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ANALYSIS OF MEDICAL DATA FROM FATAL ROAD CRASHES

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Abstract

This report, based upon data in the Federal Office of Road Safety *Fatality File* database analyses various aspects of medical outcomes resulting from fatal road crashes in Australia in 1988. In particular the report describes the nature of injuries suffered by those killed and quantifies the degree to which certain factors contribute to crash survival or, in the case of those killed, the timing of death. There is also a brief section examining crashes in which death resulted from low severity injuries.

Keywords

Fatal crashes, road fatalities, injury outcomes, alcohol, timing of death, statistical analysis, seatbelts

Notes

(1) FORS research reports are disseminated in the interests of information exchange.
(2) The views expressed are those of the authors and do not necessarily represent those of the Commonwealth Government.

Analysis of Medical Data from Fatal Road Crashes

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Executive Summary

INTRODUCTION

This report, based upon data in the Federal Office of Road Safety 'Fatality File' database, analyses various aspects of medical outcomes resulting from fatal road crashes in Australia in 1988. In particular the report describes the nature of injuries suffered by those killed and quantifies the degree to which certain factors contribute to crash survival or, in the case of those killed, the timing of death. There is also a brief section examining crashes in which death resulted from low severity injuries.

The 'Fatality File' is a unique source of data on fatal crashes in Australia. Not only is it the only major nationally consistent road safety database, but it is also the only road safety data source that combines detailed information about the crash event and people involved with a precise description of the resultant trauma.

DESCRIPTION OF INJURIES SUFFERED BY THOSE FATALLY INJURED

A description of injuries suffered by those killed in road crashes revealed that 76% of all fatalities had at least one injury to the head and 71% had at least one injury to the thorax. Just under one half of all fatalities suffered an abdominal injury.

The percentage of fatally injured car occupants with injuries to the head and chest is strongly related to the age of the person killed. In general older people killed were less likely to have suffered head injuries but more likely to have thoracic injuries.

Injury patterns for fatally injured passenger car occupants were strongly influenced by the collision point of impact. For example, those dying in overturn crashes tended to have a disproportionately high number of serious injuries confined to the head or to the head and thorax simultaneously.

Serious injuries to the spine, in particular the cervical spine, were more common among female than among male fatalities. Car occupants who died in a vehicle with a mass less than 1250 kgs were also more likely to have suffered a serious spinal injury.

FACTORS AFFECTING INJURY OUTCOME

Many crash factors affect the probability of surviving a severe crash. This probability is reduced if a person is over 60 years old, is trapped or ejected, or is not wearing a seat belt. The risk is also greater when the posted speed limit is 80 kph or more. In two car crashes the risk is also affected by vehicle mass, with occupants of smaller cars being at greater risk. In addition, although technical issues prevent precise estimates of effects, the data suggest that people with significantly elevated blood alcohol levels are more likely to die in a crash of given severity.

Detailed analysis of data from the driver and the front left seat passenger in single vehicle accidents shows the importance of seat belt wearing, point of impact and ejection in determining the outcome of a crash. In these crashes impacts on the same side that a person is sitting are much more dangerous to that person than impacts on the other side.

FACTORS AFFECTING SURVIVAL TIME

For those killed the timing of death is strongly associated with the overall level of injuries as measured by the Injury Severity Score (ISS). Those with a greater level of injury are more likely to die before medical assistance arrives, and more severely injured people are more likely to die before reaching hospital.

Although the ISS is supposed to take into account the total effect of all injuries, the presence or absence of severe injury to specific regions of the body provides additional information on survival time over and above the information provide by the ISS. In particular head injuries generally appear to be more serious than their AIS score would indicate, and in consequence their contribution to the ISS is too low.

A number of other factors were also found to affect survival time. Fatally injured car occupants under 13 years old are more likely to die before receiving medical assistance than other fatally injured car occupants and they generally do not survive as long as other fatally injured car occupants. Presumably car occupants under 13 years old have much better prospects of survival if they do not die within a few hours. Fatally injured pedestrians generally survive much longer than fatally injured car occupants.

Fatally injured road users with a blood alcohol content over 0.100 tend to survive for a shorter time than those with a lower blood alcohol content. This suggest that the earlier finding, that car occupants who were intoxicated were more likely to die in a given crash, is at least partly explained by alcohol's potentiation of injuries received as opposed to a tendency for an intoxicated person to suffer more severe injuries.

The probability of dying before receiving medical assistance was greater for all road users when the posted speed limit was 80 kph or over than when it was lower. The probability of dying before receiving medical assistance or within one hour was greater for car occupants whose vehicles were damaged beyond repair.

FATALITIES RESULTING FROM LOW SEVERITY INJURIES

About a quarter of all fatalities had injuries which they would be expected to survive. Just over 18% of these died from causes unconnected with the crash, or as a secondary result of their original injuries. Of the rest a large proportion had head injuries, 77% for fatally injured car occupants and 76% for other road users. Substantial percentages, 46% and 52% for car occupants and other road users respectively, had serious head injuries and no serious injuries to any other region of the body, compared with 14% for all car occupant fatalities and 19% for all other road user fatalities.

Chapter 1

Introduction

The 1988 Fatality File is a detailed database containing information relating to all fatal road crashes in Australia that occurred in 1988. Fatal road crashes include any crash that occurred on a public road and resulted in at least one death within thirty days. In fact there are three distinct data files, the first giving details of the crashes, the second giving details of the vehicles involved, and the third giving details of all people involved whether or not they were injured. Each crash and vehicle is uniquely identified so that injuries to road users can be related to circumstances of the crash, and to features of the vehicles involved. A detailed description of the data is given in the Federal Office of Road Safety publication, "Fatality File 1988: documentation of file structure". and in reports on the collection of the data by AGB: McNair. The data is summarized in "Standard tables: 1988 road fatality file", Federal Office of Road Safety, 1991.

Analysis of the injury data, in particular relating it to characteristics of people, vehicles and crashes leads to suggested areas for improvement in occupant protection, and indicates to what extent improved trauma management might be beneficial. However three things limit the interpretation of the data.

First we would like to compare the crashes with similar crashes which did not result in fatalities in order to estimate the probability of a fatality in any particular set of circumstances. We would also like to compare fatal crashes with non-fatal crashes in general to see what distinctive features fatal crashes have. For example of 1446 passenger car occupants killed, 24% were known to be not wearing seat belts whereas, according to Fildes et al (1991), in exposure studies 6% of occupants were observed to be not wearing seat belts. This probably reflects the efficacy of seat belts in preventing fatalities, but it is also possible that not wearing a seat belt is indicative of more reckless behaviour in general. This issue cannot be resolved completely by only considering fatal crashes, although some conclusions can be drawn from those crashes involving both belted and unbelted car occupants.

Second the data is incomplete for several variables which have important effects on the outcome of a crash. For 1147 car occupants it is not known whether or not they were wearing a seat belt. For many vehicles details of the model and year are not available, so an accurate estimate of car mass cannot be made. Blood alcohol content is not available for 4120 individuals.

Because the rate of seat belt wearing is high in Australia it is plausible to assume that a person is wearing a seat belt in the absence of evidence to the contrary. However the rate of seat belt wearing in fatal crashes may well not be similar to that in the general population. Where the make of a car is known but not the model the average mass for cars of that make can be used as an estimate of its mass. For blood alcohol content it is plausible to assume that in many case persons under 18 years old will have a zero or low blood alcohol content. For some individuals it is known that their blood alcohol content is between 0.05 and 0.08, so a value of 0.065 can be used. These substitutions introduce additional random variation, and may also introduce systematic effects. Fatally injured persons whose blood alcohol content is recorded are typically more seriously injured than those whose blood alcohol content is not recorded. However the alternative to making substitutions like this is to omit large numbers of individuals from some of the statistical analyses.

Third there are inconsistencies in the data which have to be resolved before analysis, and the conclusions drawn may depend on how this is done. For example two variables indicate whether or not a particular individual died. The first is injury severity, and the second is a check variable which indicates whether or not a person died. These are inconsistent for six individuals. Also the time that a fatally injured person survived can be estimated from the difference between time of death and the time of the crash. In many cases this is inconsistent with the variable which gives direct information on survival time.

It should also be borne in mind that some variables are inherently easier to determine objectively than others, for example, posted speed limit as opposed to the speed of vehicles. Hence it is easier to assess the effects of speed limits than the effects of vehicle speed.

Details of injuries are unavailable for 155 fatally injured people. Naturally these people cannot be included in consideration of patterns of injury, but they may be included in assessment of the effect of various factors on the general severity of injuries.

Chapter 2

Description of injury patterns

2.1 Introduction

In this chapter we look at the patterns of injury for fatally injured road users, particularly passenger car occupants, and we look at the effects of various characteristics of the individual, the vehicle, and the crash on the relative frequency of different injury patterns. No comparisons are made with persons who are not fatally injured, so no estimates are made in this chapter of the absolute frequency of particular injuries. For example, the 747 fatally injured car occupants known to be wearing seat belts can be compared with the 337 who were not, from the point of view of whether belt use affects the pattern of injuries observed. No conclusions about the effectiveness or otherwise of seat belts in preventing injury are drawn in this chapter.

The information available on the injuries includes the region of the body involved, more detailed description of the injury, and its severity as measured by its score on the 1985 revision of the Abbreviated Injury Scale (AIS, Table 2.1) published by the American Association for Automotive Medicine. However, minor injuries, a score of one, have not been recorded in the data file.

AIS score	Description
0	No injury
1	Minor (may not require professional attention)
2	Moderate (usually requires professional attention)
3	Serious (not normally life threatening)
4	Severe (life threatening but survival probable)
5	Critical (survival uncertain)
6	Maximum (virtually unsurvivable)

Table 2.1: Abbreviated injury scale (AIS) scores

2.2 Statistical methods

The data considered in this chapter consist mainly of counts and the primary statistical technique used is the fitting of log linear models, a version of the generalized linear models described by Dobson (1990) and McCullagh and Nelder(1989). Two forms of these models are used.

For specific regions of the body, such as the head, we consider whether or not a person had serious injuries (AIS score of three or more). This minimizes the effect of difficulties in assessing injury severity accurately, and means that only two possible outcomes are considered. The effect of a particular factor such as the sex of a person is assessed in the following way. For any fatally injured individual male, say, the combined effects of any other important factors are summarized in a single index which is a measure of predisposition to head injury in the particular circumstances. This index is chosen in such a way that the probability of serious head injury increases with the index in an S-shaped curve (Figure 2.1) so that for

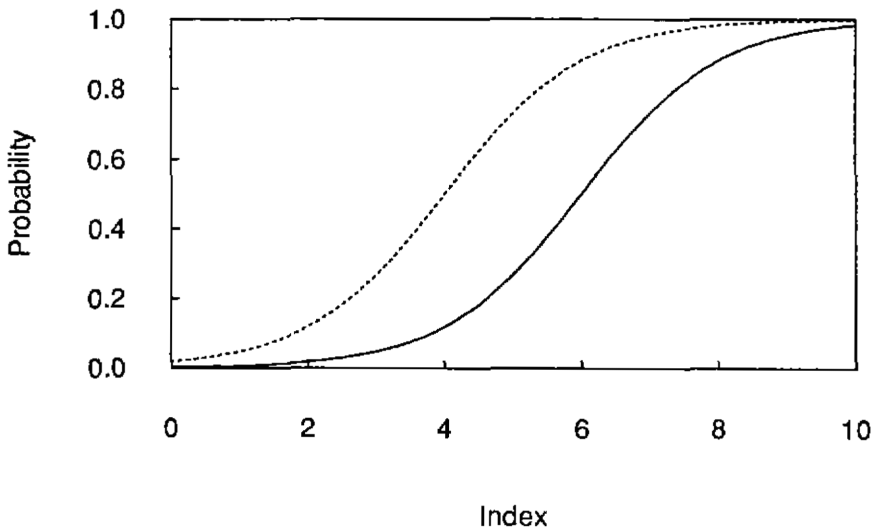

Figure 2.1: Hypothetical curves showing how the probability that a fatally injured person has a serious head injury might vary with an index defining propensity to head injury for males, continuous line, and females, dotted line

low values serious head injuries are very unlikely, and for high values serious head injuries are almost certain. We then assume that a similar curve applies for females, but that it is displaced horizontally. This displacement measures the difference between males and females. From Figure 2.1 we can see that if these relations held there would be little difference between the outcomes for males and females for low and high values of the index, and the difference is maximized at intermediate values. Another way of putting this is to say that the odds ratio is constant. If p_M and

p_F are the probabilities that for a given value of the index males and females have serious head injuries,

$$\frac{p_M}{(1-p_M)} / \frac{p_F}{(1-p_F)} \text{ is a constant,}$$

for all values of the index. To assess the effect of another factor its effect is removed from the index, and the effect of sex is included in the index.

When a factor has more than two levels, such as point of impact which can be broadly classified as front, right, left, overturn or other, several cross ratios can be calculated depending on which pair of levels is chosen. It is convenient to work with the logarithms of the odds, for example $\log(p_M/(1-p_M))$ and $\log(p_F/(1-p_F))$, in the case of males and females. For a factor with two levels, such as sex, the difference of the log odds, which is the logarithm of the odds ratio, is reported. For a factor with more than two levels, the differences between the log odds and the log odds for one of the other levels are reported. For example for a particular point of impact the difference between the log odds for that point of impact and for a frontal impact is reported. Approximate standard errors are quoted where appropriate.

This approach was implemented by assuming that the odds of serious injury are the product of terms involving characteristics of the person concerned and features of the crash. That is to say if p is the probability of receiving serious head injuries in a crash,

$$p/(1-p) = a_i b_j c_k \ldots,$$

where the constants, a_i, b_j, c_k etc., each represent the effects of the value of a particular factor. For example, the term, a, might refer to point of impact, and the possible value, a_1 might correspond to a frontal impact, a_2 to a right impact, and so on. Taking logarithms gives

$$\log(p/(1-p)) = \log a_i + \log b_j + \log c_k \ldots,$$

so that the effects of the various factors are now additive.

A number of possible terms was considered for inclusion in the model. The factor which best explained whether or not a person received serious head injuries was included first. Then a search was made for the factor which best explained the outcome in conjunction with the first factor and so on. In other words a forward stepwise selection procedure was used to select predictors. Selection was terminated when further terms failed to give substantial improvement in explanatory power, rather than purely on the basis of statistical significance. The following factors were considered as possible predictors of the probability of receiving serious head injuries for an individual car occupant, the age, sex, blood alcohol content and seating position of the person, whether or not the person was handicapped, whether or not the person was ejected, whether or not the person wore a seat belt, the posted speed limit, whether or not the car was speeding, the point of impact, the age and mass of the car, and whether or not the accident occurred in a remote or rural area. Interactions between pairs of factors were also considered. Similar analyses were done for all regions of the body, but results are not reported for regions where few people had serious injuries.

In the second type of log linear model individuals are classified according to the combinations of injuries received and various other factors. It is assumed that the number observed in a particular category depends on the multiplication of a few terms each of which captures the effect of a particular factor. Forward stepwise selection was again used to select a suitable model, but fewer candidate terms were considered. These were seating position, point of impact, age, and seat belt wearing. Additional terms were not included because this would have meant that there were very small numbers of people in many of the categories being considered and there would be little possibility of getting statistically significant results.

2.3 Classification of injuries

	MAIS score, passenger car occupants				MAIS score, all other fatalities				All fatalities
Region of body	2	3,4	5,6	Total(%)	2	3,4	5,6	Total(%)	Total(%)
Head	16	708	299	1023(74%)	6	708	322	1036(78%)	2059(76%)
Thorax	28	676	327	1031(74%)	37	619	249	905(68%)	1936(71%)
Abdomen	252	338	136	726(52%)	211	273	116	600(45%)	1326(49%)
Lower extremity	100	387	2	489(35%)	123	456	3	582(44%)	1071(39%)
External injuries	399	5	28	432(31%)	411	4	16	431(32%)	863(32%)
Upper extremity	227	111	0	338(24%)	241	96	0	337(25%)	675(25%)
Cervical spine	80	31	95	206(15%)	74	27	85	186(14%)	392(14%)
Face	125	47	0	172(12%)	72	29	0	101(8%)	273(10%)
Thoracic spine	29	19	21	69(5%)	39	28	35	102(8%)	171(6%)
Neck	5	15	8	28(2%)	3	11	10	24(2%)	52(2%)
Lumbar spine	3	2	5	10(1%)	6	3	5	14(1%)	24(1%)
Total number of individuals				1385				1336	2721

Table 2.2: Numbers of fatalities with injuries to various regions of the body

For each fatality the maximum abbreviated injury scale (MAIS) score was calculated for the injuries to each of eleven regions of the body, Table 2.2. In this Table the injuries are listed in decreasing order of total number of fatalities with injuries to the region, with the exception of spinal injuries which are grouped together.. The classification "all other fatalities" includes 504 pedestrians, 307 motor cycle riders and 209 occupants of commercial vehicles with a mass of less than 3.5 tonnes. The remaining 316 fatally individuals with information on injuries recorded were using a variety of vehicle types, none of which involved more than 100 fatalities. External injuries are injuries to the skin, such as burns, abrasions or lacerations. Lower extremity includes injuries to the pelvis as well as to the legs and feet, and upper extremity injuries include clavicle fractures as well as hand and arm injuries. For more detailed descriptions of injuries and their classification refer to the documentation of the Abbreviated Injury Scale.

Head and thorax injuries are involved in the majority of fatalities, 76% and 71% respectively. In comparison in a study of data submitted to the Major Trauma Outcome Study in the United States, Gennarelli et al (1989) reported that 67% of fatally injured vehicle occupants had head injuries. The third and fourth most commonly injured regions (49% and 39% of fatalities) were the abdomen and the lower extremities. Serious injuries to other regions of the body (AIS score of 3 or more) are much less common than for head, thorax, abdomen and lower extremity.

Table 2.3 shows the nine most common combinations of serious injury for fatally injured people. Most of the other combinations of serious injuries were suffered by a

Injured regions of body	Passenger car occupants		Other fatalities	
	Number	Percentage	Number	Percentage
Head	190	14	248	19
Head and thorax	225	16	194	14
Head, thorax and abdomen	136	10	97	7
Head, thorax and lower extremity	87	6	117	9
Head, thorax, abdomen and lower extremity	70	5	63	5
Head and lower extremity	30	2	51	4
Thorax	94	7	65	5
Thorax and abdomen	89	6	57	4
Thorax, abdomen and lower extremity	42	3	37	3
Other combinations	422	31	407	30
Total	1385	100	1336	100

Table 2.3: Main groupings for serious injuries to fatally injured people

small number of people. For example of the car occupants with serious head injuries who are included in these other combinations, 25 had serious injuries to the head and spine, six to the head and face, four to the head and upper extremities, two to the head, neck and spine, two to the head, spine and upper extremities, two had serious head injuries and serious external injuries, one had serious injuries to the head and neck, one to the head, spine and face, and one had serious injuries to the head, spine and face together with serious external injuries.

Rather than have a very large "other" category, in Table 2.4 these injuries combinations have been added into the "head" group, and similarly for the remaining eight most common combinations, people who had that combination in conjunction with serious external injuries, or serious injuries to the spine, neck, face or upper extremities have been added into the corresponding group. In effect in Section 2.4

Injured regions of body	Passenger car occupants		Other fatalities	
	Number	Percentage	Number	Percentage
Head	234	17	284	21
Head and thorax	301	22	252	19
Head, thorax and abdomen	177	13	125	9
Head, thorax and lower extremity	122	9	166	12
Head, thorax, abdomen and lower extremity	101	7	91	7
Head and lower extremity	48	3	69	5
Thorax	115	8	80	6
Thorax and abdomen	98	7	63	5
Thorax, abdomen and lower extremity	55	4	50	4
Other combinations	134	10	156	12
Total	1385	100	1336	100

Table 2.4: Main groupings for serious injuries to the head, thorax, abdomen or lower extremity, possibly with serious injury to other regions of the body

of this chapter we concentrate on injuries to the four most important regions, and in particular to those combinations of serious injuries to these regions which occur most frequently. For car occupants the largest contributions to the "other" category in this revised grouping are 21 fatally injured people with no serious injury, and 20 with serious injury to the thorax and lower extremities but no other region of the body.

In the rest of this section we consider injuries to the various regions of the body in more detail.

2.3.1 Head and thorax injuries

Table 2.5 shows that the most common head injuries are cerebrum lesions and skull fractures. There were 1092 individuals with both skull fractures and cerebrum lesions. This is 86% of all individuals with skull fractures, and is 35% more than would be expected if these injuries occurred independently.

Whether or not a fatally injured car occupant had serious (AIS score of three or more) head injuries depended on whether or not the person was over 60 or not and

	AIS score, Passenger car occupants				AIS score, Others			
Injury	2	3,4	5,6	Total	2	3,4	5,6	Total
Cerebrum lesions	0	59	1	60(835)	0	65	2	67(894)
Skull fractures	6	36	0	42(587)	7	44	0	51(687)
Brain stem lesions	0	0	16	16(219)	0	0	19	19(248)
Cerebellum lesions	0	12	0	12(166)	0	13	0	14(182)
Whole area	0	0	5	5(73)	0	0	4	4(57)

Table 2.5: Percentages of fatalities with different types of head injury, actual numbers in brackets

the point of impact. The log odds ratio for those over 60 and those 60 or under was -1.33$\pm$0.151. There are two possible interpretations of this; either older people are less prone to head injuries, or, more likely, older people die from injuries to other regions of the body which a younger person would have a better chance of surviving and this differential survival is much less marked for head injuries. Table 2.6 shows the effect of point of impact. Head injuries are less common for frontal impacts than for other points of impact.

Point of impact	Logarithm of odds	Number of individuals
front	-0.29$\pm$0.083	490
right	0.08$\pm$0.137	243
left	0.18$\pm$0.131	268
overturn	0.21$\pm$0.153	225
other	0.22$\pm$0.198	135

Table 2.6: Log odds of serious head injury for various points of impact amongst car occupant fatalities, with approximate standard errors

Table 2.7 shows that the most common injuries to the thorax are to the lungs and the rib cage. For these injuries the association was similar to that for skull fractures and cerebrum lesions; 658 people had both injuries which is about 35% more than would be expected by chance association.

Whether or not a fatally injured car occupant had serious thorax injuries depended very much on whether or not the person was under 13 or not. The log odds ratio for children under 13 as opposed to people 13 or over was -1.20$\pm$0.31. There are also effects of whether or not the car was beyond repair, the log odds ratio being 0.35$\pm$0.143 and direction of impact. The latter is defined as direct if the car hit or was hit by an object on the front, side or rear so that the direction of the impact was at right angles to the car. It is defined as oblique if the impact was on the front, side or rear of the car, but not at right angles. Other situations such as impact on a corner are put in a third category. Possibly this factor acts as a surrogate for force

Injury	AIS score, Passenger car occupants 2	3,4	5,6	Total	AIS score, Others 2	3,4	5,6	Total
Rib cage	5	40	1	47(648)	6	31	1	38(506)
Lung	0	43	1	44(607)	0	40	1	41(549)
Thoracic cavity	0	22	0	22(302)	0	21	0	21(283)
Aorta	0	2	13	14(197)	0	2	10	12(154)
Myocardium	0	4	10	14(196)	0	4	7	12(156)
Pericardium	0	7	2	9(118)	0	5	1	6(80)
Diaphragm	0	9	0	10(135)	0	5	0	5(67)
Sternum	6	0	0	6(90)	5	0	0	5(69)
Vena cava	0	2	0	2(23)	0	1	0	1(16)
Massive crush	0	0	1	1(19)	0	0	1	2(22)
Trachea	0	1	1	1(19)	0	1	1	1(16)

Table 2.7: Percentages of fatalities with different types of thorax injury, actual numbers in brackets

or duration of impact. The log odds ratio for direct impact as opposed to oblique is 0.32 ± 0.149,

Injury	Age group under 13	13-17	18-25	26-40	41-60	over 60	all ages
Cerebrum lesions	68	71	67	62	61	39	60
Rib cage injuries	18	32	33	49	62	68	47
Lung injuries	33	61	51	42	38	33	44
Skull fractures	58	59	45	45	40	25	42
Thoracic cavity injuries	12	19	22	21	22	27	22

Table 2.8: Percentages of car occupant fatalities with various injuries for different age groups

Table 2.8 shows the percentages of car occupants with the most common head and chest injuries for different age groups. The most common head injuries decline in importance with age, whilst thoracic cavity and rib cage injuries increase. Lung injuries first increase in importance with age, then decrease.

2.3.2 Abdominal injuries

Table 2.9 shows that the most common abdominal injuries are to the liver and spleen. These are often associated; 315 individuals have both liver and spleen injuries, often with the same AIS score. This is over 80% more than would be expected if injuries

Injury	AIS score, Passenger car occupants				AIS score, Others			
	2	3,4	5,6	Total	2	3,4	5,6	Total
Liver	15	15	6	36(495)	11	10	5	27(356)
Spleen	11	10	2	23(322)	8	7	2	17(226)
Kidney or adrenal gland	3	2	2	8(107)	4	2	1	8(112)
Mesentary	3	1	0	5(66)	4	1	0	5(65)
Colon	1	1	0	2(32)	2	0	0	2(32)
Bladder	1	2	0	2(32)	1	1	0	2(28)
Jejunum-ileum	1	1	0	2(25)	1	0	0	1(19)
Vena cava	0	1	0	1(13)	0	1	0	1(14)
Abdominal wall	0	1	0	1(11)	0	1	0	2(21)
Stomach	0	1	0	1(11)	0	0	0	1(11)
Unspecified	2	3	0	5(71)	1	4	0	5(70)

Table 2.9: Percentages of fatalities with different types of abdominal injury, actual numbers in brackets

to the liver and spleen occurred independently. The situation is similar for liver and kidney or adrenal gland injuries, 135 individuals have both, and for spleen and kidney or adrenal gland injuries, 85 individuals have both. These associations are much stronger than those observed for different head injuries, and for different thorax injuries.

Serious abdominal injuries were generally associated with serious thorax injuries. Of the 474 fatally injured car occupants with serious abdominal injuries, 91% also had serious thorax injuries. The probability that a fatally injured car occupant had abdominal injuries was increased if the posted speed limit was 80 kph or more, log odds ratio, 0.44±0.127. It was reduced if the car overturned and the person was not ejected, log odds ratio -1.45±0.29. This reflects the importance of head injuries in this situation.

2.3.3 Spinal injuries

Table 2.10 shows the most common spinal injuries. Fatally injured female car occupants are more likely to have serious spinal injuries than males, log odds ratio 0.53±0.163. The corresponding value for injuries to the cervical spine is 0.63±0.186. In this case vehicle mass also has an effect, there being an increased rate of injury to the cervical spine in cars under 1250kg, log odds ratio 0.50±0.194. Other types of spinal injury are too infrequent for a reliable estimate to be made.

Injury	AIS score, Passenger car occupants				AIS score, Others			
	2	3,4	5,6	Total	2	3,4	5,6	Total
Cervical spine								
Fracture	5	1	0	6(80)	2	1	0	3(37)
Cord contusion	0	1	3	4(61)	0	1	3	3(46)
Cord laceration	0	0	4	4(50)	0	0	4	4(51)
Dislocation	2	1	0	3(41)	0	0	0	0(0)
Thoracic spine								
Fracture	2	0	0	2(33)	3	0	0	4(51)
Cord laceration	0	0	1	1(18)	0	0	2	2(27)
Cord contusion	0	1	0	1(17)	0	1	1	2(24)

Table 2.10: Percentages of fatalities with different types of spinal injury, actual numbers in brackets

2.3.4 Other injuries

Injury	AIS score, Passenger car occupants				AIS score, Others			
	2	3,4	5,6	Total	2	3,4	5,6	Total
Femur fracture	0	22	0	22(303)	0	22	0	22(290)
Tibia fracture	7	6	0	13(185)	9	9	0	19(249)
Fibula fracture	5	3	0	8(110)	7	6	0	14(186)
Pelvic fracture	6	2	0	8(108)	9	3	0	12(156)
Symphysis pubic separation (fracture)	0	1	0	1(20)	0	3	0	3(43)
Partial or complete amputation	0	1	0	1(16)	0	3	0	3(40)
Knee joint	0	1	0	1(13)	0	1	0	1(9)
Ankle joint	0	1	0	1(9)	0	1	0	1(16)

Table 2.11: Percentages of fatalities with different types of lower extremity injury, actual numbers in brackets

For the other body regions Tables 2.11, 2.12, 2.14, and 2.15 show all organs and specific areas which were reported injured for at least 20 individuals.

Serious injuries to the lower and upper extremities were more likely for fatally injured car occupants if the posted speed limit was 80 kph or more, log odds ratios 0.66 ± 0.138 and 0.80 ± 0.255 respectively, and if the impact was at the front or on the side on which the person was sitting, Table 2.13. Injuries to the upper extremities were also more common in cars damaged beyond repair, log odds ratio 0.78 ± 0.257.

There is some indication that serious facial injuries are more likely in cars over 10 years old, log odds ratio, 0.99 ± 0.436. They are more likely when there is a frontal

	AIS score, Passenger car occupants				AIS score, Others			
Injury	2	3,4	5,6	Total	2	3,4	5,6	Total
Humerus fracture	8	3	0	11(159)	8	4	0	11(148)
Radius fracture	4	3	0	7(99)	4	2	0	6(80)
Ulna fracture	4	3	0	7(99)	3	2	0	5(71)
Clavicle fracture	5	0	0	5(72)	6	0	0	6(81)
Whole area	0	1	0	1(16)	0	1	0	1(13)
Fracture	1	0	0	1(8)	1	0	0	1(19)

Table 2.12: Percentages of fatalities with different types of upper extremity injury, actual numbers in brackets

	Lower extremities		Upper extremities	
Point of impact	Logarithm of odds	Number of individuals	Logarithm of odds	Number of individuals
front	0.44±0.082	490	0.39±0.136	490
same side	0.34±0.105	353	0.02±0.188	353
opposite side	-0.18±0.203	126	-0.90±0.459	126
overturn	-1.24±0.190	225	-0.84±0.298	225
other	-0.20±0.175	167	0.63±0.237	167

Table 2.13: Log odds of serious injury to the lower and upper extremities for various points of impact amongst car occupant fatalities, with approximate standard errors

Injury	AIS score, Passenger car occupants				AIS score, Others			
	2	3,4	5,6	Total	2	3,4	5,6	Total
Laceration	18	0	0	18(254)	18	0	0	18(242)
Contusion	8	0	0	8(109)	8	0	0	8(105)
Abrasion	7	0	0	7(101)	11	0	0	11(152)
Burns	0	0	2	2(30)	0	0	1	1(17)

Table 2.14: Percentages of fatalities with different types of external injury, actual numbers in brackets

Injury	AIS score, Passenger car occupants				AIS score, Others			
	2	3,4	5,6	Total	2	3,4	5,6	Total
Maxilla fracture	5	2	0	6(88)	2	1	0	3(44)
Mandible fracture	4	1	0	5(72)	3	1	0	4(49)
Nasal contusion or fracture	1	0	0	1(18)	1	0	0	1(10)
Orbit fracture	1	1	0	1(17)	1	0	0	1(12)
Zygoma fracture	1	0	0	1(12)	1	0	0	1(13)

Table 2.15: Percentages of fatalities with different types of facial injury, actual numbers in brackets

Point of impact	Logarithm of odds	Number of individuals
front	0.57±0.202	490
same side	-0.79±0.350	353
opposite side	-0.60±0.655	126
overturn	0.06±0.357	225
other	0.35±0.376	167

Table 2.16: Log odds of serious facial injury amongst car occupant fatalities for various points of impact, with approximate standard errors

impact as opposed to a side impact, Table 2.16.

2.4 Factors affecting injury pattern for car occupants

In the previous section individuals were divided into ten groups according to which combinations of four body regions, head, thorax, abdomen and lower extremity, were seriously injured. Figures 2.2, 2.3, 2.4 and 2.5 show the percentages of fatally

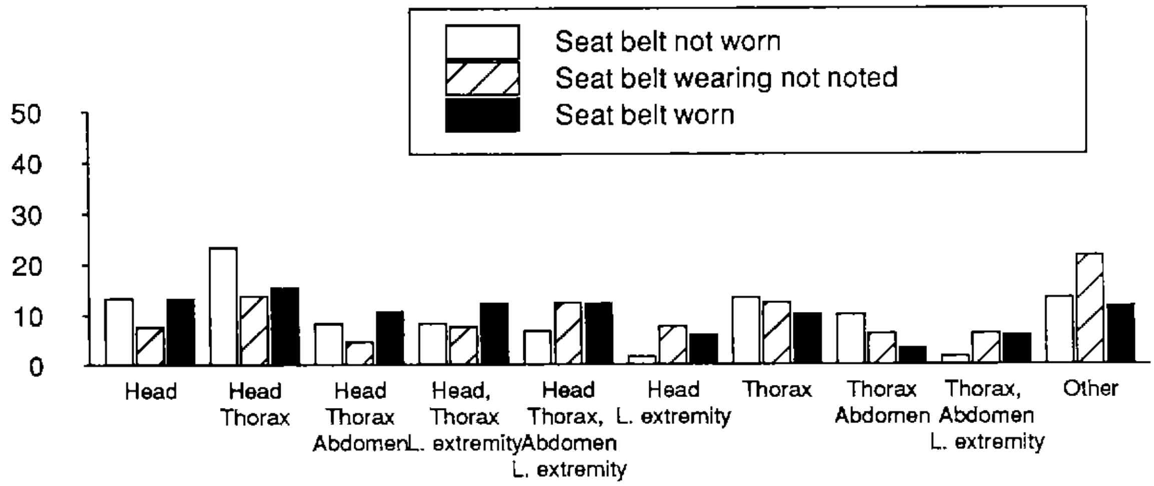

Figure 2.2: Percentages of fatalities in injury groups, drivers, frontal impacts, 60 not wearing seat belts, 65 seat belt wearing not noted, 189 wearing seat belts.

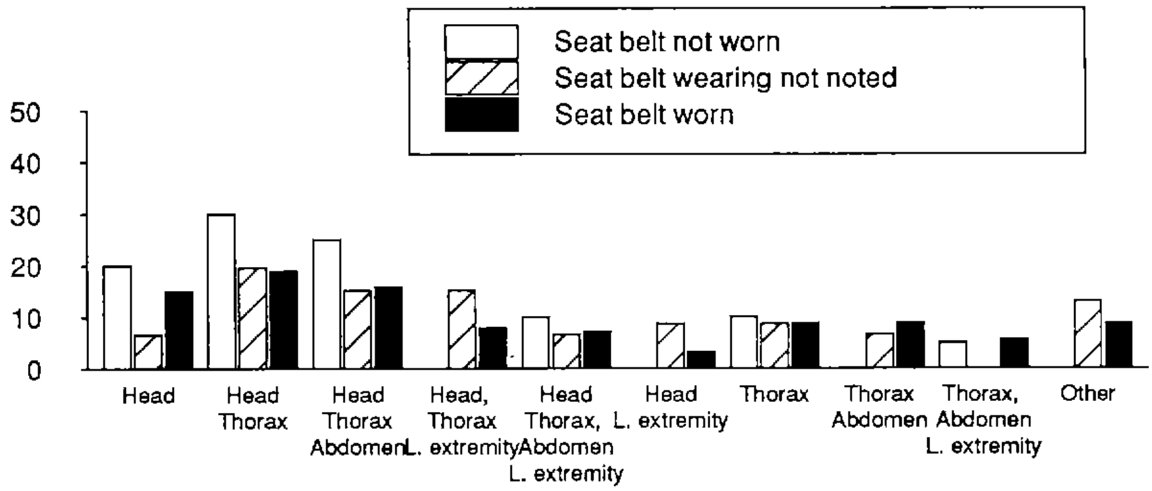

Figure 2.3: Percentages of fatalities in injury groups, drivers, right impacts, 20 not wearing seat belts, 46 seat belt wearing not noted, 126 wearing seat belts.

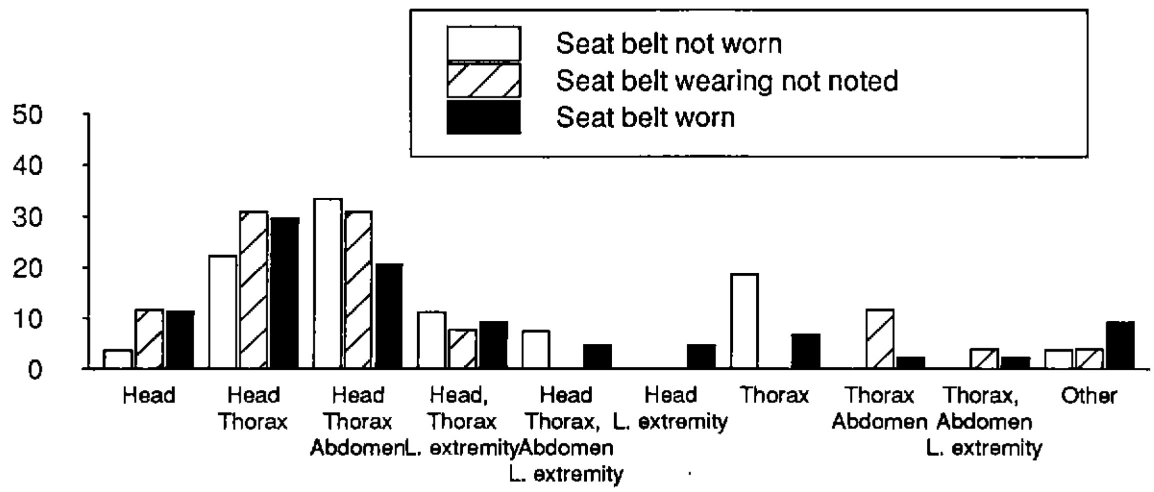

Figure 2.4: Percentages of fatalities in injury groups, drivers, left impacts, 27 not wearing seat belts, 26 seat belt wearing not noted, 44 wearing seat belts.

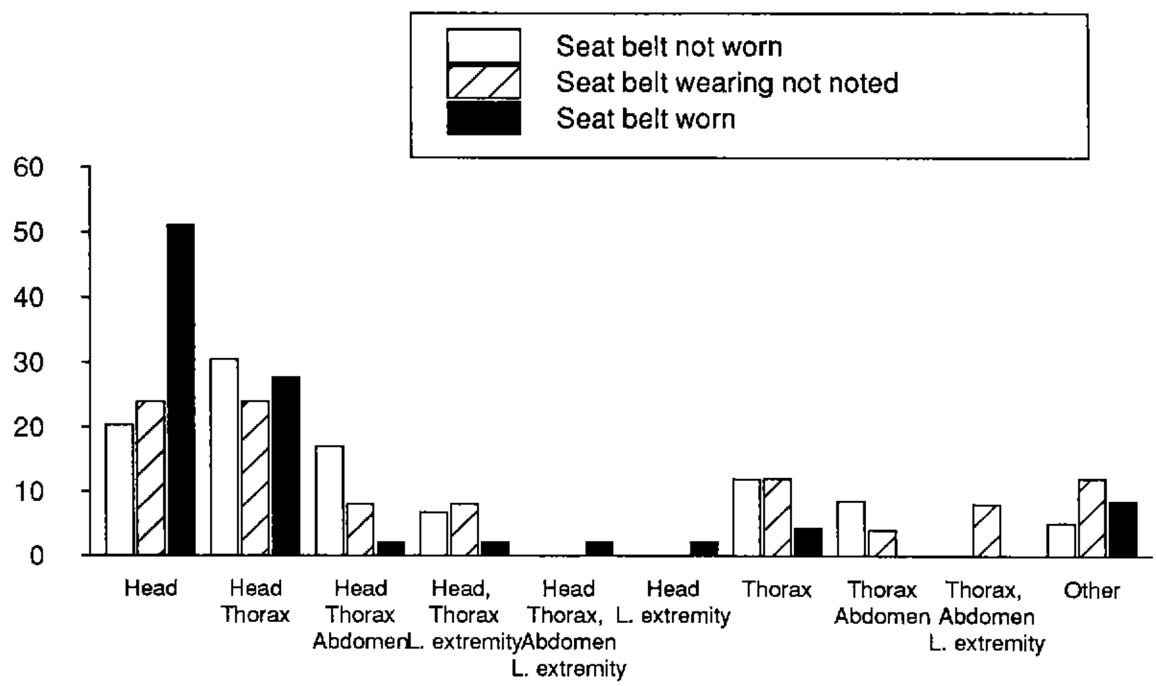

Figure 2.5: Percentages of fatalities in injury groups, drivers, overturns, 59 not wearing seat belts, 25 seat belt wearing not noted, 47 wearing seat belts.

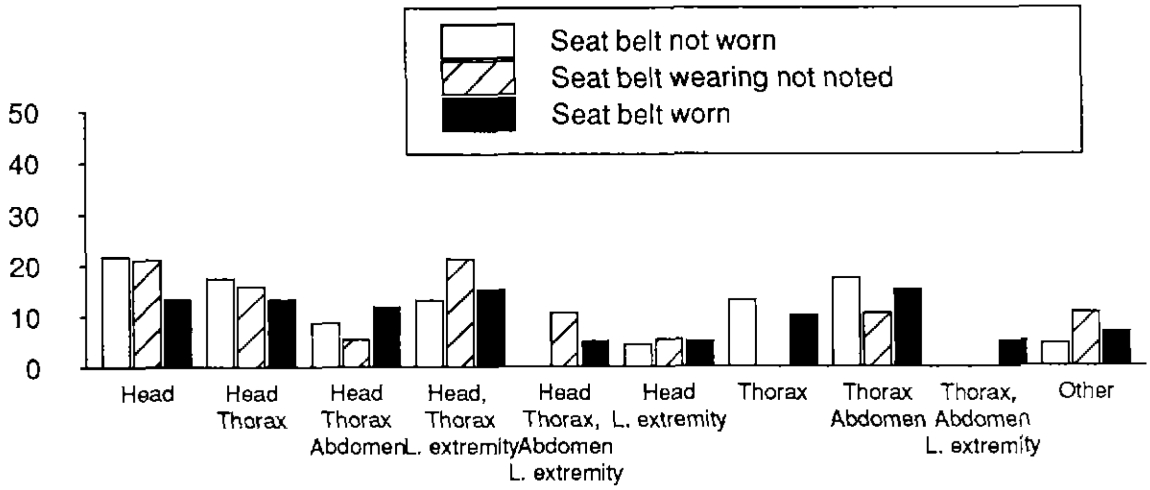

Figure 2.6: Percentages of fatalities in injury groups, front left seat passengers, frontal impacts, 23 not wearing seat belts, 19 seat belt wearing not noted, 60 wearing seat belts.

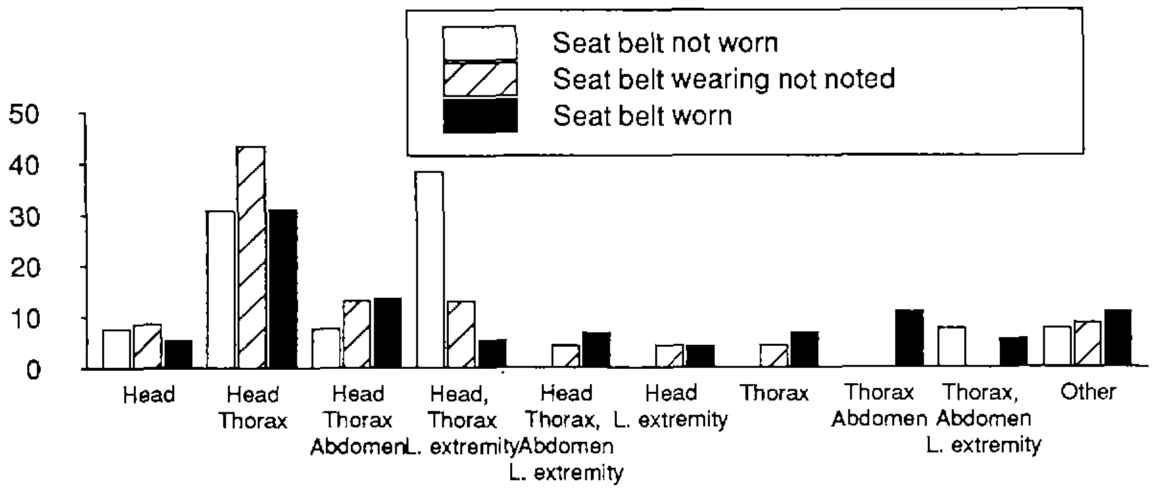

Figure 2.7: Percentages of fatalities in injury groups, front left seat passengers, left impacts, 13 not wearing seat belts, 23 seat belt wearing not noted, 74 wearing seat belts.

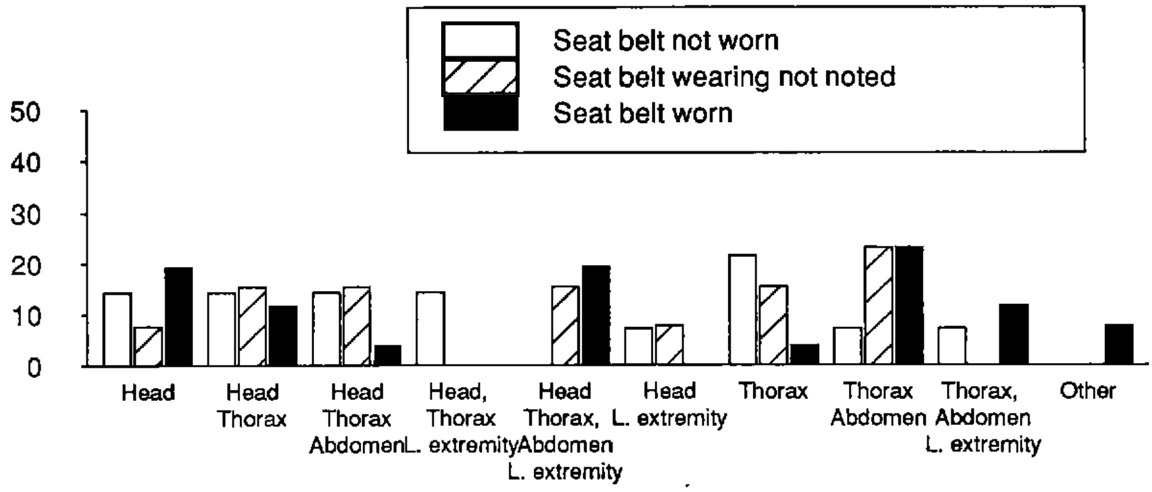

Figure 2.8: Percentages of fatalities in injury groups, outer rear seat passengers, frontal impacts, 14 not wearing seat belts, 13 seat belt wearing not noted, 26 wearing seat belts.

injured drivers in these groups for frontal impacts, right impacts, left impacts and overturns. Those definitely not wearing seat belts, those for whom seat belt wearing was not noted, and those definitely wearing seat belts are each shown separately. There was insufficient data for other seating positions to show similar results for all points of impact. Figures 2.6, 2.7 and 2.8 show the profiles for front left seat passengers in frontal impacts and in left impacts, and outer rear seat passengers in frontal impacts. Note that individuals in any of these groups may also have serious injuries to the upper extremities, spine, neck or face, or serious external injuries.

Fitting multiplicative models in the way described in section 2.2 showed that injury pattern is significantly affected at the 1% level by the point of impact, and seat belt wearing, and at the 5% level by seating position. Terms in the model involving injury and interactions between explanatory factors were not significant. Overturns lead to very different injury profiles from other points of impact, with a high proportion of serious injuries to the head, and to the head and thorax combined. Side impacts lead to a higher proportion of serious injuries to the head, thorax and abdomen simultaneously than do frontal impacts. Not wearing a seat belt also leads to a high proportion in this category.

Summary

Fatally injured persons most commonly have at least one injury to the head, 76% of all fatalities, at least one injury to the thorax, 71%, or both. The next most commonly injured area is the abdomen, 49%. The most common head injuries are cerebrum lesions and skull fractures. There is considerable association between these injuries; 86% of individuals with skull fractures also have cerebrum lesions. The situation is similar for the most common thorax injuries, to the lungs and rib cage.

Serious head injuries to fatally injured car occupants are less common for frontal impacts than other points of impact. Serious thorax injuries to fatally injured car occupants were more common for direct impacts and cars damaged beyond repair. The most common head injuries decline in importance with age, whilst thoracic cavity and rib cage injuries increase. Lung injuries first increase in importance with age, then decrease.

The most common injuries to the abdomen are to the liver, spleen and kidney or adrenal gland. In these cases the associations are stronger than for the head and thorax injuries. The number with both liver and spleen injuries is over 80% more than would be expected if these injuries occurred independently. Serious abdominal injuries are generally associated with serious thorax injuries. Of the 474 fatally injured car occupants with serious abdominal injuries, 91% also had serious thorax injuries. Serious abdominal injuries to fatally injured car occupants were more common if the posted speed limit was 80 kph or more. They were less common if the car overturned and the person was not ejected, reflecting the importance of head injuries in this situation.

Fatally injured female car occupants are more likely to have serious spinal injuries than males. This is also the case for injuries to the cervical spine. Also serious injuries to the cervical spine were more common in cars with a mass less than 1250kg.

For fatally injured car occupants serious injuries to the lower and upper extremities were more likely if the posted speed limit was 80 kph or more, and if the impact was at the front or on the side on which the person was sitting. Injuries to the upper extremities were also more common in cars damaged beyond repair. There is some indication that serious facial injuries are more likely in cars over 10 years old. They are more likely when there is a frontal impact as opposed to a side impact.

Individuals were divided into ten groups according to which combinations of four body regions, head, thorax, abdomen and lower extremity, were seriously injured. Overturns lead to very different injury profile from other points of impact, with a high proportion of serious injuries to the head, and to the head and thorax combined. For fatally injured car occupants side impacts lead to a higher proportion of serious injuries to the head, thorax and abdomen simultaneously than do frontal impacts. Not wearing a seat belt also leads to a high proportion in this category.

Chapter 3

Factors affecting injury outcome

3.1 Introduction and statistical methods

The injury outcome for an individual in a road crash can be considered both in terms of whether the person was killed, or for other people the level of medical treatment required. Whether or not a person is killed is a binomial variable. In other words, from this point of view, there are only two possible outcomes, death or survival. In this Chapter the odds of death are assumed to be the product of terms involving characteristics of the individual, such as age, and features of the crash. That is to say if p is the probability of being killed in a crash,

$$p/(1-p) = a_i b_j c_k \ldots,$$

where the constants, a_i, b_j, c_k etc., each represent the effects of the value of a particular factor. For example, the term, a_i, might refer to point of impact, and the possible value, a_1 might correspond to a frontal impact, a_2 to a right impact, and so on. In practice it is convenient to take logarithms giving

$$\log(p/(1-p)) = \log a_i + \log b_j + \log c_k \ldots,$$

so that the effects of the various factors are now additive. This approach is discussed at greater length in the previous Chapter.

The probability of being killed only has meaning for a defined population of individuals. The simplest approach is to take all people involved in fatal crashes as the reference population, so p would refer to the probability of being killed given that a person is in a fatal crash. This has the advantage that the population is precisely defined. The principal disadvantage is that since each crash involves at least one fatality the probability of death is then greater for individuals in crashes involving a small number of people, and, of course, death is certain for a crash in the data base involving only one person.

One way of allowing for this is to use the number of people in the crash as one of the explanatory factors. This is discussed in more detail in the next Section. However if a factor, such as whether or not a person is wearing a seat belt, is largely unaffected by the number of people in the crash, ignoring this difficulty will still give valid comparisons.

An alternative is to take as our reference population either all potentially fatal crashes or some subset of such crashes. Recently one of us (O'Neill, 1993) has proposed a way of doing this known as truncated logistic regression. The term truncated is used in the sense that all data from crashes which did not involve a fatality have been excluded, because they were not available. If a crash involves K people and the probability that the kth person would be killed in such a crash is p_k, then the probability that no one is killed is the product of the terms $(1 - p_k)$ denoted by $\prod_{k=1}^{K}(1 - p_k)$. For example for a crash involving three people this would be $(1-p_1)(1-p_2)(1-p_3)$. Consequently the probability that a person is killed given involvement in a fatal crash is $p_k/[1 - \prod_{k=1}^{K}(1 - p_k)]$. A drawback of this approach is that it can only be used when complete data are available for all the individuals in a crash.

A third approach is to consider matched pairs of individuals, only one of whom is killed. For example we could consider crashes involving a single vehicle with both a driver and a front left seat passenger, only one of whom is killed. Whether or not it is the driver who is killed is a binary response, and we can assess the effect of factors such as point of impact on the probability that it is the driver who is killed. The reference population here is somewhat artificial, but the results can be valuable for comparative purposes. This approach is discussed by Collett (1991) and has been used in traffic accident studies by Lui et al (1988).

When the first and third approaches are used in this Chapter a number of possible terms are considered for inclusion in the model. The factor which best explains whether or not a person survived is included first. Then a search is made for the factor which best explains the outcome in conjunction with the first factor and so on. In other words a forward stepwise selection procedure is used to select predictors. Selection is terminated when further terms fail to give substantial improvement, rather than purely on the basis of statistical significance. Forward stepwise selection is not used for truncated logistic regression because of the amount of computing time this would require.

In the analyses it is assumed that whether or not a person is killed is independent of whether or not any other person is killed. This is usually a reasonable assumption because in many crashes people do not interact with each other during the crash. It would not be strictly true when unrestrained car occupants are thrown against each other, but it is not an unreasonable approximation in such cases.

3.2 Probability of death

If a fatal crash involves n people exactly one of whom is killed, the probability that a person chosen at random is the one killed is $1/n$ and

$$p/(1-p) = 1/(n-1).$$

So for n greater than one

$$\log(p/(1-p)) = -\log(n-1).$$

Thus one way of allowing for the effect of the number of people in the crash is to include $-\log(n-1)$ as a term in the model for $\log(p/(1-p))$, with coefficient one. A term used in this way is customarily referred to as an offset variable. Other functions of n or the number of vehicle occupants could also be used. Several possibilities were tried. The effect of the adjustments was small and generally had little effect on the conclusions that would be drawn. Most factors of importance, such as seat belt wearing seem to be broadly unrelated to number of vehicle occupants. However for detailed analysis of specific types of crash such adjustments may be important.

With this approach forward stepwise selection is used to choose the terms used in the models in this section. The models in the sequence generated by forward stepwise selection are then fitted by truncated logistic regression, described in the preceding section, to confirm that similar improvements in fit are obtained with both methods of fitting. At present the computation required to use truncated logistic regression in model selection is prohibitive, but all numerical results presented in this Section are derived using truncated logistic regression.

The following factors were considered as possible predictors of the probability of death for an individual car occupant, the age, sex, blood alcohol content and seating position of the person, whether or not the person was ejected, whether or not the person wore a seat belt, the posted speed limit, whether or not the car was speeding, the point of impact, the age and mass of the car, and whether or not the accident occurred in a rural area. Interactions between factors were also considered, but these were generally not statistically significant.

When we know if a person was sitting on the right or left side of the car we can redefine right and left impacts in terms of whether the impact was on the side that the person was sitting or the opposite side. Where the make of a car was known but not its mass, the average for that make was used.

Blood alcohol	Survived	Died
Measured	1175	1072
Not measured	1513	394

Table 3.1: Numbers of car occupants whose blood alcohol content was measured

Whether or not a person's blood alcohol content was measured depended very much on whether or not the person died, Table 3.1. Of the fatally injured car occupants, the blood alcohol content of 73% was measured compared with 44% of the survivors. The data can be completed by assuming that, in the absence of a blood alcohol measurement, individuals aged over 16 in crashes between 10 p.m. and 5 a.m. have a blood alcohol content of 0.065, and that in other cases the blood alcohol content is zero. This is somewhat arbitrary, but permits us to get the results in this section.

In the analysis of the completed data, blood alcohol content was characterized in three ways. First by using the recorded value, second whether or not it exceeded 0.05, and third whether or not it exceeded 0.10. The method used for completing the data increases the apparent proportion of people with blood alcohol content in the range 0.05 to 0.10 who survived, and consequently this may lead to underestimation of the effect of blood alcohol content in this range, and inflation of the effect of a blood alcohol content over 0.10. The analysis suggests that a high blood alcohol content could have an important adverse effect, and that the collection of data in a way designed to resolve this question would be desirable. It must be remembered that the analysis here relates to the effect of blood alcohol content on the probability of survival in a crash. It does not relate to its effect on the likelihood of being involved in a crash.

For both two passenger car crashes and single passenger car crashes not involving any other vehicle the factors which best predicted the probability of death were selected by forward stepwise fitting using the offset variable described above. The models selected for further consideration were then fitted by truncated logistic regression. The terms in the model selected for two car crashes are shown in Table 3.2. and for

Factor	Selected model	Supplementary models	
Trapped	2.94±0.29	2.76±0.31	2.76±0.31
Ejected	-	1.91±0.46	1.90±0.46
Belt wearing			
Not noted	0.75±0.26		
Not worn	1.88±0.32		
Not ejected and belt not worn		0.97±35	0.94±0.35
Age			
Under 13	-0.61±0.48	-0.55±0.47	-0.55±0.47
Over 60	2.00±0.27	1.76±0.28	1.80±0.28
Mass, (change per 100kg)	-0.29±0.06	-0.28±0.06	-0.28±0.06
Speed limit 80 kph or more	1.30±0.34	1.46±0.37	-1.46±0.37
Speeding			0.23±0.30
BAC over 0.10	1.36±0.41	1.59±0.46	1.41±0.30

Table 3.2: Changes in log odds of death for individual car occupants in two passenger car crashes for factors in three models, with estimated standard errors

Factor	Selected model	Supplementary models	
Trapped	2.21±0.25	2.21±0.25	2.20±0.26
Ejected	1.94±0.26	2.38±0.26	2.33±0.26
Belt wearing			
Not noted	-0.07±0.27		
Not worn	0.72±0.24		
Not ejected and belt not worn		0.69±0.27	0.67±0.27
Speeding			0.36±0.31
BAC over 0.10	0.96±0.27	0.95±0.27	0.93±0.27

Table 3.3: Changes in log odds of death for individual car occupants in single car crashes for factors in three models, with estimated standard errors

single car crashes in Table 3.3. Some factors are important in both types of crash, point of impact, whether or not the person is trapped, seat belt wearing and blood alcohol content. Other factors are only important for one or the other type of crash, age, car mass and posted speed limit for two car crashes, whether or not the person is ejected for single car crashes.

Two further models were also fitted to both two car and single car crash data. In the first of these a new factor was created in which car occupants were classified as either ejected, not ejected and not wearing a seat belt, or not ejected and presumed to be wearing a seat belt. The idea was to separate the benefit of preventing ejection from other benefits of seat belt wearing. In fact a number of car occupants who were wearing seat belts were ejected. In the second additional model whether or not the car was speeding was also included. To complete the data, where this information was not available the car was assumed to have not been speeding. This assumption may be the reason why the effect of speeding is non significant although the effect is in the direction that would be expected.

Those parameters which are common to more than one model do not change much. However in the case of two car crashes the estimated benefit of seat belt wearing is reduced indicating that one benefit of seat belt wearing is a reduction in the chance of ejection. It should be noted that in the case of two car crashes the second and third models are fitted to a smaller data set because details of whether or not people were ejected are not available for all the people in the crashes in the first data set. As mentioned in the previous Section, if any data required for fitting the model is missing for any individual in a crash all data from that crash has to be omitted.

The changes in log odds shown are relative to that for a person aged between 13 and 60, who is wearing a seat belt, whose blood alcohol is under 0.10, who is driving a car of average mass for these crashes, (1250 kg), and who is involved in a crash where the speed limit is under 80 kph, there is a frontal impact and he is not trapped. For such a person the estimated log odds of being killed in a potentially fatal two car crash is -5.15 giving a probability of being killed of

$\exp(-5.15)/(1+\exp(-5.15)) = 0.0058$. If his blood alcohol content is over 0.10, the estimated log odds becomes -5.15+1.36=-3.79, and the probability of being killed rises to 0.022, nearly four times greater. Similar calculations can be done for the other factors.

In two car crashes occupants aged over 60 had a much higher death rate, 113 deaths out of 197 people or 57%, compared with 232 deaths out of 912 people or 25% for those aged between 13 and 60. After adjustment for the other factors in the model this difference is still highly significant. The death rate was very low for occupants aged under 13, 7 deaths out of 76 people or 9%, but after adjustment for other factors the death rate was not significantly different from that for passengers aged between 13 and 60.

Although point of impact is important for both types of crash, the pattern of results is quite different for the two types. These results must be interpreted with some caution as they refer to a notional population of fatal crashes rather than all crashes, and there may be other crashes, which for practical purposes are not potentially fatal which would need to be considered before making statements about all crashes involving a specific point of impact. However the difference between impacts on the same side that an individual was sitting and impacts on the opposite side is consistent for the two types of crash. The odds of being killed are five times greater when the impact is on the same side.

We can also estimate what the effect would be of changing some of the values of some of the factors. In the model as fitted the estimated probability that the kth person in a crash involving K people is killed, given that at least one person is killed, is $p_k/[1-\prod_{k=1}^{K}(1-p_k)]$. To estimate the benefit of universal seat belt wearing, we can change the appropriate values in the numerator, but not the denominator because the denominator gives the probability that the individual is involved in fatal crash. If for two car crashes the death rate for people definitely not wearing seat belts had been the same as for those wearing seat belts, 22 would have been killed instead of 66. For those whose seat belt wearing was not noted 42 would have been killed instead of 72, so the total number killed would have been 280 instead of 352, a reduction of 20%.

In the case of single car crashes the effect of seat belt wearing of itself is less. Of the 254 who were killed but not ejected 236 would have been killed if seat belt wearing was universal. If however we assume that wearing an appropriate seat belt could eliminate ejection completely or ejection could be prevented in some other way, of the 111 fatally injured people who were ejected only 21 would have died, Table 3.4. Thus a combination of universal seat belt wearing and elimination of ejection would have reduced the number of deaths from 365 to 257, a reduction of 30%.

The effect of the assumptions about blood alcohol content was investigated by trying two alternative sets of assumptions. First it was assumed that males over 16 whose blood alcohol content was not tested and who were involved in crashes between 10 p.m. and 5 a.m. on Friday and Saturday nights had a blood alcohol content of 0.150, and second the same assumption was made for both males and females.

Seat belt wearing	Not ejected	Ejected
Worn	151(151)	14(3)
Not noted	47(49)	20(6)
Not worn	56(36)	77(12)
Total	254(236)	111(21)

Table 3.4: Numbers of people killed in single car crashes classified by seat belt wearing and whether or not the person was ejected. The numbers who would have been killed if seat belt wearing was universal and ejection eliminated are given in brackets

	Assumptions A	Assumptions B	Assumptions C
Effect of BAC exceeding 0.10			
Two car crashes	1.36±0.41	0.72±0.35	0.57±0.33
Single car crashes	0.96±0.27	0.18±0.24	-0.11±0.23
Effect of not wearing a seat belt			
Two car crashes	1.88±0.32	1.97±0.31	1.99±0.31
Single car crashes	0.72±0.24	0.73±0.24	0.74±0.24

Table 3.5: Changes in estimated log odds of death for blood alcohol content exceeding 0.1, and for not wearing a seat belt for three sets of assumptions about blood alcohol content when it is not measured. Assumptions A are those used in fitting the models in the section. For assumptions B it was assumed that males over 16 whose blood alcohol content was not tested and who were involved in crashes between 10 p.m. and 5 a.m. on Friday and Saturday nights had a blood alcohol content of 0.150, and for assumptions C the same was assumed for both males and females, with estimated standard errors

People whose blood alcohol content is not measured tend to be survivors of the crash, so assuming a high blood alcohol content for such people will reduce the estimated effect of blood alcohol content, Table 3.5.

If we divide car occupants into three groups, those people whose blood alcohol content was not measured, those with a measured blood alcohol content of 0.10 or less, and those with a measured blood alcohol content greater than 0.10, the major difference in survival is between those not measured and the other two groups. The difference between the two measured groups is not statistically significant. Hence the effect of blood alcohol content on survival could only be decided convincingly if more data was available. However the results reported here are suggestive of an adverse effect of blood alcohol. This is consistent with results reported in Chapter 4 on the effect of blood alcohol content on survival time for fatally injured people.

3.3 Single car crashes, conditional logistic regression

Accurate estimates of the effects of some factors can be made from quite small sets of data if matched pairs of individuals are used. A natural pair to consider is the driver and front left seat passenger in a passenger car. The effect of many factors would be substantially the same for both, so if one is killed and not the other we can investigate which factors might be responsible for this difference in outcome, without the necessity for any correction for those factors which do not have different effects on the driver and the front left seat passenger.

In this Section we use conditional logistic regression (Collett, 1991) to investigate data from 173 crashes involving only a passenger car with both a driver and a front left seat passenger in which one was killed and the other survived. In 85 crashes the driver was killed and in the remaining 88 crashes the front left seat passenger killed. The factors and variables considered here are age, sex, blood alcohol content, whether or not a person was ejected, whether or not a person was wearing a seat belt, point of impact, whether or not the car was speeding, whether or not the posted speed limit was less than 80 kph, and vehicle mass. The last three would not be expected to have substantially different effects for the driver and the front passenger, and this turns out to be the case. Blood alcohol content was not considered because 125 of the front left seat passengers were not tested, and of the 48 who were tested only five survived.

Forward stepwise selection was used to choose a model which described the data. The most important factors are point of impact and whether or not a person is ejected, Tables 3.6 and 3.7. These tables show the conditional probability that the driver is killed given that out of the driver and front left seat passenger one is killed, for a fixed level of the other factors in the model. The possibility of interaction between point of impact and ejection was investigated but not found to be statistically significant. The driver is much more likely to be killed by a right impact and the passenger by a left impact. The consequences of ejection seem to be

Point of impact	Probability driver is killed	Number of crashes
Front	0.50±0.063	49
Right	0.85±0.074	22
Left	0.16±0.062	30
Overturn	0.50±0.058	72

Table 3.6: Estimated conditional probability that driver is killed rather than front seat passenger for various points of impact with approximate standard errors for fixed level of ejection and seat belt wearing factors

Ejection	Probability driver is killed	Number of crashes
Passenger	0.26±0.084	24
Driver	0.85±0.065	27
Both or neither	0.45±0.042	122

Table 3.7: Estimated conditional probability that driver is killed rather than front seat passenger according to whether either is ejected, with approximate standard errors for fixed level of point of impact and seat belt wearing factors

Seat belt wearing	Probability driver is killed	Number of crashes
Driver only	0.13±0.107	10
Passenger only	0.53±0.147	8
Both wearing a seat belt or both not	0.48±0.046	95

Table 3.8: Estimated conditional probability that driver is killed rather than front seat passenger according to whether either is wearing a seat belt, with approximate standard errors for fixed level of point of impact factor, when neither is ejected.

more serious for drivers than for passengers.

There is also some indication of a beneficial effect of seat belt wearing, particularly for passengers. Table 3.8 shows results for the 113 crashes in which neither the driver nor the front left seat passenger was ejected. If the driver is wearing a belt and the passenger is not the estimated probability that it is the passenger who is killed is 0.81, whereas in the converse situation the estimated probability that the driver is killed is 0.57. However these estimates are based on quite small numbers.

3.4 Injury severity

In addition to data on injury location, for each person in the "Fatality File" injury severity is classified in the way shown in Table 3.9. We can divide car occupants

Injury severity	Description	Passenger car Occupants	All other road users	Total
1	Not injured	1088	1086	2174
2	Injured, but no medical treatment	37	61	98
3	Received medical treatment, but not hospitalized	253	469	722
4	Hospitalized	498	1041	1539
5	Died	1410	1466	2876
Total		3286	4123	7409

Table 3.9: Injury severity as recorded for all persons

into 120 classes according to point of impact, seating position, seat belt wearing and posted speed limit. Passenger car occupants were divided into those who survived and were not hospitalized, those who survived and were hospitalized, and those who died. If we analyse the numbers in each of these groups for each of the 120 classes using a log linear model (see Chapter 2, Section 2.2) we find that all four factors have a considerable effect on injury severity, and that all the interactions between pairs of these factors have a significant effect on injury severity, but that the effect of three factor interactions is not significant. Tables 3.10 and 3.11 show the fitted numbers in various classes, for those groups in which there were more than 25 individuals. These Tables show the advantage of wearing a seat belt, particularly when the posted speed limit is less than 80 kph.

Summary

There are problems in analyzing outcome data because all the crashes include at least one fatally injured person, and comparisons with similar crashes in which no

Belt wearing	Posted speed limit	Injury severity Not hospitalized	Hospitalized	Died	Total number
Front impact					
Not worn	Under 80 kph	9.7± 3.62	15.6± 4.73	74.8±13.26	37
Not worn	80 kph or more	2.3± 1.00	18.0± 4.74	79.7±12.42	46
Not noted	Under 80 kph	68.4± 7.88	8.3± 2.03	23.3± 4.04	96
Not noted	80 kph or more	30.5± 4.77	17.0± 3.37	52.5± 6.75	95
Worn	Under 80 kph	68.3± 4.43	15.9± 1.98	15.8± 1.95	326
Worn	80 kph or more	23.9± 2.42	34.8± 3.03	41.2± 3.30	339
Right impact					
Not noted	Under 80 kph	35.6± 9.02	4.0± 1.72	60.4±12.89	29
Not noted	80 kph or more	18.6± 5.27	6.9± 2.66	74.6±13.12	38
Worn	Under 80 kph	31.6± 5.10	8.2± 2.23	60.2± 7.37	100
Worn	80 kph or more	11.3± 2.70	13.4± 3.23	75.3± 8.88	87
Left impact					
Not worn	80 kph or more	8.0± 3.58	19.6± 6.45	72.3±14.72	29
Not noted	Under 80 kph	47.7±10.43	23.9± 6.48	29.0± 7.34	32
Not noted	80 kph or more	27.3± 7.37	25.7± 7.23	47.1±10.77	29
Worn	Under 80 kph	61.4± 7.32	19.6± 3.73	19.0± 3.55	102
Worn	80 kph or more	31.8± 5.51	27.0± 4.97	41.2± 6.39	79
Overturn					
Not worn	80 kph or more	3.5± 1.50	16.3± 4.19	80.1±10.77	64
Not noted	80 kph or more	10.7± 3.98	22.9± 6.91	66.4±14.02	28
Worn	80 kph or more	16.6± 3.78	34.2± 5.68	49.2± 6.94	89

Table 3.10: Estimated expected numbers with different injury severities for various categories for car drivers, with approximate standard errors

Belt wearing	Posted speed limit	Injury severity: Not hospitalized	Hospitalized	Died	Total number
Front left passengers					
Front impact					
Not noted	Under 80 kph	66.4±10.74	13.2± 3.68	20.4± 4.93	48
Not noted	80 kph or more	41.4± 8.57	25.6± 6.31	32.9± 7.37	38
Worn	Under 80 kph	55.3± 7.48	26.6± 4.78	18.1± 3.59	81
Worn	80 kph or more	23.1± 3.29	47.8± 5.06	29.0± 3.78	167
Right impact					
Worn	Under 80 kph	43.7± 9.09	40.3± 8.73	16.0± 4.71	41
Worn	80 kph or more	22.1± 5.82	63.4±11.59	14.5± 4.43	40
Left impact					
Worn	Under 80 kph	19.8± 4.82	15.4± 4.07	64.8± 9.77	59
Worn	80 kph or more	10.6± 3.16	15.0± 4.16	74.4±11.34	51
Overturn					
Worn	80 kph or more	27.9± 5.85	44.5± 7.61	27.6± 5.68	67
Outer rear seat passengers					
Front impact					
Not noted	Under 80 kph	71.4±11.89	19.3± 5.01	9.3± 2.90	43
Not noted	80 kph or more	48.4± 8.81	35.6± 7.29	16.0± 4.24	48
Worn	Under 80 kph	53.0±10.87	33.6± 7.91	13.3± 3.91	33
Worn	80 kph or more	23.2± 4.07	55.0± 6.85	21.8± 3.97	102
Right impact					
Worn	80 kph or more	21.6± 6.70	37.2±10.02	41.2±10.58	27
Left impact					
Not noted	Under 80 kph	39.6±10.15	38.0± 9.94	22.4± 6.81	27
Worn	Under 80 kph	38.6± 8.66	29.9± 7.29	31.5± 7.55	38
Overturn					
Not worn	80 kph or more	13.3± 4.59	45.3± 9.38	41.3± 8.85	43
Worn	80 kph or more	22.6± 5.77	54.1± 9.52	23.3± 5.67	51

Table 3.11: Estimated expected numbers with different injury severities for various categories of car passengers, with approximate standard errors

one was killed cannot be made. Many crash factors affect the probability of surviving a severe crash. This probability is reduced if a person is over 60 years old, is trapped or ejected, or is not wearing a seat belt. The risk is also greater when the posted speed limit is 80 kph or more In two car crashes the risk is also affected by vehicle mass, with occupants of smaller cars being at greater risk. In addition, although technical issues prevent precise estimates of effects, the data suggest that people with significantly elevated blood alcohol levels are more likely to die in a crash of given severity.

Detailed analysis of data from the driver and the front left seat passenger in single vehicle accidents shows the importance of seat belt wearing, point of impact and ejection in determining the outcome of a crash. In these crashes impacts on the same side that a person is sitting are much more dangerous to that person than impacts on the other side.

Chapter 4

Factors affecting time to death

4.1 Introduction

The distribution of times from injury to death for fatally injured persons has an important bearing on the allocation of priorities by emergency personnel at the scene of individual crashes and on the provision of emergency services and post-injury treatment in general. The survival time of an individual can be estimated by the difference between the recorded time of death and the recorded crash time. Often neither of these is known precisely, and short survival times must be interpreted cautiously. Survival time cannot be estimated for 337 individuals, usually because the day of death is known but not the time, but in four cases the time of the crash is not known.

"Timing"	Estimated survival time 0-10 minutes	10 minutes - 1 hour	1 hour -1 day	Over 1 day	Total
Before medical or ambulance assistance	1374	56	27	6	1463
At scene or in transit to hospital	72	110	47	5	234
In hospital or after leaving hospital	12	77	432	291	812
Total	1458	243	506	302	2509

Table 4.1: Survival times compared with coded "timing" (only one person was recorded as dying after leaving hospital)

In the Fatality File the timing of death was also coded in the six categories, "Instantaneous", "Death at scene before medical or ambulance assistance", "Death at scene during medical or ambulance assistance", "Died in transit to hospital", "Died in hospital" and "Died after leaving hospital". If unsure as to whether to assign code 1, "Instantaneous death" or 2 "Death before receiving medical or ambulance assistance", coders were instructed to use code 2. Only one person was record as dying after leaving hospital. The relation between this coding and the direct estimates of survival time is shown in Table 4.1.

Although there are some discrepancies the two measures are in broad agreement. 58% of fatally injured people have an estimated survival time of ten minutes or less, and 58% are recorded as dying before receiving medical treatment. Only 7% of individuals were in one group but not the other. Of course medical assistance does not necessarily arrive precisely ten minutes after the crash. However some of the discrepancies appear to be the result of transcription errors. For example one person recorded as dying instantly is also recorded as dying at 1530, on 30th January after a crash which occurred at 1530 on 20th January. Presumably the day of death has been misrecorded.

Since over half the individuals died instantly or before receiving medical or ambulance assistance it is convenient to analyse the survival times by first examining the factors which affect whether or not a person is in this category, and second to examine the survival times for the remaining people.

4.2 Statistical methods

As in previous chapters the main statistical method used is the fitting of generalized linear models. Two versions are used. Whether or not a person dies before receiving medical assistance is a binomial variable. In other words there are only two possible outcomes. The odds of death before receiving medical assistance are assumed to be the product of terms involving firstly features of the injuries received and secondly features of the crash. For those who died after receiving medical attention the probability of dying within one hour of the crash is considered in the same way, and the distribution of the time to death is modelled by assuming that it has a gamma distribution (see, for example, Cox and Oakes, 1984), and the reciprocal of the expected time to death is the sum of terms similar to those used in analysing the probability of death before receiving medical assistance.

4.3 Effect of injuries

For all fatalities the probability that death occurred prior to receiving medical assistance depends very much on the severity of the injuries received as measured by the Injury Severity Scale (ISS). This is calculated from the Abbreviated Injury Scale (AIS) scores (see Chapter 2) in the following way. The body is divided into six regions,

1 Head, neck and cervical spine
2 Face
3 Chest and thoracic spine
4 Abdomen and lumbar spine
5 Extremities
6 External.

For each of these regions the highest AIS score is found. The squares of the three

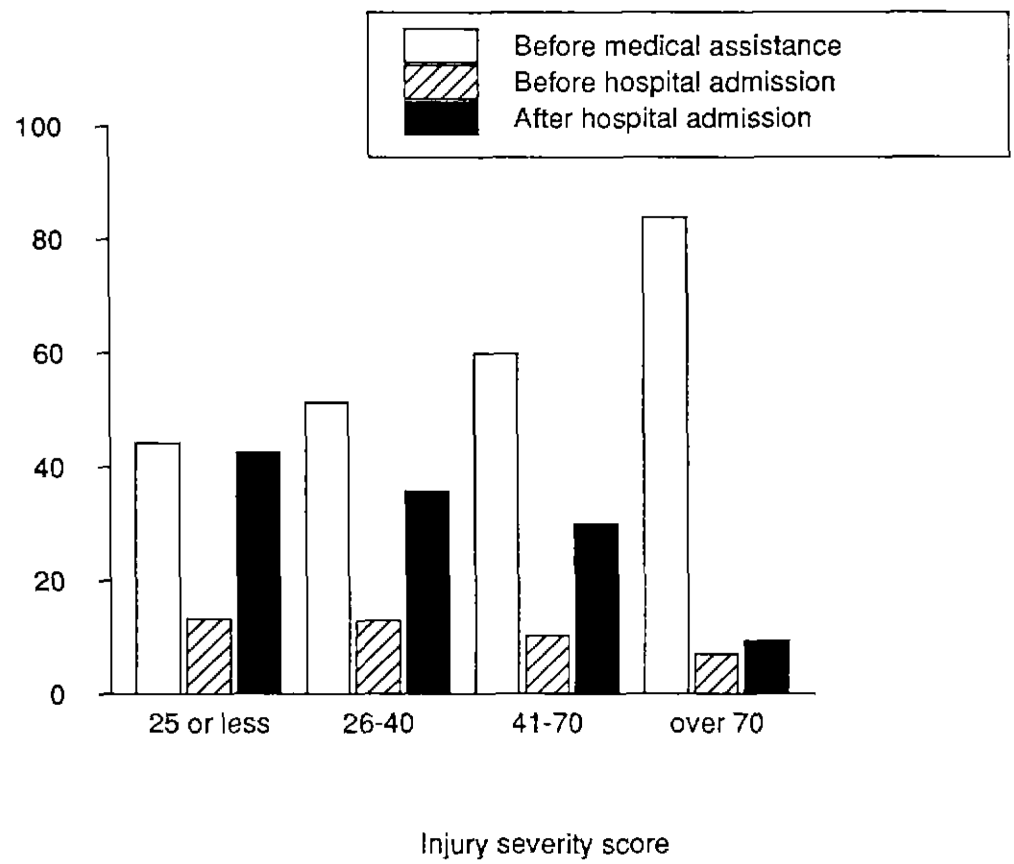

Figure 4.1: Percentage of people dying at various times by injury score. "Before hospital admission" includes both individuals who died at the scene of the crash and those who died in transit to hospital

highest are then added, except that if any AIS score is 6, the ISS is set to 75. For more detail see the AIS documentation. Figure 4.1 shows the relation between timing of death and ISS. Clearly there is a strong relationship between time of death and severity of injuries. In this Figure and in the following analyses individuals who died from causes not directly connected with the crash are excluded.

Whether or not a person dies before receiving medical assistance, including instantaneously, is more likely to be determined accurately than whether or not the person died instantaneously, and the former is used as a definition of early death in the following analyses. However results from analysis of whether or not a person was recorded as dying instantaneously, either as coded in the "timing" variable or from the estimated survival time gives broadly similar results in the sense that the same factors seem to be important in each case.

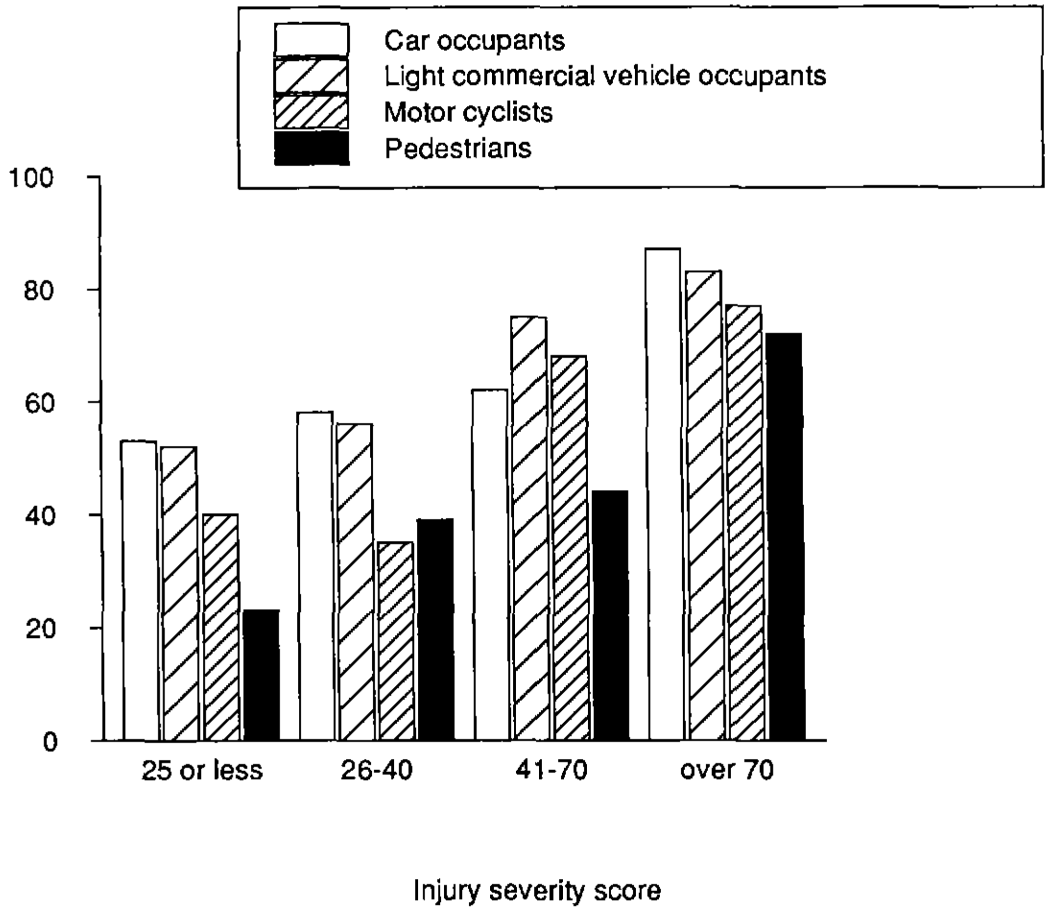

Figure 4.2: Percentages of fatally injured people dying before receiving medical attention for various injury scores

For a particular type of road user classifying people according to whether their ISS is less than 25, between 26 and 40, between 41 and 70, or over 70 gives a good predictor of the probability of death before receiving medical assistance, but the pattern varies between different types of road user, Figure 4.2. It is better to divide ISS into categories rather than using a continuous scale, in part because of the high number of deaths before receiving medical assistance associated with an ISS of 75. Car occupants show a similar pattern to occupants of light commercial vehicles. To some extent motor cyclists and their passengers are intermediate between pedestrians and car occupants.

In the case of pedestrians, but not for other road users, there was a decline in average age with increasing injury severity and with the exception of the most seriously injured pedestrians they tended to be older than other road users (Table 4.2). To

	ISS 70 or less	ISS over 70
Car occupants	36	36
Light commercial vehicle occupants	31	38
Motor cyclists	25	26
Pedestrians	47	33

Table 4.2: Average ages of fatally injured road users

some extent the results for pedestrians may reflect a tendency for pedestrians to die after hospitalization from injuries which younger road users might have survived. The great majority of pedestrian fatalities (93%) occurred in urban areas compared with 56% for passenger car occupants, so the observed results can be partially explained in terms of the faster response time for medical assistance that would be expected in such circumstances. For rural crashes differences in both age and in percentages dying before receiving medical assistance were much less for different types of road user (Table 4.3).

	Percentage dying before receiving medical assistance		Average age	
	Urban crashes	Rural crashes	Urban crashes	Rural crashes
Car occupants	57	70	37	35
Light commercial vehicle occupants	60	73	32	34
Motor cyclists	51	70	26	26
Pedestrians	36	71	46	34

Table 4.3: Average ages of fatally injured road users and percentages dying before receiving medical assistance for rural and urban crashes

Fatally injured motor cyclists tend to be younger than other fatally injured road users and this might explain why they tend to survive longer for a given ISS. Comparison with seriously injured road users who survive could help to resolve these issues. There is further discussion on the effect of non-injury factors such as age on survival time in Section 4.4.

Whether or not estimation of the probability of death before receiving medical assistance for a fatally injured individual could be improved by including information about injuries to specific regions of the body was investigated by trying the inclusion of terms for the different body regions and deciding which ones to accept using a forward stepwise procedure. After allowing for which ISS category an individual fell in, the addition of functions of the maximum AIS score for the nine body regions described in Chapter 2 was tried. The best fitting term was included in the model and the process repeated until the improvement in the model was not worthwhile.

Maximum AIS	Head	Lower extremity	External
0 or 2	0.49±0.035	0.55±0.027	0.58±0.025
3,4 or 5	0.62±0.026	0.68±0.033	0.94±0.055

Table 4.4: Estimated probability of death before receiving medical attention for ISS between 26 and 40 for car occupants with serious injury to the head, lower extremity or externally, with estimated standard errors

Maximum AIS	Chest	Arm
0 or 2	0.35±0.056	0.40±0.042
3 or 4	0.40±0.045	0.64±0.104
5	0.60±0.089	-

Table 4.5: Estimated probability of death before receiving medical attention for ISS between 26 and 40 for pedestrians with serious injury (AIS score of 3 or more) or critical injury (AIS score of 5) to the chest or arm, with estimated standard errors

For fatally injured car occupants with the same injury severity score, those with serious head, lower extremity or external injuries are more likely to die before receiving medical assistance than those without, Table 4.4. This result and results presented in Chapter 5 suggest that for many head injuries the AIS score is too low, and should be increased if ISS is to be a better predictor of survival time. The majority of fatally injured car occupants, 26 out of 30, with serious external injuries have burns.

For fatally injured pedestrians similar comments apply to chest and arm injuries, Table 4.5, except that in the case of chest injuries whether or not the injury is critical (AIS score of 5) is the most important factor. Because 85% of pedestrians have head injuries, and 65% have chest injuries it is not surprising that severity of chest injury is a better discriminator. However the results for head injury are broadly consistent with those for passenger car occupants. No fatally injured pedestrians had burns.

For other road users there is less data and estimates of the effect of injuries to particular regions of the body are less accurate. However it seems that for fatally injured motor cyclists and their passengers serious spinal injuries increase the probability of death before receiving medical assistance, and chest injuries seem to have a similar effect to that for pedestrians. Fatally injured occupants of light commercial vehicles have a lower probability of death before receiving medical assistance when they have serious abdominal injuries.

For fatally injured people who died after receiving medical attention survival time decreases with increasing ISS, Figures 4.3 and 4.4. In these figures a smooth curve has been fitted to show the general trend. There is considerable variability in these data, but only a relatively small improvement can be made by using a more complex model. In fact the severity of both chest and abdominal injuries correlates with ISS and in the case of both car occupants and other road users they can be used to give a better predictor of survival time than ISS. Tables 4.6 and 4.7 show estimated mean survival times for different severities of chest and abdominal injuries.

Maximum thorax AIS	Car occupants	Pedestrians
0 or 2	43±7.6	62±10.9
3 or 4	28±4.0	21± 3.5
5 or 6	10±2.7	14± 7.2

Table 4.6: Estimated mean survival time in hours for fatally injured people for different degrees of severity of thorax injury when death occurs after medical assistance, with approximate standard errors. Times are adjusted for severity of abdominal injury.

Maximum abdomen AIS	Car occupants	Pedestrians
0 or 2	41±4.9	43±4.4
3 or 4	8±1.5	28±9.0
5 or 6	12±3.9	5±2.7

Table 4.7: Estimated mean survival time in hours for fatally injured people for different degrees of severity of abdominal injury when death occurs after medical assistance, with approximate standard errors. Times are adjusted for severity of thorax injury.

Maximum thorax AIS	Car occupants	Pedestrians
0 or 2	0.21±0.055	0.11±0.046
3 oı 4	0.24±0.039	0.25±0.056
5	0.32±0.080	0.68±0.153

Table 4.8: Estimated probability of dying within one hour of the crash given survival until medical attention received for fatally injured pedestrians with an ISS between 26 and 40, for different degrees of severity of thorax injury, with estimated standard errors

Of 917 fatally injured people who were died after receiving medical assistance 24% died within one hour of the crash. Figure 4.5 shows the percentages for different ISS categories. After allowing for the effect of ISS category a person's maximum AIS

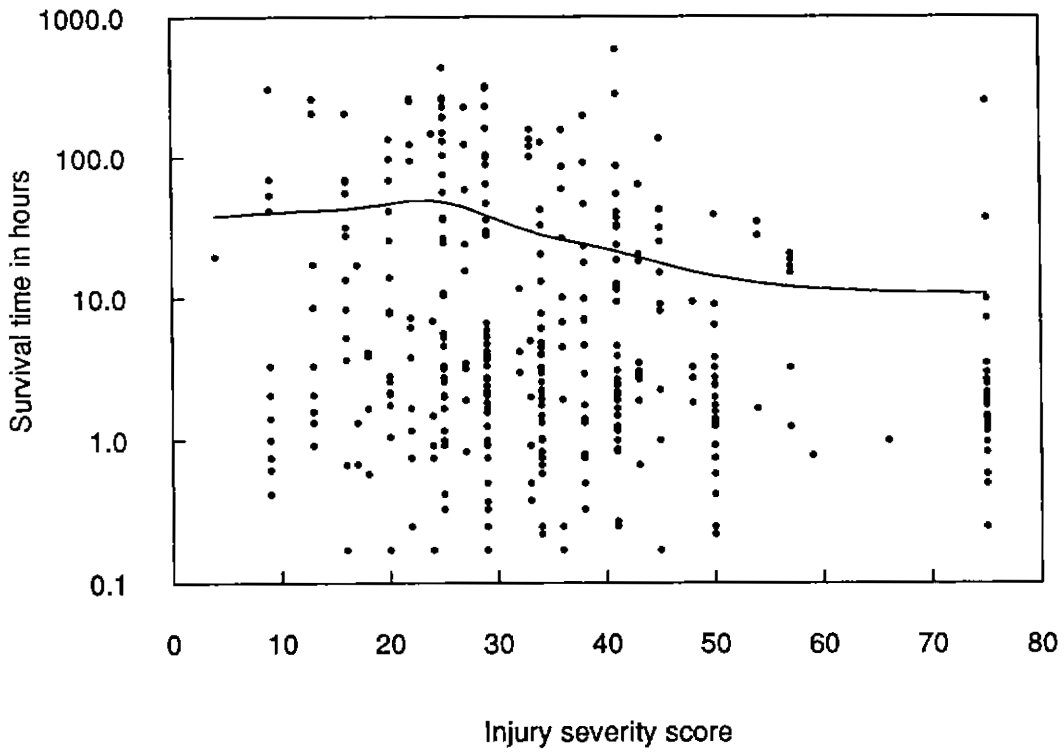

Figure 4.3: Survival time for car occupants who die after receiving medical assistance

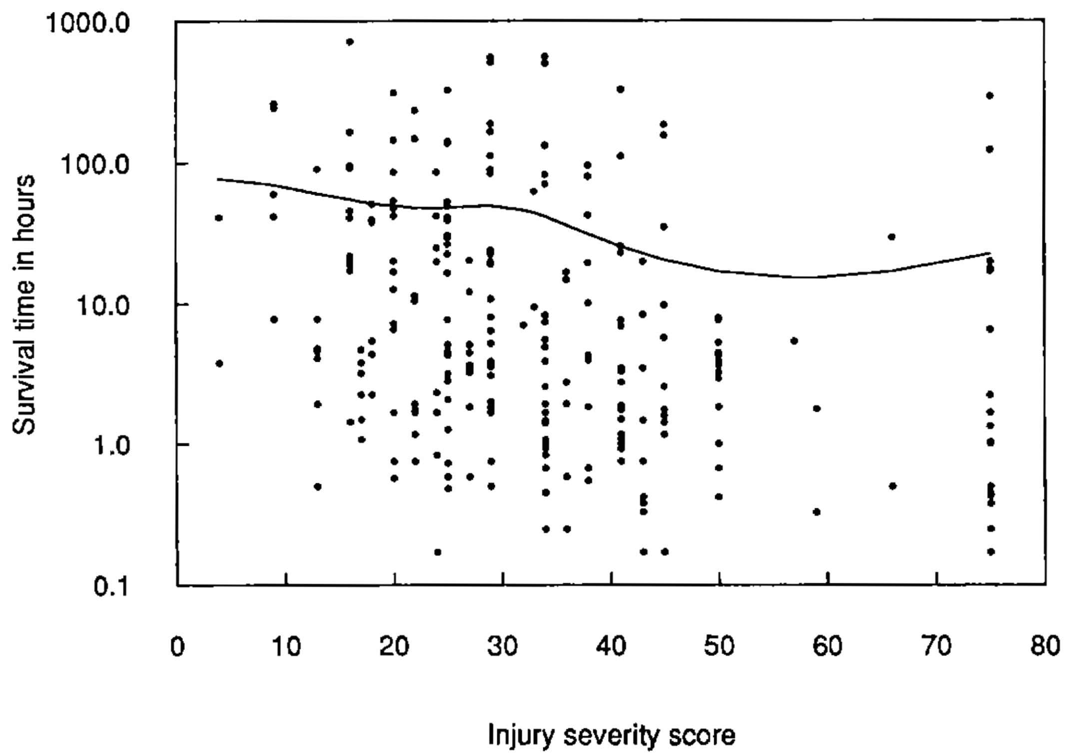

Figure 4.4: Survival time for pedestrians who die after receiving medical assistance

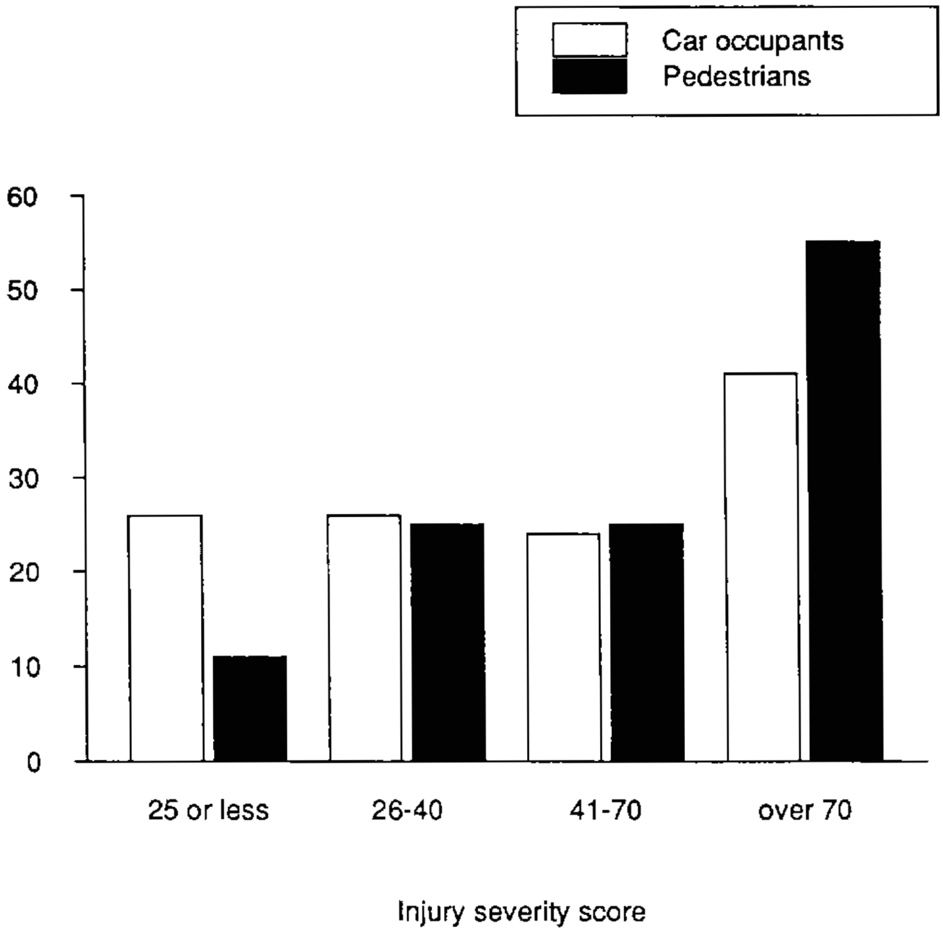

Figure 4.5: Percentage of people who died within one hour of the crash of those who died after receiving medical attention for various injury scores

score for thorax injury has an important effect on the probability of dying within one hour for pedestrians but not for car occupants, Table 4.8.

4.4 Effect of other factors

After adjusting for ISS category the main factors affecting whether or not a fatally injured car occupant dies before receiving medical assistance are age, blood alcohol content, the posted speed limit and whether or not the car was damaged beyond repair. Tables 4.9, 4.10, 4.11 and 4.12 show the effects of these factors on the probability of dying before receiving medical assistance and, given that death occurred after receiving medical assistance, the probability of death within one hour of the crash, and the estimated survival time. For pedestrians comparable figures for age, blood alcohol content and posted speed limit are included in the tables, and for mo-

Age	Probability of death before medical assistance	For death after medical assistance Probability of death within 1 hour	Survival time (hours)
Car occupants			
Less than 13 years	0.71±0.068	0.32±0.154	15±7.5
13-60 years	0.60±0.026	0.25±0.041	30±5.5
Over 60 years	0.48±0.042	0.18±0.049	28±5.7
Pedestrians			
Less than 13 year	0.24±0.057	0.28±0.085	41±17.2
13-60 years	0.44±0.048	0.20±0.058	45±12.9
Over 60 years	0.42±0.050	0.17±0.050	58±17.0

Table 4.9: Estimated effects of age on survival time when ISS is between 26 and 40. Approximate standard errors are given.

BAC	Probability of death before medical assistance	For death after medical assistance Probability of death within 1 hour	Survival time (hours)
Car occupants			
Less than 0.100	0.54±0.027	0.22±0.037	31±5.5
Over 0.100	0.73±0.034	0.38±0.083	11±3.4
Pedestrians			
Less than 0.100	0.36±0.040	0.17±0.043	46±10.1
Over 0.100	0.52±0.061	0.38±0.101	*
Motor cyclists and their passengers			
Less than 0.100	0.31±0.053	0.31±0.079	23±7.4
Over 0.100	0.45±0.076	0.47±0.130	13±5.0

Table 4.10: Estimated effects of blood alcohol content on survival time when ISS is between 26 and 40. Approximate standard errors are given.
* = insufficient data for reliable estimate

Posted speed limit	Probability of death before medical assistance	For death after medical assistance	
		Probability of death within 1 hour	Survival time (hours)
Car occupants			
Less than 80 kph	0.48±0.034	0.23±0.046	32±7.0
80 kph or over	0.64±0.026	0.25±0.041	26±4.5
Pedestrians			
Less than 80 kph	0.34±0.040	0.20±0.046	53±12.1
80 kph or over	0.68±0.061	0.27±0.106	12±5.8
Motor cyclists and their passengers			
Less than 80 kph	0.22±0.052	0.35±0.084	19±5.2
80 kph or over	0.45±0.076	0.31±0.108	28±11.0

Table 4.11: Estimated effect of posted speed limit on survival time when ISS is between 26 and 40. Approximate standard errors are given.

Vehicle damage	Probability of death before medical assistance	For death after medical assistance	
		Probability of death within 1 hour	Survival time (hours)
Repairable	0.57±0.023	0.26±0.032	34±7.3
Beyond repair	0.69±0.015	0.48±0.028	24±4.3

Table 4.12: Estimated effects of extent of vehicle damage on survival time of fatally injured car occupants when ISS is between 26 and 40. Approximate standard errors are given.

tor cyclists and their passengers comparable figures for blood alcohol content and posted speed limit are included.

Fatally injured car occupants under 13 years old do not survive as long as other car occupants, presumably because they have much better prospects of survival if they do not die within a few hours. However results for pedestrians are not consistent with this. If we consider the probability of death within one hour of the crash for a fatally injured person who received medical attention, results are similar for different types of road user.

Fatally injured road users with a blood alcohol content over 0.100 tend to survive for a shorter time than those with a lower blood alcohol content, except that for fatally injured pedestrians there is insufficient data to estimate accurately the expected survival time for those with a blood alcohol content over 0.100 who died after receiving medical assistance. The effect of varying the assumptions about blood alcohol content when it was not measured was investigated using the same alternative assumptions as were used in Chapter 3. The proportion of fatally injured road users whose blood alcohol content is not measured is much smaller than for other road users, and the effect of varying the assumptions is negligible. Stewart (1989) has also reported an adverse effect of elevated blood alcohol content on survival time.

The probability of dying before receiving medical assistance was greater for all road users when the posted speed limit was 80 kph or over than when it was lower. The probability of dying before receiving medical assistance or within one hour was greater for car occupants whose vehicles were damaged beyond repair.

Summary

For those killed the timing of death is strongly associated with the overall level of injuries as measured by the Injury Severity Score (ISS). Those with a greater level of injury are more likely to die before medical assistance arrives, and more severely injured people are more likely to die before reaching hospital.

Although the ISS is supposed to take into account the total effect of all injuries, the presence or absence of severe injury to specific regions of the body provides additional information on survival time over and above the information provide by the ISS. In particular head injuries generally appear to be more serious than their AIS score would indicate, and in consequence their contribution to the ISS is too low.

A number of other factors were also found to affect survival time. Fatally injured car occupants under 13 years old are more likely to die before receiving medical assistance than other fatally injured car occupants and they generally do not survive as long as other fatally injured car occupants. Presumably car occupants under 13 years old have much better prospects of survival if they do not die within a few hours. Fatally injured pedestrians generally survive much longer than fatally injured car occupants.

Fatally injured road users with a blood alcohol content over 0.100 tend to survive for a shorter time than those with a lower blood alcohol content. This suggest that the earlier finding, that car occupants who were intoxicated were more likely to die in a given crash, is at least partly explained by alcohol's potentiation of injuries received as opposed to a tendency for an intoxicated person to suffer more severe injuries.

The probability of dying before receiving medical assistance was greater for all road users when the posted speed limit was 80 kph or over than when it was lower. The probability of dying before receiving medical assistance or within one hour was greater for car occupants whose vehicles were damaged beyond repair.

Chapter 5

Cases of unexpected death

5.1 Cases of low injury severity

Of the 2876 people killed 652 are known to have had injuries which they would be expected to survive. Their overall injury severity scores (Chapter 4) were 25 or less and the maximum AIS score (Chapter 2) for any region of the body was four. Of these people four were trapped under water, and 38 died from causes not connected with the crash. A further 82 died as a secondary result of the initial injuries. The cause of death is not available for three people, leaving 528 who died as a direct result of crash injuries which they would have been expected to survive.

A large proportion of these people had head injuries with an AIS score of three or more, 77% for passenger car occupants and 76% for other fatalities. The comparable percentages for more seriously injured people are 80% and 74% respectively. In contrast the less seriously injured people had much lower rates of injury to other parts of the body. For example, for thorax the figures are 30% and 38% for less seriously injured people and 78% and 83% for more seriously injured people. Of the passenger car occupant fatalities, excluding those trapped under water and those who did not die as a direct result of their injuries, 46% had serious head injuries and no serious injuries to any other region of the body compared with 14% for all car occupant fatalities, Table 2.3. The corresponding percentages for other road users are 19% and 52%.

It seems that these deaths can largely be explained in terms of the unfavourable outcome of head injuries, and the similarity of the percentages with head injuries in the various groups suggest that other factors are unlikely to be of importance. This result is consistent with the findings of Kraus et al(1985). In their study no patients with an ISS of 24 or less died unless a brain injury was one of their most severe injuries.

Summary

About a quarter of all fatalities had injuries which they would be expected to survive. Just over 18% of these died from causes unconnected with the crash, or as a secondary result of their original injuries. Of the rest a large proportion had head injuries, 77% for fatally injured car occupants and 76% for other road users. Substantial percentages, 46% and 52% for car occupants and other road users respectively, had serious head injuries and no serious injuries to any other region of the body, compared with 14% for all car occupant fatalities and 19% for all other road user fatalities.

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