THE RISK OF WHIPLASH INJURY IN THE REAR SEAT COMPARED TO THE FRONT SEAT IN REAR IMPACTS.

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ABSTRACT

195 rear impacts with both front- and rear-seat occupants in the struck car were selected, where at least one occupant sustained permanent disability. There was a significantly higher disability risk for the female rear seat occupant compared with the male driver. Furthermore, a higher risk was found for female rear-seat compared with female front-seat passengers. The disability risk for occupants of the driver´s seat was three times higher for females than for males, and four times higher for females in the rear seat. In the future, test methods should consider the risk of whiplash injury both in the front and the rear seat.

Keywords: whiplash, rear impacts, rear seat, disability

THE MAIN PUBLIC HEALTH PROBLEMS concerning neck injuries AIS 1 are those leading to long-term disability. Apart from the human perspective, the long-term disabilities are responsible for the major part of the costs (Spitzer et al 1995). Most occupants who suffer whiplash injury do not develop chronic symptoms. Nygren (1984) found that one out of ten occupants sustained medical disability a year after a collision, and Galasko et al (1996) showed that 8% still had symptoms two years after the impact. When studying neck injury risk factors for occupants it is important to separate the duration of symptoms since initial symptoms do not seem to be a valid predictor of the risk of permanent disability (Krafft 2002).

The risk of neck injury in the rear seat is rarely studied. The following studies describe the risk of initial neck injury. Based on reported, initial whiplash symptoms to an insurance company, Lövsund et al (1988) found a 50% lower risk in the rear seat compared to the front seat in rear impacts, when sex was taken into account. In another study by Berglund and colleagues (2002), the relative risk of reported, initial symptoms was over 40% hogher for occupants in the passenger front seat, and nearly 80% higher in the driver´s seat, compared to the rear seat. Otremski et al (1989) also found a lower risk of initial symptoms in the rear seat compared to the front and driver´s seat, but the study did not separate the risk for different impact directions. No study mentioned above, has controlled for crash severity in the investigated crashes.

The aim of this study was to compare different seating positions with respect to the risk of permanent disability to the neck in rear impacts, where the crash severity has been controlled for by using the paired comparison method.

MATERIAL AND METHOD

All neck injuries reported to Folksam, a Swedish insurance company, in rear impacts with both front- and rear-seat occupants in the struck car, were selected. Another inclusion criteria was that at least one occupant in each vehicle had sustained permanent disability. Occupants under 18 year of age were excluded. The study population represented 554 occupants in 195 crashes. Of the 554 occupants, 224 sustained a permanent disability. Information about seating position, age and sex were received from the injury file at Folksam for the disabled occupants, and the same data was collected for the uninjured occupants, by questionnaires to the disabled occupants. The response rate to the questionnaires was 81 %. All cases from 1990 to 1999 were used.

In this study, permanent disability was defined as long-term consequences judged by the Swedish Road Traffic Injury Commission (TSN); less severe disabilities (1-10%), were established by the insurance company. In Sweden all injuries that occur in car crashes where the victims require medical treatment are ranked according to a national disability scale ranging from 1 to 100% (Försäkringsförbundet 1996). The criteria for determining the extent of the permanent medical disability are related to loss of function, pain, and/or mental dysfunction, estimated by medical specialists. There is no relationship to the patient's occupation or social situation. Normally the degree of disability is not established until three to five years after a crash. A preliminary estimation of the degree of disability is determined about one year after the crash. In this study, all disabled occupants are defined as "disabled", irrespective of degree of disability. Generally, whiplash symptoms remaining after at least one year lead to a disability degree of 3 to 18%.

The injury outcome depends on the severity of the crash. However, this factor is not known for the individual cases in this study. In order to normalise for crash severity, the paired comparison method was used in analysing the relative risk of long-term consequences for different seating positions and with regard to sex. This method is based on the fact that the injury risk is a continuous function of crash severity, and was originally used by Evans (1986).

Using the paired comparison method, the numbers of disabilities for different seating positions in the same car were compared, see table 1. Matched pairs were established from each crash, where both front- and rear-seat occupants were seated and therefore exposed to the same crash severity. For instance, male driver – male rear-seat occupant, where at least one of them was disabled.

Table 1. Number of disabled and not disabled car occupants for different seating positions.

	Seat position z		
Seat position y		Disabled	Not Disabled
	Disabled	X1	X2
	Not Disabled	X3	

The risk relationship between the seating positions studied is calculated according to estimation (1).

$$(1) \qquad R = (x_1 + x_2) / (x_1 + x_3)$$

The relative risks between occupant seating positions and sex were generated in steps. The twelve possible combinations between seating position and sex were calculated and the male driver was set to 1. Two independent estimations were made on the basis that there were many observations and that they were mutually exclusive (female rear-seat occupants to drivers, and female drivers to female rear-seat occupants). All other relative risks were estimated on the basis of these three originally chosen and calculated risks. In order to generate risk ratios that were based on as many cases as possible, the individual risk ratios for all combinations were averaged. Thus all relative risks, except for the initial three, are based on three observed risk ratios.

The variance for the risk ratios was based on the approximate method for the variance of ratios Hägg et al (1992).

RESULTS

The total number of disabled and not disabled occupants is shown in the appendix. The occupant age distribution for different seating positions is shown in Table 2. Female passengers in the front seat, were more represented in the age group 55 years or older, than for other positions. However, Berglund et al (2002) found that the risk of whiplash injury did not vary substantially with age, in rear impacts. For other impact directions, the risk decreases above approximately 50 years of age (Berglund et al 2002, Jacobsson et al 2000).

Table 2. The gender and age distribution for different seating positions in the vehicle. FSP = front seat passenger, RSP= rear seat passenger.

	Males			Females		
	Driver % (n)	FSP % (n)	RSP % (n)	Driver % (n)	FSP % (n)	RSP % (n)
18-35 year	34 (42)	58 (31)	60 (43)	41 (29)	35 (22)	54 (93)
36-55 year	31 (39)	30 (16)	25 (18)	38 (27)	29 (18)	27 (46)
55- year	18 (23)	11 (6)	14 (10)	7 (5)	35 (22)	19 (33)
Unknown*	17 (21)	0 (0)	0 (0)	13 (9)	0 (0)	0 (0)

** FSPs and RSPs whose age was unknown were excluded inthe case of occupants under 18 years of age. For the driver´s seat, the occupants were assumed to be 18 years or older.*

Table 3. Combinations of disabled occupants in rear impacts based on tables 2-13 in the appendix. D=driver, FSP=front-seat passenger, RSP=rear-seat passenger, m=male, f=female

Combination	Risk ratio	Combination	Risk ratio	Combination	Risk ratio
FSPm/Dm	0.91	RSPm / Dm	0.50	RSPm/FSPm	0.40
FSPf /Df	0.37	RSPf/Df	0.77	RSPf/FSPf	1.30
FSPf /Dm	1.09	RSPf/Dm	2.33	RSPf/FSPm	2.25
FSPm/Df	0.23	RSPm/Df	0.18	RSPm/FSPf	0.14

In Table 3, the risk ratios, based on real-life disability outcome (appendix), for different combinations between seating position and sex, are shown. To calculate the relative risks for the same combinations (Table 4), the following estimations were made:

A. First estimate (arbitrarily chosen) : Dm (male driver) =1
B. Second estimate (most common combination): RSPf (female rear-seat pass.) = 2.33
C. Third estimate (second most common combination, independent of second estimate): Df (female driver) = 3.03
D. All other estimates derived from estimates A-C

Table 4. Estimates of all combinations of position and sex, from estimation A-D.

	Males	Females
Driver	1 (1st estimate)	3.03 (3rd estimate)
Front-seat passenger	0.91	1.44
Rear-seat passenger	0.41	2.33 (2nd estimate)

There was a significant difference between the risk for the female rear-seat occupant and the male driver position, as well as for the female rear-seat and the female front-seat passenger. In contrast to other studies, there was an increased risk for female passengers in the rear-seat compared to the front-seat (see Table 4).

The risk difference between the sexes varied with different seating positions. There was a significant difference between males and females for the driving and the rear-seat position. However, the risk of disability for occupants of the driver´s seat, was three times higher for females than for males; and for rear-seat passengers, the risk for females was four times higher than for males (see Table 4).

In order to validate the results, both the estimated calculation and the real outcome in Table 3, a comparison was made in Table 5. It can be seen that the differences between the estimated and observed ratios were limited.

Table 5. Estimates of all combination of positions and sex (table 3) applied to risk ratios (real outcomes in brackets).

Combination	rate	Combination	rate	Combination	rate
FSPm/Dm	0.91 (0.91)	RSPm/Dm	0.41 (0.50)	RSPm/FSPm	0.45 (0.40)
FSPf /Df	0.48 (0.37)	RSPf*/Df**	0.77	RSPf/FSPf	1.62 (1.30)
FSPf /Dm	1.44 (1.09)	RSPf*/Dm	2.33	RSPf/FSPm	2.50 (2.25)
FSPm/Df	0.30 (0.23)	RSPm/Df	0.14 (0.18)	RSPm/FSPf	0.28 (0.14)

*= 2nd estimate, derived from Dm = 1, ** = 3rd estimate, derived from FRPf=2.33

DISCUSSION

Most studies concerning risk of whiplash injuries are focused on the front seat occupants, especially the driver. Some studies have presented the risk in the rear seat (Berglund et al 2002, Jacobsson et al 2000, Otremski et al 1989, Lövsund et al 1988) based on the initial symptoms that occur after the collision. This study contributes with results based on permanent disabling whiplash injuries and also data controlled for crash severity. This kind of data has not been presented before. Occupants that sustain disability to the neck represent approximately 10% of all whiplash injuries that are reported to the insurance companies in Sweden.

Whiplash injuries are complex in the sense that the injury mechanism is not fully understood, and epidemiological markers are an essential ingredient in understanding the nature of the risk factors of the injury. As the attempt to minimise whiplash injuries is implicitly related to long-term outcome, epidemiological markers should be related to these long-term consequences, unless they are identical to those of short-term duration. However, an earlier study has shown that the initial injury outcomes for whiplash injuries do not seem to reliably predict the risk of disability (Krafft 2002). It is therefore necessary to separate for duration of symptoms to analyse risk factors. The study showed that there was no correlation between risk of short- and long-term consequences for occupants in twenty-six different car models.

The definition of disability in this study was based on the Swedish Road Traffic Injury Commission classification of a whiplash injury, leading to long-term consequences at least one year after the impact, and the degree of disability is estimated by medical specialists. The disability scale has not been validated; however, this should not influence the results in this study, since the same estimation has been made for all occupants, irrespective of seating position.

One of the most difficult problems in evaluating the safety in car design by means of real life data, is the handling of exposure problems. This problem involves both the number of occupants in collisions and the severity of these crashes. Both mass data as well as crashes evaluated by crash recorders show, that there is a strong relation between impact severity and risk of injury (Eichberger et al 1996**,** Krafft et al 1997). More recently, it has been shown, that the strongest link is between acceleration and risk of injury, especially more long-lasting symptoms, (Krafft et al 2002b). It is therefore important not only to be able to control for impact severity; the method used is also suitable also for impact severity parameters other than change of velocity. By using matched pairs in rear impacts, where both occupants in the front and rear seat were represented, and where the injury status for all occupants is known, the exposure parameters mentioned above, are controlled. In this case, the method is adequate for change of velocity, mean acceleration and peak acceleration.

For the purpose of comparing both seating position and sex, in the same vehicle, it was necessary to modify the usual paired comparison method, by applying more steps of the estimation. However, the estimates proved to be consistent, showing similar estimations for different combinations of seating position and sex. Given the results, it seems advisable to repeat the analysis both with other data sources, as well as with other evaluation techniques.

For each seating position there was a higher risk of disability for females than for males. However, the same pattern was not found between the sexes; partly the result were the opposite. For men, there was only a small difference between the front-seat occupants, while the risk decreased from the front-seat to the rear-seat. The disability risk for females, on the other hand, was lowest when the occupant was seated in the passenger seat in the front. In fact, females had more than twice as high a disability risk as rear-seat passengers, compared with male drivers. The reasons for these results are difficult to understand and several questions are raised. It is evident that any hypothesis about the injury mechanism must take this finding into account, if the findings are consistent with other epidemiological studies. Jacobsson and Norin (1999) found similar results from rear-end impact sled tests with a rear-impact dummy (BioRID), where the NIC value in the rear seat was higher compared to the front seat.

The most significant results of this study are clearly linked to the explanation of injury mechanisms. It seems to be a fact, that for both the driving positions as well as for the rear seat, the risk of injury for female occupants is further underscored. The difference between males and the females in the rear seat seems to be the most difficult to explain. While the crash pulse experienced by the car is the same for all occupants, the pulse transferred to the occupant in the rear seat might be closer to the car pulse, and therefore stiffer. It might be that the female is more sensitive to the nature of the crash pulse. This does not, however, immediately explain the difference between the occupants´ positions in the front seat, and the fact that the female is more sensitive to whether, she is a driver or a passenger than the male front-seat occupant is. There might therefore be an interaction between seating posture and the crash pulse that might influence the risk of disability to the neck.

Another difference between the sexes and position is the use of seat belts. In the study by Morris et al in 1996 an increase in whiplash injury was found if the seat belt had been used in rear impacts. Also, in an earlier study (Krafft 1998), the use of seat belts among disabled occupants with whiplash injury, was higher compared with the general use of seat belts in the rear seat. However, seat-belt use had been self-reported among the disabled, which may have influenced the result. Furthermore, seat belts are less fequently used in the rear seat than in the front, but there are also results from questionnaires analysed by the Swedish National Road Administration (2002) that females use seat belts to a greater extent than males, especially in the rear seat. Further studies are necessary to corroborate this point.

There was a significant lower risk for the female front-seat passenger compared with the female driver. This might have to do with a difference in seating position of the body, especially the thorax spine and the head. The driver can be assumed to lean the upper body further forward than the front-seat passenger. An increased distance between the head and head restraint/ seat-back rest, has shown a relationship with increased risk of whiplash injury (Olsson et al 1990, Jacobsson et al 1994). A seat-belt pre-tensioner that is activated in the pre-crash phase could prevent the increased distance between the upper body and the seat back/ head restraint.

The difference in results of this study compared with studies based on the initial injury outcome, indicate that it is not possible to predict permanent disability using the initial injury outcome. Therefore, to further clarify the issue, studies need to be separated with regard to duration of symptoms, seating position and sex. However, even if not all the parameters behind the results could be explained, the risk of disability in the rear seat is unacceptably high. Test methods and criteria must also be developed for the rear seat and should be included in vehicle crashworthiness programmes with respect to whiplash injuries.

CONCLUSIONS

- There was a significant higher risk of permanent disability for female rear-seat passengers than for male drivers.

- There was a significant higher risk of permanent disability for female rear-seat passengers than for female front-seat passengers

- The risk of permanent disability was four times higher for females than for males in the rear seat.

- The risk of permanent disability was three times higher for female drivers than for male drivers.

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APPENDIX

FSP=front seat passenger, RSP= rear seat passenger.

Table1. Number of disabled and non-disabled occupants for different seating positions and sex.

	Males Disabled (n)	Males Total (n)	Femlaes Disabled (n)	Females Total (n)
Driver	39	125	44	70
FSP (>=18 year)	13	53	19	62
RSP (>=18 year)	14	71	95	172

Table 2-13. Number of occupants for different combinations based on seat position and sex.

Table 2. Driver male- RSP male

		Driver	
		Disabled	Not disabl.
Rear seat passenger	Disabled	3	6
	Not disabl.	15	

Table 3. Driver female – RSP female

		Driver	
		Disabled	Not disabl.
Rear seat passenger	Disabled	6	18
	Not disabl.	25	

Table 4.Driver male – RSP female

		Driver	
		Disabled	Not disabl.
Rear seat passenger	Disabled	9	61
	Not disabl.	21	

Table 5. Driver female – RSP male

		Driver	
		Disabled	Not disabl.
Rear seat passenger	Disabled	0	3
	Not disabl.	17	

Table 6.FSP male – RSP male

	Front	seat	passenger
		Disabled	Not disabl.
Rear seat	Disabled	1	3
	Not disabl.	9	

Table 7. .FSP female– RSP female

	Front	seat	passenger
		Disabled	Not disabl.
Rear seat	Disabled	4	22
	Not disabl.	16	

Table 8. .FSP male – RSP female

	Front	seat	passenger
		Disabled	Not disabl.
Rear seat	Disabled	0	18
	Not disabl.	8	

Table 9. .FSP female – RSP male

	Front	seat	passenger
		Disabled	Not disabl.
Rear seat	Disabled	0	1
	Not disabl.	6	

Table 10. Driver male- FSP male

		Driver	
		Disabled	Not disabl.
Front seat passenger	Disabled	1	9
	Not disabl.	10	

Table 11.Driver female-FSP female

		Driver	
		Disabled	Not disabl.
Front seat passenger	Disabled	4	3
	Not disabl.	15	

Table 12. Driver male- FSP female

		Driver	
		Disabled	Not disabl.
Front seat passenger	Disabled	2	10
	Not disabl.	9	

Table 13. Driver female- FSP male

		Driver	
		Disabled	Not disabl.
Front seat passenger	Disabled	1	2
	Not disabl.	12	