THE INJURY EXPERIENCE OF ADULT REAR SEAT CAR PASSENGERS

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ABSTRACT

The effectiveness of rear lap and diagonal seat belts at limiting injuries during car collisions is estimated to be 40%. The nature, severity and frequency of injuries to belted and unbelted outboard rear seat passengers is described. The mechanisms and sources of injury are prioritised and discussed. It is shown that population differences, varying kinematics and restraint characteristics all combine to produce somewhat different levels of use and effectiveness for rear occupants in comparison to those in the front.

REAR SEAT CAR PASSENGERS accounted for 14.4% (252) of the UK's car occupant fatalities in 1995, and 74.6% (188) were adults (Road Accidents Great Britain, 1995). Cars sold within the UK since April 1987 have been required to have rear seat belts fitted. However, legislation didn't require rear adult passengers to use available seat belts until 1993. Surveys investigating car occupants seat belt wearing rates, have found that between 43% and 48% of rear passengers 14 years and older use their belts in the UK (Restraint Use By Car Occupants, 1996). This is in contrast to front belt usage where observed rates are around 90%.

Surprisingly little research has been devoted to the question of the use and effectiveness of rear seat belts in Europe. It is often assumed that their acceptability and performance in crashes is the same as for the front seats, and yet there are good and obvious reasons why that is not the case. The rear seat occupant population is very different. There are many children in the age range 8 to 15 years who are around the approximate anthropometry of the 5th percentile female. There are proportionally more elderly and more female people in the rear compared to the front seat. Such population considerations have an influence on injury tolerance and hence seat belt effectiveness and usage.

There are interior design differences which affect belt performance. Most rear seats are of the bench variety rather than bucket seats. This can provide a different seat belt geometry in some cases, with less favourable lap section location relative to the iliac spines. In the front there is always an instrument panel which is contacted by the knees in most instances where the velocity change exceeds 30 km/hr. This means that in higher energy front crashes a substantial proportion of an occupant's energy is transferred through these knee contacts, reducing seat belt loads. It also has the effect of limiting submarining, the rotation of the pelvis out from under the lap section of the belt. The kinematics of the restrained rear seat occupant are different as there are no equivalent limiting knee contacts. The backs of the front seats are much more compliant and deformable, hence the rear restraint systems have to manage proportionally more of the crash energy. Therefore, it is a more challenging condition from the point of view of rear restraint design. Limiting submarining in the rear seats for instance becomes a particular concern.

There is a low incidence of intrusion into the rear section of the passenger compartment. This means that in very high energy crashes the restraint system will be stressed severely in comparison to the front seat zone, where intrusion from forward and side structures is controlling the occupant's energy.

Hence field accident analysis can provide a useful indication as to the relative importance of some of these issues. Because rear seat adult occupancy is only around 10%, the data sources for adequate statistical analysis are limited. This paper is an attempt to address some of these issues.

METHODOLOGY

Six hundred and twenty rear seat car passengers who were 15 years or older, and had been involved in collisions documented by the UK's Co-operative Crash Injury Study (CCIS) were analysed. The CCIS is an ongoing project which has collected real world in-depth data since 1983 (Mackay et al., 1985; Hassan et al., 1995). Vehicle examinations are undertaken at recovery garages several days after the collision. Car occupant injury information is collected from hospital records, coroners reports and questionnaires sent to survivors. Injury severities are rated according to the Abbreviated Injury Scale (AIS; AAAM 1990 Revision). Accidents are investigated according to a stratified sampling procedure which favours cars containing fatal or seriously injured occupants as defined by the British Government definitions of fatal, serious and slight. This study analysed car and occupant records for accidents that occurred between April 1992 and December 1995. The data collected before this period is currently not compatible with later cases.

All adult rear seat occupants involved in all impact types were initially selected. Table 1 details the injury rates of front and rear car occupants aged

15 years and older. The percentage of occupants with a Maximum Abbreviated Injury Scale (MAIS) greater than 1 is shown, and MAIS>2 in the parenthesis. The sources of injury for outboard Rear Seat Passengers (RSPs) are investigated. The analysis specifically considers only adult outboard occupants whose cars experienced a front, a non-struck side or a rollover collision. Lap and diagonal seat belts are generally considered to be effective at reducing the risk of injury for these collision types. In parallel, Front Seat Passengers (FSPs) were selected who also experienced a front, a non-struck side or a rollover collision, and their injury rates compared with those of the RSPs. Occupants with and without seat belts were compared. Finally, only front impacts were selected for RSPs and their injury rates recorded against their crash severity. The crash severity was assessed from vehicle damage dimensions using the CRASH3 programme (NHTSA, 1982). The selection required the car's collision to have been described by an Estimated Test Speed (ETS); in most cases this is broadly equivalent to change in velocity.

Table 1: Occupants Injury Severity according to the British Government Definitions, and percent MAIS > 1.

Injury Severity	Front Car Occupants Only (Drivers & Front Passengers)			Rear Passengers Only		
	N	%	% MAIS>1	N	%	% MAIS>1
Fatal	272	4.9	97 (96)	18	2.9	100 (100)
Serious	1584	28.5	66 (24)	152	24.5	68 (30)
Slight	2383	42.8	10 (1)	297	47.9	10 (0.7)
No injury	1243	22.3	0.5 (0)	137	22.1	0
Not Known	81	1.5	17 (4)	16	2.5	44 (13)
Total	5563	100	-	620	100	-

Values in parenthesis are the % MAIS $\geq$ 3 per severity measure.

There were 79 adult occupants who were known to have been sitting in the centre rear position. Only 5 of these were known to have used their seat belts (59 were known to have been unbelted). No cars in our study to date have been fitted with a centre lap and diagonal seat belt. The only restraints fitted to the centre rear position in our sample were static lap belts. The analysis of these occupants will form a separate study.

ANALYSIS

The collision types for front and rear outboard occupants (over 14 years old) are presented in Figure 1. Only three point lap and diagonal automatic retractor seat belts are included in the following analysis. Occupants were grouped by their MAIS (MAIS=0, MAIS=1 and MAIS>1). There are considerably more front seat occupants than rear ones and some caution must be applied to these simple comparisons. However, some basic trends are apparent. Front impacts for belted occupants can be seen to account for approximately twice the percentage of MAIS>1 injuries for front compared with

Figure 1a. Collision Types for Belted Front Seat Occupants (N = 3984)

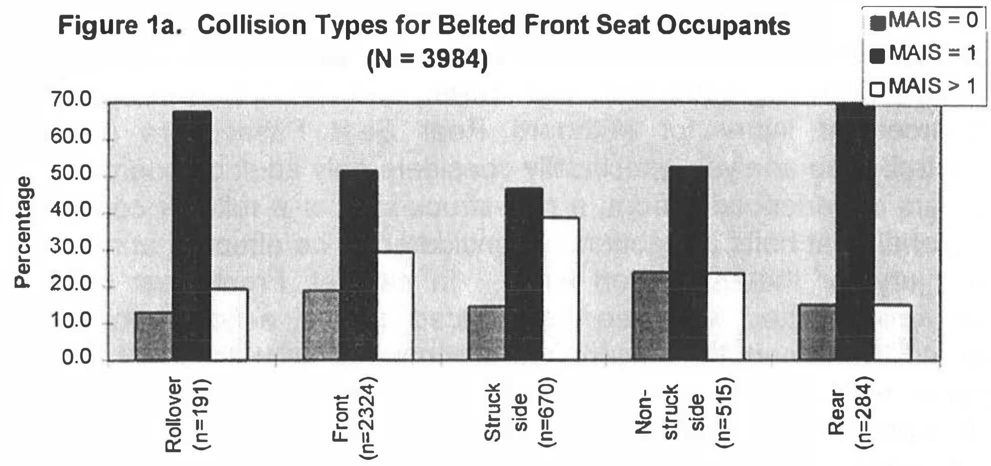


Figure 1b. Collision Types for Belted Rear Seat Occupants (N = 176)

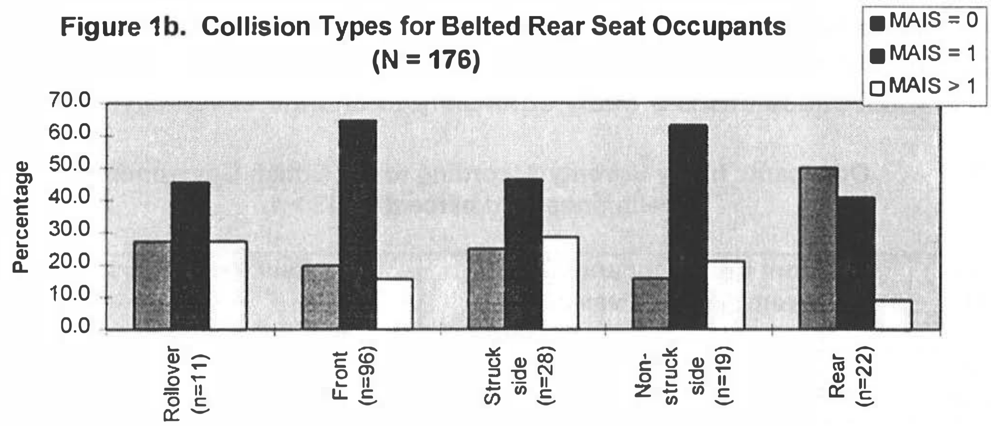


Figure 1c. Collision Types for Unbelted Front Seat Occupants (N = 531)

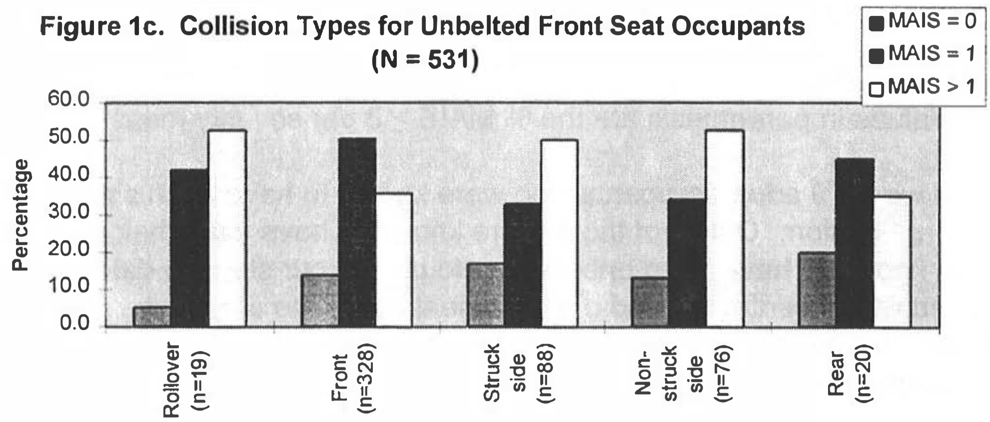
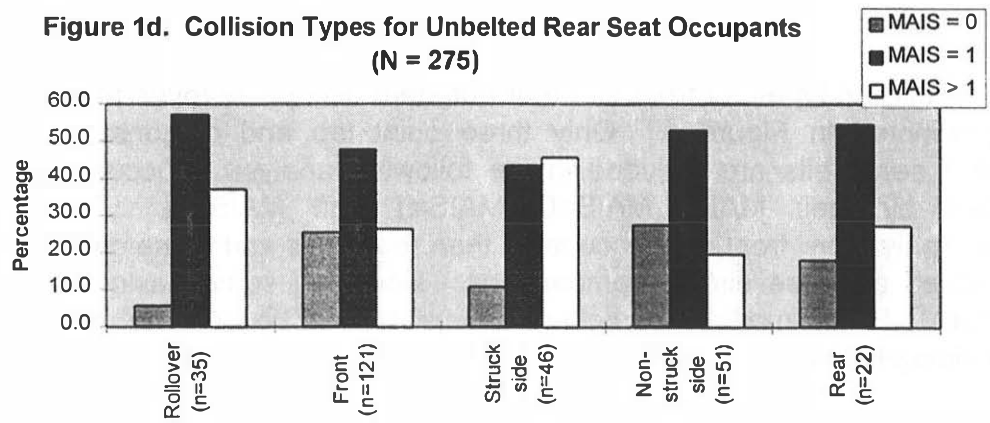


Figure 1d. Collision Types for Unbelted Rear Seat Occupants (N = 275)



rear passengers. Further, the unbelted rear passengers have a lower rate of MAIS>1 injuries for all impact types than the unbelted front occupant.

Figure 2 outlines the occupants gender distributions for drivers, FSPs and RSPs (outboard seating positions only). Within our sample there are significantly more male drivers than females, and significantly more female FSPs than males. However, RSPs were more or less evenly distributed, suggesting that there are no significant gender differences for rear adult outboard seat occupancy. An association was found between seat belt usage and occupant gender for the front seat occupants only (drivers $\chi^2 = 30.03$, df = 1, $p < 0.01$ and FSP $\chi^2 = 17.33$, df = 1, $p < 0.01$). In both cases women were found to be more likely to have used their seat belts. However, a significant association between gender and belt use was not found for RSPs ($\chi^2 = 2.58$, df = 1, $p = 0.11$). In our sample the overall seat belt usage rates were 88.5% for drivers, 88.4% for FSPs and 38.3% for RSPs (34.4% and 42% for male and female RSPs respectively)

Figure 2: Occupant Type Distributions

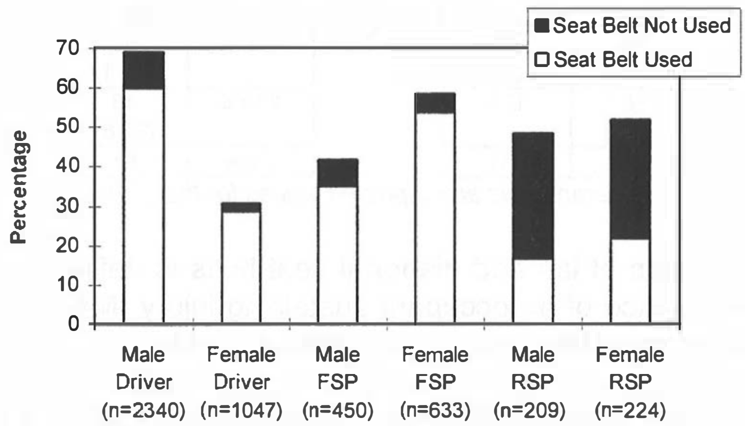
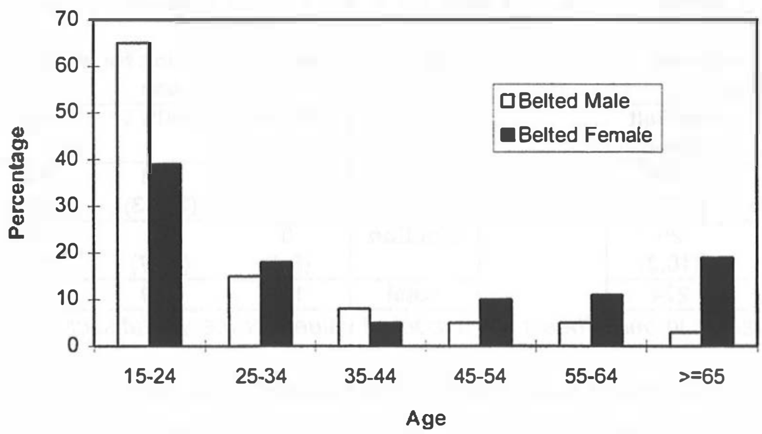


Figure 3: Rear Outboard Seat Belt Usage Rates for all Impacts



The male and female RSPs restraint usage rates are shown against age in figure 3. When seat belts were worn a significant difference was found between males and females ages (median ages were:- male = 21.5 years and female = 29.5 years; $\chi^2 = 8.96$, df = 1, $p < 0.01$). Further, restrained RSPs were significantly older than unrestrained ones (median ages were :- belted = 26 years and unbelted = 22 years; $\chi^2 = 5.39$, df = 1, $p < 0.05$).

REAR LAP AND DIAGONAL SEAT BELT EFFECTIVENESS

Tables 2a and 2b show that outboard rear lap and diagonal seat belts are significantly associated with a reduction in the risk of MAIS > 1 injury for all impact types ($\chi^2 = 8.42$, df = 2, $p < 0.05$) and frontal collisions only ($\chi^2 = 6.37$, df = 2, $p < 0.05$).

Table 2a: All impacts - MAIS by belt use

MAIS	Seat Belt Used	Seat Belt Not used	Total
0	43 (38.4)	56 (60.6)	99
1	102 (93.2)	138 (146.8)	240
2 to 6	34 (47.4)	88 (74.6)	122
Total	179	282	461

Table 2b: Front impacts - MAIS by belt use

MAIS	Seat Belt Used	Seat Belt Not used	Total
0	19 (22.1)	31 (27.9)	50
1	62 (53.1)	58 (66.9)	120
2 to 6	15 (20.8)	32 (26.2)	47
Total	96	121	217

(Values in parenthesis are expected values for the χ^2 statistics.)

The effectiveness of lap and diagonal seat belts is defined as the percent reduction in the chance of an occupant sustaining injury (MAIS > 1) compared to the unrestrained condition, and is calculated as below:-

$$\text{effectiveness} = \frac{(\text{unbelted MAIS} > 1 \text{ rate}) - (\text{belted MAIS} > 1 \text{ rate})}{\text{unbelted MAIS} > 1 \text{ rate}} \%$$

The effectiveness of rear seat belts in preventing MAIS > 1 for our sample is 39% for all crash types (Table 2a) and 41% for frontal impacts (Table 2b).

Table 2c: Ejection against Seat Belt use

	Belt Used	No Belt Used
No Ejection	178 (168.3)	248 (257.7)
Ejection	1 (10.7)	26 (16.3)
Total	179	274

Table 2d: MAIS by Ejection for all impacts and belt use

	MAIS 0	MAIS 1	MAIS 2	MAIS 3 to 6
No Ejection	127 (118.6)	258 (251.3)	69 (72.9)	42 (53.2)
Ejection	0 (8.4)	11 (17.7)	9 (5.1)	15 (3.8)
Total	127	269	78	57

(Values in parenthesis are expected values for the χ^2 statistics.)

Within our sample there were 16 RSP fatalities. Six of these were involved in lateral collisions and seated on the struck side. Only one belted passenger died. He was 77 years old and sustained an AIS 5 chest injury due to loading from the diagonal portion of the belt. The impact was unclassifiable and no ETS could be calculated. Eight of the fatalities were either fully or partially ejected from their cars. Belt usage was found to influence the incidence of ejection. There were 27 RSPs who were ejected from their vehicles, and only one was wearing a lap and diagonal seat belt (Table 2c, $\chi^2 = 15.41$, df = 1, $p < 0.01$). The use of rear belts was found to significantly limit ejection and thus reduce the risk of serious injury (Table 2d, $\chi^2 = 50.82$, df = 3, $p < 0.01$). Previous studies have quantified that rear seat passengers experience almost twice as many rollover impacts as other passengers and have a seven times greater chance of being ejected (Bodiwala, 1989; Tunbridge, 1988).

Table 3 describes the injury sources for the major body regions for belted and unbelted outboard RSPs for all impact types. The highest injury severity per body region (MAIS) is recorded for each passenger and correlated to a source . The lower extremities are detailed for only the maximum leg injury. If both legs sustained injuries of an equal AIS severity, these are summed, and the total given in the parenthesis. The injuries to the upper extremities are not included in this analysis, as there were few known contact sources. There were 368 and 564 injuries correlated for belted and unbelted RSPs respectively. Of these injuries 12.2% (45) for belted and 22% (124) for unbelted were AIS > 1. Therefore, in our sample seat belts reduced the risk of an AIS > 1 injury for all impact types by approximately 45%.

The most common cause of belted RSP's injury at AIS > 1, was chest injury due to seat belt loads. Nine individuals (5%) sustained such an injury from the diagonal portion of the belt. Three (1.7%) sustained thoracic injuries greater than AIS 2 (two received AIS 4, and one AIS 5). Unbelted occupants sustained an AIS > 1 most frequently (13.5%) to the head (cranium). Notable contact sources were the seat or head restraint in front of them, external objects and the car's roof.

Some 15.6% of belted RSPs sustained minor neck strains (AIS = 1) without head or neck impacts, whereas only 4.6% of unbelted occupants received this injury. Further, belted RSPs are documented as having head or face contacts with the head restraint or seat in front of them. There was no clear evidence of serious injury (AIS > 1) due to these contacts. However, femur and leg fractures are attributed to seat contacts for belted passengers.

No attempt has been made to investigate the incidence of restrained front occupants injuries due to restrained or unrestrained RSPs. Several authors including Huelke(1974), Rattenbury(1979) and Griffiths(1976), have found an increased risk of front occupant injury when loaded by an unrestrained RSP. Figure 3h and Figure 5 describe belted RSPs sustaining leg fractures due to contacts with the front seats. Therefore, an increased risk of front occupant injury from interaction with RSPs could exist when all the car's occupants are belted.

Table 3: Injury sources for 179 belted and 282 unbelted RSPs.

Table 3a. Injury Source for Cranium

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
B or other pillar	1	4.2	3	33.3	-	-	-	-
Non contact	-	-	-	-	-	-	2	5.3
External object	-	-	-	-	-	-	4	10.5
Flying glass	-	-	-	-	1	2.4	-	-
Head Restraint	3	12.5	1	11.1	2	4.8	3	7.9
Seat	3	12.5	-	-	2	4.8	3	7.9
Side roof rail	-	-	-	-	1	2.4	1	2.6
Side glass	2	8.3	2	22.2	3	7.1	1	2.6
Roof	1	4.2	1	11.1	1	2.4	4	10.5
Windscreen	-	-	-	-	1	2.4	1	2.4
Other	1	4.2	-	-	2	4.8	3	7.9
Not known	13	54.2	2	22.2	29	69.0	15	39.5
Total	24	100.0	9	100.0	42	100.0	38	100.0

Table 3b. Injury Source for Face

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
B or other pillar	1	3.3	-	-	1	1.0	-	-
External Object	-	-	-	-	1	1.0	3	37.5
Flying glass	1	3.3	-	-	1	1.0	-	-
Head Restraint	5	16.7	-	-	12	12.5	-	-
Seat	6	20.0	-	-	19	19.8	-	-
Side roof rail	-	-	-	-	2	2.1	2	25.0
Side glass	3	3	-	-	10	10.4	-	-
Windscreen	-	-	-	-	3	3.1	-	-
Other	1	3.3	-	-	10	10.4	-	-
Not known	13	43.3	-	-	37	38.5	3	37.5
Total	30	100.0	-	-	96	100.0	8	100.0

Table 3c. Injury Source for Neck

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Neck impact	3	6.5	-	-	3	5.4	1	20.0
Head impact	13	28.3	-	-	23	41.1	2	40.0
No impact	28	60.9	3	100.0	13	23.2	1	20.0
Not known	2	4.3	-	-	17	30.4	1	20.0
Total	46	100.0	3	100.0	56	100.0	5	100.0

Table 3d. Injury Source for Thorax

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
B or other pillar	-	-	-	-	1	3.0	-	-
Door	3	6.5	-	-	3	9.1	7	35.0
Seat	-	-	-	-	10	30.3	1	5.0
Seat belt	36	78.3	8	88.9	-	-	-	-
Side, other	-	-	-	-	-	-	2	10.0
Other	1	2.2	-	-	3	9.1	7	35.0
Not known	6	13.0	1	11.1	16	48.5	3	15.0
Total	46	100.0	9	100.0	33	100.0	20	100.0

Table 3e. Injury Source for Abdomen

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Door	1	2.5	-	-	3	9.1	5	55.6
Seat	-	-	-	-	10	33.3	1	11.1
Seat belt	34	85.0	3	60.0	-	-	-	-
Side, other	-	-	-	-	1	3.0	-	-
Other	1	2.5	-	-	5	15.2	2	22.2
Not known	4	10.0	2	40.0	14	42.4	1	11.1
Total	40	100.0	5	100.0	33	100.0	9	100.0

Table 3f. Injury Source for Thoracic and Lumbar Spine

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Spine impact	2	18.2	-	-	3	25.0	2	18.2
Indirect loading	7	63.6	-	-	3	25.0	3	27.3
Not known	2	18.2	1	100.0	6	50.0	6	54.5
Total	11	100.0	1	100.0	12	100.0	11	100.0

Table 3g. Injury Source for Pelvis

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Direct front load	-	-	1	10.0	-	-	2	20.0
Direct Side Load	-	-	2	20.0	-	-	4	40.0
Other	-	-	-	-	-	-	2	20.0
Not known	45	100.0	7	70.0	-	-	2	20.0
Total	45	100.0	10	100.0	-	-	10	100.0

Table 3h. Injury Source for Right and Left Thighs (highest AIS per passenger)
Values in parenthesis are the total number of injuries to both thighs per MAIS group.

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Compartment Side	0	-	1	16.7	4	18.2	2	22.2
Seat	2	40.0	3	50.0	7	31.8	3	33.3
Other	-	-	-	-	-	-	1	11.1
Not known	3	60.0	2	33.3	11	50.0	3	33.3
Total	5 (7)	100.0	6 (7)	100.0	22 (28)	100.0	9 (11)	100.0

Table 3i. Injury Source for Right and Left Knees (highest AIS per passenger)
Values in parenthesis are the total number of injuries to both knees per MAIS group.

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Compartment Side	-	-	-	-	2	6.7	-	-
Seat	3	23.1	1	50.0	14	46.7	1	33.3
Other	-	-	-	-	2	6.7	1	33.3
Not known	10	76.9	1	50.0	12	40.0	1	33.3
Total	13 (17)	100.0	2 (2)	100.0	30 (37)	100.0	3 (3)	100.0

Table 3j. Injury Source for Right and Left lower legs (highest AIS per passenger)
Values in parenthesis are the total number of injuries to both legs per MAIS group.

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Compartment Side	-	-	-	-	-	-	2	28.6
Facia	-	-	-	-	2	4.1	-	-
Seat	16	47.1	-	-	28	57.1	1	14.3
Other	1	2.9	-	-	2	4.1	-	-
Not known	17	50.0	-	-	17	34.7	4	57.1
Total	34 (41)	100.0	-	-	49 (72)	100.0	7 (8)	100.0

Table 3k. Injury Source for both Ankles and Feet (highest AIS per passenger)
Values in parenthesis are the total number of injuries to both ankles and feet per MAIS group.

Injury Source	Belted				Non-Belted			
	MAIS = 1		MAIS ≥ 2		MAIS = 1		MAIS ≥ 2	
	N	%	N	%	N	%	N	%
Under Seat	6	50.0	-	-	11	45.8	3	75.0
Other	2	16.7	-	-	1	4.2	1	25.0
Not known	4	33.3	-	-	12	50.0	-	-
Total	12 (15)	100.0	-	-	24 (31)	100.0	4 (4)	100.0

FRONT, NON-STRUCK SIDE AND ROLLOVER COLLISIONS

The injury rates per body region have been compared in Table 4 for belted and unbelted front and rear passengers. Only front, non-struck side and rollover collisions were considered as the lap and diagonal restraint is generally accepted to be most effective during these collisions. There were only 24 RSPs in the sample who wore lap and diagonal belts and sustained an overall MAIS > 1 for this subset. Therefore, potential analysis is limited.

FRONT IMPACTS ONLY (WITH KNOWN IMPACT SEVERITY)

Figure 4 shows belted and unbelted RSPs injury outcomes following front impacts. MAIS values are grouped, 0 and 1; and 2 to 6 (MAIS > 1). No significant difference was found between the median ETS for belted and unbelted MAIS > 1 cumulative percent curves (median ETS = 36 km/hr, χ^2 = 0.015, df = 1, p = 0.9). However, approximately 70% (8) of the belted passengers were rated MAIS = 2 only. Whereas, 48% (11) of the unbelted passengers were rated MAIS > 2. Therefore, there was a tendency for the unrestrained to be more severely injured. However, the small sample size should be borne in mind when these results are considered. There was no significant association found between gender or age and belt use at MAIS > 1. Further, no significant difference was found for the distribution of ETS at MAIS>1 between belted FSPs and RSPs (median ETS = 36 km/hr, χ^2 = 0.0007, df = 1, p = 0.98). There is some suggestion that restrained occupants are somewhat more vulnerable to minor injury in the rear than unrestrained occupants.

Table 4: MAIS > 1 and MAIS > 2 Injury rates for the major boby regions.

	FSPs Belted (N=755)		FSPs Unbelted (N=114)		RSPs Belted (N=126)		RSPs Unbelted (N=207)	
	% MAIS >1	% MAIS >2	% MAIS >1	% MAIS >2	% MAIS >1	% MAIS >2	% MAIS >1	% MAIS >2
Head (Cranium)	7.2	2.5	12.3	6.1	3.2	0.8	10.1	3.4
Face	0.8	-	0.9	-	-	-	3.4	0.5
Neck (Incl. Cervical Spine)	2.4	0.9	1.8	-	0.8	-	1.0	0.5
Upper Extremities	8.3	1.7	13.2	3.5	6.3	-	8.7	1.0
Thorax	10.9	3.8	6.1	5.3	6.3	1.6	5.3	4.3
Abdomen	2.1	1.2	2.6	1.8	3.2	1.6	1.9	0.5
Spine (Thoracic & Lumbar)	2.8	0.5	-	-	0.8	-	3.9	1.4
Lower Extremities	7.0	2.8	7.9	2.6	3.2	2.4	7.7	4.8

Clearly there are different mechanisms responsible for belted and unbelted RSPs injuries. The belted RSPs who sustained a MAIS > 2 following a frontal impact are detailed in table 5. Their injuries can be summarised as to the chest, abdomen and femur fractures.

Figure 4: Front impact speed distributions for rear passengers

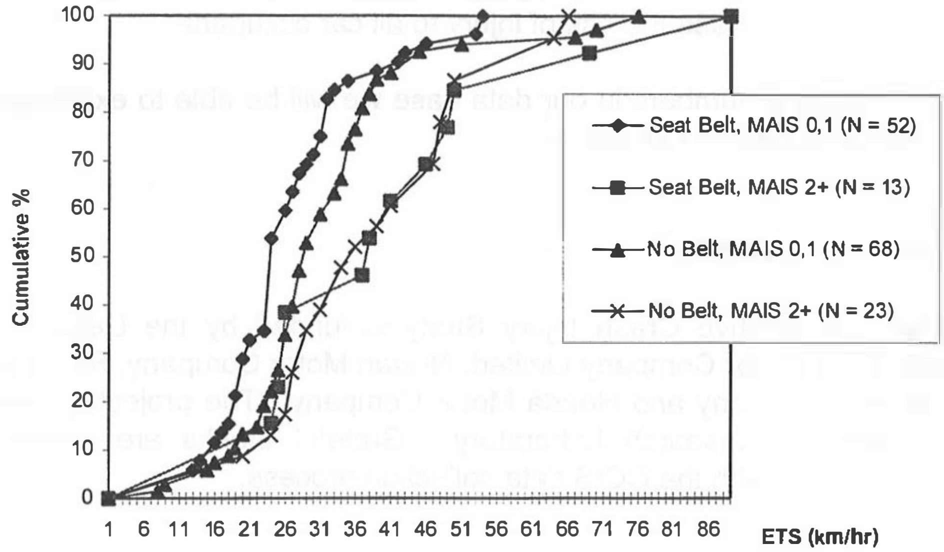


Table 5: Belted Adult RSPs Involved In Frontal Impacts Who Sustained MAIS > 2.

Occ No.	Injury Descriptions (AIS in parenthesis)	MAIS	ETS km/hr	Sex	Age	Height (m)	Weight (kg)
1	Multiple rib fractures with pneumo-thorax (4) & spleen contusion (3).	4	36	male	47	n/k	n/k
2	Femur fracture (3).	3	48	male	23	n/k	n/k
3	Small bowel perforation (3).	3	68	male	20	1.8	57
4	Flail chest (4); liver & kidney lacerations (2) & Cervical spine disc fracture (2).	4	40	female	36	1.6	54
5	Rib fractures (2) & two femur fractures (3).	3	45	female	n/k	n/k	n/k

CONCLUSIONS

This study has begun to discriminate the injury outcomes for restrained and unrestrained rear seat occupants and to compare them to those in the front seats. Population differences have a clear influence on effectiveness with elderly restrained rear occupants appearing as a factor which diminishes the overall effectiveness of restraints. By implication, some of the serious chest and abdominal injuries described above relate to rear belt geometry and the specific way in which the seat belt was being worn.

Forward contacts by restrained rear occupants wearing lap and diagonal belts striking their heads on front seat backs give indications of the trajectories of their heads in collisions. Belted RSPs head and leg contacts with front seats must be expected, and the possible interaction between front and rear occupants could increase the risk of injury to all car occupants.

With increasing numbers in our data base we will be able to examine these issues more precisely in the future.

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REFERENCES

American Association for Automotive Medicine. The Abbreviated Injury Scale 1990 Revision. AAAM, Arlington Heights, Illinois, USA; 1990.

Bodiwala et. al. Protective Effect of Rear Seat Restraints During Car Collisions. The Lancet, February 18th 1989.

Griffiths D. K. et. al. Car Occupant Fatality and the Effect of Future Safety Legislation. 20th Stapp Car Crash Conference. SAE Warrendale. USA. 1976
Haberl, J., Eichinger, S., Wintershoff, W. New Rear Safety Belt Geometry - A Contribution to Increase Belt Usage and Restraint Effectiveness. S.A.E. 870488

Hassan, A. M., Hill, J.R., Parkin, S., Mackay, G.M. Secondary Safety Developments: Some Applications of Field Data. Autotech 1995; IMechE; 1995.

Huelke D. F. et. al. The Hazard of the Unrestrained Occupant. 18th American Association for Automotive Medicine. 1974.

Kraft, M., Nygren, C., Tingvall C. Rear seat occupant protection. A study of children and adults in the rear seat of cars in relation to restraint use and car characteristics. Journal of Traffic Medicine 1990; 18:51-60.

Lundell, B., Mellander, H., Carlsson, I. Safety Performance of a Rear Seat Belt System with Optimized Seat Cushion Design. Passenger Car Meeting, Dearborn, Michigan. June 8-12, 1981. S.A.E.; 1981:810796

Mackay, G. M., Galer, M. D., Ashton, S. J., Thomas, P. D. The Methodology of In-depth Studies of Car Crashes in Britain. International Congress and Exposition; 1985; Detroit, Michigan, USA.: S.A.E.; 1985:365-390.

NHTSA. CRASH3 User's Guide. USA. Department of Transportation, National Highway Traffic Safety Administration; 1982.

NHTSA. Rear Seat Lap Shoulder Belts in Passenger Cars. Office of Regulatory Analysis Plans and Policy. Final Regulatory Evaluation. April 1989

Padmanaban, J., Ray, R. Safety Performance of Rear Seat Occupant Restraint Systems. S.A.E. 922524. 1992.

Rattenbury S. J. The Biomechanical Limits of Seat belt Protection. American Association for Automotive Medicine Conference. 1979.

Restraint Use by Car Occupants, 1994-96. LF 2074. Transport Research Laboratory. UK. 1996.

Road Accidents Great Britain: 1995. The Casualty Report. The Department of Transport. HMSO, London. 1995.

Tunbridge et. al. An In-Depth Study of Road Accident Casualties and their Injury Patterns. RR 136. Transport Research Laboratory. UK. 1988.