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"A COMPARISON OF INJURY SEVERITY PATTERNS FOR UNRESTRAINED, LAP BELTED, AND TORSO RESTRAINED OCCUPANTS IN AUTOMOBILE ACCIDENTS."

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ABSTRACT

The multi-disciplinary accident investigation reports comprising a census of towaway accidents in Washtenaw County, Michigan, were statistically analyzed in order to observe the effects on injury associated with wearing a lap belt or torso restraint. The analysis controls on accident configuration, crash severity, seated location, and ejection.

AUTOMOBILE SAFETY LITERATURE has for a period of years amply demonstrated that active restraint systems (lap belts and torso devices) tend to reduce the severity of injury sustained by people involved in car crashes (1,2)*. One important result of these findings has been an awareness by people in the safety field of the desirability of increasing the restraint usage rate among the motoring public (3). Consequently, recent public policy efforts have been made to ensure a greater use of restraining devices - laws requiring occupants to wear their safety belts have been introduced into a number of state legislatures and the automobile manufacturers have been developing sophisticated interlock systems designed to induce people to use their restraints. Clearly, then, despite the emergence of passive safety restraining equipment such as airbags, public policy will continue to rely upon active restraints as an important injury reduction mechanism. Information regarding the precise effects which belted restraint systems have on injury is of importance for formulating useful public policies pertaining to restraint use.

This paper presents the findings obtained from a systematic statistical analysis of the effects of wearing a lap belt or a torso device upon the overall injury severity recorded for drivers and right front passengers. The analysis controls on accident

* Numbers in parentheses designate References at end of paper.

configuration by considering these effects, in turn, for frontal impact crashes and for side impact crashes. Moreover, the analysis controls upon the severity of the crash and ejection for both frontal and side impact accidents. Finally, the occupant's seating location is controlled when considering the frontal impact crashes.**

The data used in the analysis are drawn from the Collision Performance and Injury Report file maintained by the Highway Safety Research Institute. The information contained in this file consists of the Multi-Disciplinary Accident Investigation reports submitted by the government and industry sponsored crash investigation teams which have been automated for computer uses (6). However, this study only considers the subset of cases in the file which comprise the census of new American manufactured towaways occurring in Washtenaw County (Ann Arbor), Michigan for the 1970-1973 period (4). The subset was chosen in order to present a distribution of injury severity values unbiased by case selection criteria. However, the distributions should not be considered as a basis for drawing inferences about national restraint usage rates since provincial biases dictate the levels observed for this one county. Yet, the functional relationships observed between the various control factors, restraint system usage, and injury severity should not be prejudiced by use of this county's towaway census data.

The severity of the occupant's injury is recorded in the file in terms of the Abbreviated Injury Scale (5). There are eleven severity level values in the AIS scale (none, minor, non-dangerous-moderate, non-dangerous-severe, dangerous-serious, dangerous-critical, fatal lesions in one region, fatal lesions in two regions, fatal lesions in two or more regions, fatal with details unknown). All of the analyses in this paper use a seven level version of this scale (0 through 6+) in which all of the various AIS values denoting fatal injury are collapsed into one category (6+). The AIS scale is not an interval measure of injury - that is, a scale value of four cannot be assumed to be twice as severe as a scale value of two. Also, there is unfortunately no

** The analysis reported upon in this paper is a refined version of a section in a larger earlier work: Ray Shortridge and Fred Preston, "A Study of Restraint-System Use and Effectiveness," 241 pages, Highway Safety Research Institute, June, 1973.

clear substantive interpretation of the AIS scale in terms of dollars lost or degree of activity restriction. As a consequence, care must be exercised when drawing conclusions when this scale is included in the statistical techniques used in the analysis.

FRONTAL IMPACT CRASHES

This section of the analysis considers only those drivers and right front passengers whose vehicles sustained their principal damage in the front end. The first table presents the distribution of injury severity values recorded for the occupants according to whether they were unrestrained, wore only a lap belt, or used a torso device.

Table 1 clearly indicates that the occupants with torso restraints were much less likely to have been severely or fatally injured than those with lap belt only or unrestrained. On the other hand, the occupants with lap belts were somewhat less likely to have been killed than the unrestrained people but more likely to have been severely injured (AIS-4,5) than the unrestrained.

Table 1 - Injury Severity Values for Drivers and Right-Front Passengers by Restraint System Usage (Frontal Impact)

	0	1	2	3	4	5	6+	N
No Restraint	217	319	45	38	1	4	9	633
Lap Belt	93	95	8	7	3	4	2	212
Torso	17	9	1	0	0	0	0	27

	0	1	2	3	4	5	6+
No Restraint	34.3%	50.4%	7.1%	6.0%	0.2%	0.6%	1.4%
Lap Belt	43.9%	44.8%	3.8%	3.3%	1.4%	1.9%	0.9%
Torso	63.0%	33.3%	3.7%	0.0%	0.0%	0.0%	0.0%

However, the severity of the crash conceivably could affect the level of the injury sustained by the occupants. One might suppose that the probability that an occupant would be seriously or fatally injured would be greater in more severe crashes than in less destructive ones despite the use of a restraint. If the unrestrained occupants were in accidents which tended to be more severe than those for restrained people, then the injury reduction observed for occupants using a restraining device may in fact be due to the difference in crash severity and not to

the restraint. It is desirable, then, to control on crash severity in order to gauge the net effect of restraint usage on injury. One measure of crash severity is the vehicle deformation extent code reported by the investigator and this is used in the subsequent analysis as the control variable for crash severity.

The approach adopted in this analysis imposes a statistical control upon crash severity. A regression model using the vehicle deformation extent code as the index for crash severity was used to predict an injury severity level for each occupant. This predicted injury value is the severity one would expect the occupant to have sustained given the damage to the car. (See Appendix A). This technique was applied to the drivers and right-front passengers involved in front-end crashes. Table 2 and Figure 1 contain the mean predicted injury and the mean recorded injury for the three restraint usage categories.

Table 2 - Mean Predicted and Mean Recorded Injury Levels by Restraint System Use (Frontal Impact)

	Predicted Injury	
	Mean	Standard Deviation
No Restraint	0.90	0.62
Lap Belt	0.91	0.65
Torso	0.84	0.50

	Recorded Injury	
	Mean	Standard Deviation
No Restraint	0.95	1.06
Lap Belt	0.84	1.12
Torso	0.41	0.57

This analysis shows that, on the whole, unrestrained occupants are more severely injured than one would expect given the severity of their accidents. The mean injury level for unrestrained people was about 0.05 AIS units greater than that predicted by the regression model. Those wearing a lap belt evidenced a mean injury level of about 0.07 AIS units lower than the predicted mean while the mean recorded injury for those occupants using a torso device was 0.43 AIS units lower than the crash severity model predicted. For the Washtenaw County towaway "census", the use of a restraint system reduces the average injury severity sustained by the occupant

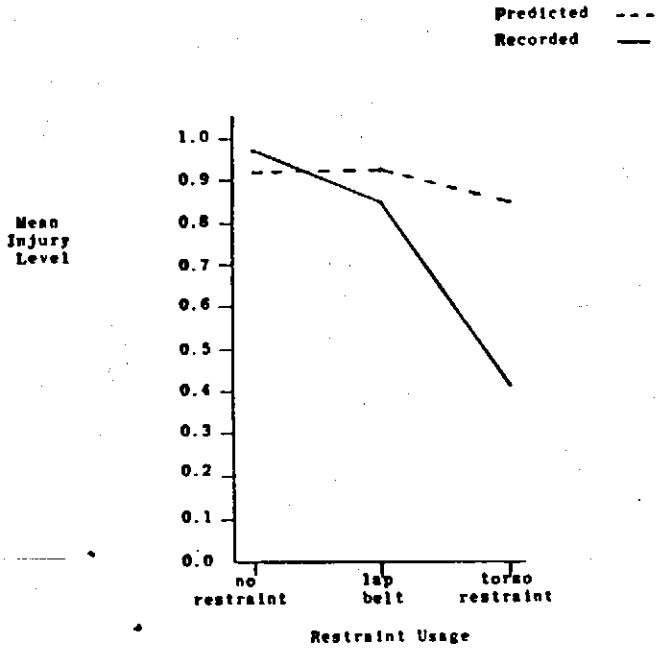

Fig. 1 - Mean values for predicted and recorded injury levels by restraint usage (Frontal Impact)

below that which is to be expected given the severity of the accident.

The auto safety literature has amply demonstrated that ejection from the vehicle usually results in severe injury to the passenger and that restraining belts, when used, effectively reduce the likelihood of ejection (7). The following analysis assesses the effect of the restraint systems for those occupants who were not ejected either partially or totally from the vehicle. Table 3 contains the distribution of injury severity values for those occupants who were not ejected either totally or partially from their vehicles.

The distribution of recorded injuries for the 628 unrestrained occupants who were unejected does not differ markedly from that observed for the total set of 633 unrestrained people (see Table 1). Those people with lap belts (none of whom were ejected) were still slightly less likely to have been killed than the unejected unrestrained occupants but were again somewhat more likely to have been seriously injured (AIS-4,5) than the unejected un-

Table 3 - Distribution of Injury Severity Values for Unejected Occupants by Restraint-Use Categories (Frontal Impact)

Frequency

	0	1	2	3	4	5	6+	N
No Restraint	217	319	43	36	1	4	8	628
Lap Belt	93	95	8	7	3	4	2	212
Torso	17	9	1	0	0	0	0	17

Percent

	0	1	2	3	4	5	6+
No Restraint	34.6	50.8	6.8	5.7	0.2	0.6	1.3
Lap Belt	43.9	44.8	3.8	3.3	1.4	1.9	0.9
Torso	63.0	33.3	3.7	0.0	0.0	0.0	0.0

restrained occupants (3.3% to 0.8%, respectively). However, none of the people wearing a torso device was ejected so the distribution of injuries is the same as found in Table 1 - no fatalities and no serious injuries.

Statistical control was imposed upon the severity of the accident for the set of unejected occupants. The regression model predicted an injury level for each person on the basis of the degree of deformation sustained by the vehicle. Table 4 and Figure 2 present the mean injury values predicted by

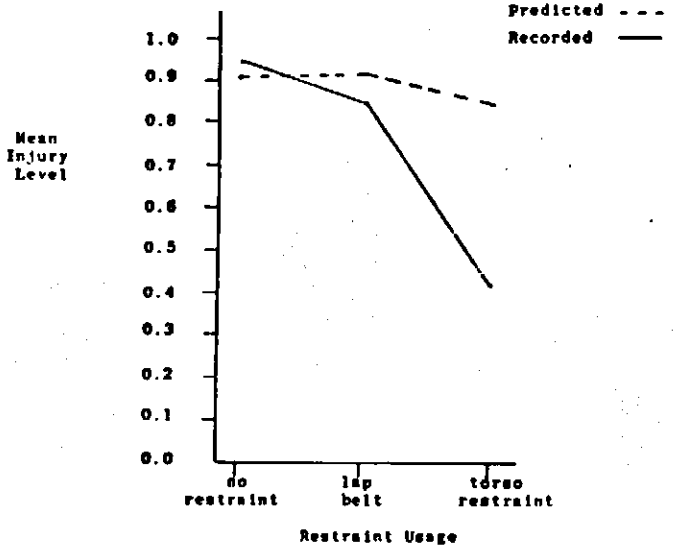

Fig. 2 - Mean values for predicted and recorded injury levels by restraint usage for unejected occupants (Frontal Impact)

Table 4 - Mean Predicted and Mean Recorded Injury Levels by Restraint System Use for Unejected Occupants (Frontal Impact)

	Predicted Injury Mean	Standard Deviation
No Restraint	0.89	0.60
Lap Belt	0.90	0.64
Torso	0.83	0.50
	Recorded Injury	
No Restraint	0.93	1.04
Lap Belt	0.84	1.12
Torso	0.41	0.57

the crash severity factor and the means for the recorded injury levels for the unejected occupants.

Although the exclusion of the non-ejected cases reduced the mean of the injury level recorded for the unrestrained occupants, a marked injury reduction effect associated with using a restraint system is still in evidence. The mean recorded injury level for unrestrained people is 0.04 AIS units higher than that predicted by the crash severity model. On the other hand, the mean recorded injury level for lap belted and torso-restrained occupants is 0.06 and 0.42 AIS units, respectively, lower than the level one would expect given the severity of their crashes. The graph in Figure 2 clearly illustrates the decline in injury associated with wearing a restraint, particularly a torso device. Hence, even when controlling an ejection and crash severity, using a restraint system on the whole seems to reduce the level of injury sustained by the occupants.

This section addresses the question of whether the occupant's seated location affects the level of injury sustained in the accident. There are two issues involved in this question: first, do restraining devices exercise injury reduction effects for both seating locations which are attributable to lap belts and to torso restraints, and, second, are these effects the same for drivers as for right front passengers. The analysis will deal with each issue in turn.*

* Only frontal impact crashes are considered with seating location controlled. For an analysis of the effect of restraint use on injury in side impact crashes, see: Fred Preston, Ray Shortridge, "An Evaluation of the Effectiveness of Side-Door Beams Based on Accident Exposure", Highway Safety Research Institute, September, 1973. (UM-HSRI-SA-

To assess whether restraints reduce the injury level sustained by both drivers and right front passengers the means of the recorded injury values for each restraint-use group are compared with the means of the expected injury values for each seating location. The predicted injury levels were obtained from the regression model using the vehicle damage extent code as the predictor variable and the occupant's recorded injury severity as the dependent variable. This procedure controls on accident severity. Then the occupants were divided into two groups--drivers and right front passengers. Table 5 presents the means for the predicted and the recorded injury severity variables for drivers while a graphic portrayal is contained in Figure 3.

Table 5 - Mean Values for Predicted and Recorded Injury Levels by Restraint Use for Drivers (Frontal Impact)

	No Restraint	Lap Belt Only	Torso
Predicted Mean	0.90	0.89	0.81
Recorded Mean	0.92	0.80	0.36

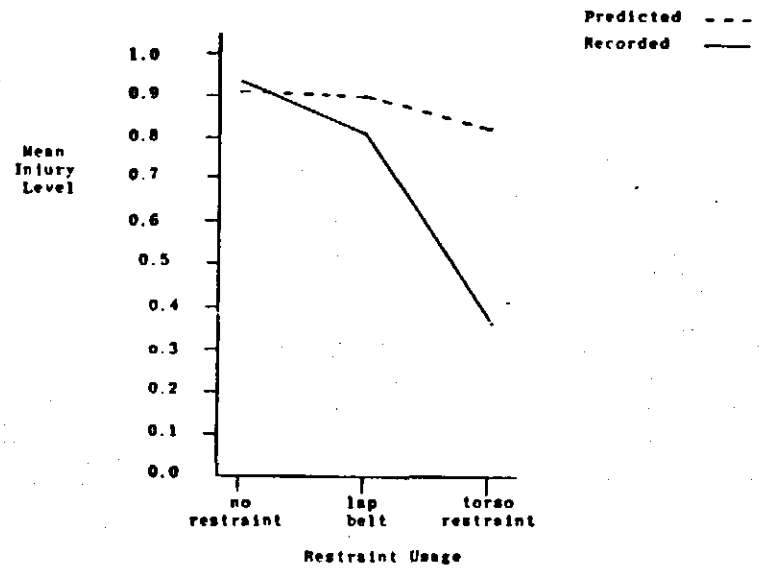

Fig. 3 - Mean values for predicted and recorded injury levels by restraint usage for drivers (Frontal Impact)

The data indicate that the restraining devices are associated with an injury reduction in the case of drivers. Using only a lap belt reduces the mean injury value by 0.09 AIS units from the level predicted by the crash severity model. Wearing a torso device is associated with a reduction of 0.45 AIS units below the expected level.

The comparable information for right front passengers is contained in Table 6 and Figure 4. The table indicates that for right front passengers using a restraining device is associated with a reduction in the mean injury values relative to the levels predicted by the crash severity regression model. Those using only a lap belt has an average recorded injury

Table 6 - Mean Values for Predicted and Recorded Injury Levels by Restraint Use for Right Front Passengers (Frontal Impact)

	No Restraint	Lap Belt Only	Torso
Predicted Mean	0.89	0.97	0.96
Recorded Mean	1.02	0.95	0.60

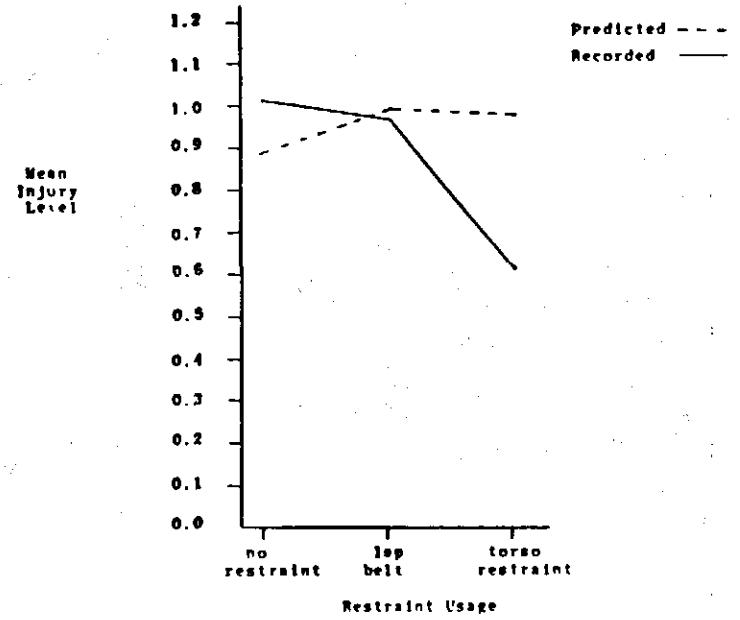

Fig. 4 - Mean values for predicted and recorded injury levels by restraint usage for right front passengers (Frontal Impact)

level 0.02 AIS units lower than expected given the severity of the crash. The comparable reduction for people wearing a torso device was 0.36 AIS units.

Although the use of a restraint system correlates with a reduction of injury relative to the level to be expected given the crash severity, it appears that the effect is greater for drivers than for right front passengers particularly for those wearing only a lap belt. Table 7 and Figure 5 compare the means for the predicted and recorded injury levels obtained for drivers and right front passengers who wore lap belts.

It is evident that right-front passengers tended to be involved in accidents of somewhat greater severity than were the drivers because the mean of the predicted injury is greater for people in the right seat than for those who were driving. However,

Table 7 - Mean Values for Predicted and Recorded Injury Levels for Lap Belted Occupants by Seated Location (Frontal Impact)

	Drivers	Right Front
Predicted Mean	0.89	0.97
Recorded Mean	0.80	0.95

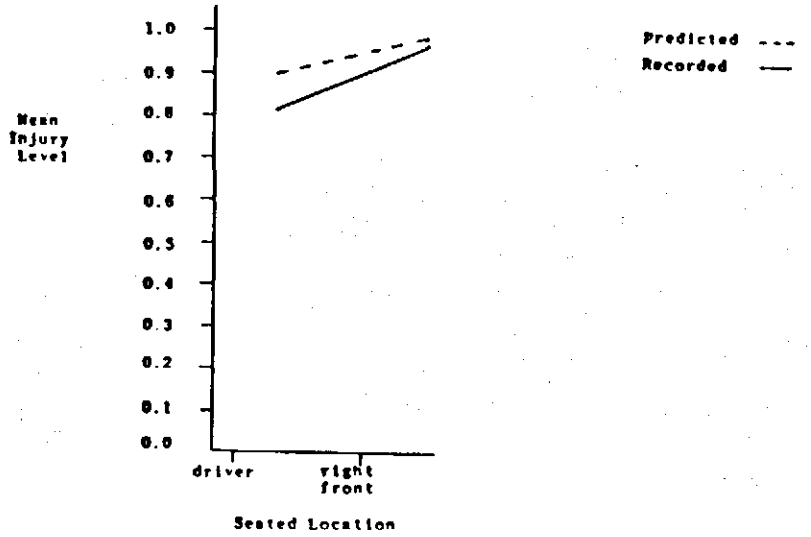

Fig. 5 - Means for predicted and recorded injury levels for lap belted occupants by seated location (Frontal Impact)

the reduction in injury associated with using a lap belt is 0.02 AIS units for right-front passengers as compared with a reduction of 0.09 AIS units for drivers.

Table 8 and Figure 6 presents the same comparison of mean injury levels for those occupants using a torso restraint. The mean of the predicted injury values is greater for right front passengers than for drivers which indicates that the people in the right front seat tended to be involved in more serious accidents. Notwithstanding this observation, the use of a torso device is associated with a considerable reduction in injury for the right front passengers (0.36 AIS units). However, the reduction is greater for drivers (0.45 AIS units).

Table 8 - Mean Values for Predicted and Recorded Injury Levels for Users of Torso Devices by seated Location (Frontal Impact)

	Drivers	Right Front
Predicted Mean	0.81	0.96
Recorded Mean	0.36	0.60

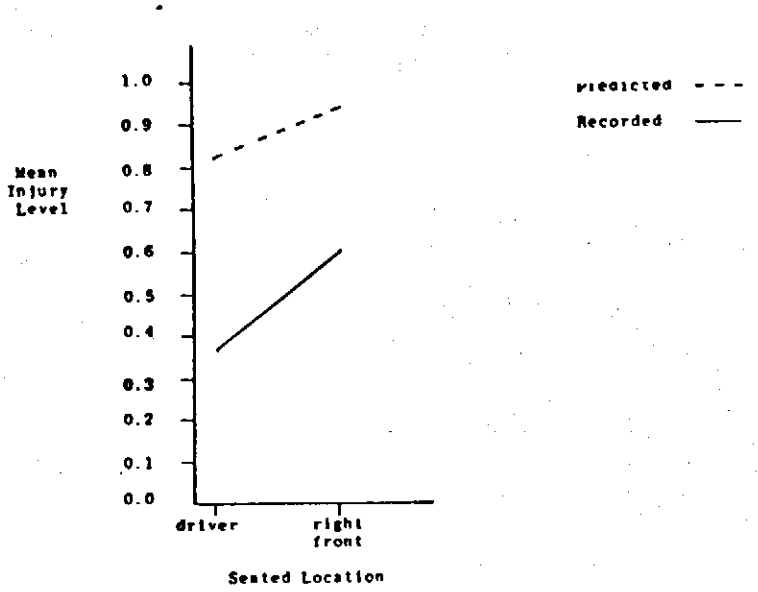

Fig. 6 - Means for predicted and recorded injury levels for users of torso restraints by seated location (Frontal Impact)

Thus, there is a tendency for restraints to be less effective in reducing the level of injury for right front passengers than for drivers when controlling for the severity of the crash. In particular, this differential effect is noticeable in the case of lap belted people where the reduction for right front passengers is only 0.02 AIS units. For both seating locations, the use of a torso device is correlated with a greater reduction in injury than when the person is wearing only a lap belt.

SIDE IMPACT CRASHES

A comparable analysis was performed for those occupants whose vehicles sustained the principal direct damage on the side. The following table presents the distribution of injury severity values for the three restraint-use groups.

Table 9 - Injury Severity Levels by Restraint System Usage (Side Impact)

	Frequency							
	0	1	2	3	4	5	6+	N
No Restraint	101	139	22	10	4	3	12	291
Lap Belt	56	46	6	3	0	2	3	116
Torso	8	7	0	2	0	0	0	17

	Percent						
	0	1	2	3	4	5	6+
No Restraint	34.7	47.8	7.6	3.4	1.4	1.0	4.1
Lap Belt	48.3	39.7	5.2	2.6	0.0	1.7	2.6
Torso	47.1	41.2	0.0	11.8	0.0	0.0	0.0

The data indicate that a greater proportion of unrestrained occupants received an injury than did those using either lap belts or torso restraints (65.3% compared with 51.7% and 52.9%, respectively). Moreover, the proportion of occupants receiving a fatal or life-threatening injury (AIS=4 or more) was somewhat greater for unrestrained occupants than for those using either type of restraining device (6.5% compared with 4.3% and 0.0%, respectively).

The regression model incorporating the vehicle damage extent code was used to calculate a predicted injury severity level for each occupant. The predicted injury values is an estimate of the occupant's injury level which is to be expected given

the severity of the crash. Table 10 and Figure 7 contain the mean predicted injury level for the three restraint-use groups and, for comparison, the means for the injury severity levels actually recorded for these groups.

Table 10 - Mean Injury Severity Levels for the Predicted and Recorded Injury Severity Values by Restraint Use Groups (Side Impact)

	Predicted	
	Mean	Standard Deviation
No Restraint	1.04	0.74
Lap Belt	0.92	0.60
Torso	1.20	0.62

	Recorded	
	Mean	Standard Deviation
No Restraint	1.09	1.37
Lap Belt	0.82	1.24
Torso	0.76	0.97

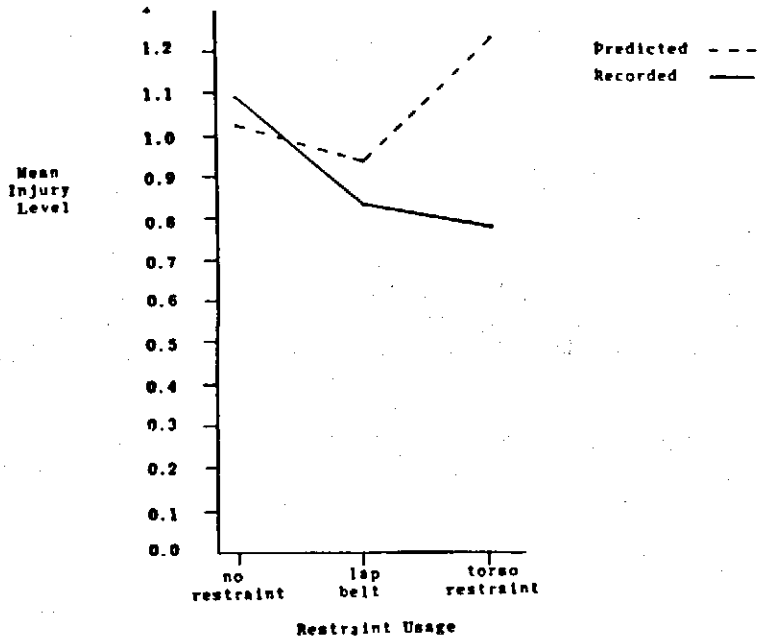

Fig. 7 - Mean values for predicted and recorded injury levels by restraint usage (Side Impact)

The table indicates that using a restraining device is associated with a lower level of injury than one would predict on the basis of the degree of deformation induced to the car. The average recorded injury level for unrestrained occupants is 0.05 AIS units greater than the mean for the injury level predicted by the crash severity variable. However, the mean for those wearing a lap belt only was 0.10 AIS units lower than the mean expected value while the mean for those using a torso device was 0.44 units less than the mean of the severity values predicted by the model. Figure 7 illustrates these effects by graphing the means of the predicted and actual injury levels for the three restraint-use categories.

This analysis was repeated for the set of occupants who were not ejected from their vehicle in order to control the ejection factor. Table 11 presents the distribution of injury severity values for the unejected occupants by use of restraint group.

Table 11 - Distribution of Injury Severity Values for Unejected Occupants by Restraint-Use Category (Side Impact)

	Frequency							
	0	1	2	3	4	5	6+	N
No Restraint	101	136	20	9	3	2	9	280
Lap Belt	56	46	6	3	0	2	2	115
Torso	8	7	0	2	0	0	0	17

	Percent						
	0	1	2	3	4	5	6+
No Restraint	36.1	48.6	7.1	3.2	1.1	0.7	3.2
Lap Belt	48.7	40.0	5.2	2.6	0.0	1.7	1.7
Torso	47.1	41.2	0.0	11.8	0.0	0.0	0.0

The data indicate that there is a slightly lower proportion of lap belted occupants sustaining a life-threatening or fatal injury (AIS-4 or more) than unrestrained occupants (3.4% as compared with 5.0%, respectively). There are no life-threatening injuries reported for occupants wearing a torso restraint.

The regression technique was used to control on the severity of the accidents in which the unejected occupants were involved. A regression model predicted an injury level for each occupant based upon the amount of crush to his vehicle. Table 12 presents the mean predicted injury level calcula-

Table 12 - Mean Predicted and Mean Reported Injury Levels by Restraint System Use for Unejected Occupants (Side Impact)

	Predicted Mean	Predicted Standard Deviation
No Restraint	0.96	0.66
Lap Belt	0.87	0.54
Torso	1.12	0.56

	Reported Mean	Reported Standard Deviation
No Restraint	1.00	1.26
Lap Belt	0.77	1.15
Torso	0.76	0.97

ted for each restraint-use group and the mean of the injury values actually recorded for each occupant in the restraint system usage categories.

The use of a restraint exercises an injury reduction effect when accident severity is controlled for the set of unejected occupants. The mean recorded injury level for people with lap belts was 0.10 AIS units less than expected given the severity of their accidents while the comparable value for those using a torso device was 0.36 AIS units. The mean for the injury values recorded for unrestrained people exceeded the expected mean by 0.04 AIS units. Figure 8 depicts the differences in these means. Using a restraining device, particularly, a torso system, is associated with an overall reduction in injury level when both ejection and accident severity are controlled.

CONCLUSIONS

Analyzing the Washtenaw County towaway-accident census cases indicates that wearing a restraint tends to be associated with a lower level of overall injury severity than one would expect given the severity of the crash. This pattern is observed for both frontal impact and side impact accident configurations. Restraining devices seem to exercise this injury reduction effect even when one analyzes only those occupants who were not ejected from their vehicle. For both frontal and side impact configurations, the difference between the mean of the injury level to be expected given the crash severity and the mean of the injury level actually recorded for the

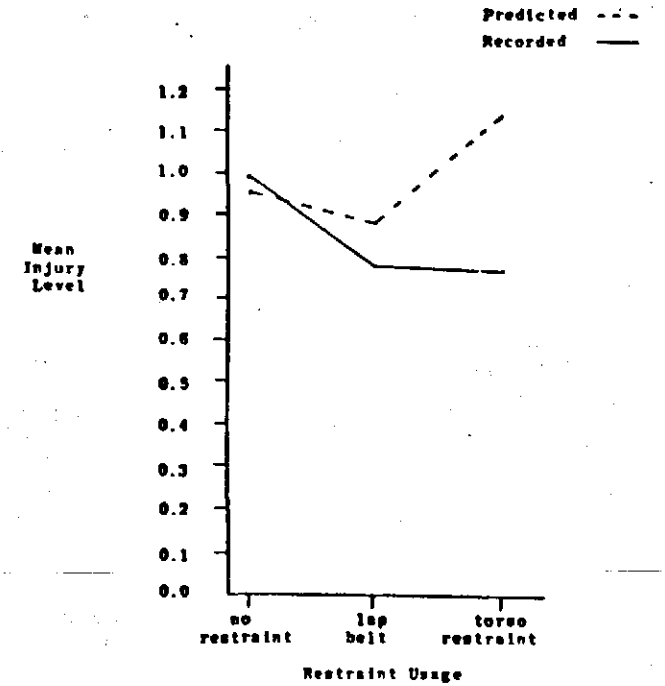

Fig. 8 - Mean values for predicted and recorded injury levels by restraint usage for unejected occupants (Side Impact)

occupant was greater for users of torso restraints than for users of lap belts. This suggests that torso devices generally exercise a greater injury reduction effect than do lap belts. Also, the analysis revealed that wearing either restraint is associated with an overall reduction in injury for both drivers and right front passengers. However, the degree to which a lap belt or torso restraint seemed to reduce the injury level was less for right front occupants than for drivers.

APPENDIX A

The analyses in this paper employ a statistical model in order to control on crash severity. A primary reason for using statistical rather than physical controls is that the relationships can be more efficiently displayed by using the regression model than by subsetting the cases into a large number of tables. The statistical model is used to predict an injury

severity value for each occupant according to the severity of the crash in which the occupant was involved. One measure of crash severity is the extent of the deformation reportedly sustained by the occupant's vehicle as a result of direct impact damage. The predicted injury value is calculated by regressing the recorded injury severity variable (the Abbreviated Injury Scale code value) upon the vehicle deformation variable:*

$$Y_i = b_o + b_1 X_{1_i} + \text{residual variance} \qquad (1)$$

By comparing the mean predicted injury with the mean recorded injury for each restraint-use group, one obtains a measure of the effects of using lap or torso restraints upon the injury sustained by the occupants with the relative seriousness of the accidents controlled.

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* The use of regression on the non-interval injury severity scale is discussed in James O'Day, et.al., "Statistical Inference from Multidisciplinary Accident Investigations," Highway Safety Research Institute, June, 1973.

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configuration by considering these effects, in turn, for frontal impact crashes and for side impact crashes. Moreover, the analysis controls upon the severity of the crash and ejection for both frontal and side impact accidents. Finally, the occupant's seating location is controlled when considering the frontal impact crashes.**

The data used in the analysis are drawn from the Collision Performance and Injury Report file maintained by the Highway Safety Research Institute. The information contained in this file consists of the Multi-Disciplinary Accident Investigation reports submitted by the government and industry sponsored crash investigation teams which have been automated for computer uses (6). However, this study only considers the subset of cases in the file which comprise the census of new American manufactured towaways occurring in Washtenaw County (Ann Arbor), Michigan for the 1970-1973 period (4). The subset was chosen in order to present a distribution of injury severity values unbiased by case selection criteria. However, the distributions should not be considered as a basis for drawing inferences about national restraint usage rates since provincial biases dictate the levels observed for this one county. Yet, the functional relationships observed between the various control factors, restraint system usage, and injury severity should not be prejudiced by use of this county's towaway census data.

The severity of the occupant's injury is recorded in the file in terms of the Abbreviated Injury Scale (5). There are eleven severity level values in the AIS scale (none, minor, non-dangerous-moderate, non-dangerous-severe, dangerous-serious, dangerous-critical, fatal lesions in one region, fatal lesions in two regions, fatal lesions in two or more regions, fatal with details unknown). All of the analyses in this paper use a seven level version of this scale (0 through 6+) in which all of the various AIS values denoting fatal injury are collapsed into one category (6+). The AIS scale is not an interval measure of injury - that is, a scale value of four cannot be assumed to be twice as severe as a scale value of two. Also, there is unfortunately no

** The analysis reported upon in this paper is a refined version of a section in a larger earlier work: Ray Shortridge and Fred Preston, "A Study of Restraint-System Use and Effectiveness," 241 pages, Highway Safety Research Institute, June, 1973.

clear substantive interpretation of the AIS scale in terms of dollars lost or degree of activity restriction. As a consequence, care must be exercised when drawing conclusions when this scale is included in the statistical techniques used in the analysis.

FRONTAL IMPACT CRASHES

This section of the analysis considers only those drivers and right front passengers whose vehicles sustained their principal damage in the front end. The first table presents the distribution of injury severity values recorded for the occupants according to whether they were unrestrained, wore only a lap belt, or used a torso device.

Table 1 clearly indicates that the occupants with torso restraints were much less likely to have been severely or fatally injured than those with lap belt only or unrestrained. On the other hand, the occupants with lap belts were somewhat less likely to have been killed than the unrestrained people but more likely to have been severely injured (AIS=4,5) than the unrestrained.

Table 1 - Injury Severity Values for Drivers and Right-Front Passengers by Restraint System Usage (Frontal Impact)

	0	1	2	3	4	5	6+	N
No Restraint	217	319	45	38	1	4	9	633
Lap Belt	93	95	8	7	3	4	2	212
Torso	17	9	1	0	0	0	0	27

	0	1	2	3	4	5	6+
No Restraint	34.3%	50.4%	7.1%	6.0%	0.2%	0.6%	1.4%
Lap Belt	43.9%	44.8%	3.8%	3.3%	1.4%	1.9%	0.9%
Torso	63.0%	33.3%	3.7%	0.0%	0.0%	0.0%	0.0%

However, the severity of the crash conceivably could affect the level of the injury sustained by the occupants. One might suppose that the probability that an occupant would be seriously or fatally injured would be greater in more severe crashes than in less destructive ones despite the use of a restraint. If the unrestrained occupants were in accidents which tended to be more severe than those for restrained people, then the injury reduction observed for occupants using a restraining device may in fact be due to the difference in crash severity and not to the restraint. It is desirable, then, to control on crash severity in order to gauge the net effect of restraint usage on injury. One measure of crash severity is the vehicle deformation extent code reported by the investigator and this is used in the subsequent analysis as the control variable for crash severity.

The approach adopted in this analysis imposes a statistical control upon crash severity. A regression model using the vehicle deformation extent code as the index for crash severity was used to predict an injury severity level for each occupant. This predicted injury value is the severity one would expect the occupant to have sustained given the damage to the car. (See Appendix A). This technique was applied to the drivers and right-front passengers involved in front-end crashes. Table 2 and Figure 1 contain the mean predicted injury and the mean recorded injury for the three restraint usage categories.

Table 2 - Mean Predicted and Mean Recorded Injury Levels by Restraint System Use (Frontal Impact)

	Predicted Injury	
	Mean	Standard Deviation
No Restraint	0.90	0.62
Lap Belt	0.91	0.65
Torso	0.84	0.50

	Recorded Injury	
	Mean	Standard Deviation
No Restraint	0.95	1.06
Lap Belt	0.84	1.12
Torso	0.41	0.57

This analysis shows that, on the whole, unrestrained occupants are more severely injured than one would expect given the severity of their accidents. The mean injury level for unrestrained people was about 0.05 AIS units greater than that predicted by the regression model. Those wearing a lap belt evidenced a mean injury level of about 0.07 AIS units lower than the predicted mean while the mean recorded injury for those occupants using a torso device was 0.43 AIS units lower than the crash severity model predicted. For the Washtenaw County towaway "census", the use of a restraint system reduces the average injury severity sustained by the occupant

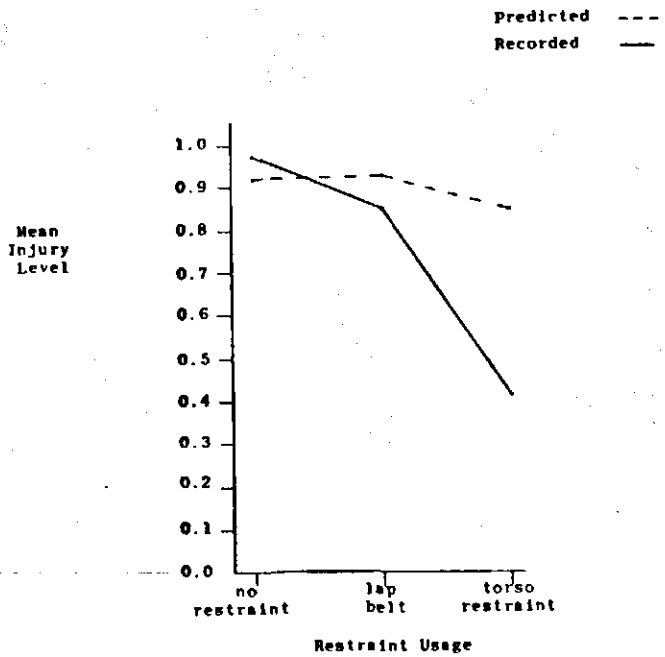

Fig. 1 - Mean values for predicted and recorded injury levels by restraint usage (Frontal Impact)

below that which is to be expected given the severity of the accident.

The auto safety literature has amply demonstrated that ejection from the vehicle usually results in severe injury to the passenger and that restraining belts, when used, effectively reduce the likelihood of ejection (7). The following analysis assesses the effect of the restraint systems for those occupants who were not ejected either partially or totally from the vehicle. Table 3 contains the distribution of injury severity values for those occupants who were not ejected either totally or partially from their vehicles.

The distribution of recorded injuries for the 628 unrestrained occupants who were unejected does not differ markedly from that observed for the total set of 633 unrestrained people (see Table 1). Those people with lap belts (none of whom were ejected) were still slightly less likely to have been killed than the unejected unrestrained occupants but were again somewhat more likely to have been seriously injured (AIS-4,5) than the unejected un-

Table 3 - Distribution of Injury Severity Values for Unejected Occupants by Restraint-Use Categories (Frontal Impact)

Frequency

	0	1	2	3	4	5	6+	N
No Restraint	217	319	43	36	1	4	8	628
Lap Belt	93	95	8	7	3	4	2	212
Torso	17	9	1	0	0	0	0	17

Percent

	0	1	2	3	4	5	6+
No Restraint	34.6	50.8	6.8	5.7	0.2	0.6	1.3
Lap Belt	43.9	44.8	3.8	3.3	1.4	1.9	0.9
Torso	63.0	33.3	3.7	0.0	0.0	0.0	0.0

restrained occupants (3.3% to 0.8%, respectively). However, none of the people wearing a torso device was ejected so the distribution of injuries is the same as found in Table 1 - no fatalities and no serious injuries.

Statistical control was imposed upon the severity of the accident for the set of unejected occupants. The regression model predicted an injury level for each person on the basis of the degree of deformation sustained by the vehicle. Table 4 and Figure 2 present the mean injury values predicted by

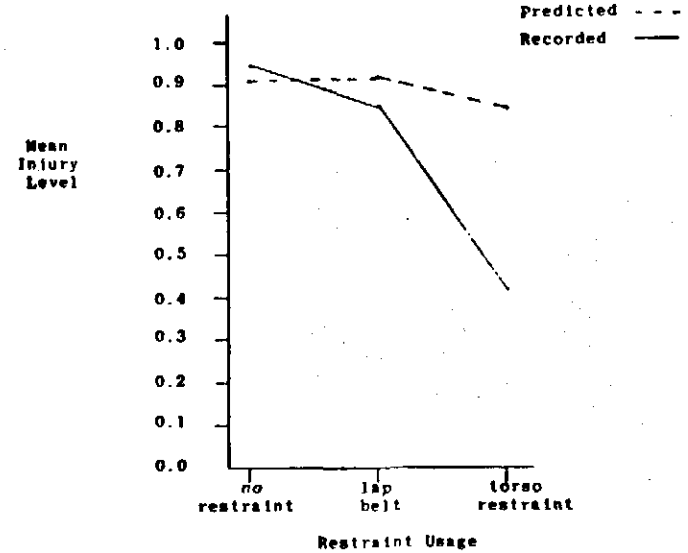

Fig. 2 - Mean values for predicted and recorded injury levels by restraint usage for unejected occupants (Frontal Impact)

Table 4 - Mean Predicted and Mean Recorded Injury Levels by Restraint System Use for Unejected Occupants (Frontal Impact)

	Predicted Injury Mean	Standard Deviation
No Restraint	0.89	0.60
Lap Belt	0.90	0.64
Torso	0.83	0.50
	Recorded Injury	
No Restraint	0.93	1.04
Lap Belt	0.84	1.12
Torso	0.41	0.57

the crash severity factor and the means for the recorded injury levels for the unejected occupants.

Although the exclusion of the non-ejected cases reduced the mean of the injury level recorded for the unrestrained occupants, a marked injury reduction effect associated with using a restraint system is still in evidence. The mean recorded injury level for unrestrained people is 0.04 AIS units higher than that predicted by the crash severity model. On the other hand, the mean recorded injury level for lap belted and torso-restrained occupants is 0.06 and 0.42 AIS units, respectively, lower than the level one would expect given the severity of their crashes. The graph in Figure 2 clearly illustrates the decline in injury associated with wearing a restraint, particularly a torso device. Hence, even when controlling an ejection and crash severity, using a restraint system on the whole seems to reduce the level of injury sustained by the occupants.

This section addresses the question of whether the occupant's seated location affects the level of injury sustained in the accident. There are two issues involved in this question: first, do restraining devices exercise injury reduction effects for both seating locations which are attributable to lap belts and to torso restraints, and, second, are these effects the same for drivers as for right front passengers. The analysis will deal with each issue in turn.*

* Only frontal impact crashes are considered with seating location controlled. For an analysis of the effect of restraint use on injury in side impact crashes, see: Fred Preston, Ray Shortridge, "An Evaluation of the Effectiveness of Side-Door Beams Based on Accident Exposure", Highway Safety Research Institute, September, 1973. (UM-HSRI-SA-73-8).

To assess whether restraints reduce the injury level sustained by both drivers and right front passengers the means of the recorded injury values for each restraint-use group are compared with the means of the expected injury values for each seating location. The predicted injury levels were obtained from the regression model using the vehicle damage extent code as the predictor variable and the occupant's recorded injury severity as the dependent variable. This procedure controls on accident severity. Then the occupants were divided into two groups--drivers and right front passengers. Table 5 presents the means for the predicted and the recorded injury severity variables for drivers while a graphic portrayal is contained in Figure 3.

Table 5 - Mean Values for Predicted and Recorded Injury Levels by Restraint Use for Drivers (Frontal Impact)

	No Restraint	Lap Belt Only	Torso
Predicted Mean	0.90	0.89	0.81
Recorded Mean	0.92	0.80	0.36

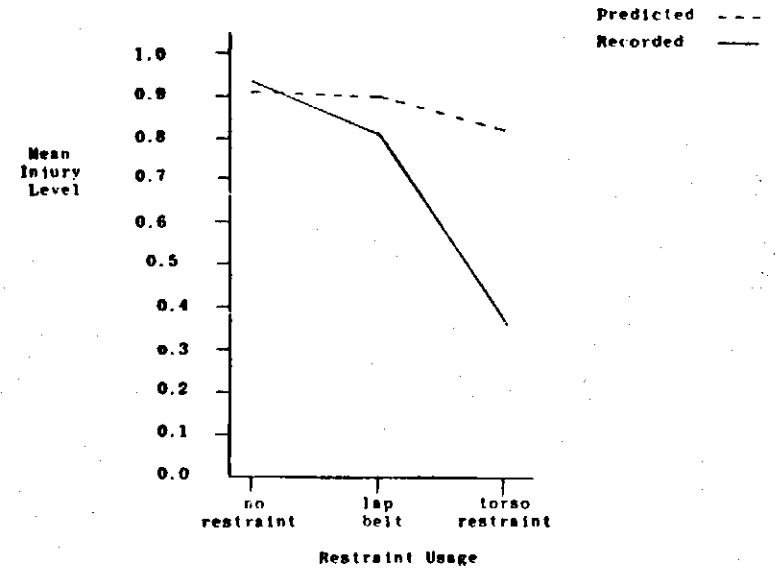

Fig. 3 - Mean values for predicted and recorded injury levels by restraint usage for drivers (Frontal Impact)

The data indicate that the restraining devices are associated with an injury reduction in the case of drivers. Using only a lap belt reduces the mean injury value by 0.09 AIS units from the level predicted by the crash severity model. Wearing a torso device is associated with a reduction of 0.45 AIS units below the expected level.

The comparable information for right front passengers is contained in Table 6 and Figure 4. The table indicates that for right front passengers using a restraining device is associated with a reduction in the mean injury values relative to the levels predicted by the crash severity regression model. Those using only a lap belt has an average recorded injury

Table 6 - Mean Values for Predicted and Recorded Injury Levels by Restraint Use for Right Front Passengers (Frontal Impact)

	No Restraint	Lap Belt Only	Torso
Predicted Mean	0.89	0.97	0.96
Recorded Mean	1.02	0.95	0.60

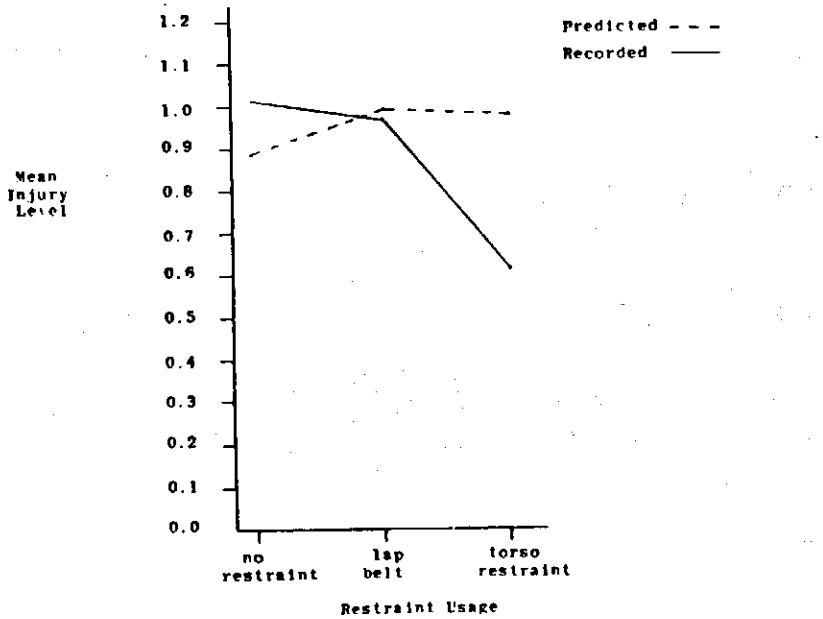

Fig. 4 - Mean values for predicted and recorded injury levels by restraint usage for right front passengers (Frontal Impact)

level 0.02 AIS units lower than expected given the severity of the crash. The comparable reduction for people wearing a torso device was 0.36 AIS units.

Although the use of a restraint system correlates with a reduction of injury relative to the level to be expected given the crash severity, it appears that the effect is greater for drivers than for right front passengers particularly for those wearing only a lap belt. Table 7 and Figure 5 compare the means for the predicted and recorded injury levels obtained for drivers and right front passengers who wore lap belts.

It is evident that right-front passengers tended to be involved in accidents of somewhat greater severity than were the drivers because the mean of the predicted injury is greater for people in the right seat than for those who were driving. However,

Table 7 - Mean Values for Predicted and Recorded Injury Levels for Lap Belted Occupants by Seated Location (Frontal Impact)

	Drivers	Right Front
Predicted Mean	0.89	0.97
Recorded Mean	0.80	0.95

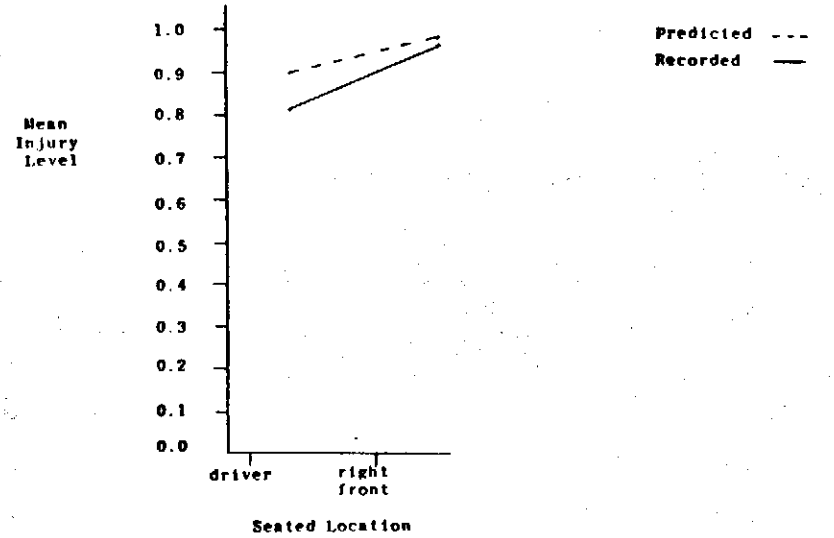

Fig. 5 - Means for predicted and recorded injury levels for lap belted occupants by seated location (Frontal Impact)