reduction in organ injury is about the same for rollover and non-rollover accidents.

Brain injuries, like organ injuries, show no reductions in their severity, but a general decrease in their incidence is associated with using a restraint system. Unlike the organs, however, this reduction in the incidence of injury is found only at lower and middle VDI levels. The decrease of injuries when using restraints is about the same for all speeds, and for the driver and right front passenger alike. Although there are reductions in the incidence of brain injury for both the rollover and non-rollover accidents, they are greater for the rollover situations. The most significant reductions in brain injury associated with restraints is found for the case of single accidents.

The incidence of head injuries is generally reduced with restraint system use, but only in the single vehicle and roll-over accidents is the severity also reduced. As with the brain, the reduction of injuries occurs only at low and middle VDI extents. All speed brackets and both driver and right front passenger positions exhibit reductions in the incidence of head injury. Non-rollover accidents show a much greater reduction of injury occurrence than do rollovers when the occupant wears a restraint device, and the reduction is significant only in the non-rollover situation.

Regarding chest injuries, generally there is a decrease in the incidence of injury associated with using a restraint system. However, a definite increase in the number of chest injuries occurs in head-on crashes at VDI levels 6 through 9. This contrasts with a decrease at lower VDI levels, notably in single car accidents. Moreover, there is a reduction of severity of the chest injuries sustained at speeds over 60, but an increase in the incidence of chest injury occurs for rear-end crashes for that same speed bracket. Fewer injuries result from wearing a restraint system for both the driver and passenger to about an equal degree. Restraints reduce the incidence and severity of chest injuries to a greater extent in rollovers than in non-rollovers.

Restraints do not seem to reduce the incidence of injury to the neck region, but, in general, they do reduce the severity of neck injuries. The reduction in severity is especially noticeable for speeds ranging from 30 to 60 and for VDI levels 3 to 5. The reduction in severity occurs equally for the driver and the right front passenger, but is more pronounced in rollovers than in non-rollovers. Most reductions of neck injury severity occur in single car and in head-on crashes. However, the evidence shows that there is an increase in the incidence of neck injuries in head-on crashes mostly to drivers. In addition, read-end crashes at speeds of 31 to 60 also show a substantial increase in the incidence of neck injuries.

The incidence of shoulder injury is not reduced by the use of a restraint system. However, significant reductions in the severity of the injuries are obtained when using a restraint. Severity is reduced only at high VDI levels (6 to 9) and equally for drivers and right front passengers. Restraint devices are more effective in reducing shoulder injury severity in rollovers than in non-rollovers, and most prevalently, in single car crashes.

Like the neck and shoulder, the incidence of injury to the pelvis region is not reduced by wearing a restraint system. However, a general reduction in the severity of the injuries is obtained. Severity is decreased most noticeably at VDI levels 6 to 9 and somewhat proportionally with speed -- the greater the speed, the greater the reduction of pelvic injury severity. Drivers show a much greater reduction in pelvic injury severity when using restraints than do right front passengers. The incidence of injury is increased significantly at VDI extent 3 to 5, and in the T/L intersection configuration. The increase occurs for right front passengers at low speeds in head-on crashes and for drivers in rear-end accidents.

Back injuries show no general increase or decrease in either incidence or severity when restraints are used. However, we observe definite effects for certain situations. For example, there is a marked decrease in the incidence of back injury at low VDI levels, especially in single car accidents. However, at VDI levels 3 to 5, there is an equally marked increase in the incidence of back injury in head-on and T/L type configurations. There is also a general increase in the incidence of back injuries at speeds of 31 to 60 miles per hour that is most prevalent in the head-on and rear-end configurations, but this increase also occurs at low speeds in head-on crashes. The limited number of serious back injuries precludes firm conclusions being drawn about injury severity.

Finally, the number of injuries to the abdomen is generally increased with the use of a restraint system. Increases are significant at all speeds less than 60, and at all VDI levels, where the increase in the incidence of injury rises with the extent of the damage. The increase occurs in non-rollover accidents, but, interestingly, does not occur in rollover situations. The increase in injury is most significant for women -- both as drivers and as passengers. However, the mean level of abdominal injury sustained by women is significantly reduced by wearing a restraint. This reduction is not found for men.

2.7 Torso Restraints and Fatal Injury

Section 2.2 presents the comparative overall injury severity levels for restrained and unrestrained CPIR file occupants. The following three-dimensional bivariate distribution graph of Table 16 shows that users of restraints, both lap and torso, were less likely to have been fatally injured than unrestrained occupants.

However, three occupants were killed while wearing torso restraints. We intensively examined the data records for the three torso-restrained occupants who were killed. First, we listed the parts of the vehicle which produced injuries to the selected regions of their bodies. Table 38 contains this information.

The table does not reveal a pattern among the contact areas producing injury to the three case occupants. The A-pillar and windshield figure prominently in the first case occupant's injuries; the roof top and steering assembly in the second, and the roof side rails in the third. However, the A-pillar and surface side interiors do produce thorax injuries to cases one and three. A study of the full reports provided by the accident investigation teams for these three cases reveals that the circumstances surrounding the accidents were markedly dissimilar so that a strict comparability of injury patterns is not possible.

The examination of the full reports also suggests that being fully restrained did not increase the likelihood of fatality for these three occupants. Case number one was a

Figure 31

Distribution of Percentages of Overall Injury Severity for Occupants in Three Restraint Use Categories

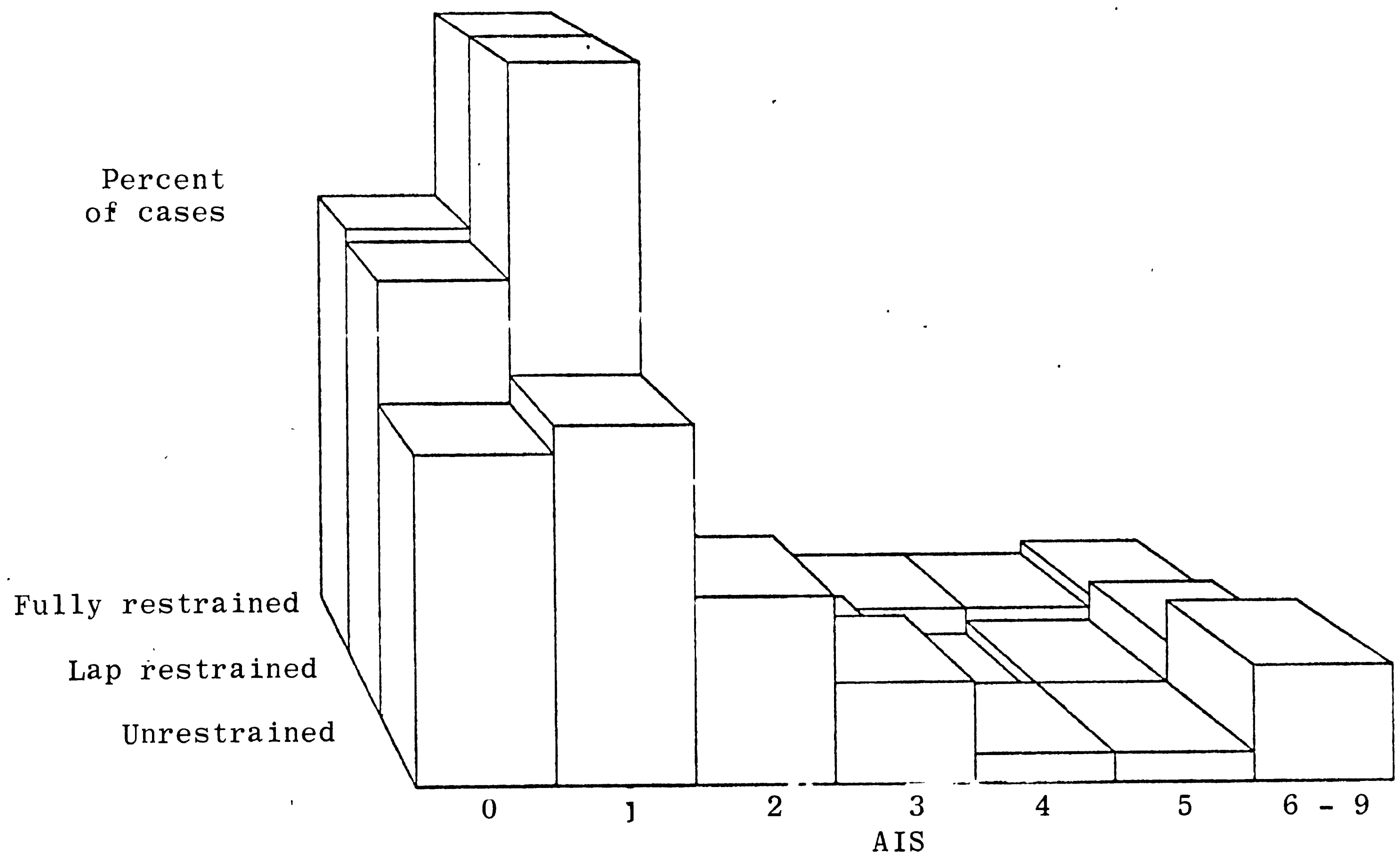


TABLE 38

VEHICLE AREAS CONTACTING BODY REGIONS OF FATALLY INJURED FULLY RESTRAINED OCCUPANTS

	Organs	Brain
Case #1	Instrument Panel A-Pillar	Windshield A-Pillar Hood
Case #2	None	None
Case #3	None	None

	Face	Head
Case #1	Windshield	Windshield A-Pillar Hood
Case #2	Roof Top Sunvisors	Roof Top
Case #3	None	Roof Side Rails

	Neck	Shoulder
Case #1	None	None
Case #2	Steering Assembly Instrument Panel	Steering Assembly
Case #3	None	None

	Thorax	Abdomen
Case #1	A-Pillar Surface Side Interiors	None
Case #2	Steering Assembly	Instrument Panel Hardware Items Heater or AC Ducts
Case #3	A-Pillar Surface Side Interiors	None

right front occupant involved in a two car crash, both vehicles travelling at about 50 to 60 miles per hour. The other car, travelling the wrong way down a divided highway with a driver who had been drinking, struck the right front side of the case occupant's car. The case occupant's vehicle was deformed a maximum of 59 inches from the principal force of impact at one o'clock. The right A-pillar was displaced rearward about 8 inches, and the instrucment panel on the right was displaced rearward about 18 inches. Case two was a driver who lost control of his car and left the road. After hitting a sign, the vehicle ascended an 18-foot embankment and, while airborn for about 130 feet, broke the tops of small trees. After colliding with a larger tree, the car rotated more than 180 degrees and went over a second embankment which was about 28 feet high, coming to rest on its wheels in a body of water. The third case involved a women driving a Volkswagen Beetle who was sideswiped by a two-trailer truck with a total weight of about 75,000 pounds. One of the 7,000-pound trailers, hauling about 24,000 pounds of sheetrock, evidently rode up over the left front and left side of the Volkswagen. Thus, the narratives for these cases suggest that severe injury or death was likely regardless of whether the occupant wore or did not wear a torso restraint.

SECTION III: RESTRAINT SYSTEM USE AND VEHICLE PARTS CONTACTED BY INJURED OCCUPANTS

3.1 The data and analysis techniques

To this point we have been concerned with the question of whether restraint systems are effective or not, and have seen that they are in many situations and are not in some others. In this section we attempt to discover why they are effective or why they are not by comparing interior contact points for restrained and unrestrained occupants, and the severity of the injuries resulting from these contacts. The CPIR file lists up to ten contact points for the overall body and up to four for each region of the body. We have grouped these possible contact points into ten general areas of the car: instrument panel, windshield (including mirror), floor (including shift), steering wheel, side, side glass, roof (including visors), front seatback (including headrest), restraint system, outside objects (including flying glass), and one type of injury mechanism that does not require contact, impact force.

The question of significance is determined by conducting statistical tests (t tests) of the differences between both mean severity and per cent injured from each contact area for restrained and unrestrained persons. For each accident situation or variable pertaining to an accident that exhibits a significant restraint effect on injury severity we present a table indicating the incidence and severity of injury for each contact area. However, the reported severity of contact with any given point is in actuality the highest severity of injury that occurred to the overall body or to a specific body region for those occupants whose body or body region contacted the particular point. This means that the injury whose severity was reported was not necessarily produced by contact with the given point, only that the given contact point was among those contacts, one of which was responsible for the reported injury. This has the effect of tending to increase the reported severity of those contacts that actually produce the less severe injuries. Unfortunately, we are not able to accurately judge the extent of this increase and so must admit that we cannot compare the severity of injury directly induced by contact with given points, but can only compare the severity of injury associated, perhaps indirectly, with contact with a particular area of the car. Given this complication, we can still attempt to explain the restraint effect for each accident variable by comparing both the incidence and associated severity of contacts for the restrained and unrestrained occupants. Any significant or notable differences in the compared values are discussed. If a particular difference appears large but is not mentioned, it is because the scarcity of cases keeps it from being significant. If a cell is empty it is because there are not enough cases in it to warrant analysis. Furthermore, the symbol "<<" in place of a mean injury severity level indicates that there are four or fewer cases in that subset of the cell -- too few to yield a meaningful comparison of associated severity.

Besides analyzing the differences between restrained and unrestrained occupants, further insight into each accident variable is gained by comparing the figures across the rows of the table for each contact area, and down the columns for each body region or accident variable. By comparing across a row, we see the differences in the relative amounts of contact with a particular contact area among the body regions or for the various values of an accident variable. As an example, from Table 39 we find that when restraints are not worn, 27.6% of all organ injuries are from the wheel, whereas only 4.6% of brain injuries are wheel induced. This does not mean that there are more wheel injuries to the organs than the brain; instead, it means that of all the organ injuries, 27.6% were from the wheel; and of all the brain injuries, 4.6% were caused by the wheel. Comparing these figures with the 11.8%

of all the injuries that come from wheel contact shows that the wheel is overinvolved in internal organ injuries but under-involved in brain injuries. The mean associated severity of injuries can be compared directly -- wheel induced injuries to both the organ and the brain appear to be associated with more severe AIS values than other body regions, and organ injuries especially so. On the other hand, looking down one column shows the pattern of injuries for one body region or for one value of an accident variable. As another example from Table 39, wheel and side induced organ injuries for unrestrained occupants are not appreciably different in either incidence or severity. Also, the roof is not a factor at all. In this way we obtain an understanding of how one body region or value of accident variable compares with the general case, or with other body regions or other values of the accident variables.

3.2 Overall injury producing contact points

The first analysis will be for all cases taken together. This will then serve as a basis for comparison with any particular situation. Because of the large number of cases, there are more statistically significant findings obtained than in the other analyses of this section. We will discuss only the effects of restraints. The data are presented in Table 39.

For all body regions together, the use of restraints results in a significant reduction in the severity of injury from outside contact; relative decreases in the amount of instrument panel, windshield, roof, front seatback, and outside contact, and relative increases in wheel and restraint system contacts. The differences in windshield and restraint system contacts between restrained and unrestrained occupants are by far the most notable.

Now we consider each body region in turn. The results show that for unrestrained occupants the internal organs are

TABLE 39

CONTACT POINT COMPARISON FOR ALL CASES

All Cases		Overall Per-cent	Overall Mean Sev-erity	Organ Per-cent	Organ Mean Sev-erity	Brain Per cent	Brain Mean Sev-erity	Head Per-cent	Head Mean Sev-erity
Dash	$\overline{RSU}$	21.60	2.15	18.90	4.96	8.33	3.14	6.60	1.95
	RSU	17.30	2.17	6.90	<<	8.90	3.13	4.90	2.40
Windshield	$\overline{RSU}$	12.90	2.07			21.90	2.72	29.80	1.38
	RSU	6.10	2.14			18.90	3.71	18.60	1.61
Floor	$\overline{RSU}$	5.43	2.52						
	RSU	6.63	2.73						
Wheel	$\overline{RSU}$	11.80	2.11	27.60	5.11	4.60	2.82	3.50	1.48
	RSU	15.30	1.94	34.50	5.00	11.10	3.00	7.30	1.40
Side	$\overline{RSU}$	16.10	2.56	21.50	4.90	18.60	3.82	17.30	2.02
	RSU	15.20	2.44	31.00	4.89	16.70	4.07	11.30	2.26
Side Glass	$\overline{RSU}$	3.51	2.48			3.90	2.29	7.30	1.51
	RSU	4.52	2.10			1.10		12.30	1.44
Roof	$\overline{RSU}$	6.41	2.39			17.00	3.01	17.10	1.85
	RSU	5.05	2.24			16.70	3.60	21.10	1.65
Front Seatback	$\overline{RSU}$	5.21	1.88					3.80	1.56
	RSU	3.32	1.68					4.90	1.00
Restraints	$\overline{RSU}$	.198	2.38	-	-				
	RSU	9.50	2.26	17.20	3.80				
Outside	$\overline{RSU}$	3.68	3.91	14.90	5.02	15.20	4.41	8.40	3.12
	RSU	2.19	3.10	-	-	10.00	5.22	6.40	3.31
Hyper-extension	$\overline{RSU}$	4.06	1.46						
	RSU	5.05	1.48						

TABLE 39 (CONTINUED)

All Cases		Neck Per-cent	Neck Mean Sev-erity	Shoulder Per-cent	Shoulder Mean Sev-erity	Chest Per-cent	Chest Mean Sev-erity	Back Per-cent	Back Mean Sev-erity
Dash	$\overline{RSU}$	4.10	2.48	13.90	1.30	18.00	2.06	4.10	1 40
	RSU	3.90	1.60	5.60	1.00	7.70	2.07	-	-
Windshield	$\overline{RSU}$	6.50	2.35						
	RSU	3.10	1.50						
Floor	$\overline{RSU}$								
	RSU								
Wheel	$\overline{RSU}$	5.30	2.17	7.70	1.18	35.80	1.87		
	RSU	9.30	1.58	13.20	1.30	48.00	1.82		
Side	$\overline{RSU}$	8.50	2.15	32.00	1.38	19.30	2.54	17.40	1.31
	RSU	2.30	〃	31.10	1.14	17.00	2.29	8.80	1.60
Side Glass	$\overline{RSU}$	2.50	2.06						
	RSU	0.80							
Roof	$\overline{RSU}$	5.60	2.81	5.30	1.26				
	RSU	0.80	-	1.10					
Front Seatback	$\overline{RSU}$	9.90	1.71	9.30	1.35	7.00	1.87	13.30	1.19
	RSU	12.40	1.06	8.90	1.25	3.80	2.00	8.80	1.40
Restraints	$\overline{RSU}$	-	-	-	-	-	-	-	-
	RSU	3.90	1.00	6.70	1.00	6.60	1.83	22.80	1.54
Outside	$\overline{RSU}$	5.60	3.84	8.80	1.74	5.60	3.34	7.10	1.65
	RSU	0.80	〃	-	-	1.60	1.33	-	-
Hyper-extension	$\overline{RSU}$	36.30	1.24	3.50	1.13	2.10	1.29	25.30	1.15
	RSU	43.40	1.09	11.10	1.10	6.00	1.18	40.40	1.13

TABLE 39 (CONTINUED)

All Cases		Abdomen Per-cent	Abdomen Mean Sev-erity	Pelvis Per-cent	Pelvis Mean Sev-erity
Dash	$\overline{RSU}$	15.20	2.19	17.80	2.28
	RSU	2.80	<<	2.40	<<
Windshield	$\overline{RSU}$				
	RSU				
Floor	$\overline{RSU}$			5.30	1.78
	RSU			1.20	<<
Wheel	$\overline{RSU}$	37.00	1.76	11.40	1.88
	RSU	17.60	1.26	4.80	1.25
Side	$\overline{RSU}$	18.10	2.52	38.10	1.69
	RSU	6.50	2.57	31.30	1.54
Side Glass	$\overline{RSU}$				
	RSU				
Roof	$\overline{RSU}$				
	RSU				
Front Seatback	$\overline{RSU}$	4.50	2.00	6.10	1.73
	RSU	-	-	-	-
Restraints	$\overline{RSU}$	0.41	<<	0.30	<<
	RSU	66.70	1.67	55.40	1.35
Outside	$\overline{RSU}$	8.60	2.95	8.30	2.37
	RSU	-	-	-	-
Hyper-extension	$\overline{RSU}$				
	RSU				

overinvolved in wheel and side induced injuries, but when restraints are worn there is a greater tendency for the internal organs to be injured by the restraints themselves. However, there are also relatively fewer instrument panel and outside object contacts for internal organs of restrained persons. For unrestrained people the brain exhibits more windshield and roof injuries than other body regions. With restraints there are relatively more steering wheel induced brain injuries and more severe windshield contacts, but fewer side glass contact than occur to those without restraints. The unrestrained head is also contacting the windshield and roof more often than the other body parts do, but with restraints it is not hitting the windshield and side proportionately as much as if unrestrained. On the other hand, the head is hitting the wheel and side glass relatively more often with restraint use. The increase in windshield contacts for the heads of unrestrained occupants is especially notable. Moreover, front seatback induced injuries of the head are less severe for restrained persons. The neck suffers more impact force injuries than the other body regions. There is a relative decrease in windshield, side, roof, and outside neck injuries, but more restraint caused neck injuries. Furthermore, impact force and front seatback injuries of the neck are less severe when restraints are worn, which may be the main reason for the decrease in neck injury severity with restraint use observed in Section II. Shoulder injuries are most frequently from side contact. With restraints the shoulders are hitting the instrument panel, roof, and outside proportionately less often, but the restraint system itself more often. Also, there are relatively more impact force shoulder injuries with restraints. The differences in instrument panel and impact force injuries to the shoulder are most notable. When the side or instrument panel are contacted by the restrained shoulder, injury is less severe. These reductions in severity probably are the reason for the decrease in shoulder injury severity for restrained persons. The main injury causing area for the chest is the wheel. With restraint use the chest is receiving proportionately fewer instrument panel and front seatback injuries, and is hitting outside objects relatively less often. However, the wheel and restraints are being contacted relatively more often, and there are more impact force injuries to the chest with restraints. Back injuries are most frequently from impact force. When restraints are worn, injuries from the side and outside are proportionately less numerous, but impact force and restraint caused back injuries are relatively more prevalent. The shift to more impact force injuries for restrained backs is marked. For the unrestrained abdomen the main cause of injury is the wheel. However, we see a reduction in the incidence of wheel, side, instrument panel, outside and front seatback injuries, and a corresponding increase in restraint caused injuries with restraint use. Wheel injuries to the abdomen are less severe with restraints. The pelvis exhibits more side injuries than the other body regions. There are relatively fewer instrument panel, floor, wheel, front seatback and outside contacts, but instead more restraint contacts with restraint use. While no one contact area exhibits a significant reduction in pelvic injury severity with restraint use, the severity of restraint caused pelvic injuries is less than the injuries caused by other areas of the car, and since this is the most common cause of pelvic injury for restraint wearers, this may be a reason for the reduction in pelvic injury severity for restrained people that was observed in Section II.

These results suggest that the pattern of contacts changes for restraint wearers. Specifically, with restraints the upper body is not as free to move forward, upward or to the side as if unrestrained. The evidence for this is the reduced head and neck contact with the windshield, less chest and shoulder contact with the instrument panel, less neck and shoulder contact with the roof, and fewer head and neck injuries from side contact with restraint use. Restraints also keep the shoulder from hitting the side and instrument panel as severely. However, restraints do not keep the upper body from hitting the wheel, as evidenced by relatively more head and chest contact with the wheel when restraints are worn. Nor do restraints stop the head from hitting the side glass, since there are proportionately more head injuries from this contact area for restrained individuals (although there are fewer brain injuries from side glass contact). Another difference in the injury pattern for restraint wearers is that they suffer relatively more impact force injuries to the shoulder, chest, and back than those that are unrestrained. However, neck injuries of this type are less severe for restrained persons. The effect of restraints on the injury pattern for the lower body is to trade off instrument panel, wheel, side and front seatback injuries for more restraint caused injuries, and these restraint injuries are generally less severe than the other injuries. Finally, there is a strong tendency toward less outside object contact for all the body regions of restrained occupants.

3.3 Injury producing contact points by VDI

The question of the effectiveness of restraint systems at various VDI levels has already been answered, but we have yet to see why they are effective. By analyzing contact points at each VDI level, we hope to answer this question. Table 40 gives the data.

In comparing the injury patterns of unrestrained occupants only for the two lower brackets of VDI extent we find, as one would expect, that there are less severe injuries at VDI of 1 and 2 than at VDI of 3 to 5. There are so few cases with VDI of 6 to 9 that analysis of this bracket is fruitless. A comparison of the severtiy of injuries from each separate contact area at the two VDI brackets shows that for unrestrained occupants, there are less severe roof, outside, wheel, instrument panel, windshield, floor, side, side glass, and impact force injuries at VDI of 1 and 2. As for the incidence of injuries, there are relatively fewer floor, side, side glass, and outside contacts, but more wheel and impact force injuries at the lower VDI bracket.

We now make similar comparisons for the separate body regions of unrestrained occupants in Tables 40 through 46. In general, there is a tendency toward more severe injuries to all body regions

TABLE 40

CONTACT POINT COMPARISON FOR
OVERALL INJURIES AT SELECTED VDI LEVELS

		Overall VDI = 1,2		Overall VDI = 3-5	
		Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{R}S\overline{U}$	23.80	1.37	20.70	2.24
	RSU	15.10	1.46	17.30	2.12
Windshield	$\overline{R}S\overline{U}$	14.80	1.48	12.80	2.20
	RSU	5.35	1.17	6.43	1.98
Floor	$\overline{R}S\overline{U}$	3.85	1.53	5.35	2.37
	RSU	3.12	1.21	7.10	2.34
Wheel	$\overline{R}S\overline{U}$	14.10	1.42	11.40	2.27
	RSU	20.50	1.25	13.30	1.94
Side	$\overline{R}S\overline{U}$	13.60	1.59	17.00	2.66
	RSU	14.30	1.53	16.10	2.52
Side Glass	$\overline{R}S\overline{U}$			3.95	2.48
	RSU			4.42	2.03
Roof	$\overline{R}S\overline{U}$	5.72	1.50	6.32	2.37
	RSU	4.90	1.68	5.35	2.20
Front Seatback	$\overline{R}S\overline{U}$	5.16	1.19	5.16	1.90
	RSU	6.01	1.19	2.28	2.00
Restraints	$\overline{R}S\overline{U}$	0.41	2.50	0.08	<<
	RSU	9.80	1.55	10.20	2.28
Outside	$\overline{R}S\overline{U}$			4.38	3.73
	RSU			1.47	2.82
Hyper-extension	$\overline{R}S\overline{U}$	6.08	1.25	3.74	1.60
	RSU	6.90	1.03	5.35	1.58

at higher VDI levels. The changes in the pattern of injuries for the unrestrained occupant as VDI goes up can be seen by comparing the percent of contacts across the rows of each table. Specifically, for the unrestrained occupant there are relatively fewer windshield but more side and outside contacts for the head as VDI goes up, proportionately fewer wheel and impact force induced chest injuries at the higher VDI extents, and less wheel contact but more injuries from all other sources to the abdomen at VDI levels greater than 2. All this suggests that at the lower VDI levels the injuries to unrestrained occupants are often from the head hitting the windshield, the chest and abdomen hitting the wheel, and from impact force. At the greater VDI levels the head and chest hit the side more often and impact force injuries are not as prevalent, but outside object contact is more so. Almost all injuries are more severe at the higher VDI levels.

These results are for the unrestrained occupant, but how is the restrained occupant's injury pattern changed by VDI, and how is it different from the unrestrained case? In general, the changes in the relative percent of injuries from each contact area as VDI goes up that are evidenced for the unrestrained occupant are also true for the restrained occupant. However, the magnitudes of these changes are often different and in the case of instrument panel and windshield contact the trend is reversed. While there is a slightly smaller incidence of injury from the instrument panel and windshield at the higher VDI levels than at the lower levels for the unrestrained person, there is a slightly greater proportion of instrument panel and windshield contact for the restrained occupant at the high VDI extents. Furthermore, there is a much greater decrease in the relative number of wheel and front seatback injuries as VDI goes up for the restrained than for the unrestrained occupant. On the other hand, the drop in the percent of impact force injuries from the lower to the higher VDI levels is much more pronounced for the unrestrained occupant. Finally, the increase in outside contacts as VDI goes up is greater for the unrestrained person. If we compare the incidence and severity of contacts at each of the two VDI brackets separately, we see that at the lower VDI bracket the restrained person is hitting the instrument panel and windshield proportionately less often, but the wheel and restraints more frequently than the unrestrained person does. In addition, the windshield and floor contacts are less severe but the impact force injuries more severe with restraints. At the higher VDI bracket there are fewer instrument panel, windshield, front seatback and outside contacts with restraint use, but more restraint and impact force caused injuries. Wheel injuries are less severe with restraint use.

These results show that restraint use eliminates most of the windshield and instrument panel contacts. This is true at both VDI brackets, but especially so at the lower VDI bracket. Furthermore, those restrained occupants that contact the windshield at the lower VDI levels do so less severely than the unrestrained occupants. Wheel contact is more prevalent with restraints at VDI of 1 and 2, but at VDI of 3 to 5 it is about as frequent as for those without restraints. However, the severity of wheel contact is reduced for those with restraints at the higher VDI bracket. Front seatback involvement is substantially reduced at VDI of 3 to 5 for restrained occupants, while impact force injuries are significantly less prevalent at this bracket for the unrestrained. As VDI goes up, outside object contact becomes much more of a factor for the unrestrained person.

Now we partition the data by body regions. Table 41 shows the contact areas for the head for the two brackets of VDI extent. On comparing the percentages of contacts for unrestrained people between Tables 41 and 40 we see that the changes in injury patterns as VDI goes up are generally the same for the head as for the overall body.

As VDI goes up, the proportion of windshield induced head injuries goes down but side and outside contact for the head goes up for those that do not wear restraints. Restraint wearers show similar trends but their proportion of side glass injuries goes down while the relative number of roof contacts goes up

TABLE 41

CONTACT POINT COMPARISON FOR
HEAD INJURIES AT SELECTED VDI LEVELS

		Head VDI = 1,2		Head VDI = 3-5	
		Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{RSU}$	7.63	1.15	5.86	2.00
	RSU	3.08	"	4.84	2.33
Windshield	$\overline{RSU}$	37.90	1.11	28.70	1.49
	RSU	20.00	1.00	16.90	1.52
Floor	$\overline{RSU}$				
	RSU				
Wheel	$\overline{RSU}$	4.80	1.06	3.27	1.67
	RSU	7.69	1.20	7.26	1.00
Side	$\overline{RSU}$	13.00	1.24	18.40	2.01
	RSU	9.23	1.00	16.10	2.50
Side Glass	$\overline{RSU}$	6.78	1.17	7.77	1.47
	RSU	20.00	1.00	8.06	1.70
Roof	$\overline{RSU}$	18.10	1.34	15.90	1.77
	RSU	16.90	1.00	24.20	1.73
Front Seatback	$\overline{RSU}$	3.10	1.00	3.68	1.74
	RSU	12.30	1.00	2.41	"
Restraints	$\overline{RSU}$				
	RSU				
Outside	$\overline{RSU}$			10.90	2.93
	RSU			4.03	3.40
Hyper-extension	$\overline{RSU}$				
	RSU				

as VDI increases. The magnitude of the increase in outside object caused injuries is also less than for unrestrained occupants. At VDI of 1 and 2 there are fewer instrument panel and windshield contacts and proportionately more side glass and front seatback head injuries with restraint use. Furthermore, windshield, side, and roof contacts for the head are less severe with restraints. At VDI of 3 to 5 there are less windshield and outside contacts, and more roof induced head injuries. Wheel contact is also less severe for restrained people.

This suggests that it is the head that accounts for the reduction of windshield contacts for restrained persons that was observed in Table 40, and it is also the head that is a major factor in the relative drop in front seatback injuries as VDI goes up with restraint use. Interestingly, the heads of restraint wearers are relatively more involved in roof contact than those of restraint non-wearers as VDI goes up.

Table 42 reveals that the unrestrained neck is overinvolved in front seatback and impact force injuries at VDI of 3 to 5. Comparing the neck injury patterns of restrained and unrestrained individuals, we see that there are significant decreases in the severity of wheel induced and impact force neck injuries with the use of restraints. It appears that the previously observed decrease in the severity of neck injuries at this VDI bracket with restraint use is primarily from the decreased impact force and wheel contact severity.

Table 43 presents a comparison of contact areas resulting in chest injury. A comparison of chest contacts for restrained and unrestrained occupants shows some notable differences between restrained and unrestrained occupants in the trends in percent of contact as VDI goes up. The relative frequency of instrument panel contact for the chest increases and the frequency of side contact decreases as the VDI achieves values of 6 to 9 for restrained persons but not for those without restraints. Wheel contact for the chest increases as VDI goes up for the restrained occupant but goes down for the unrestrained. Impact force chest injuries decrease more sharply between VDI of 1 and 2 and 3 to 5 for those without restraints. At the lowest VDI bracket there are fewer instrument panel contacts, more

TABLE 42

CONTACT POINT COMPARISON FOR
NECK INJURIES AT A SELECTED VDI LEVEL

<u>Neck</u>

VDI = 3-5

		Percent	Mean Severity
Dash	$\overline{RSU}$	4.35	2.86
	RSU	3.08	<<
Windshield	$\overline{RSU}$	5.59	2.83
	RSU	4.61	<<
Floor	$\overline{RSU}$		
	RSU		
Wheel	$\overline{RSU}$	4.35	2.64
	RSU	7.69	1.00
Side	$\overline{RSU}$	8.39	2.15
	RSU	4.61	<<
Side Glass	$\overline{RSU}$		
	RSU		
Roof	$\overline{RSU}$	6.21	2.70
	RSU	1.54	<<
Front Seatback	$\overline{RSU}$	9.01	1.66
	RSU	9.23	1.17
Restraints	$\overline{RSU}$		
	RSU		
Outside	$\overline{RSU}$	7.14	4.00
	RSU	1.54	<<
Hyper-extension	$\overline{RSU}$	35.70	1.34
	RSU	40.00	1.12

TABLE 43

CONTACT POINT COMPARISON FOR
CHEST INJURIES AT SELECTED VDI LEVELS

		Chest VDI = 1,2		Chest VDI = 3-5		Chest VDI = 6-9	
		Per-cent	Mean Sev-erity	Per cent	Mean Sev-erity	Per cent	Mean Sev-erity
Dash	$\overline{RSU}$	16.70	1.50	18.90	2.10	16.70	2.73
	RSU	8.50	1.50	3.80	2.75	20.70	2.00
Windshield	$\overline{RSU}$						
	RSU						
Floor	$\overline{RSU}$						
	RSU						
Wheel	$\overline{RSU}$	39.70	1.24	36.47	1.85	27.60	3.37
	RSU	48.90	1.26	46.20	1.53	58.60	3.41
Side	$\overline{RSU}$	15.10	1.97	20.30	2.56	20.50	3.16
	RSU	17.00	1.00	19.80	2.90	6.90	<<
Side Glass	$\overline{RSU}$						
	RSU						
Roof	$\overline{RSU}$						
	RSU						
Front Seatback	$\overline{RSU}$	5.90	1.21	6.60	1.55	10.30	3.25
	RSU	6.40	<<	1.90	<<	6.90	<<
Restraints	$\overline{RSU}$			-	-	-	-
	RSU			9.40	2.00	3.50	<<
Outside	$\overline{RSU}$			6.40	3.56	5.10	2.75
	RSU			1.90	<<	-	-
Hyper-extension	$\overline{RSU}$	5.90	1.29	1.10	1.29		
	RSU	8.50	1.00	6.60	1.29		

wheel contacts, and fewer severe side contacts for the chest when restraints are worn. At VDI of 3 to 5 there is still relatively less instrument panel contact, and more wheel contact, but also less front seatback and outside contact, and more restraint and impact force induced chest injuries to restraint wearers. Finally, at VDI of 6 to 9 there are proportionately more wheel contacts and fewer side contacts for the chest, and the instrument panel contacts are less severe with restraints.

This implies that the chest of restrained persons is not hitting the instrument panel except at VDI levels of 6 to 9, at which point such contacts are not eliminated, but are reduced in severity. The wheel is involved in a larger percentage of chest injuries for those with restraints at all VDI levels, but especially so at levels of 6 to 9. The side becomes less of a factor at this VDI bracket for those with restraints.

There are too few back injuries to enable us to draw conclusions about the effects of restraints on the severity of back injury from the various contact areas. By comparing Table 44 with Table 39, we see that the back is overinvolved in impact force injuries when compared to other body regions. Comparing percentages of contacts between the two VDI brackets of Table 44 shows that as VDI goes up there is a tendency toward less side contact for the back for restrained people but more such contacts for those without restraints. At both VDI brackets there are more restraint and impact force back injuries for restraint users but at VDI of 3 to 5 there are fewer side contacts than if unrestrained.

These results show that impact force and restraints are prime factors in back injuries to restraint wearers at all VDI levels.

An examination of Table 45 reveals that for the abdomen there is a large reduction in the amount of wheel contact for unrestrained people as VDI goes from the 1 and 2 bracket to the 3 to 5 bracket. This is not true for restrained occupants. At the lower VDI bracket the major cause of abdomen injuries for those with restraints is the wheel; for those with restraints it is the restraint system itself. At VDI of 3 to 5 there are

TABLE 44

CONTACT POINT COMPARISON FOR
BACK INJURIES AT SELECTED VDI LEVELS

		Back VDI = 1,2		Back VDI = 3-5	
		Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{RSU}$				
	RSU				
Windshield	$\overline{RSU}$				
	RSU				
Floor	$\overline{RSU}$				
	RSU				
Wheel	$\overline{RSU}$				
	RSU				
Side	$\overline{RSU}$	14.10	1.46	20.00	1.26
	RSU	11.10	<<	6.57	<<
Side Glass	$\overline{RSU}$				
	RSU				
Roof	$\overline{RSU}$				
	RSU				
Front Seatback	$\overline{RSU}$	10.90	1.30	16.30	1.14
	RSU	-	-	8.70	1.50
Restraints	$\overline{RSU}$	-	-	-	-
	RSU	22.20	<<	21.70	1.80
Outside	$\overline{RSU}$	7.60	1.86		
	RSU	-	-		
Hyper-extension	$\overline{RSU}$	27.20	1.20	25.20	1.41
	RSU	55.60	1.00	39.10	1.16

TABLE 45

CONTACT POINT COMPARISON FOR
ABDOMEN INJURIES AT SELECTED VDI LEVELS

		Abdomen VDI = 1,2		Abdomen VDI = 3-5		Abdomen VDI = 6-9	
		Per- cent	Mean Sev- erity	Per- cent	Mean Sev- erity	Per- cent	Mean Sev- erity
Dash	$\overline{RSU}$			17.70	2.24	12.50	2.17
	RSU			-	-	-	-
Windshield	$\overline{RSU}$						
	RSU						
Floor	$\overline{RSU}$						
	RSU						
Wheel	$\overline{RSU}$	67.70	1.29	31.70	1.92	35.40	1.82
	RSU	14.60	1.67	18.20	1.08	18.20	‹‹
Side	$\overline{RSU}$			21.30	2.43	16.70	3.00
	RSU			6.06	3.75	-	-
Side Glass	$\overline{RSU}$						
	RSU						
Roof	$\overline{RSU}$						
	RSU						
Front Seatback	$\overline{RSU}$			4.88	1.63		
	RSU			-	-		
Restraints	$\overline{RSU}$	-	-	-	-	-	-
	RSU	65.90	1.44	71.20	1.60	54.50	1.83
Outside	$\overline{RSU}$			7.93	2.54	8.33	3.25
	RSU			-	-	-	-
Hyper-extension	$\overline{RSU}$						
	RSU						

relatively more instrument panel, wheel, side, front seatback and outside contacts for the abdomens of those without restraints, but more restraint contact for those with restraints. Moreover, wheel contact is less severe with restraint use. This pattern is the same at the highest VDI bracket except that the front seatback is not an injury factor, and there are too few wheel induced abdomen injuries for restrained people to be able to compare severity of injuries from that source.

These results imply that restraints produce a trade off of abdomen injuries from other areas of the car for restraint caused injuries, and that especially at the lower VDI levels the main abdomen injury causation area for unrestrained occupants is the wheel.

Although there are small numbers of pelvic injuries at VDI of 6 to 9, we see from Table 46 that the primary cause of injury for restraint wearers is from the restraints themselves. There are not enough cases to make a contact by contact comparison of severity, but it appears that the decrease in severity of pelvic injuries noted in Section II is because the seat belt caused injuries are less severe than the types of injuries that the unrestrained pelvis is receiving.

3.4 Injury producing contact points by speed

Another variable that gives an indication of the severity of the crash is speed at impact. We would like to know how injuries change with increasing speed and how restraints work at these speeds. The necessary comparisons are presented in Table 47.

Table 47 presents the comparisons of incidence and severity of overall injury from the various contact areas at each of three brackets of impact speed. Comparing across the rows for the unrestrained occupant we see few marked trends except a tendency for more outside contacts and fewer impact force injuries as impact speed goes up. The trends for restrained occupants are similar except there seems to be a small trend toward more windshield induced injuries and a decrease in front seatback contacts

TABLE 46

CONTACT POINT COMPARISON FOR
PELVIS INJURIES AT A SELECTED VDI LEVEL

Pelvis

VDI = 6-9

		Percent	Mean Severity
Dash	$\overline{RSU}$	25.80	2.56
	RSU	8.30	<<
Windshield	$\overline{RSU}$		
	RSU		
Floor	$\overline{RSU}$		
	RSU		
Wheel	$\overline{RSU}$	12.90	2.15
	RSU	8.30	<<
Side	$\overline{RSU}$		
	RSU		
Side Glass	$\overline{RSU}$		
	RSU		
Roof	$\overline{RSU}$		
	RSU		
Front Seatback	$\overline{RSU}$	8.06	2.60
	RSU	-	-
Restraints	$\overline{RSU}$	-	-
	RSU	75.00	1.67
Outside	$\overline{RSU}$	12.90	2.38
	RSU	-	-
Hyper-extension	$\overline{RSU}$		
	RSU		

TABLE 47

CONTACT POINT COMPARISON FOR
OVERALL INJURIES AT SELECTED SPEEDS

		0-30 mph		30-60 mph		>60 mph	
		Percent	Mean Severity	Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{RSU}$	22.80	1.56	21.60	2.65	19.90	3.54
	RSU	16.30	1.42	19.00	2.76	21.10	3.06
Windshield	$\overline{RSU}$	13.80	1.59	13.20	2.57	11.00	3.07
	RSU	3.29	1.35	7.13	2.64	6.58	2.60
Floor	$\overline{RSU}$	4.36	1.74	6.40	2.89	7.65	4.07
	RSU	6.00	2.00	6.76	3.16	10.50	4.25
Wheel	$\overline{RSU}$	12.80	1.54	11.40	2.60	11.70	3.83
	RSU	17.60	1.35	13.70	2.48	15.80	2.92
Side	$\overline{RSU}$	15.30	2.01	16.50	2.95	14.50	3.61
	RSU	15.30	1.67	17.20	3.06	13.20	3.90
Side Glass	$\overline{RSU}$	3.21	1.94	3.46	2.90	3.06	3.50
	RSU	3.29	1.35	4.94	2.89	2.63	2.50
Roof	$\overline{RSU}$	5.22	1.77	6.92	2.74	5.87	3.87
	RSU	3.71	1.54	5.12	2.50	6.58	5.60
Front Seatback	$\overline{RSU}$	5.55	1.60	5.37	2.13	5.87	2.30
	RSU	5.14	1.44	2.38	2.00	1.32	<<
Restraints	$\overline{RSU}$	0.165	1.80	0.239	2.67	0.255	<<
	RSU	9.57	1.78	9.87	2.67	9.21	2.86
Outside	$\overline{RSU}$	2.38	3.33	3.62	4.02	7.40	4.41
	RSU	1.71	1.83	2.56	3.79	1.32	<<
Hyper-extension	$\overline{RSU}$	6.08	1.31	2.23	1.88	1.02	2.75
	RSU	6.57	1.26	3.47	1.74	2.63	<<

as speed increases that is not apparent for the unrestrained occupants. At impact speeds less than 30 there are relatively fewer instrument panel, windshield, and roof induced injuries and more wheel and restraint system contacts when restraints are worn than when they are not. In addition, there are less severe wheel, side, side glass, and outside contacts with restraint use. As speeds increase to the 31 to 60 range the differentials in the amounts of instrument panel and wheel contacts are no longer the case, but windshield injuries are still fewer and restraint injuries still more prevalent for restrained persons. The front seatback ceases to be as much of an injury source for the restrained occupant at this speed bracket as at lower speeds, but continues to be so for the unrestrained person. There are no significant differences in injury severity for any contact area when restraints are worn at the 31 to 60 speed bracket. As speeds increase past 60 the difference in the relative amounts of windshield contact between restrained and unrestrained people is less and it cannot be said that there is any real difference in these amounts. The unequal rates of front seatback and restraint system contacts at speeds of 31 to 60 are still true at speeds greater than 60. In addition, there are relatively more outside object contacts for unrestrained occupants at this speed bracket. The only difference in the severity of injuries is for roof contact, where those with restraints suffer more severe injuries.

As for individual body regions, it appears from Table 48 that the restrained pelvis is being hurt by side and seat belt contact at speeds of 31 to 60, but primarily from the seat belt at speeds over 60, although there are very few cases at the highest speeds. Unrestrained pelvises suffer more instrument panel, wheel, front seatback and outside contacts at speeds of 31 to 60 and, while the lack of cases makes strong conclusions impossible, it appears that this pattern is true at the highest speeds also. This suggest that the previously noted trend toward less severe pelvic injuries at the highest speeds with restraint use is because the unrestrained pelvises are being thrown around more, resulting in more

TABLE 48

CONTACT POINT COMPARISON
FOR PELVIC INJURIES AT SELECTED SPEEDS

		30-60 mph		>60 mph	
		Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{RSU}$	23.60	2.54	21.40	2.33
	RSU	-	-	-	-
Windshield	$\overline{RSU}$				
	RSU				
Floor	$\overline{RSU}$				
	RSU				
Wheel	$\overline{RSU}$	11.50	1.78	25.00	3.00
	RSU	-	-	14.30	<<
Side	$\overline{RSU}$	36.30	1.91	17.90	3.00
	RSU	39.50	1.80	14.30	<<
Side Glass	$\overline{RSU}$				
	RSU				
Roof	$\overline{RSU}$				
	RSU				
Front Seatbakc	$\overline{RSU}$	8.92	2.00		
	RSU	-	-		
Restraints	$\overline{RSU}$	-	-	-	-
	RSU	50.00	1.32	71.40	1.80
Outside	$\overline{RSU}$	5.73	2.78	17.90	2.60
	RSU	-	-	-	-
Hyper-extension	$\overline{RSU}$				
	RSU				

severe injuries, whereas the restrained pelvises are receiving the less severe seat belt injuries. At speeds over 60 there are relatively more outside and side induced chest injuries for those that do not wear restraints, but more restraint caused injuries for users of restraints. There is also a significant reduction in the severity of wheel induced chest injuries with restraint use, which is probably the main reason for the previously observed decrease in chest injury severity at this speed bracket.

Summarizing then, restraint use generally reduces both the incidence and severity of contacts in low speed crashes. The most notable effects of restraints are to reduce windshield and instrument panel contacts, but to cause more injuries by themselves. They also keep the body from hitting the wheel, side, and side glass as severely as if unrestrained. As speeds go up, these reductions in severity are no longer apparent, but the head still avoids hitting the windshield and there are fewer front seatback injuries. At the highest speeds there are still fewer windshield and front seatback injuries, and there are relatively fewer outside injuries with restraint use. Interestingly, roof contact is more severe with restraints at higher speeds. The pelvis is trading off more severe injuries from various parts of the car for less severe restraint caused injuries, while the chest is not hitting the wheel as hard with restraints at the higher speeds.

3.5 Injury producing contact points by seat location

The position of the occupant in the car could be a factor affecting his injury pattern, and it could also be a factor in how the restraint system works. Accordingly, we compare the driver with the right-front passenger in Table 49 -- there are too few cases for the other seated positions to yield significant conclusions.

We have seen earlier that the use of restraints reduces both the incidence and severity of injuries to the driver, but

TABLE 49

CONTACT POINT COMPARISON FOR
OVERALL INJURIES BY SEAT LOCATION

		Driver		Right Front	
		Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{RSU}$	20.00	2.17	33.20	2.12
	RSU	16.80	2.12	22.10	2.31
Windshield	$\overline{RSU}$	12.50	2.07	16.70	2.17
	RSU	6.30	1.98	6.50	2.80
Floor	$\overline{RSU}$	6.76	2.97	4.05	2.66
	RSU	7.05	2.69	5.63	2.92
Wheel	$\overline{RSU}$	17.40	2.08	1.99	3.07
	RSU	19.10	1.94	0.87	<<
Side	$\overline{RSU}$	16.50	2.51	14.50	2.86
	RSU	15.10	2.30	16.50	2.87
Side Glass	$\overline{RSU}$	3.57	2.50		
	RSU	4.19	2.14		
Roof	$\overline{RSU}$	7.21	2.38	5.25	2.53
	RSU	5.24	2.38	4.76	1.43
Front Seatback	$\overline{RSU}$	1.82	2.05	2.39	2.17
	RSU	2.48	1.85	3.90	1.67
Restraints	$\overline{RSU}$	0.213	2.78	0.07	<<
	RSU	7.91	2.44	13.00	1.97
Outside	$\overline{RSU}$	3.33	3.33	4.58	4.04
	RSU	2.10	3.32	3.03	2.43
Hyper-extension	$\overline{RSU}$	4.07	1.46	4.05	1.61
	RSU	4.77	1.54	6.49	1.20

using restraints reduces only the incidence of injury for the right-front passenger. Hence, there is a significant difference in the severity reducing effect of restraints between the two seated positions. However, on looking at the individual contact areas of the car, we find that the only significant differences in injury severity are reductions in the severity of roof and impact force caused injuries for the restrained versus the unrestrained right-front passenger. This certainly does not indicate why there would be a difference in the severity of overall injuries for the driver only, but one possible explanation of this result is that the instrument panel, windshield, floor, wheel, side, and side glass contacts are less severe for the restrained driver when compared to the unrestrained driver, whereas they are often more severe for the restrained right-front passenger, although all the differences in the severity of injury from these individual contact areas are too small to be significant by themselves. As for the incidence of contact, there are relatively fewer instrument panel and windshield contacts with restraints for both seated positions, but the reduction in instrument panel contacts is especially marked for the right-front passenger. Restraint induced injuries are proportionately more numerous for restraint wearers in both seated positions, but the increase is greater for the right-front passenger.

In summary,it is obvious that the driver is hitting the wheel more frequently than does the passenger, while the passenger is contacting the instrument panel more often than the driver does. Restraints work equally well for both seated positions in reducing the frequency of windshield contact and are also very effective in reducing the amount of instrument panel contact, but especially for the right-front passenger. They do inflict some injuries of their own, however, and this occurs more often to the right-front passenger.

3.6. Injury producing contact points in single-car accidents

The data concerning single-car accidents is presented in Table 50.

A comparison of Table 50 with Table 39 shows that single-car accidents are in general characterized by more severe injuries than other configurations. For the unrestrained occupant the severity of wheel, instrument panel, windshield, floor, side, and impact force injuries is significantly greater in this situation than in other situations, and the incidence of contact with the roof and outside objects appears to be more than in other cases.

TABLE 50

CONTACT POINT COMPARISON FOR SINGLE VEHICLE ACCIDENTS

		Overall		Head		Neck		Shoulder	
		Percent	Mean Severity	Percent	Mean Severity	Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{RSU}$	19.80	2.68	6.25	2.63	4.40	3.86	8.77	1.47
	RSU	19.70	2.70	7.14	2.00	6.25	<<	5.90	<<
Windshield	$\overline{RSU}$	10.80	2.30	23.60	1.64	6.92	3.36		
	RSU	6.18	1.62	14.30	1.25	6.25	<<		
Floor	$\overline{RSU}$	6.26	2.92						
	RSU	8.53	2.55						
Wheel	$\overline{RSU}$	10.50	2.50	2.31	1.80	6.29	2.60	8.77	1.33
	RSU	15.00	2.61	3.57	<<	18.80	<<	11.80	<<
Side	$\overline{RSU}$	15.40	2.98	15.30	2.55	5.03	2.13	24.60	1.45
	RSU	11.80	2.63	5.40	<<	-	-	41.20	1.00
Side Glass	$\overline{RSU}$	3.62	2.84	6.02	1.88				
	RSU	5.29	1.89	10.70	1.67				
Roof	$\overline{RSU}$	9.22	2.56	20.80	1.90	11.30	3.06	10.50	1.28
	RSU	8.53	2.52	37.50	1.67	-	-	-	-
Front Seatback	$\overline{RSU}$	4.61	2.32	3.94	1.94	7.55	2.33	9.94	1.53
	RSU	1.47	3.00	-	-	-	-	11.80	<<
Restraints	$\overline{RSU}$	0.188	2.75			-	-	-	-
	RSU	9.41	2.81			6.25		17.60	
Outside	$\overline{RSU}$	5.84	4.33	13.90	3.65	13.20	4.14	12.90	1.86
	RSU	2.94	2.40	7.14	2.50	-	-	-	-
Hyper-extension	$\overline{RSU}$	2.73	1.76			23.90	1.21		
	RSU	2.35	2.13			37.50	1.00		

As for particular body regions, the head is hitting the windshield, side, and instrument panel more severely in single-car crashes, and it is also contacting outside objects more frequently. The neck, however, is receiving fewer impact force injuries, but relatively more roof and outside object injuries than in other configurations. For the shoulder of unrestrained individuals, there are relatively fewer instrument panel induced injuries in single-car accidents, but more injuries from the roof than in other types of accidents.

Restraints have a significant effect on this pattern of injuries. We have seen previously that with restraints there is a significant reduction in the severity of injuries and a less significant (.0770) reduction in the relative incidence of injuries for users over nonusers. Also, there are proportionately fewer windshield, side, front seatback, and outside injuries with restraints, but there is an increase in wheel and restraint induced injuries.

More insight can be gained by considering each specific body region and its contacts with the various areas of the car, with and without restraints. For the head, the severity of injuries sustained by windshield contact is reduced significantly with restraints, which suggests that the observed decrease in severity of overall injuries from that contact point is due at least in part to the head region. The relative incidence of head injuries is reduced for windshield, side, and outside contact by the use of restraints, but increased for the roof. The only significant reduction in the severity of neck injuries for restraint wearers is from impact force injury. Thus the previous finding of reduced severity of injuries to the neck in single-car collisions is probably due to this reduction in impact force injury severity for restraint users. There are less severe shoulder injuries from side contact when restraints are worn, but proportionately more restraint caused injuries. The decrease in shoulder injury severity, then, is probably because the shoulder is not hitting the side as hard when the person is restrained.

restrained.

From these results we can conclude that single-car accidents are characterized by more severe injuries than normal, mainly from hitting the side, wheel, instrument panel, windshield, and floor. With restraints in this type of accident, the occupant's head hits the roof relatively more often, but the windshield less often and much less severely than if he did not wear restraints. Impact force injuries to the neck are markedly reduced in severity with restraints. Shoulder injuries from the side are also less severe with restraints. Outside object and front seatback caused injuries are fewer, but there are more seat belt induced injuries. In general, with restraints there is a significant reduction in severity of injuries and a less significant reduction in the incidence of injuries in single-car accidents.

3.7 Injury producing contact points in head-on accidents

The head-on accident analysis suffers from a lack of cases, and hence many results are inconclusive. Therefore, we make no statements comparing contact areas in head-on crashes with all crashes in general. We can state, however, that in head-on crashes there are more injuries and more serious injuries than in most other types of accidents.

The previous analysis of restraint system effects indicated that although there is no significant difference in either the incidence or the severity of overall injury with restraint use in head-on crashes, there is a significant reduction of neck injury severity and a significant increase in the relative number of neck, back, and abdomen injuries associated with the use of a restraint.

By analyzing the contact data in Table 51 we find that there are proportionately fewer neck injuries from windshield contact. This suggests that the reduction in severity seen previously is

TABLE 51

CONTACT POINT COMPARISON FOR HEADON ACCIDENT CONFIGURATION

		Neck		Back		Abdomen	
		Percent	Mean Severity	Percent	Mean Severity	Percent	Mean Severity
Dash	$\overline{RSU}$					16.30	3.14
	RSU					-	-
Windshield	$\overline{RSU}$	13.80	2.50				
	RSU	-	-				
Floor	$\overline{RSU}$						
	RSU						
Wheel	$\overline{RSU}$					51.20	1.59
	RSU					14.30	[illegible]
Side	$\overline{RSU}$	10.30	1.50				
	RSU	-	-				
Side Glass	$\overline{RSU}$						
	RSU						
Roof	$\overline{RSU}$						
	RSU						
Front Seatback	$\overline{RSU}$			22.20	[illegible]		
	RSU			10.00	[illegible]		
Restraints	$\overline{RSU}$					2.30	[illegible]
	RSU					85.70	1.30
Outside	$\overline{RSU}$						
	RSU						
Hyper-extension	$\overline{RSU}$	42.20	1.65	35.30	1.00		
	RSU	42.10	1.22	66.70	1.00		

at least in part because the restrained neck is not sustaining the more severe windshield injuries. Note that the relative frequency of impact force injury to the neck is approximately the same for restrained and unrestrained occupants in this configuration. The observed increase in back injuries with restraints is probably due to the increase in relative number of back injuries from contact with the restraint system itself. The increase in abdominal injuries with restraint use is seen to be from the large number of restraint caused abdominal injuries, although this increase is partly offset by a relative reduction in wheel injuries for the driver's abdomen, and instrument panel injuries for the right-front passenger's abdomen with restraints.

We can conclude that in head-on accidents the use of restraints increases the incidence of neck injuries, but their severity is reduced. One factor in this reduction is that with restraints there are fewer severe windshield injuries of the neck. Impact force injuries to the back are increased with restraints in head-on crashes. Abdominal injuries are proportionately more frequent due to an increase in restraint caused injuries, although the incidence of wheel and instrument panel injuries to the abdomen is considerably reduced.

3.8 Injury producing contact points for T/L intersection accidents

One might suspect that in T/L crashes there would be more side contact than normal, but compared to all accidents in general, T/L intersection crashes show no major differences in incidence of injury for any area of contact, including the side. However, there are significant reductions in the severity of overall injuries for instrument panel, windshield, floor, and side glass contact and impact force type injuries when compared to all configurations taken together. However, there are no corresponding severity reductions for any specific body region.

The effects of restraints on the pattern of injuries in T/L intersection configurations can be determined by analyzing Table 52. Restraints significantly reduce the severity of wheel, side glass and front seatback induced injuries. The reduction in severity of roof induced injuries is close to being significant (.0516). There are considerably fewer windshield, instrument panel, roof, and front seatback contacts, but more restraint caused injuries when restraints are worn.

Regarding the body regions, restraints significantly reduce the severity of head injuries resulting from roof contact, not only when compared to nonwearers in T/L crashes but also when compared to restraint wearers in other configurations. This is probably the reason for the reduction in the severity of roof inflicted injuries with restraints. The use of restraints also reduces the severity of side glass injuries to the head. This is true when comparing users to nonusers in T/L crashes and also to users in other types of accidents, although this conclusion can only be made for drivers because there are too few right-front passengers in this situation. The incidence of windshield and outside injuries to the head is significantly reduced with restraints, but the relative amount of side glass contact for head is increased for those with restraints. There are relatively fewer instrument panel contacts for the shoulder, but more impact force shoulder injuries for restrained occupants. An interesting phenomenon shows up for chest injuries. The use of restraints results in significantly less severe chest injuries from side contact for drivers, but in more severe chest injuries from side contact for right-front passenger when compared to nonusers. There is also a reduction in the severity of wheel induced chest injuries, but this attains significance only for drivers because there are too few right-front passenger cases to enable us to draw any conclusion for this position. Chest contact with the instrument panel is reduced with restraints for both seated positions, but because of the scarcity of cases

TABLE 52

CONTACT POINT COMPARISON FOR
T/L TYPE ACCIDENT CONFIGURATION

		Overall		Head		Shoulder	
		Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity
Dash	$\overline{RSU}$	20.30	1.75	6.40	1.56	8.77	1.47
	RSU	14.20	1.66	4.50	2.25	5.90	<<
Windshield	$\overline{RSU}$	13.20	1.79	30.60	1.16		
	RSU	5.30	1.50	15.90	1.50		
Floor	$\overline{RSU}$	4.98	2.18				
	RSU	6.73	2.71				
Wheel	$\overline{RSU}$	11.50	1.81	3.80	1.20	8.77	1.33
	RSU	13.20	1.40	8.00	1.00	11.80	
Side	$\overline{RSU}$	20.00	2.41	19.20	1.84	24.60	1.45
	RSU	20.90	2.22	17.40	1.93	41.20	1.00
Side Glass	$\overline{RSU}$	4.69	2.11	10.00	1.38		
	RSU	6.97	1.52	19.30	1.12		
Roof	$\overline{RSU}$	5.03	2.28	14.70	1.87	10.50	1.28
	RSU	2.88	1.58	14.80	1.15	-	-
Front Seatback	$\overline{RSU}$	5.09	1.79			9.94	1.53
	RSU	2.16	1.00			11.80	<<
Restraints	$\overline{RSU}$	0.002	1.75			-	-
	RSU	11.50	1.92			17.60	<<
Outside	$\overline{RSU}$	2.40	3.76	7.70	2.34	12.90	1.86
	RSU	1.44	3.50	2.30		-	-
Hyper-extension	$\overline{RSU}$	3.55	1.24				
	RSU	3.85	1.31				

TABLE 52 (CONTINUED)

		Chest of Driver		Chest of Right Front Pass.		Back	
		Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity
Dash	$\overline{RSU}$	6.60	1.80	45.10	1.57		
	RSU	-	-	27.80	2.60		
Windshield	$\overline{RSU}$						
	RSU						
Floor	$\overline{RSU}$						
	RSU						
Wheel	$\overline{RSU}$	43.40	1.70				
	RSU	51.00	1.16				
Side	$\overline{RSU}$	32.90	2.71	23.10	2.05	23.90	1.25
	RSU	30.60	1.80	38.90	3.71	16.00	1.20
Side Glass	$\overline{RSU}$						
	RSU						
Roof	$\overline{RSU}$						
	RSU						
Front Seatback	$\overline{RSU}$					11.10	1.14
	RSU					4.00	[illegible]
Restraints	$\overline{RSU}$					-	-
	RSU					28.00	1.43
Outside	$\overline{RSU}$	3.90	3.22				
	RSU	-	-				
Hyper-extension	$\overline{RSU}$					23.90	1.06
	RSU					36.00	1.30

TABLE 52 (CONTINUED)

		Abdomen		Pelvis of Driver		Pelvis of Driver	
		Per- cent	Mean Sev- erity	Per- cent	Mean Sev- erity	Per- cent	Mean Sev- erity
Dash	$\overline{RSU}$	11.40	1.57			15.00	1.50
	RSU	-	-			-	-
Windshield	$\overline{RSU}$						
	RSU						
Floor	$\overline{RSU}$						
	RSU						
Wheel	$\overline{RSU}$	36.70	1.66	12.00	1.45		
	RSU	24.10	1.08	3.10	<<		
Side	$\overline{RSU}$	29.10	2.65	55.40	1.49	52.50	1.90
	RSU	11.10	2.83	31.30	1.10	64.70	1.91
Side Glass	$\overline{RSU}$						
	RSU						
Roof	$\overline{RSU}$						
	RSU						
Front Seatback	$\overline{RSU}$						
	RSU						
Restraints	$\overline{RSU}$	-	-	-	-	-	-
	RSU	57.40	1.26	40.60	1.23	29.00	1.40
Outside	$\overline{RSU}$						
	RSU						
Hyper- extension	$\overline{RSU}$						
	RSU						

the reduction achieves a significance of only .07 for the right-front passenger. The only significant difference in injuries to the back is that there are more restraint caused back injuries for those with restraints. The abdomen is receiving less severe wheel caused injuries with restraints. Both abdomen and pelvis evidence more restraint system caused injuries, but also a relative decrease in wheel, side, and instrument panel induced injuries with restraints. By considering seated positions and their effect on pelvic injuries in this configuration, we see that the wheel and side contact reductions are only for the driver, while the decrease in instrument panel contact for the pelvis is only for the right-front passenger. This pattern is probably also true for the abdomen. Furthermore, only for the driver is there a reduction in the severity of pelvic injuries from side contact. In fact, the difference in side induced pelvic injury severity levels between restrained drivers and restrained right-front passengers is significant in this configuration. There is also a difference in side caused pelvic injury severity levels between the two seated positions for nonrestrained occupants, but it is smaller and less significant (.0887).

From these results we can conclude that T/L crashes result in generally less severe injuries than normal. Restraints keep the head from hitting the side glass and roof as severely, and from hitting the windshield as frequently. Restraints seem to be more effective for the driver because they reduce the severity of side induced injuries to the chest and pelvis for the driver but actually increase the severity for the right-front passenger. They also reduce the severity of wheel induced chest, abdomen, and pelvis injuries for the driver. However, restraints themselves are the cause of many back, pelvis, and abdomen injuries. In summary, in T/L crashes restraints act to reduce the number of injuries by keeping the body from being thrown around, but they are associated with more impact force and restraint contact injuries. However, their net effect is to reduce the incidence of injury. The severity of injuries is reduced mainly for the driver by limiting the severity of his contact with the wheel and side.

3.9 Injury producing contact points in sideswipe accidents

There are few remarkable results for the sideswipe configuration.

Table 53 reveals that there are no differences in the incidence of contact with any area of the car between the sideswipe and all accidents in general, but there are significantly fewer severe instrument panel contacts in sideswipes than in other crashes.

We have reported previously that the use of restraints in sideswipes significantly reduces the incidence of injury. Upon examining each row of Table 53 separately, we find no marked differences in severity of injury when restraints are worn. There is, however, relatively more side contact but less side glass contact with restraints.

The only conclusion to be drawn is that sideswipe accidents are generally less severe than other types of accidents. In general, restraints reduce the incidence of injuries. They allow side contact but tend to prevent side glass contact. However, we can see no reduction of injury severity by use of restraints.

3.10 Regarding injury producing contact points for rear-end accidents.

Rear-end crashes are notable for their lack of significant effects. For this reason, we do not analyze this configuration.

3.11 Injury producing contact points in rollover accidents

More people are injured and they are injured more severely in rollover situations than in non-rollovers.

Upon comparing Table 54 with Table 39, we find that for the unrestrained person there are relatively fewer but more severe instrument panel and windshield contacts but more roof and outside object contacts in rollovers than in non-rollovers. The data

TABLE 53

CONTACT POINT COMPARISON
FOR SIDESWIPE ACCIDENTS

		Percent	Mean Severity
Dash	$\overline{RSU}$	18.60	1.73
	RSU	11.50	1.71
Windshield	$\overline{RSU}$	10.20	2.45
	RSU	4. 9	<<
Floor	$\overline{RSU}$		
	RSU		
Wheel	$\overline{RSU}$	11.20	1.88
	RSU	11.50	1.86
Side	$\overline{RSU}$	15.80	2.44
	RSU	27.90	2.35
Side Glass	$\overline{RSU}$	5.12	2.09
	RSU	1. 6	<<
Roof	$\overline{RSU}$	8.84	2.89
	RSU	11.50	2.57
Front Seatback	$\overline{RSU}$	3.72	1.63
	RSU	1. 6	<<
Restraints	$\overline{RSU}$		
	RSU		
Outside	$\overline{RSU}$		
	RSU		
Hyper-extension	$\overline{RSU}$	6.05	1.38
	RSU	3. 3	<<

TABLE 54

CONTACT POINT COMPARISON FOR ROLLOVER ACCIDENTS

		Overall		Head		Neck		Shoulder	
		Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity
Dash	$\overline{RSU}$	13.60	2.52						
	RSU	10.60	1.65						
Windshield	$\overline{RSU}$	6.93	2.65	14.10	1.83				
	RSU	3.75	2.17	7.90	<<				
Floor	$\overline{RSU}$	2.79	2.68						
	RSU	6.88	1.36						
Wheel	$\overline{RSU}$	7.15	2.16						
	RSU	7.50	2.33						
Side	$\overline{RSU}$	18.00	2.57	13.60	1.96	8.60	2.00	24.80	1.32
	RSU	16.30	2.19	10.50	3.50	15.40	<<	43.80	1.00
Side Glass	$\overline{RSU}$	4.58	2.29	4.80	1.60				
	RSU	8.75	1.79	7.90	1.00				
Roof	$\overline{RSU}$	16.40	2.54	34.00	1.67	20.40	3.00	18.60	1.29
	RSU	15.00	2.25	42.10	1.81	-	-	6.25	1.00
Front Seatback	$\overline{RSU}$	3.46	1.38			8.60	1.13	4.42	1.20
	RSU	2.50	1.75			-	-	12.50	1.50
Restraints	$\overline{RSU}$	-	-			-	-	-	-
	RSU	11.90	1.89			23.10	<<	18.80	1.00
Outside	$\overline{RSU}$	10.40	3.99	17.90	4.03	20.40	3.79	20.40	1.57
	RSU	1.25	1.50	-	<<	7.69	1.00	-	-
Hyper-extension	$\overline{RSU}$	2.46	1.36			17.20	1.13		
	RSU	4.38	1.57			30.80	1.00		

TABLE 54 (CONTINUED)

		Chest		Pelvis	
		Per-cent	Mean Sev-erity	Per-cent	Mean Sev-erity
Dash	$\overline{RSU}$	10.30	2.19		
	RSU	5.88	<<		
Windshield	$\overline{RSU}$				
	RSU				
Floor	$\overline{RSU}$				
	RSU				
Wheel	$\overline{RSU}$	20.00	1.84		
	RSU	23.50	1.00		
Side	$\overline{RSU}$	20.60	2.34	36.70	1.36
	RSU	11.80	<<	27.30	1.33
Side Glass	$\overline{RSU}$				
	RSU				
Roof	$\overline{RSU}$	6.45	2.10		
	RSU	5.88	<<		
Front Seatback	$\overline{RSU}$				
	RSU				
Restraints	$\overline{RSU}$	-	-	-	-
	RSU	11.80	<<	72.70	1.50
Outside	$\overline{RSU}$	18.70	3.24	28.30	2.12
	RSU	-	-	-	-
Hyper-extension	$\overline{RSU}$				
	RSU				

from Table 54 can also be used to compare contacts with various areas of the car for the restrained versus the unrestrained occupant in rollovers. One effect of restraints is to decrease the severity of overall injuries resulting from instrumnet panel contact and floor contact. As is mentioned above, there are more severe instrument panel caused injuries in rollovers for unrestrained occupants. For restrained people, however, these injuries are actually less severe than in non-rollovers. Thus, the use of restraints produces a significant effect on this type of injury. Floor injuries sustained by the unrestrained occupant are about as severe in rollovers as in non-rollovers, but with restraints they are significantly less severe in rollovers than in non-rollovers. This again indicates a significant effect of restraints on the severity of injuries from this contact area. The use of restraints also reduces the relative number of injuries resulting from outside object and windshield contact, but increases the incidence of floor and restraint system caused injuries.

By looking at the various body regions, further insight into the effect of restraints in rollovers is obtained. For example, side contact for the shoulder results in less severe injuries when restraints are worn. As for the incidence of injury to various body regions, there are proportionately fewer outside object caused injuries to the head. There are also relatively smaller numbers of roof, outside, and front seatback induced neck injuries, but more restraint system caused injuries with restraint use. The shoulder is receiving relatively more injuries from the side and restraint system, but fewer outside and roof contacts. For the chest and pelvis, there are relatively fewer outside contacts, but more restraint system injuries.

This suggests that rollovers result in generally more severe injuries than nonrollovers, with a higher proportion of extremely hazardous ejections, and more violent contacts. Restraints do their job by keeping some body regions from hitting or being hit by parts of the car and reducing the severity of contact for other regions. Specifically, they allow the head to hit the roof of the car, but the neck and shoulders are being restrained from roof contact. As in other configurations, there is less windshield contact for the head with restraints. The neck is not hitting the front seatback as much with restraint use, but the shoulder is hitting the side relatively more often but not as severely. The pelvis is receiving relatively more injuries from the restraint system itself. A major benefit of restraints is the reduction of outside contact, primarily from ejection.

SECTION IV: A SUMMARY OF THE REPORT

The concluding observations are presented as a self-contained entity, and are intended as a digest of the entire report that can be read separately.

The report consists of three related investigations of restraint usage and effectiveness.

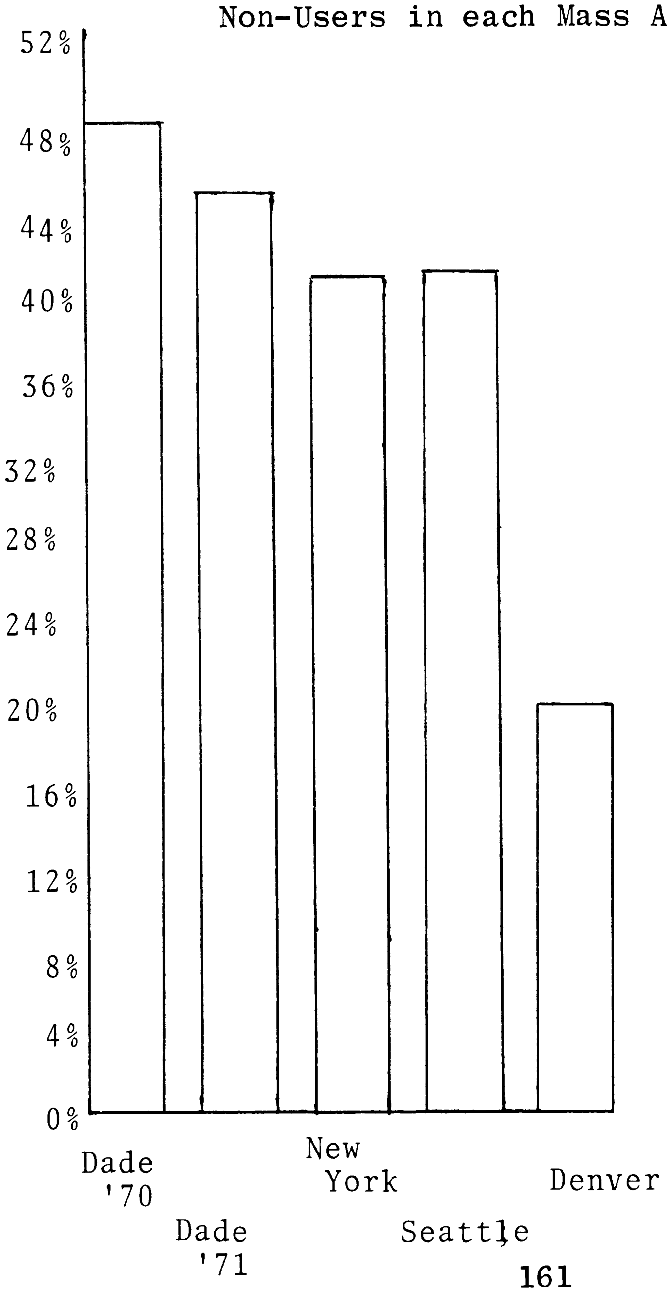
The first part is concerned with a determination of the demographics of restraint system usage -- in other words, who uses them, and who doesn't. The reason for this part of the study is that this knowledge could be valuable in the effort to increase restraint usage. The determination is accomplished by drawing on the Collision Performance and Injury Report, Revision 3, Occupant File, and the five mass accident data files maintained by the HSRI: Denver County, Cornell Level I, Seattle, Dade County (1970), and Dade County (1971). However, there are different data collection procedures used to obtain the various files and this is reflected in Figure 32 comparing the proportions of the restraint users in each of the mass accident files.

While there may be some differences in usage rates due to reporting biases, this is no problem if we analyze each file separately.

The factors that are deemed important in a demographic analysis of usage are sex and age from the mass accident files, and type of road on which the accident occurred, speed of case vehicle at impact, and the driver's physiological condition from the CPIR file. The determination of the effect of these factors on restraint usage is accomplished by comparing the proportions of users at various levels of each of the factors. The hypothesis is that there is no effect, and only if the difference in the proportions is so great that there is virtually no chance that it could be due to random error do we reject the hypothesis and conclude that there is an effect. This chance is generally taken to be less than .05 and if this is the case, we call the differ-

Figure 32

Proportions of Restraint Users and Non-Users in each Mass Accident File



ences"significant." This same statistical procedure is used throughout the report -- whenever an effect is to be measured, the assumption of no effect is made and is rejected only if the data conclusively show otherwise. One problem inherent in these tests is that the significance level depends not only on the size of the difference but also on the number of cases involved. Thus a sizable difference may not be significant because the number of cases is just too small.

In the age analysis, all five mass accident files indicate that about 5% fewer drivers 16 to 21 years of age use their restraints than those over 22 years old, a difference that is significant. Figure 33 exhibits the age comparison for the five mass accident files.

In addition to not using their restraints, the 16 to 21 age group also is overinvolved in accidents in general. Consequently, we suspect that if the objective is to increase the restraint usage of those most likely to be involved in accidents, it can best be realized by focusing efforts to encourage restraint usage on this age group.

The comparison of usage rates between sexes indicates that there are some noticeable differences. Interestingly, these differences are not the same for the various data files, or between drivers and passengers, or even from one time to another. This is illustrated in Figure 34.

Although most of the differences in restraint usage illustrated above are significant, none is strong enough to indicate that a person's sex is a good predictor of his restraint usage.

The CPIR file is consulted for information as to the effect of speed and type of road on the use of restraints. It indicates that there is a significantly higher proportion of restraint users among those who travel on limited access roads than those who don't (25.6% vs. 18.5%). The hypothesis that this is really a reflection of a speed effect is not accepted, since the differences in restraint usage at various speeds are not significant.

Figure 33

Proportions of Restraint Users and Non-Users in Each Mass Accident File by Age

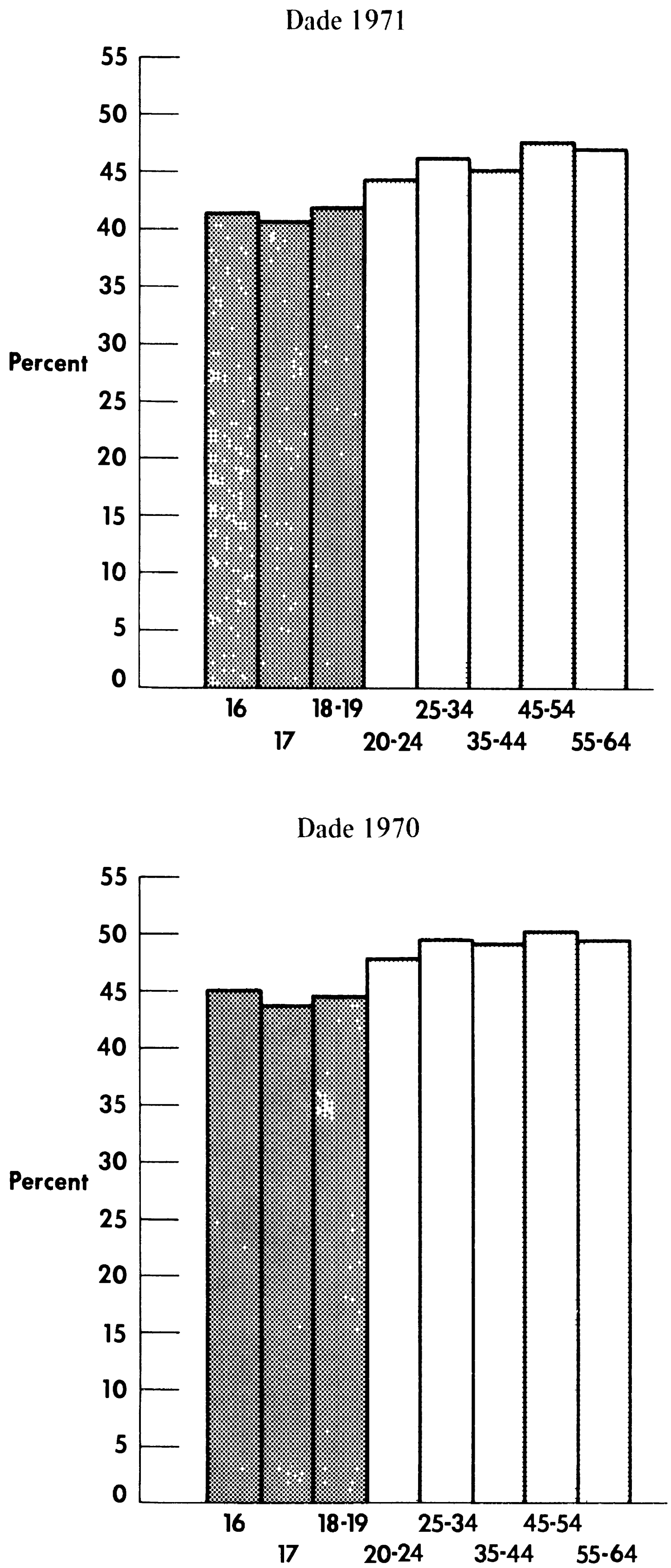
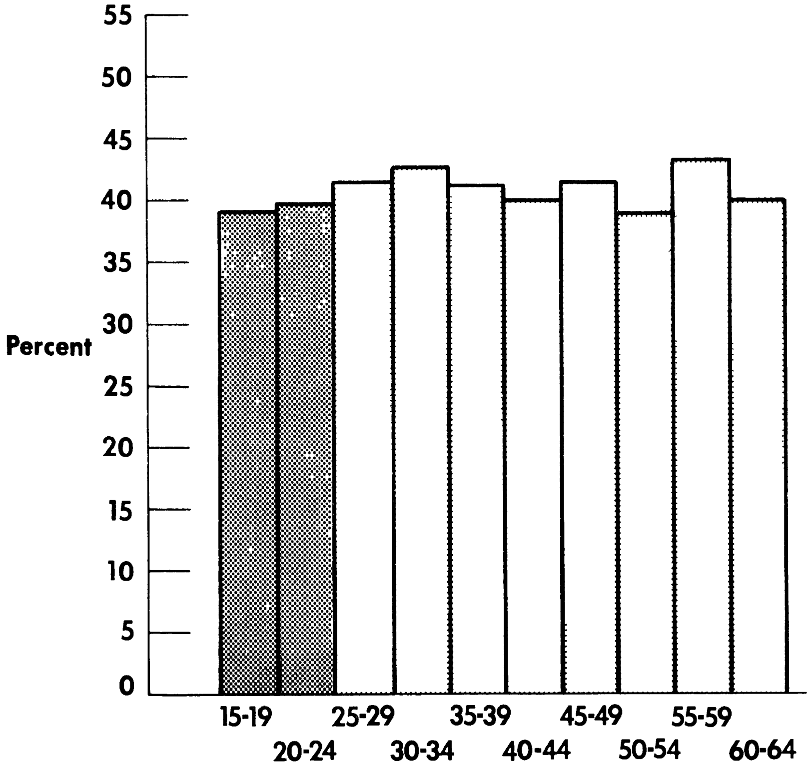


Figure 33 (contd.)

King County



New York Counties

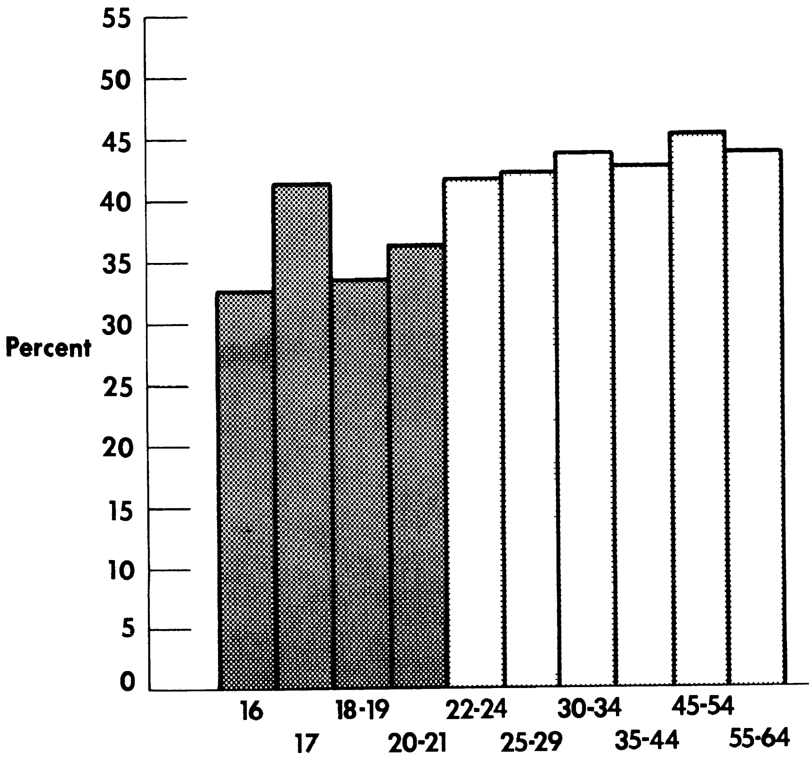


Figure 33 (Contd)

Restraint Use by Age, Denver

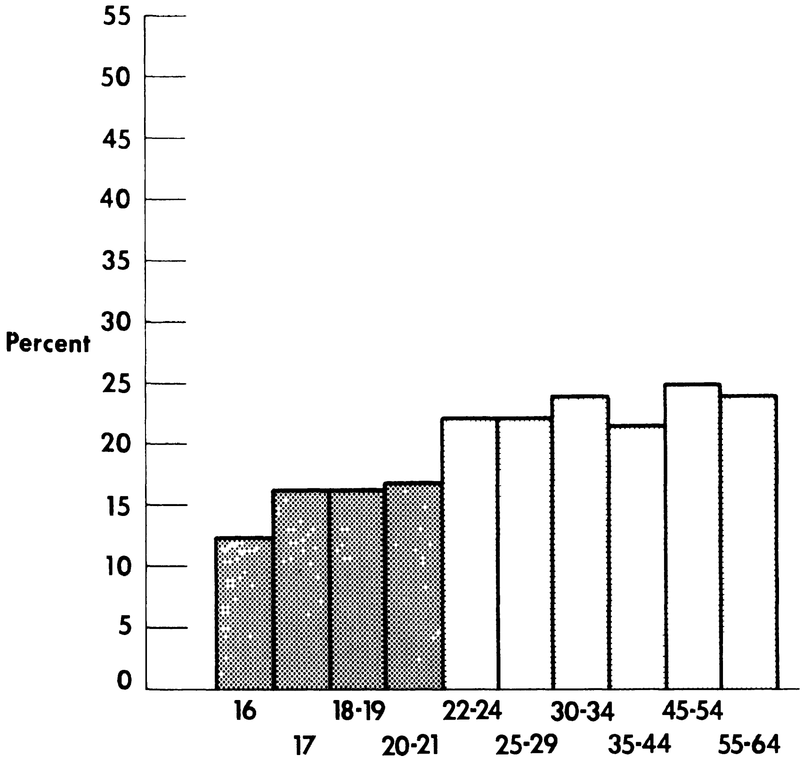


Figure 34

Restraint Use by Sex

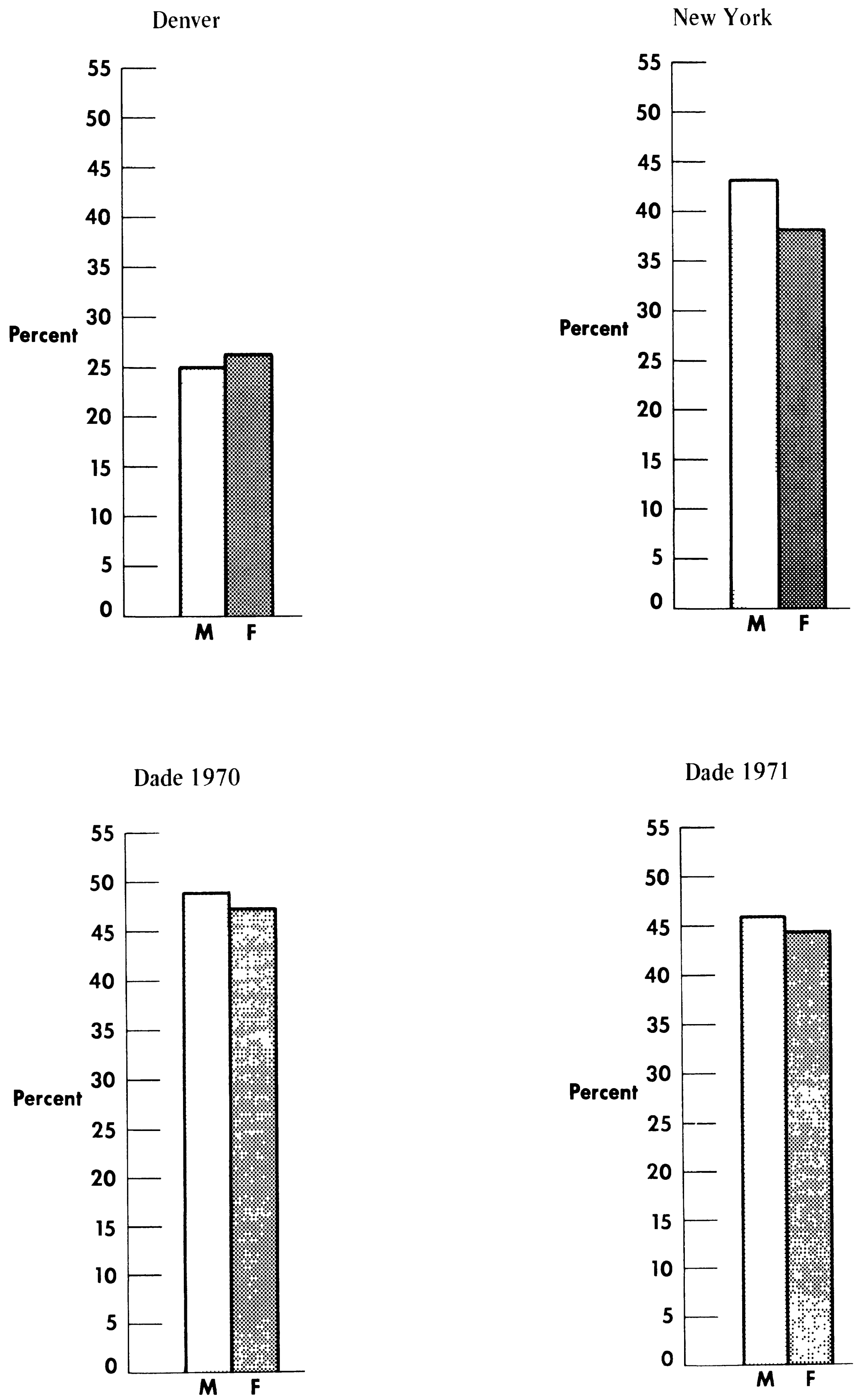
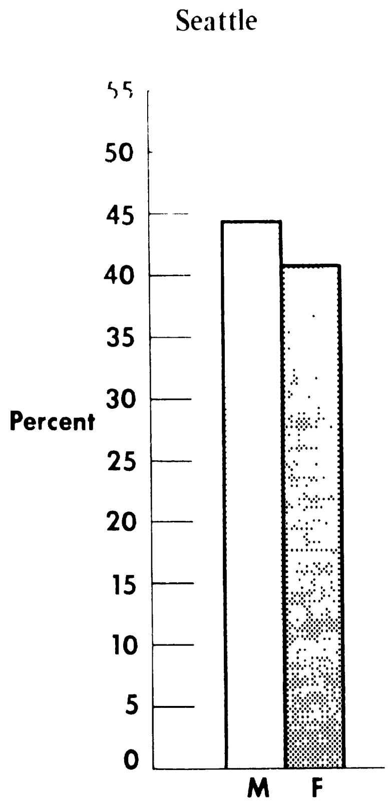


Figure 34 (Contd.)



Hence, it cannot be said that the reason those persons driving on expressways use their restraints more often is because they are going at a greater speed.

Figure 35 reveals the effect of the driver's physiological condition on his restraint usage.

Grouping the drunk and drinking drivers together as one class yields the result that those drivers who drink are significantly less likely to wear their restraints, but as with the sex factor, this is not a good predictor of their restraint usage.

The conclusions to be drawn from this part of the study are that the drivers least likely to wear their restraints are the 16 to 21 year olds, the drinkers, and those not using limited access highways. The evidence also suggests that there are no groups among those tested that exhibit high usage rates.

Another question addressed in the first part of the report is the distribution of methods of circumventing the seat belt buzzer system, and secondly, its effectiveness in increasing seat belt use. The approach to an answer was through a survey of drivers of 1972 and 1973 American-made cars. Since the buzzer was only installed in post-January 1972 cars, the drivers of cars produced prior to this time constituted the control group.

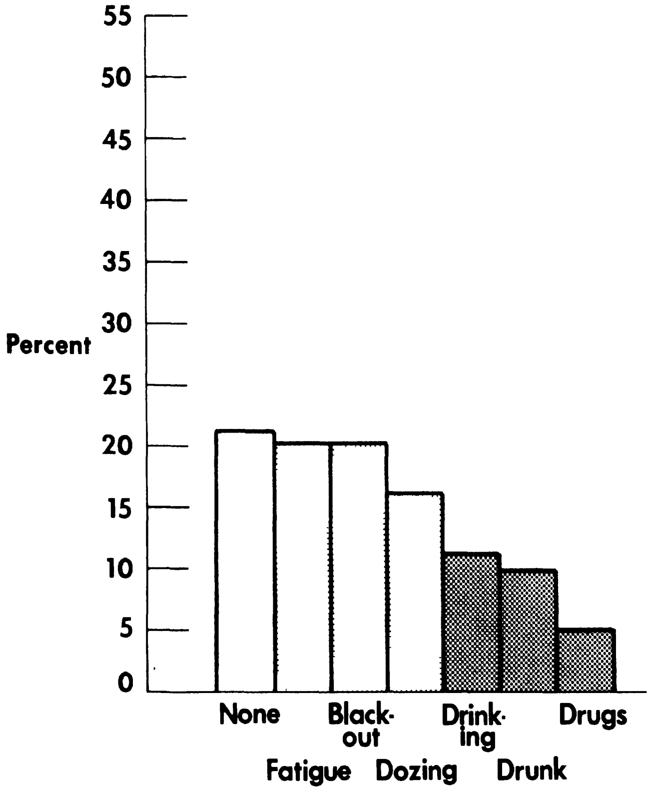
It was decided that the measure of the effect of the buzzer would be the difference between the percentages of seat belt wearing in pre-buzzer cars and in buzzer equipped cars. In order to determine the effect of other factors such as advertizing on seat belt wearing habits, the control group was asked the difference in their percentage seat belt use from the previous year -- a span of time comparable to the time that the buzzer was affecting the other subjects.

The survey was conducted in the parking lots of two shopping centers near Ann Arbor during the latter part of November and early December, 1972. Both weekdays and weekends were utilized.

In addition to the change in their seat belt wearing habits, those who had buzzers and did not use their seat belts all the time were also asked how they foiled the buzzer.

Figure 35

Proportion of Restraint Users and Non-Users by Drivers Physiological Condition



Because individuals find it hard to specify their percentage use of restraints in precise terms, it was decided to have them report their percentage seat belt usage with one of four responses: "none of the time," "less than half the time," "more than half the time," and "all the time," These four answers were then associated with the values 1.00, 2.00, 3.00, and 4.00 respectively, of a continuous variable. It was this variable on which further calculations were performed.

It was also recognized that the potential change in the seat belt wearing habits of an individual depended on his prior seat belt use -- someone who always wore their seat belt would be unaffected by the buzzer, whereas someone who never wore their seat belt could potentially change to 100% use. Accordingly, Table 55 compares not only the net change in seat belt use for all respondents, but also the change for those in each of the four categories of prior restraint use.

We see from the table that the buzzer indeed produces a difference in seat belt use over and above that produced by other factors, and this is true for all categories of prior use except those that always wore their seat belts.

The primary question is the distribution of methods of beating the buzzer and Table 56 shows this distribution.

The primary method of beating the buzzer is simply to keep it permanently buckled.

This survey depends on the respondents giving honest answers to questions concerning seat belt use and does not use a truly random sample of the driving population. Both criticisms are valid, but unavoidable, given the necessary limitations of the project. However, it is felt that the distribution of ways of beating the buzzer reflects no biases attributable to attitudes of the subjects toward the interviewer.

The second part of this study is an analysis of the effect of restraints on both the incidence and severity of injury. The data for this analysis come from the CPIR file. Although this file is biased towards an over-representation of cases in which people were injured, there seems no reason to believe that the distribution of injuries is otherwise biased in regards

Table 55

Effectiveness of the Seat Belt Buzzer System

Categorized by Previous Use

Prior Use Variable	Mean Subsequent Use	Buzzer Difference $[d_1]$	$P[d_1=0]$	Mean Subsequent Use	No Buzzer Difference $[d_2]$	$P[d_2=0]$	d_1-d_2	$P[d_1-d_2=0]$
1.00	1.94	+.94	.0000	1.32	+.32	.0157	+.63	.0003
2.00	3.11	+1.11	.0000	2.27	+.27	.0406	+.85	.0000
3.00	3.45	+.45	.0531	3.00	0.0	1.000	+.45	.0271
4.00	3.90	-.10	.1094	3.89	-.11	.3306	+.01	.50

All Cases

Mean Prior Use Variable	Subsequent Use	Buzzer Difference $[\bar{d}_1]$	Mean Prior Use in Percent	Mean Subsequent Use	No Buzzer Difference $[\bar{d}_2]$	$\bar{d}_1-\bar{d}_2$	$p[\bar{d}_1-\bar{d}_2=0]$
2.31	2.93	+.62	2.42	2.55	+.13	+.49	.0026

Table 56

Distribution of Methods of Beating the Buzzer

Method	Number	Percent
Buckle seat belt but not around occupant	56	59.6%
Deform seat belt so it cannot retract	5	5.3%
Disconnect or tear out mechanism	10	10.6%
Let it buzz	1	1.1%
Fasten seat belt to some object to keep it from retracting	18	19.1%
Buzzer self-failure	4	4.3%

to restraint usage, conditions surrounding the accident, or the areas of the body sustaining injuries.

We compare the incidence and severity of overall injuries to restrained and unrestrained occupants, and test for statistical significance of the differences. We also do this for injuries to selected body regions.

One problem with this approach is that there may be some interrelationship between restraint users and the type of accidents they are involved in. For example, restraint users might by nature be more cautious and therefore involved in less severe accidents. To eliminate this possible bias, we control on several factors that might have an effect on the severity of the accident, such as speed at impact, vehicle deformation, rollovers, and accident configuration. We also control on seated position.

It would have been valuable to have conducted our analyses for both lap belted and fully restrained occupants separately, but with only 2% of the occupants fully restrained it was decided to combine these two categories into one.

The first presentation is a series of graphs depicting the per cent of restrained or unrestrained cases that were injured at various levels of severity for each accident configuration or associated accident variable, such as speed. The severity of injury is measured by a variable called Abbreviated Injury Scale and denoted AIS. It is treated here as a continuous variable but with only integer values assigned for each injury. They range from 0 (no injury) to 9 (fatal injuries to 3 or more separate body regions) for overall injuries, and to 6 (fatal) for injury to each body region. A comparison of the graphs for restrained and unrestrained occupants indicates not only the relative proportion of injuries (by comparing the curves at AIS of 0, no injury) but also suggests the relative severity of the resulting injuries. The graphs are presented as Figures 7 through 29 of the main report. Among the many implications, the most general is that restraint use results in a general reduction of both the incidence and severity of injury.

We next test the differences in the per cent of injuries between restrained and unrestrained occupants for statistical significance. As before, we do this not only for overall injuries, but also for injuries to each body region. Furthermore, we also perform this analysis while controlling on factors related to the accident, such as configuration, speed, etc. Finally we compare the differences at various levels of these factors in an effort to see if they have an effect on restraint operation.

The following figures reveal the relative proportions of overall injuries and injuries to specific body regions for restraint wearers and nonwearers. Statistical analysis reveals that with restraints the incidence is reduced significantly for overall injuries and injuries to the organs, brain, head, and chest. The increase in abdominal injuries for restrained occupants is also significant. (See Figures 36 and 37.)

Statistical analysis of the incidence of injury for restrained and unrestrained persons reveals that the use of restraints significantly reduces the incidence of injury in T/L intersection and sideswipe configurations. Upon testing for differential restraint effects among the configurations however, we find that there is no significant difference in the incidence of overall injury among the various configurations. This lack of significance is probably due to the scarcity of cases for some of the accident types. However, we do find that restraints exert significantly different effects on the incidence of neck, back, and abdomen injuries in the various types of accidents. Specifically, there are significant increases in the per cent injured when restraints are worn in head-on collisions for these body regions. This is not to say that there are not significant restraint effects on other body regions and in other configurations, but the lack of cases renders many tests of equality of effects inconclusive.

Figure 36

Injury Rate for Restrained and Unrestrained Occupants

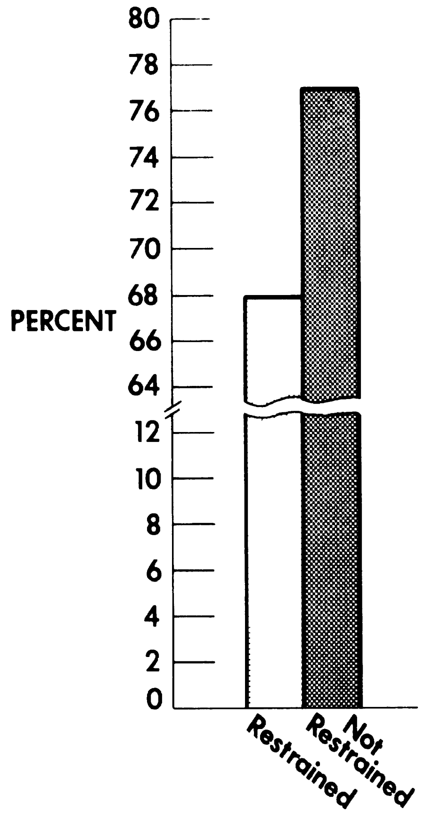
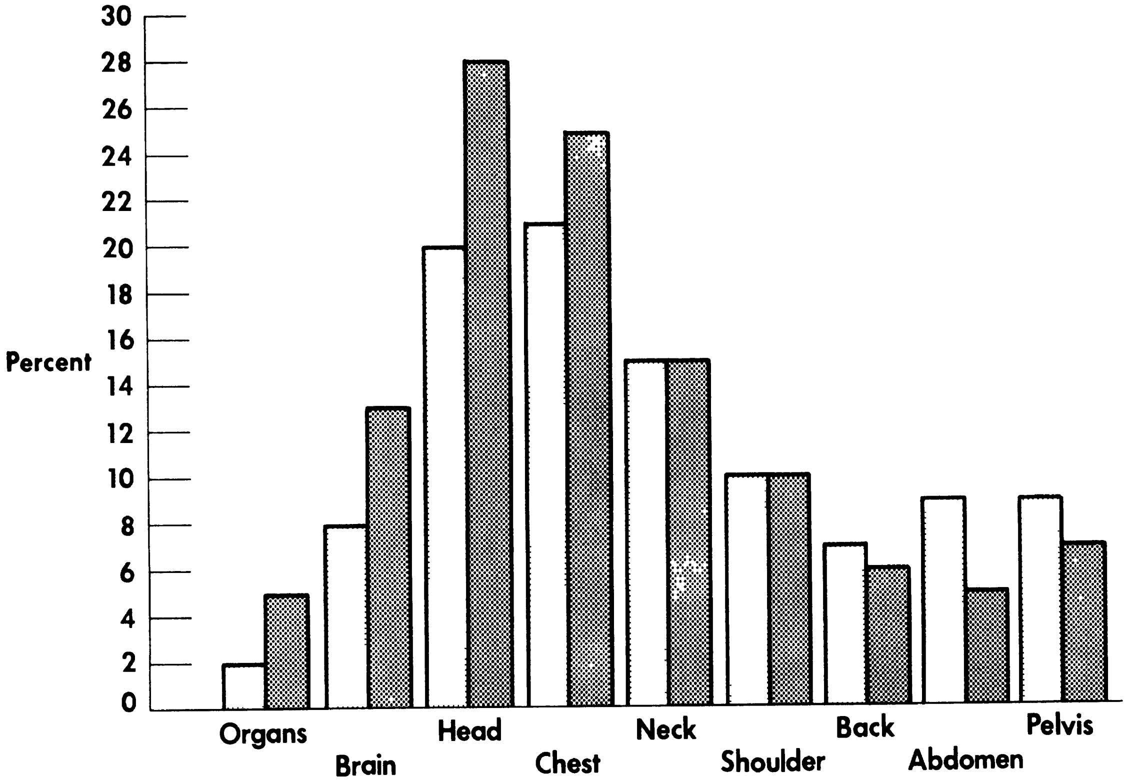


Figure 37

Proportions of Injuries Incurred to Select Body Regions by Restrained and Unrestrained Occupants



The rollover situation, while not in itself an accident configuration, is a possible result of collisions, and we consider here whether restraints exert a differential effect in this situation. The data reveal that the incidence of injury is reduced in both rollovers and non-rollovers with restraints, and it cannot be concluded that there is any difference in restraint effect in the two situations. However, for both chest and abdomen injuries there is a significantly different restraint effect in rollovers than in non-rollovers, while the difference in the effect on organ injuries is also marked but not as significant (.07 chance that it is due to random error). For all these specific body regions it is in the rollover situation where restraints are more effective.

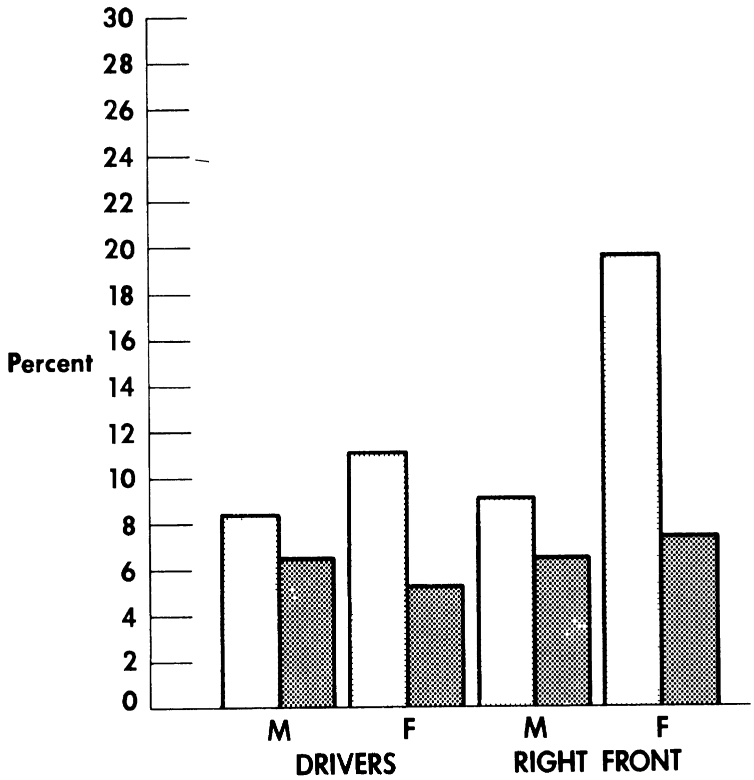
An analysis of seated position shows that only for the abdomen do we see a different restraint effect between the driver and right-front passenger. In this case there are increases in abdominal injury for both positions when restraints are worn, but the increase is much more pronounced for the right-front passenger. Thinking that this may be because of an actual sex effect, Figure 38 is presented to indicate the abdominal injuries for the two seated positions by sex. This shows that not only is there a different restraint effect between seated positions but also between the two sexes, with females more likely to receive abdominal injuries than males when restraints are worn.

The speed at impact variable is partitioned into three brackets: 0-30 mph; 31-60 mph; and greater than 60 mph. There are no significant differences in the effects of restraints on the incidence of injury at these three speed levels for overall injuries or for any specific body regions except organs, where there is a greater reduction at higher speeds.

Another variable that is in a sense related to the seriousness of the collision is the amount of sheet metal crush produced. This is reported in the CPIR file as the Vehicle Deformation Index Extent Code (VDI) and ranges from 1 to 9, with 9 being the most damaging. We partition this scale into three brackets: 1 and 2, 3 to 5, and 6 to 9. It turns out that organs, chest,

Figure 38

Proportion of Abdominal Injuries Incurred by Restraint Users and Non-Users by Seated Position and Sex



back, and abdomen all exhibit significantly different restraint effects for the three brackets. For the organs, there is a greater reduction in the proportions of injuries for restrained versus unrestrained occupants at higher VDI levels, whereas the abdomen reveals a greater increase in injuries at higher VDI levels for restrained people. For both the chest and the back there is a reversal from decrease to increase in injuries with restraints as VDI goes up.

The next portion of the study compares the severity of injuries received by restrained and unrestrained occupants. The severity figure is the mean AIS value of all injuries. We do not compare across configurations or values of the related variables as we did in the last portion of the study.

Figure 39 presents the mean injury levels for restrained and unrestrained occupants for those body regions where the difference in means attains statistical significance.

This figure reveals that the use of a restraint system significantly reduces the severity of the overall injuries sustained, and injuries specifically to the neck, shoulder, and pelvis.

Controlling on accident configurations, we find a statistically significant reduction in overall injury severity with restraints only in single-car accidents (see Figure 40). In this configuration there are also reductions in head, neck, and shoulder injury severity. While head-on accidents show no significant restraint effect on overall injury severity, neck injury severity is reduced significantly with restraints.

The rollover analysis indicates that overall injuries, and injuries to the head, neck, and shoulder are significantly reduced in severity in rollovers only. This suggests that restraints are more effective in rollovers than non-rollovers. (See Figures 41, 42).

Figure 43 shows that restraints are especially effective in reducing the severity of overall injuries at speeds over 60 mph. The analysis also indicates that this effect is true for the chest,

Figure 39

Mean Severity of Injury Incurred by Restraint Users and Non-Users to Selected Body Regions

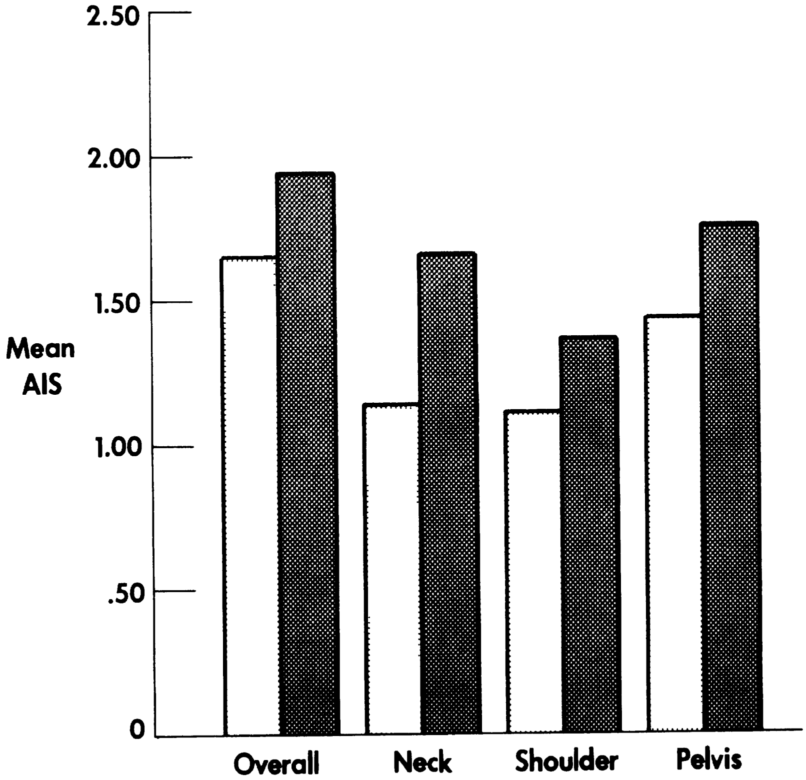


Figure 40

Mean Overall Injury Severity by
Restraint Users and Non-Users
by Accident Configuration

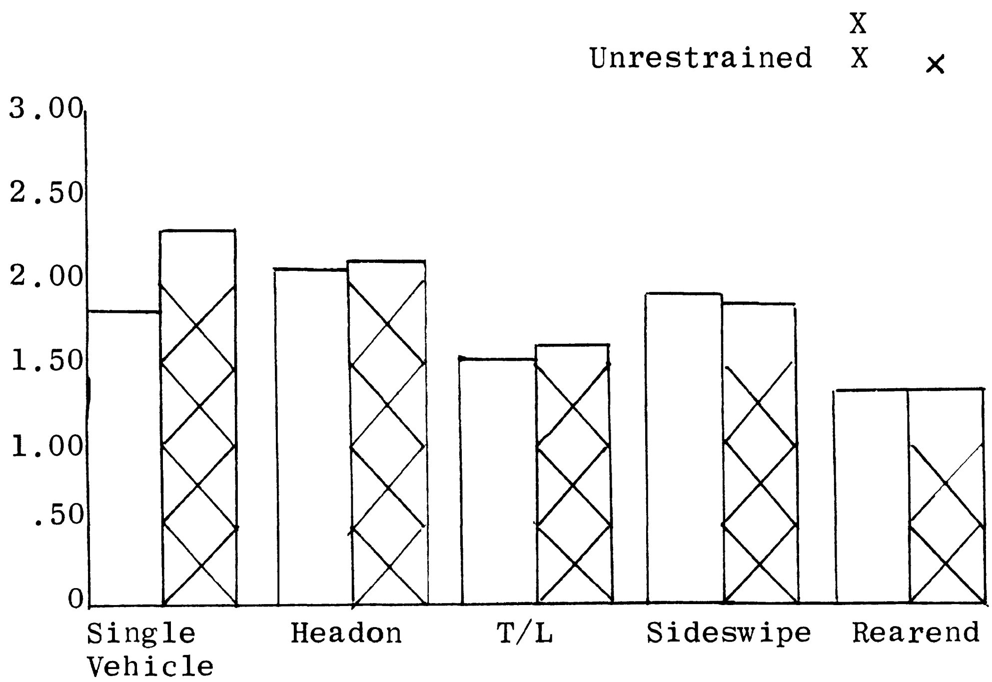


Figure 41

Mean Overall Injury Severity by Restraint Users and Non-Users in Rollover and Non-Rollover

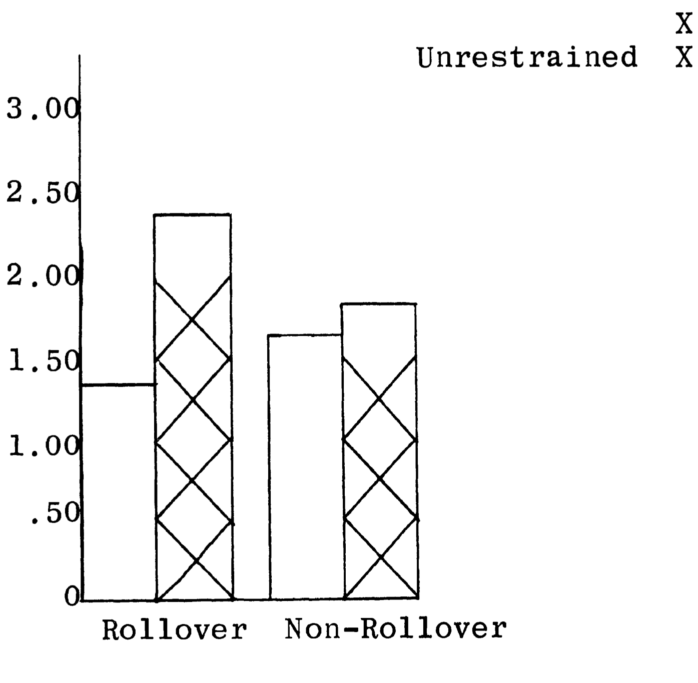


Figure 42

Mean Severity of Injury Incurred by Users and Non-Users of Restraints in Rollover Accidents

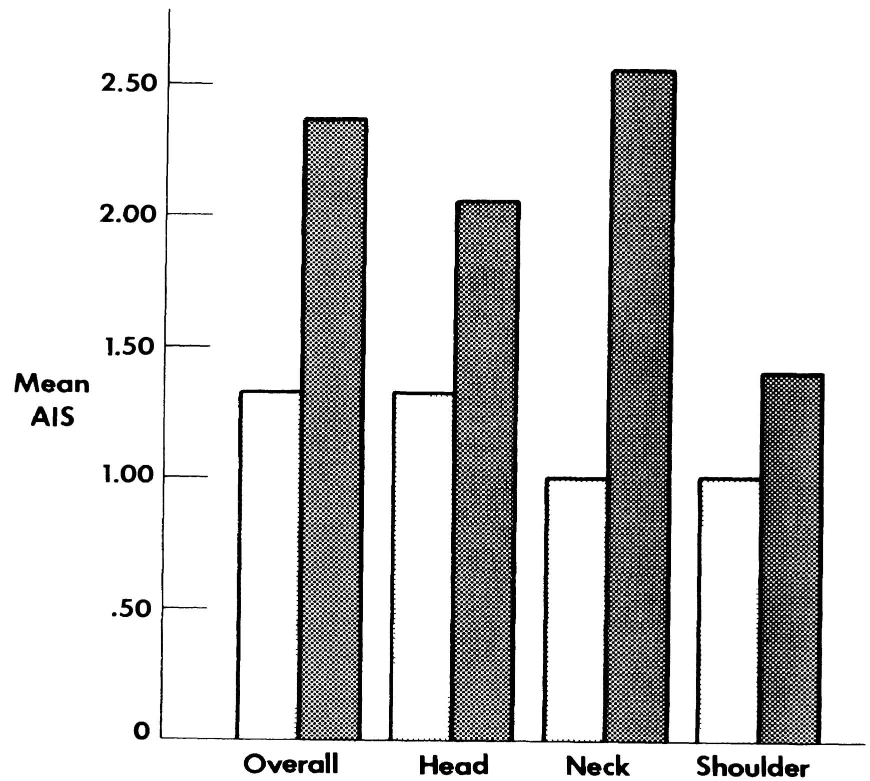
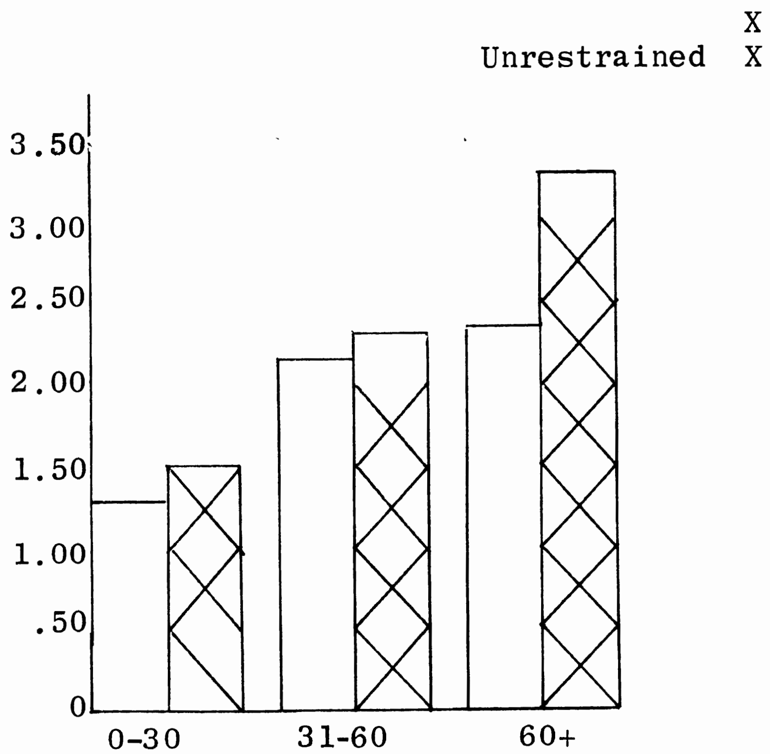


Figure 43

Mean Overall Injury Severity by
Restraint Users and Non-Users
by Speed of Impact



while there is a trend towards larger reductions in the severity of pelvic injuries as speed increases also.

Figure 44 reveals that at VDI of 3 to 5 there is a reduction of overall injury severity with the use of restraints. This is also true for the neck. Shoulder , pelvis, and abdomen injury severity is reduced significantly at VDI of 6 to 9.

One problem with the analysis of seated positions is that there are a lot fewer cases of right-front passenger injuries and thus a general lack of significant differences in severity. Nonetheless, the use of restraints results in a greater reduction of injury severity for drivers than right-front passengers. This reduction is significant for drivers. (See Figure 45).

The final part of this study is an analysis of contact points. By comparing the incidence and severity of injury from the various contact points in the car, we can gain insight into why the effects seen in previous sections occurred. It can also indicate the relative degree of injury production from various interior objects. As in the previous sections, we also control on certain variables related to the accident in an effort to see how the pattern of injuries changes at different values of these variables, and how restraints affect these changes.

The CPIR file lists up to ten contact points for the overall body and up to four for each region of the body. We group these contact points into ten general areas of contact: instrument panel, windshield, floor, steering wheel, side, side glass, roof, front seatback, restraint system, and outside objects, and one injury mechanism that does not require contact, impact force.

The severity of injury given for various contact areas should not be interpreted as resulting directly from contact with the area. This figure is actually the highest severity of injury that occurs to the overall body or to a specific body region for those occupants whose body or body region contacted the particular

Figure 44

Mean Overall Injury Severity by Restraint Users and Non-Users by VDI

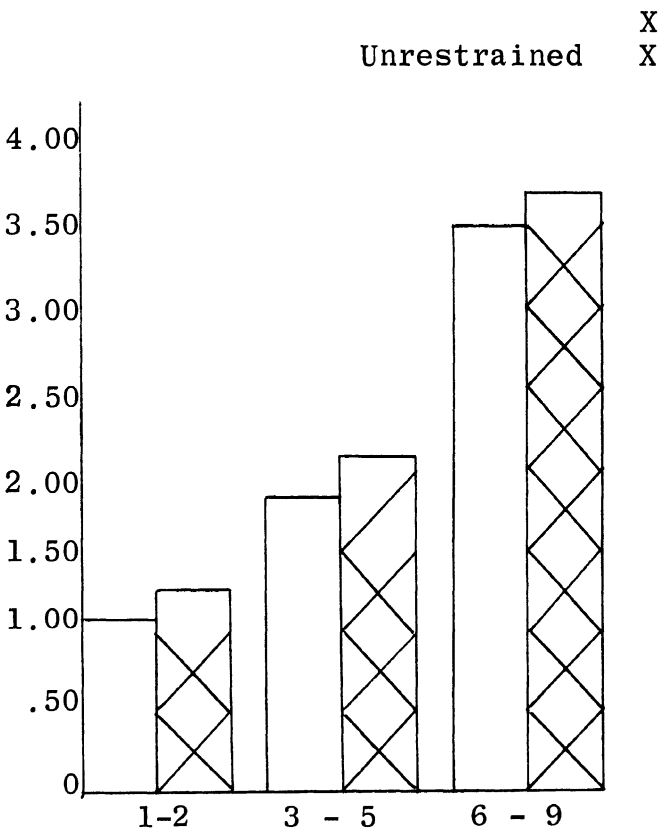
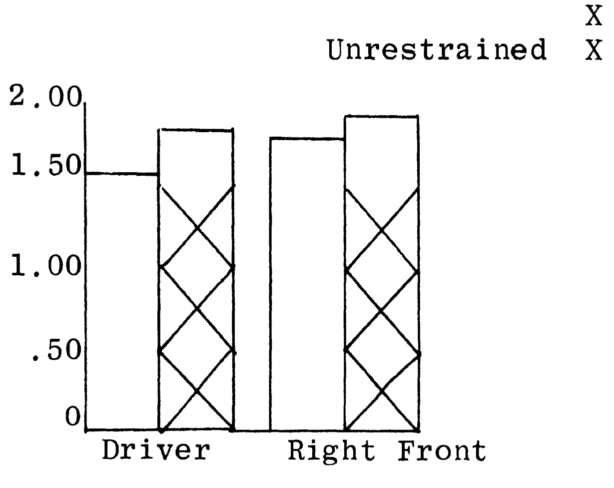


Figure 45

Mean Overall Injury Severity by Restraint Users and Non-Users by Seated Position



area, and thus the severity of the injury is only associated, perhaps indirectly, with the particular contact area.

The figures in this part of the study present comparisons of relative incidence and associated severity of injury for each contact area where there were sufficient cases. This is done by superimposing a pair of bars, one for restrained and the other for unrestrained occupants. The abscissas, or widths, of the bars are the relative per cent of all injuries to restrained or unrestrained people that are caused by contact with the particular area, and the ordinates, or heights, of the bars give the mean AIS associated with the contact. By comparing the overlaps we see the difference in relative proportions of injuries and associated severity.

Figure 46 reveals that there is a significant reduction in the severity of injury from outside contact and a relative decrease in the incidence of instrument panel, windshield, roof, front seatback, and outside object contacts when restraints are worn, but an increase in the relative number of injuries caused by the wheel and restraint system itself. In general, with restraint use the upper body is receiving less contact, or less serious contact, from the front, side and top of the passenger compartment, although the wheel is still being hit and the head is not restrained from side glass contact. The lower body is being restrained from hitting the wheel, instrument panel, sides, floor and other lower parts of the car's interior, but is instead receiving the less serious restraint system induced injuries. One major benefit of restraints is that they keep the body from being ejected.

Figure 47 demonstrates how the pattern of injuries changes with increasing VDI, and the effect of restraints on these changes. As would be expected, the severity of injuries increases as VDI goes up. There are also more floor, side, side glass, and outside induced injuries at the higher VDI brackets. The effect of restraints in reducing windshield and instrument panel contact for the head and chest, and increasing wheel con-

Figure 46

Contact Point Comparison for Overall Injuries

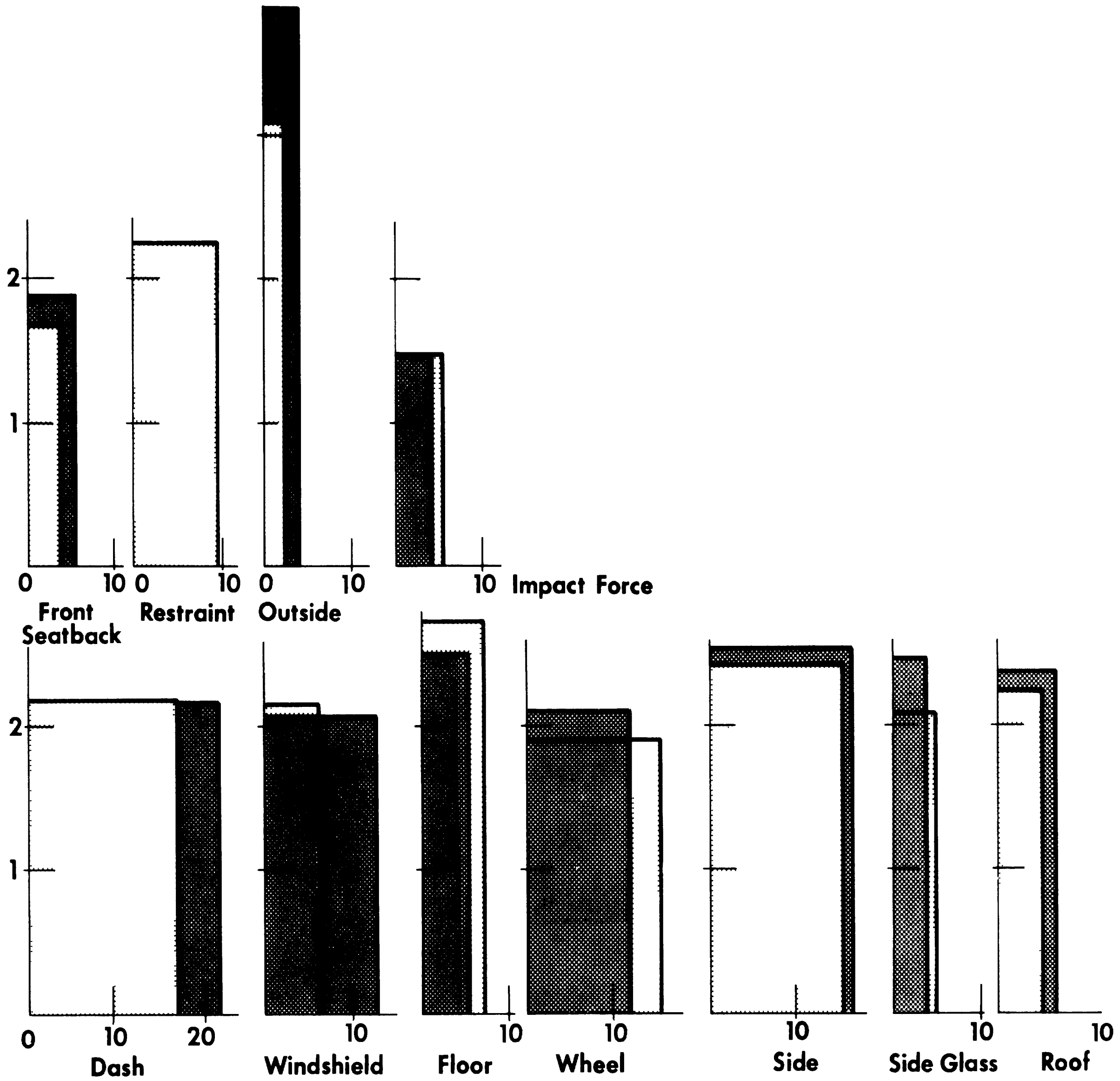


Figure 47

Contact Point Comparison for VDI

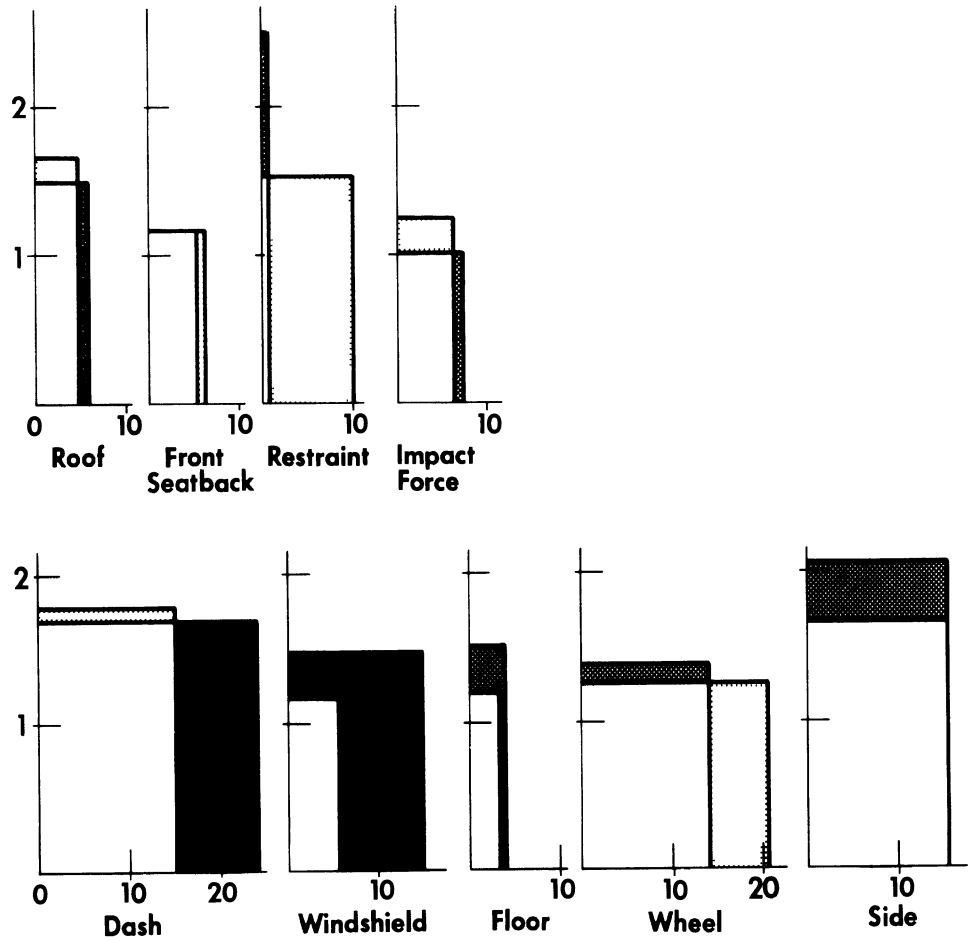
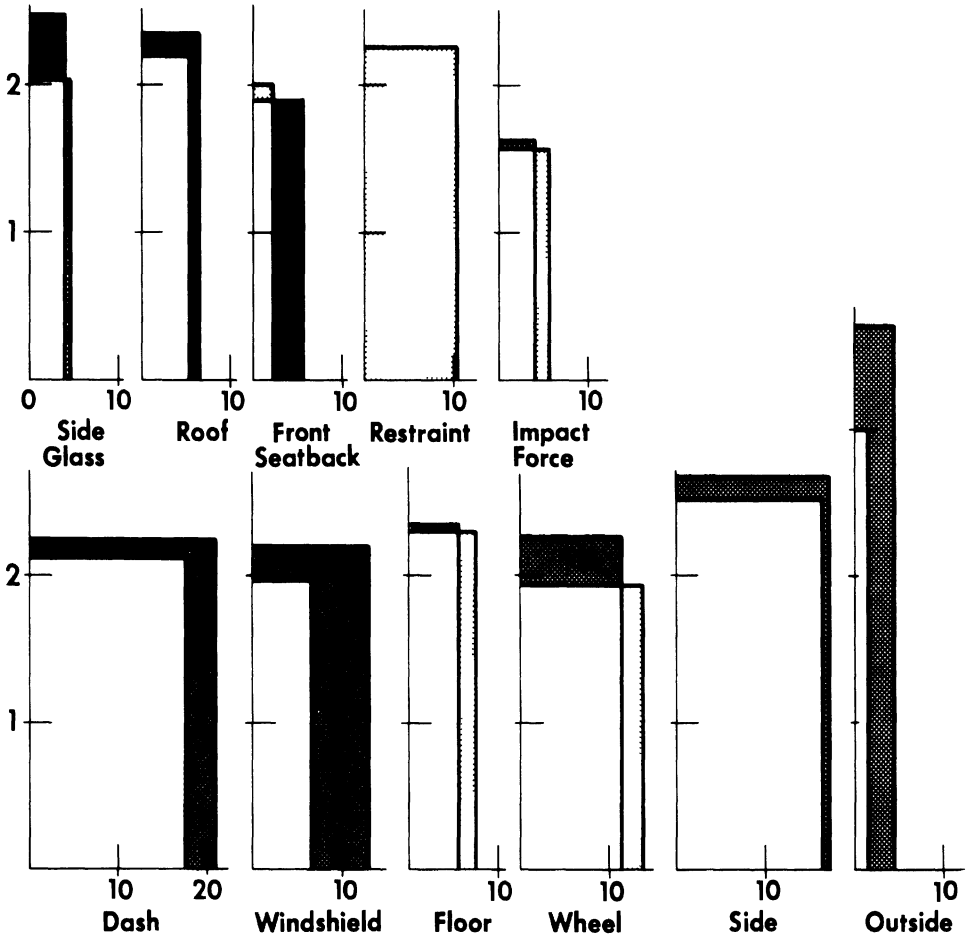


Figure 47 (Cont.)



tact for the chest, is apparent at all VDI brackets. The decrease in wheel contact for the abdomen with restraint use is less marked as VDI goes up, but the severity of such contacts is significantly decreased for restraint wearers at the higher VDI bracket. Front seatback and outside contacts become relatively more frequent for the unrestrained occupant at VDI of 3 to 5, while impact force injuries are more prevalent for the restrained at this bracket.

Figure 48 shows the effect of impact speed on restraints, and many of the effects of increasing VDI are true for increasing speed also. Increasing speeds mean more severe injuries. The effect of restraints in preventing windshield contact is not affected by increasing speed, but their effect on reducing instrument panel contacts decreases with greater speeds. The reduction of wheel, side, and side glass contact with restraints is only at the lower speed bracket. As with increasing VDI, there are relatively fewer front seatback and outside object contacts for restrained persons as speeds increase. Pelvic injuries are less severe at higher speeds because there is a trade-off of more severe contacts for the unrestrained pelvis for less severe restraint caused injuries at these speeds.

Figure 49 reveals that among unrestrained occupants, the driver hits the wheel more often and the right-front passenger hits the instrument panel more frequently. Restraint induced injuries are more prevalent for the restrained right-front passenger than the driver.

Figure 50 shows that single-car accidents are generally more severe than the average. There are also more roof and outside contacts than normal. Restraint use results in fewer and less severe windshield and outside contacts, less severe side glass injuries, and fewer side induced injuries. The reduction in the severity of neck injuries for restrained occupants in this configuration is due primarily to less severe impact force injuries with restraint use. The decrease in shoulder injury severity is because the shoulder of restrained persons is hitting the side

Figure 48

Contact Point Comparison for Speed

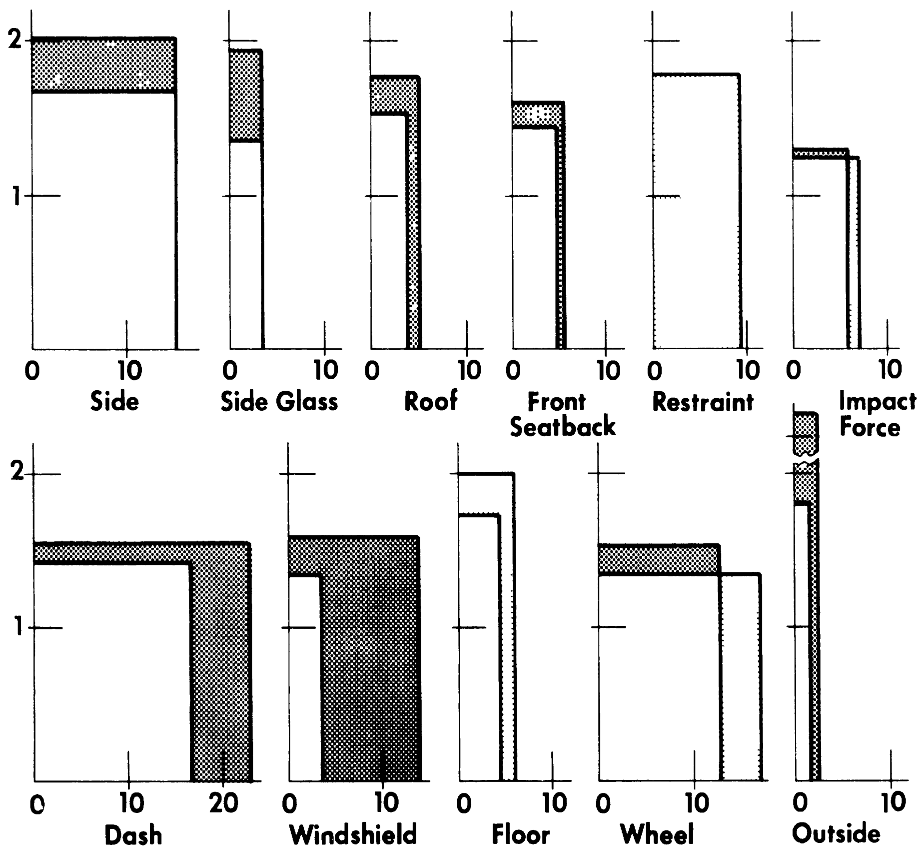


Figure 48 (Cont.)

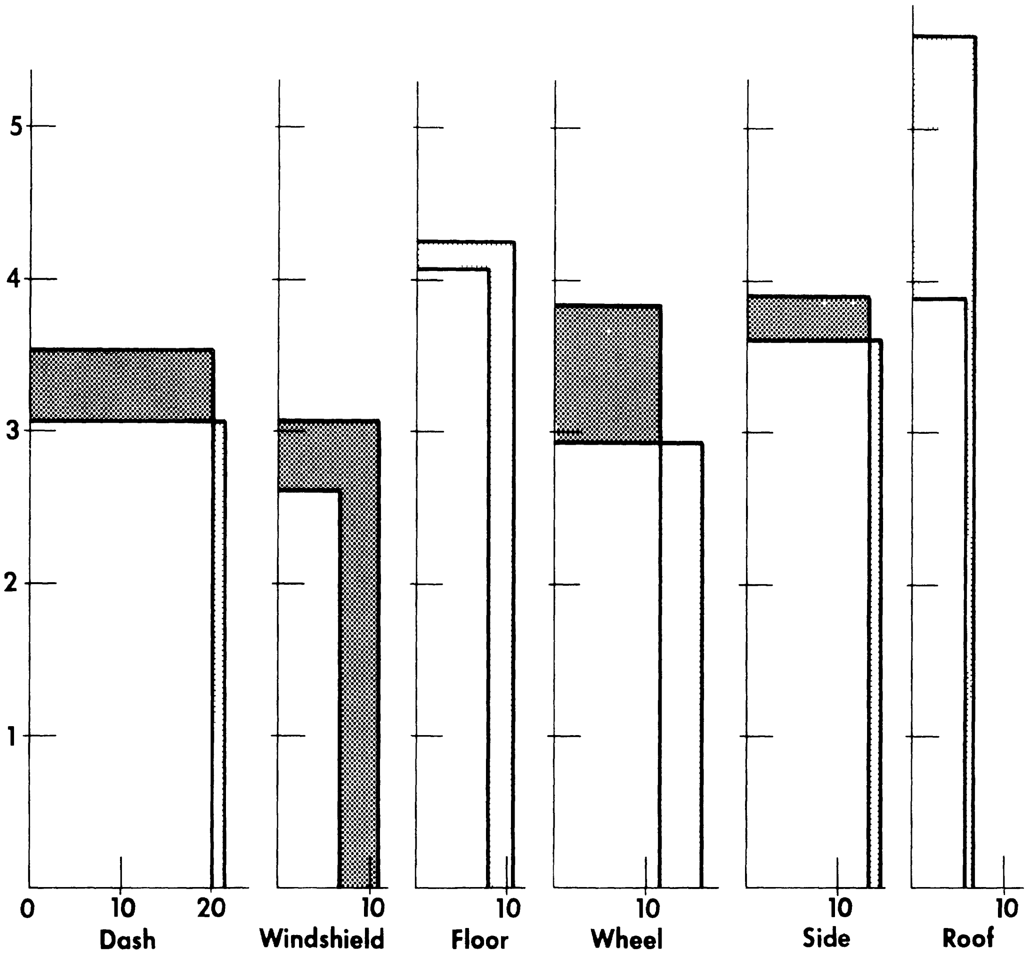


Figure 48 (Cont.)

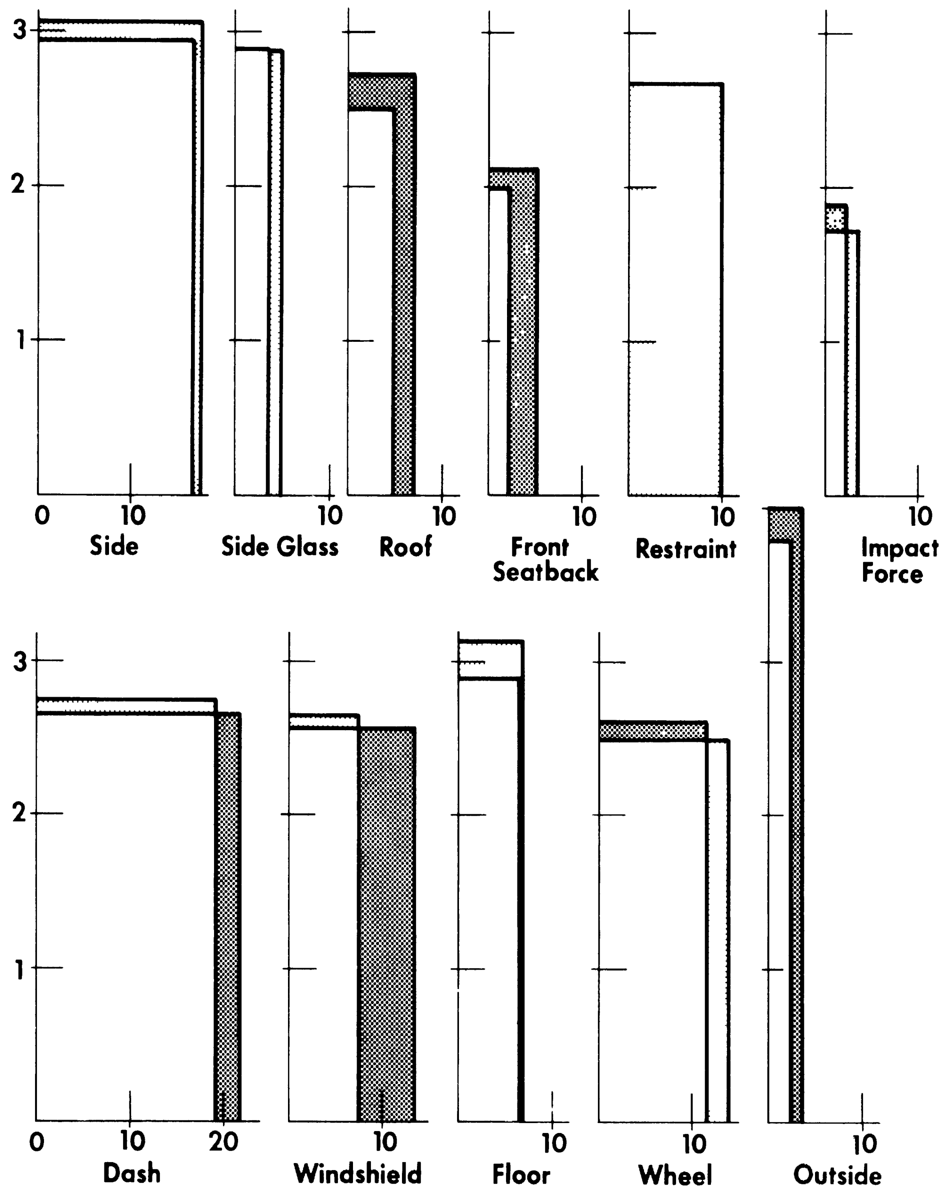


Figure 49

Contact Point Comparison for Seated Position

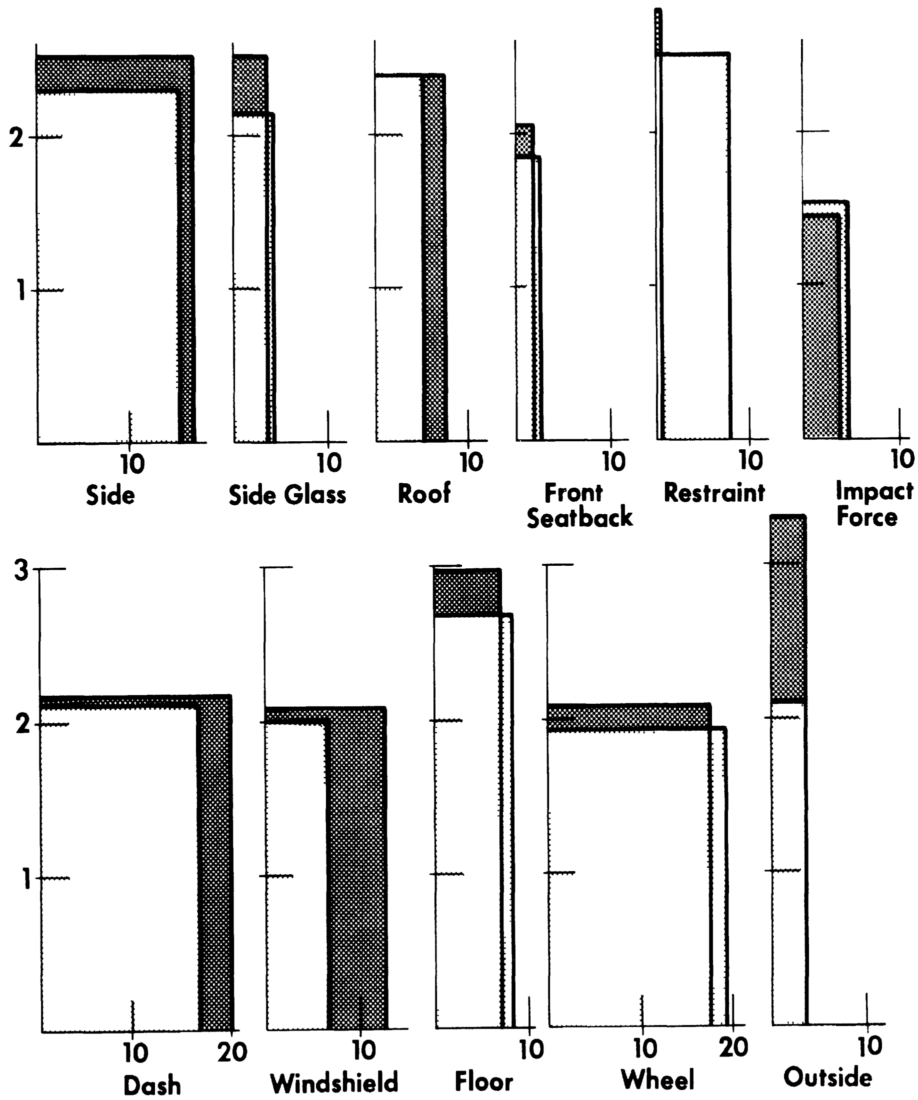


Figure 49 (Cont.)

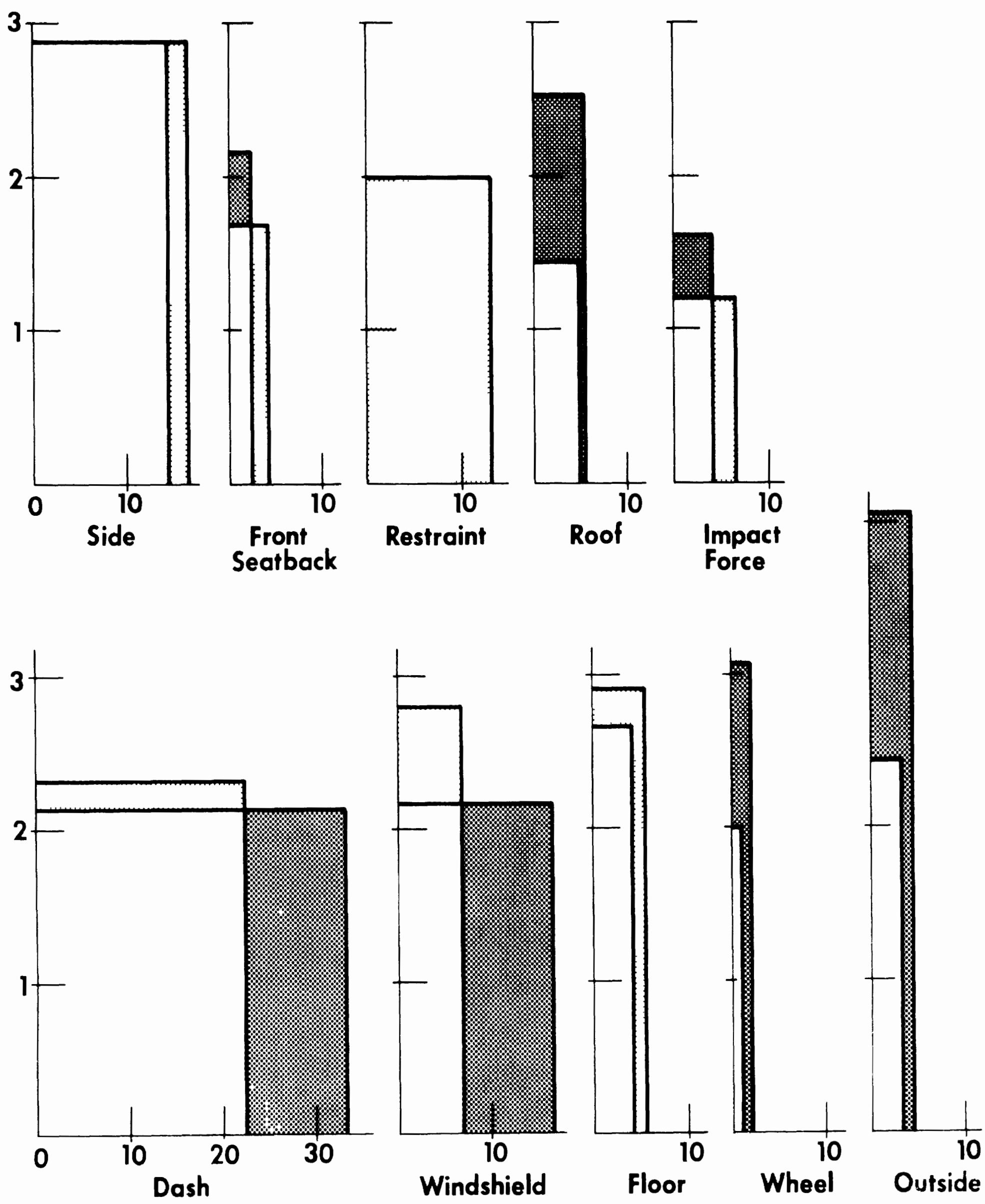


Figure 50

Contact Point Comparison for Single-Car,
T/L, and Sideswipe Accidents

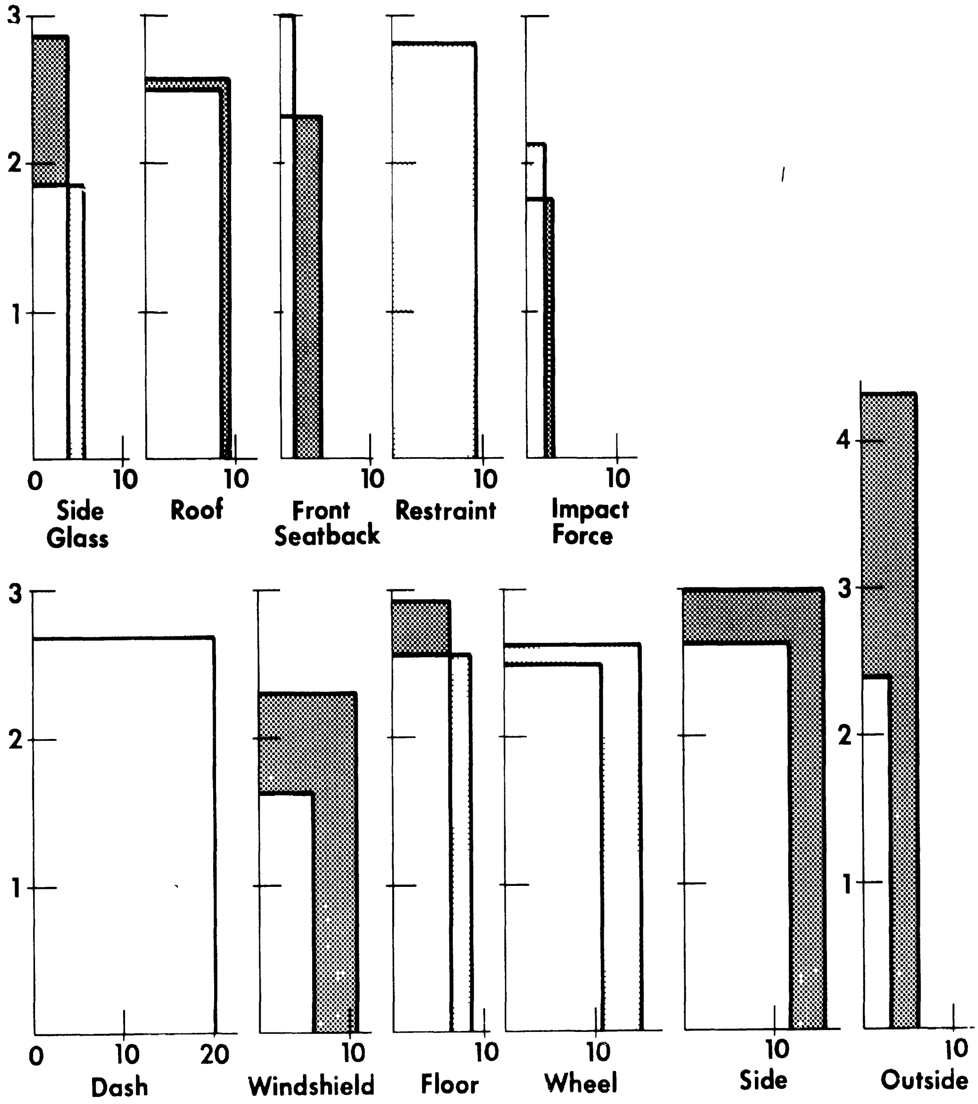


Figure 50 (Cont.)

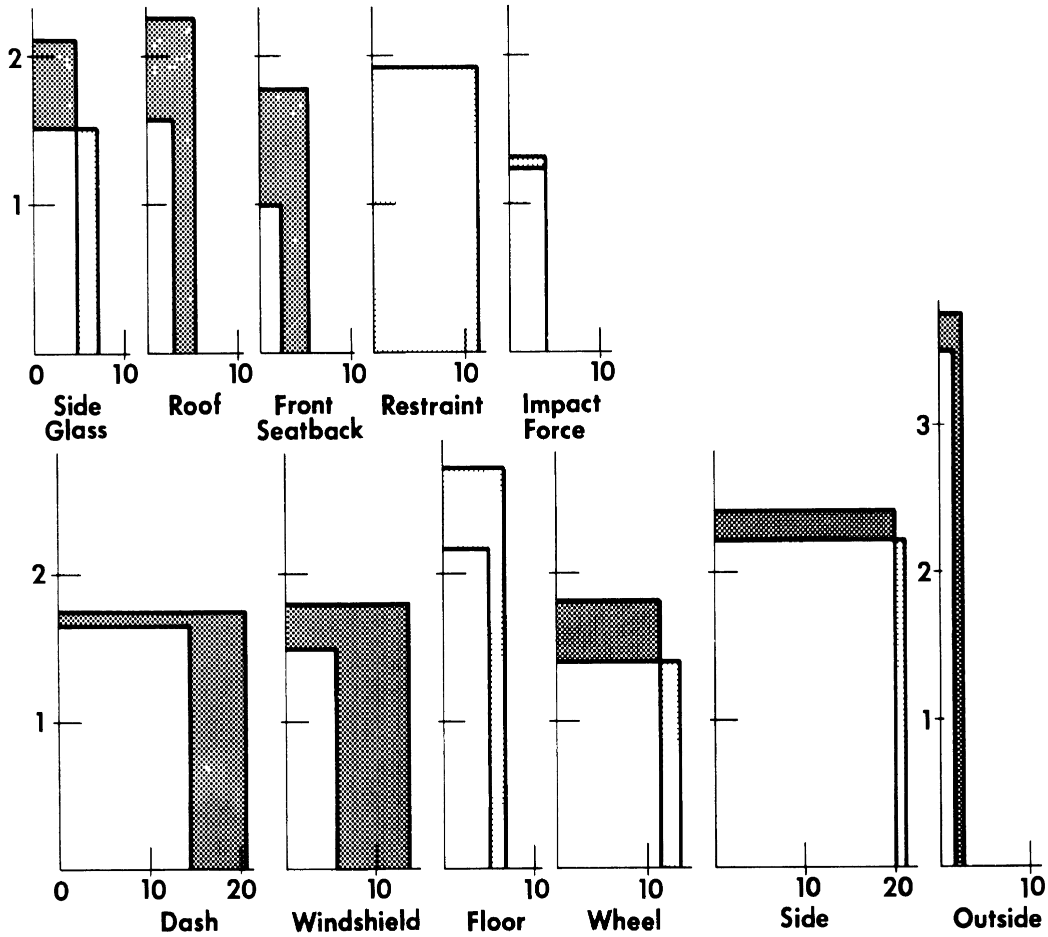
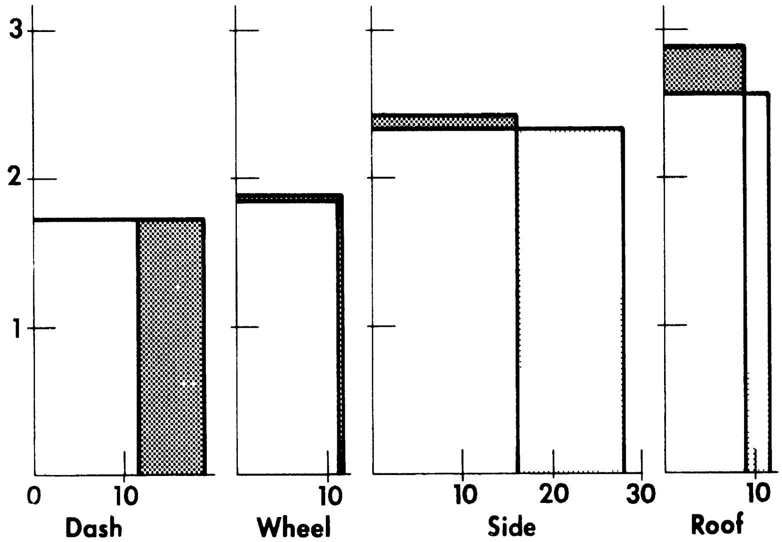


Figure 50 (Cont.)



less severely.

Although not graphed, the analysis of head-on crashes shows that they are more severe than normal, and one cause of the reduced severity of neck injuries with restraints in this configuration is because there are fewer of the more severe windshield contacts for the restrained neck. Most back injuries to restrained persons in this configuration are from impact force, and most abdominal injuries are from the restraints themselves.

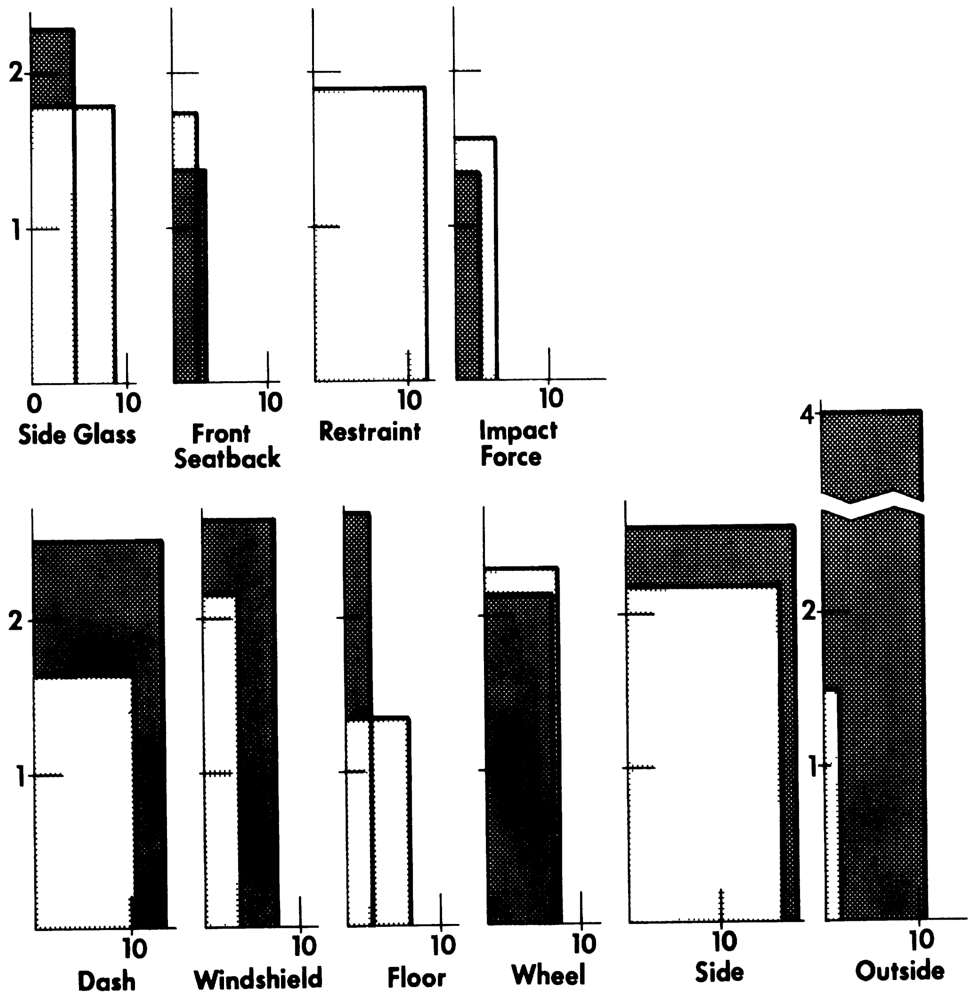
As for the T/L intersection crash, the effect of restraints in this situation is similar to the general case. However, in addition to not hitting the windshield and instrument panel, the head is also not hitting the side glass and roof as severely in this configuration as if unrestrained. Wheel induced chest injuries are not as severe for restrained occupants and there is not the marked increase in relative frequency of such contacts with restraint use that is seen in other configurations. There is a difference in the effect of restraints between the two seated positions in this case, and this is evidenced by a decrease in the severity of side induced chest and pelvis injuries for the driver but an increase in chest injuries for the right-front passenger. As is true in the general case, abdomen injuries from wheel contact are decreased with restraint use, but the restraints themselves inflict some abdominal injuries.

Figure 50 also reveals that sideswipe accidents are less severe than the others. No other conclusions are drawn, however.

Figure 51 shows that rollovers are generally more severe than non-rollovers. The unrestrained person suffers more roof and outside object contacts than normal. Restraints have an effect on injuries by preventing the outside object contacts, but they do not stop the head from hitting the roof. As in other situations, they also reduce the amount of windshield contact but are the cause of some injuries also. The major factors in the high reduction of injury severity with restraints in this case is that there are less serious injuries from instrument panel and floor contact, and fewer of the very severe ejections.

Figure 51

Contact Point Comparison for Rollovers



The attempt here has been to present the many findings in an organized and succinct fashion. Unfortunately they are not amenable to a few brief summary statements. It is hoped that they would further the purposes of the paper set forth at the beginning.

References

1. Boris Tourin, John W. Garrett, Safety Belt Effectiveness in Rural California Automobile Accidents, Cornell Aeronautical Laboratory, Inc., 1960.

2. G. Grimes, "The Effectiveness of Car Seat Belts," International Safety and Traffic Review, 1963.

3. A Study of Seat Belts in Wisconsin Automobile Accidents, Cornell Aeronautical Laboratory, September 1963.

4. James S. Williams, "The Nature of Seat Belt Injuries," Proceedings Fourteenth Stapp Car Crash Conference, pp. 44-65.

5. Janis Sube, H. Haskell Ziperman, William J. McIver, "Seat Belt Traums to the Abdomen," American Journal of Surgery, vol. 113.

6. I.D. Neilson, "The Dynamics of Seat Belts in Motor Car Head-on Impacts," Ergonomics and Safety in Motor Car Design, pp. 11-25.

7. Jaakko K. Kihlberg, Efficacy of Seat Belts in Injury and Non-injury Crashes, in Rural Utah, Cornell Aeronautical Laboratory, Inc., May, 1969.

8. G. Grime, "Accidents and Injuries to Car Occupants Wearing Safety Belts," Automobile Engineer, vol. 58.

9. R.E. Mettelka, R.A. Matson, A Report on Seat Belt Use in Wisconsin, 1963-1965, Wisconsin Motor Vehicle Department, Madison, Wisconsin.

10. "Buckle Up", 1970 Seat Belt Study compiled by the Washington State Patrol.

11. Motivating Factors in the Use of Restraint Systems, National Analysts, Inc., September, 1971.

12. B.J. Campbell, P.F. Waller, F.M. Council, Seat Belts: A Pilot Study of their Use Under Normal Driving Conditions, Highway Safety Research Center, University of North Carolina, November, 1967.

13. Dean I. Manheimer, Glen D. Mellinger, Helen M. Crossley, "A Follow-up Study of Seat Belt Usage," Traffic Safety Research Review, vol. 10.

14. B.N. Farr, Seat Belts--the Proportion of Cars Fitted and of Occupants Using Them, Road Research Laboratory, Crowthorne England, 1970.

15. George W. Snedecor and William G. Cochran, Statistical Methods, sixth edition, pp. 22-29.

16. Report of the Williamsburg Conference on Highway Safety Research, November 29-30, December 1, 1972 Vehicle Research Institute, Society of Automotive Engineers, Inc., p. 15.

17. Leon S. Robertson and William Haddon, Jr., The Buzzer-Light Reminder System and Safety Belt Use, pre-publication copy distributed by the Insurance Institute for Highway Safety, September, 1972.

18. Final Report by the Highway Safety Research Institute on Contract Number DOT-HS-031-1-037, Multidisciplinary Accident Investigation Report Automation, October , 1972; 5 Volumes, DOT/HS 800 767 through DOT/HS 800 771.