Z Rechtsmed (1984) 92 : 199–204

Zeitschrift für
Rechtsmedizin

The Effect of the Unrestrained Back Seat Passenger on the Injuries Suffered by Drivers and Front Seat Passengers in Head-on Collisions

P. Löwenhielm and P. Krantz

Department of Forensic Medicine, University of Lund, Sölvegatan 25, S-223 62 Lund, Sweden

Summary. In head-on collisions, loose items in the rear of the car, such as luggage or unrestrained back seat passengers can cause substantial loading on the back of the front seats. The purpose of this paper is to study if such loading increases the injury severity for the front seat occupants. Data were collected from all fatal automobile accidents for a period of 1 year in Sweden. Information was collected about the survivors as well as the deceased. Head-on collisions were selected, and the injuries of the front seat occupants were scored according to the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS). In evaluating the injury severity, the collision energy was taken into account. The results indicate that belted front seat passengers sustain a higher injury risk with an unrestrained passenger in the back seat. These results are valid for collision speeds below 45 km/h.

Key words: Car occupant – Head-on collision – Injury severity – Seat belt loading

Zusammenfassung. Bei Frontalkollisionen können lose Gegenstände auf den Rücksitzen von Personenkraftwagen – wie Gepäck, nicht angegurtete Passagiere – zu einer erheblichen Belastung der Rücklehne der Vordersitze führen. In der vorliegenden Studie wird untersucht, ob durch eine derartige Belastung die Schwere der Verletzungen bei Vordersitzinsassen erhöht wird. Die erforderlichen Daten stammen von sämtlichen Kraftwagenunfällen mit tödlichem Ausgang, die sich während 1 Jahres in Schweden ereignet haben. Die Angaben betreffen auch die Überlebenden, und die Körperverletzungen beim Fahrer und Beifahrer auf dem Vordersitz der Fahrzeuge wurden entsprechend der „Abbreviated Injury Scale" (AIS) und der „Injury Severity Score" (ISS) aufgeschlüsselt. Bei der Bestimmung der Verletzungsschwere wurde die Kollisionsenergie berücksichtigt. Die Resultate deuten darauf hin, daß die Fahrzeuginsassen auf den Vordersitzen einem größeren Verletzungs-

Offprint requests to: P. Löwenhielm, M.D. (address see above)

risiko ausgesetzt sind, wenn sich ein nicht angegurteter Insasse auf dem Rücksitz befindet. Dieses Resultat gilt für Kollisionsgeschwindigkeiten unter 45 km/h.

Schlüsselwörter: Frontalkollision, Verletzungsrisiko auf den Vordersitzen bei nicht angegurteten Insassen auf den Rücksitzen – Traumatologie, Verletzungen bei Frontalkollision

Legislation made seat belt use compulsory in Sweden in 1975, but applied to front seat occupants only. Taxis were not included. Objections to the exceptions have been raised as it is assumed that objects in the back seat, e.g., unrestrained passengers, luggage, or dogs, may increase the risk of injury to the front seat occupants, especially in head-on collisions. Bohlin (1977) considered that unbelted back seat occupants provide a main injury risk to the front seat occupants. Niederer et al. (1977), Nahum et al. (1967), and Mackay et al. (1975) have shown evidence of overloading of the front seat occupants by back seat passengers. As the use of seat belts on the back seat is quite uncommon in Sweden, the above mentioned effects should be expected in automobile accidents in the Swedish environment, too. To study this, the present investigation evaluated all fatal automobile accidents in the whole of Sweden in 1975.

Material and Methods

The basic data were compiled from 458 accidents involving 1,366 persons, of whom 560 were killed at the scene of the accident or died within 1 year of their injuries. Accident data relevant to the dead as well as to the injured who survived were collected from police reports, photographs from the scene of the accident, as well as of the damaged cars, autopsy reports, and medical records.

From these basic data the head-on collisions were selected, i.e., accidents with an 11, 12, or 1 o'clock direction of impact. Occupants of cars that were driven under lorries or occupants who were thrown out of cars were excluded.

The injuries of the front seat occupants were grouped according to the *type* (i.e., aortic rupture, skull fracture, etc.), the *location* (head, neck, thorax, etc.), and the *seriousness*. In evaluating the seriousness, the Abbreviated Injury Scale (AIS, 1976 revision) was used. For the overall injury assessment, the Injury Severity Score (ISS) was applied.

When the severity of a collision is to be assessed, the change in velocity of the impact is the most suitable variable. The absolute velocity change is never known with accuracy. The velocity change is, however, usually proportional to the degree of deformation of the car; consequently, an assessment of deformation should provide a useful tool to estimate the energy dissipated during that phase of the accident when the body injuries are likely to occur.

To comprehend the energy of impact, the deformation of different zones of the cars was estimated, and the deformation score for each zone was squared and the squares were added together. The value thus achieved represents the energy of impact. This approach was described by Krantz and Löwenhielm in 1980. In this matter, the weight of the back seat passengers should also be considered. The majority of the back seat passengers survives the accidents, and in the medical records collected, information on the weight of the patient was, as a rule, lacking. Thus, the potential effect of a variable loading of the front seat occupants caused by different weights of the back seat passengers has not been taken into consideration in the present study. There was no positive information on loose items (i.e., luggage) in the back seat in any of the cases studied.

Table 1. Number of drivers and front seat passengers in head-on collisions related to seat belt use and presence of back seat passenger behind

	Seat belt used	Seat belt not used	Seat belt users
Driver with back seat passenger behind	36	22	62%
Driver without back seat passenger behind	139	71	66%
Front seat passenger with back seat passenger behind	25	18	58%
Front seat passenger without back seat passenger behind	55	32	63%

Table 2. Average ISS for front seat occupants with and without unrestrained passenger behind in relation to seat belt use. Frontal collisions

	Seat belt used (ISS)	Seat belt not used (ISS)
Driver with back seat passenger behind	23.4	31.3
Driver without back seat passenger behind	22.7	29.9
Front seat passenger with back seat passenger behind	21.2	26.3
Front seat passenger without back seat passenger behind	15.1	31.7

Results and Discussion

Of 261 back seat occupants, 11 (4.4%) were restrained. It is significant that these 11 persons all survived the accidents, whereas 60 of the 250 (24%) unrestrained back seat occupants were killed.

If alone, the unrestrained back seat passenger sits in the middle of the back seat sometimes. In these cases "sitting behind" was defined as true for the driver in an 11 o'clock collision, as true for the front seat occupant in a 1 o'clock collision, and not true for either of the front seat occupants in a 12 o'clock collision. There were only left-hand-driven cars in this investigation. Considering these distinctions, there was an unrestrained back seat occupant behind the driver or the front seat occupant in 25% of the cases (101 of 398 persons) (Table 1).

Twenty-five per cent is near to the frequency of 23% given by Niederer et al. (1977). Of the 139 belted drivers, 131 wore 3-point lap-shoulder belts, seven wore 2-point lap-belts, and in one case it could not be established which type had been worn. The corresponding figures for the 55 belted front seat passengers were 48, 2, and 5, respectively.

Table 3. Average relative impact energy sustained by front seat occupants with and without unrestrained passengers behind in relation to seat belt use. Frontal collisions

	Seat belt used (impact energy)	Seat belt not used (impact energy)
Driver with back seat passenger behind	18.5	16.3
Driver without back seat passenger behind	14.5	15.7
Front seat passenger with back seat passenger behind	21.5	12.9
Front seat passenger without back seat passenger behind	18.6	16.8

Table 4. Average ISS for restrained and unrestrained front seat occupants with and without unrestrained passengers behind in relation to relative impact energy level. Frontal collision

	Relative impact energy interval			
	0–1 ISS	2–10 ISS	11–30 ISS	>30 ISS
Driver with back seat passenger behind	8.2	21.2	28.4	48.8
Driver without back seat passenger behind	7.2	22.5	29.1	46.1
Front seat passenger with back seat passenger behind	1.3	25.5	30.5	31.9
Front seat passenger without back seat passenger behind	4.8	22.9	26.9	30.2

In Table 2, the average ISS for the drivers and the front seat passengers in head-on collisions is presented. Except for the unbelted front seat passenger group, there seems to be a slight increase in the injury severity when there was an unbelted passenger in the back seat. This increase/decrease must be judged with reference to impact energy. In Table 3, the average impact energy is indicated for the groups defined in Table 2. Comparing the values given in Tables 2 and 3, it is evident that there is a positive correlation between the ISS and the impact energy, i.e., for all the groups there is an increase of injury severity when the impact energy increases. Thus, it is not possible to compare the groups when the impact energies differ significantly. On the other hand, the injury reducing effect of the seat belt is apparent from Tables 2 and 3. In this case, there is a negative correlation between ISS and impact energy except for the drivers without an unbelted passenger in the back seat. In this case, the impact energies are of the same magnitude and can be compared anyhow. Krantz and Löwenhielm (1980) presented an investigation on the injury-reducing effect of seat belts, showing

Table 5. Injuries scaled according to AIS in restrained front seat passengers without and with unrestrained passenger behind in the relative impact energy interval 2–10 (<45 km/h), frontal collision

Restrained front seat passenger with unrestrained passenger behind

		AIS						
Region	*N*	0	1	2	3	4	5	6
Head	5	3	0	0	0	0	0	2
Thorax	5	1	0	0	1	2	0	1
Abdomen	5	4	0	1	0	0	0	0

Restrained front seat passenger without unrestrained passenger behind

		AIS						
Region	*N*	0	1	2	3	4	5	6
Head	12	6	1	4	1	0	0	0
Thorax	12	10	0	0	2	0	0	0
Abdomen	12	10	0	0	0	1	1	0

that the ISS was related to the impact energy. This method was applied in the present investigation. Krantz and Löwenhielm (1980) found that a critical level for fatal injury was about ISS = 25. Referring to Table 2, this value falls between the belted and the unbelted groups.

To take the impact energy dependence into consideration, four energy levels were chosen as there were not many cases. To obtain groups of comparable sizes the four groups were defined as follows: (1) minor or no impact, IE = 0–1; (2) moderate impact, IE = 2–10; (3) powerful impact, IE = 11–30, and (4) very powerful impact, IE > 30. In Table 4, the average ISS vs the relative impact energy is presented.

Impact energy 10 corresponded to a velocity of about 45 km/h. The ISS for the driver groups correlated well with the energy levels studied. For the front seat passengers, the ISS values were somewhat higher when there was an unrestrained passenger behind, but this difference was not significant. For lower impact energies, the results for the drivers and the front seat passengers were quite comparable, but as the impact energy increased a significant difference was obtained. The reason for this difference was that the driver in high velocity accidents reached the steering wheel, irrespective of the seat belts being used or not. In a restrained position, the driver's head often hit the steering wheel. Mackay et al. (1975) indicated that in a sample of simple frontal collisions, over 60% of the drivers wearing seat belts struck the steering wheel with their heads. Rattenbury (1979) found that about 50% of the drivers struck the steering wheel when the speed was about 50 km/h. The use of seat belts was not taken into consideration in the results presented in Table 4. No marked change in injury severity was obtained if the use of seat belts was taken into account, but for two groups:

restrained front seat passengers with and without an unrestrained back seat passengers behind and in the impact energy interval IE = 2–10. With 5 and 12 persons, respectively, these groups were small. It was not purposeful to apply statistical methods to such small test groups. The specific injuries in the groups, however, gave some information. In Table 5, the injuries are presented for the head, thorax, and abdomen—scaled according to AIS. The most striking differences were that more serious injuries to head and thorax were suffered by the front seat passengers with an unrestrained passenger behind. Two persons in this group were killed, whereas all of the front seat passengers without a passenger behind survived the accidents. Although it was impossible to ascertain an increased risk of additional injury to the front seat occupants, caused by unrestrained passengers in the rear of the car, it should be recalled that the basic data of this investigation were gathered from fatal accidents. However, the results obtained for the passenger group suffering impact energy of 2–10 may indicate that the possible benifits of reducing overloading of the front seat occupants are obtained in collision velocity changes below 45 km/h.

References

Bohlin N (1977) Fifteen years with the three-point safety belt. Proc 6th IAATM Conf, Melbourne, p 142

Krantz P, Löwenhielm P (1980) Injury response in belted and unbelted car occupants related to the car crash energy in 458 accidents. Proc 5th IRCOBI Conf, Birmingham, p 305

Mackay GM, Gloyns PF, Hayes HRM, Griffiths DK, Rattenbury SJ (1975) Serious trauma to car occupants wearing seat-belts. Proc 2nd IRCOBI Conf, Birmingham, p 20

Nahum AM, Siegel AW, Hight PV (1967) Injuries to rear seat occupants in automobile collisions. Proc 11th Stapp Car Crash Conf, Society of Automotive Engineers (SAE), p 159

Niederer P, Walz F, Zollinger U (1977) Adverse effects of seat-belts and causes of seat-belt failures in severe car accidents in Switzerland during 1976. Proc 21st Stapp Car Crash Conf, Society of Automotive Engineers (SAE), p 53

Rattenbury SJ, Gloyns PF, Hayes HRM, Griffiths DK (1979) The biomechanical limits of seat belt protection. Proc 23rd AAAM Conf, Louisville, KY, p 162

Received September 21, 1983