INJURY RISK FUNCTIONS IN FRONTAL IMPACTS USING RECORDED CRASH PULSES

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ABSTRACT

Knowledge of human injury tolerance levels, especially the level of impact severity likely to produce an injury, is important in the design of a crashworthy road transport system. Such knowledge can be achieved from studies of real-life impacts where the link between impact severity and injury outcome is analysed. In order to get adequate injury risk functions it is important that valid and reliable crash severity data is used.

The aim of this paper was to present injury risk functions based on real-life frontal crashes where crash severity was measured with on-board crash pulse recorders. The crash pulse recorders measure the acceleration time history in the impact phase of a collision. Results from 178 frontal collisions with an overlap of more than 25% and with an angle within +/- 30 degrees from straight frontal have been analysed. A mix of 18 car models of 4 different makes was included in the study.

The study shows the potential in using real-life data to establish injury risk functions to be used as guidelines in the design of a crashworthy road transport system. The results showed variations in the ability of explaining risk of injury depending on the crash severity parameter used. Based on the limited number of car models studied, acceleration seemed to better describe injury risk than did change of velocity in frontal impacts. In order to have lower than 25% risk of an AIS2+ injury, it was found that mean acceleration should be kept below 8 *g* and peak acceleration below 26 *g*. At every crash severity interval women were found to have a higher injury risk of AIS1 injuries than did men. Also the risk of AIS2+ injuries was found to be higher for women than for men at a crash severity above 25 km/h or 7 g. At every crash severity older drivers above 50 years age were found to have higher risk of AIS2+ injuries than had drivers below 50. Furthermore drivers were found to have higher AIS2+ injury risk than did front seat passengers at mean acceleration above 8 g. At crash severities where the airbags are likely to be deployed a large reduction in the risk of AIS1 as well as AIS2+ injuries was found.

KEY WORDS: injury risk, crash recorder, mean acceleration, peak acceleration, impact severity

THE LONG-TERM GOAL of a new strategy for the road traffic safety in Sweden is no fatalities or long-term disabilities in the road-transport system (Kommunikationsdepartementet 1997). To be able to reach this goal, knowledge of the level in impact severity possible for humans to be exposed to in the road transport system without exceeding the limits where fatalities or serious injuries occur must be used as design criteria. For the car manufacturer it is essential to know the mechanical force the human body can tolerate without being killed or seriously injured. For the designer of the complete road transport system it is, however, important to know tolerance levels in terms of the link between crash severity, such as delta-v or acceleration, and injury outcome. This is illustrated in Figure 1. Knowledge about human injury tolerance levels is therefore important for all responsible bodies in the road transport system. Furthermore, road designers must know up to what level in impact severity vehicles can protect their occupants in order to design road side objects in such a way human injury tolerance levels are not exceeded in case of a collision. Car manufacturers must be sure that the road environment can take care of the car in such a way the injury tolerance levels are not exceeded at the speed limits on the roads.

Big efforts have been made to reduce injury and fatality rates in passenger cars. The efforts have mainly been focused on the passive safety of the vehicle, such as introducing various interior passive safety systems and improving the vehicle structure mainly to avoid intrusion. Knowledge of human tolerance levels for different injury types have been in mind in the work. The development of the design of roadside objects has, however, only to a minor extent focused on the human injury tolerance levels.

Knowledge of human injury tolerance levels can be achieved from different sources and with different perspectives in mind. Traditionally, crash tests with volunteers or animals have been conducted to assess the levels of mechanical force humans can tolerate without being injured (refs). Such information has been used mainly by the car manufacturers in the design of vehicle passive safety systems.

Studies aimed at evaluating injury tolerance in impact severity based on real–life crashes are rare. Some studies have been presented, though with limited number of crashes and car models involved (Kullgren 1998, Kullgren et al. 2000). Such information is more important in the design of a crashworthy road transport system. The quality of real-life data has also been a limiting factor in such studies (Kullgen and Lie 1998). By improving the validity and reliability in data from real-life crashes, studies of the link between impact severity and injury outcome could be a useful way of gaining such knowledge. Looking at car crashes as a dose-response model, the risk of injury or fatality versus impact severity is the function that could be used to describe human tolerance.

When creating injury risk functions some different statistical methods have been presented. The Maximum Likelihood method (Versace 1971) and a method developed by Mertz and Weber (1982) has been used to calculate injury risk, mainly risk of fractures, as a function of mechanical force. A more recent method, called modified Maximum Likelihood method, was presented by Nakahira et al. (2000).

Another method has been used by Kullgren et al. (1995), where injury risk has been calculated as the ratio of injured drivers and all drivers for intervals in crash severity. Risk functions can be generated based on the observations. Injury risk curves calculated from real-life crashes with recorded crash pulses have been presented for AIS1+ and AIS2+ injuries and for neck injuries in frontal impacts (Kullgren et al. 1995, Kullgren 1998, Kullgren et al. 2000). The number of observations was in these studies relatively low, which influences the accuracy, especially at high crash severity. Also neck injury risk in rear end impacts have been presented for approximately 40 crashes using the same method (Krafft et al. 2001).

The aim of this paper is to further analyse and present injury risk functions based on real-life frontal crashes where crash severity was measured with on-board crash pulse recorders. The number of crashes was higher than in the previous studies, especially regarding the severe crashes.

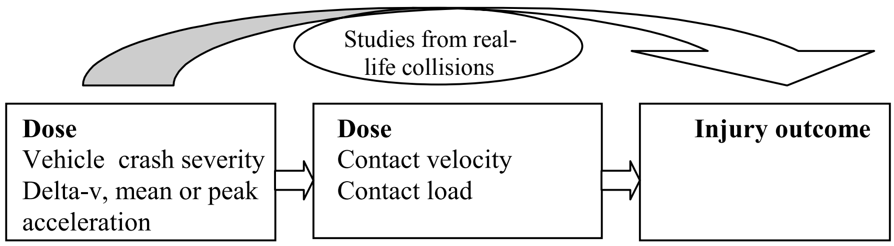


Figure 1 - Links between dose as vehicle crash severity and occupant contact severity, and injury outcome.

MATERIAL AND METHODS

Impact severity was measured with a crash pulse recorder, called CPR, which measured the acceleration time history in the impact phase. The CPR records the movements of a mass in a spring-mass-system on a photographic film. Aldman et al. (1991) and Kullgren (1998) have described the CPR and the analysis of the recordings from the CPR.

Acceleration was measured in the principle direction of force within +/- 30 degrees. Crash pulses were filtered at approximately 60 Hz. Change of velocity and mean and peak accelerations were calculated from the crash pulses.

Since 1992, CPRs have been installed in approximately 150,000 vehicles comprising 4 different car makes and 18 models in Sweden aimed at measuring frontal impacts. Five of these models have been sold both with and without airbags. The car fleet has been monitored since 1992, and every accident with a repair cost exceeding 5000 US$ has been reported via a damage warranty insurance. The accident data collection system has previously been described by Kamrén et al. (16).

The study includes impact severity and injury data for drivers and front seat passengers in 178 frontal impacts with an overlap of more than 25% (measured as the proportion of the front that was deformed) and with an angle within +/- 30 degrees from straight frontal. Only restrained occupants were included. Belt use was verified from inspections of the seat belt systems.

There were 178 drivers and 65 front seat passengers. 119 of the cars were fitted with driver airbags. There were 133 male and 43 female drivers, two drivers with unknown sex, and 16 male and 34 female front seat passengers.

Table 1 - Number of occupants

	Drivers (178)	Passengers (65)
Male	133	16
Female	43	34
Unknown sex	2	15
Number of airbags	119	18

The injuries were collected from hospital records, questionnaires sent to the occupants or from insurance claims. The injuries were classified according to the 1985 revision of the Abbreviated Injury Scale (AAAM 1985).

The impact severity measurements were divided into intervals for each severity parameter. In most plots the of delta-v the interval is 10 km/h, mean acceleration 4 g and peak acceleration 10 g, but in one plot 2 and 5 g intervals were used for mean acceleration. Injury risk was plotted and calculated as the proportion of injured occupants in each interval. In all plots the injury risk for each interval was plotted. To illustrate the injury risk, "smooth curve fits" in the software Kaleidagraph (2000) were used to connect the observations. No mathematical injury risk functions was calculated.

RESULTS

The majority of crashes had a change of velocity between 10 and 40 km/h, see Figure 2. The average change of velocity for the sample was 23.9 km/h, the average mean acceleration was 6.3 g and the average peak acceleration was 16.8 g. The risk to sustain an MAIS2+ injury was found to be 20% at either a delta-v of 30 km/h, or a mean acceleration of 8 g or a peak acceleration of 25 g, see Figures 3, 4 and 5. To compare which parameter of delta-v and mean and peak accelerations that best distinguish between MAIS1+ and MAIS2+ injuries, the ratio of severity level at a certain injury risk level could be compared for the three crash severity parameters. At an injury risk of 40% the ratio is 3.5 for delta-v and mean acceleration, while it is 6.5 for peak acceleration. In the interval 20 to 40 km/h, an approximate difference of 50 percentage units in injury risk between MAIS1+ and MAIS2+ injuries can be seen. The same difference can be seen between 5 and 10 g in mean acceleration. For peak acceleration between 10 and 35 g, between 50 and 60 percentage units difference in risk for MAIS1+ and MAIS2+ injuries can be seen. Table 3 indicate that to be below 25% in injury risk, delta-v should be below 30 km/h, mean acceleration should be below 8 g and peak acceleration should be below 26 g.

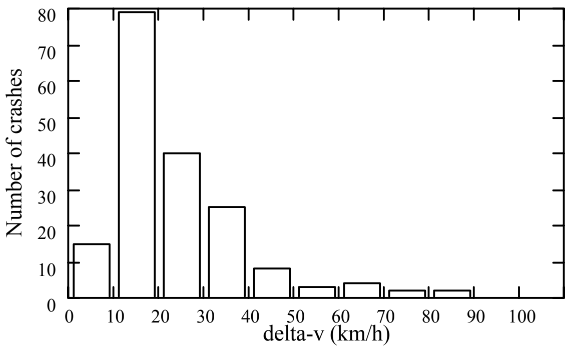


Figure 2 - Number of crashes at different delta-v intervals. n=178

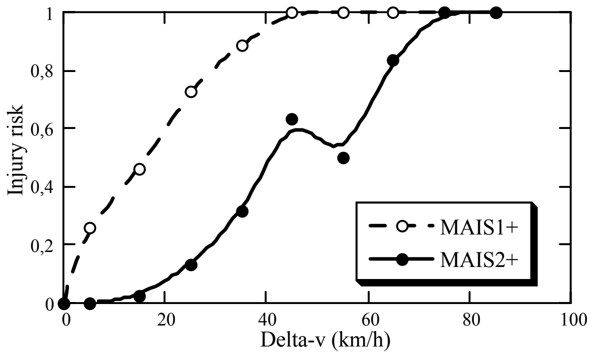


Figure 3 - Injury risk, MAIS1+ and MAIS2+, for front seat occupants versus delta-v. n=242

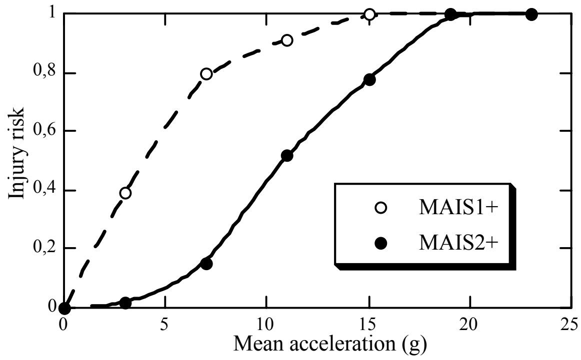


Figure 4 - Injury risk, MAIS1+ and MAIS2+, for front seat occupants versus mean acceleration. n=242

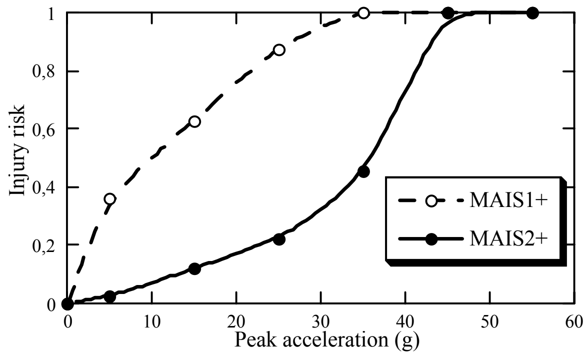


Figure 5 - Injury risk, MAIS1+ and MAIS2+, for front seat occupants versus peak acceleration. n=242

Table 2 - Delta-v, mean and peak accelerations at three MAIS2+ injury risk levels.

MAIS2+	Delta-V, (km/h)	Mean acc., (g)	Peak acc., (g)
25% risk	30	8	26
50% risk	40	11	35
75% risk	65	14	40

Figure 6 shows a correlation between Delta-v and mean acceleration. There were, however, some crashes with relatively large change of velocity, while the mean acceleration was relatively small. In these crashes only AIS1 injuries were observed. Figure 7 shows that mean and peak acceleration were not as well correlated at the more severe crashes as were delta-v and mean acceleration. It can also be noted the AIS2+ injuries may occur at either high mean acceleration or at high peak acceleration. It was also found that AIS2+ injuries may occur at a wide range of severity, see both Figure 6 and 7, indicating that other severity parameters than those related to acceleration, such as intrusion, are influencing the injury risk.

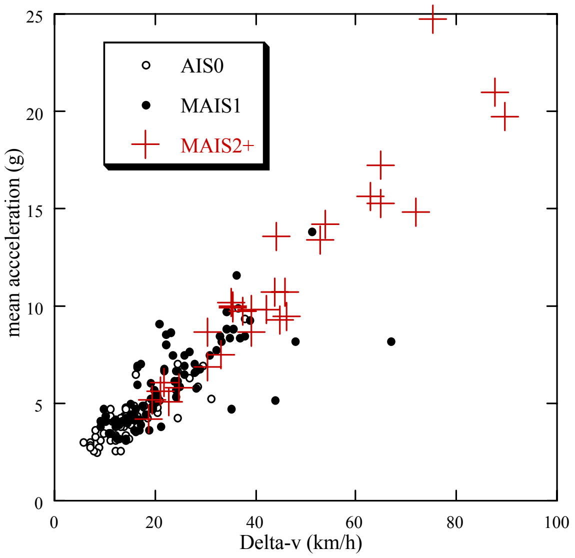


Figure 6 - Correlation between delta-v and mean acceleration for AIS0, MAIS1 and MAIS2+ injuries. n=178

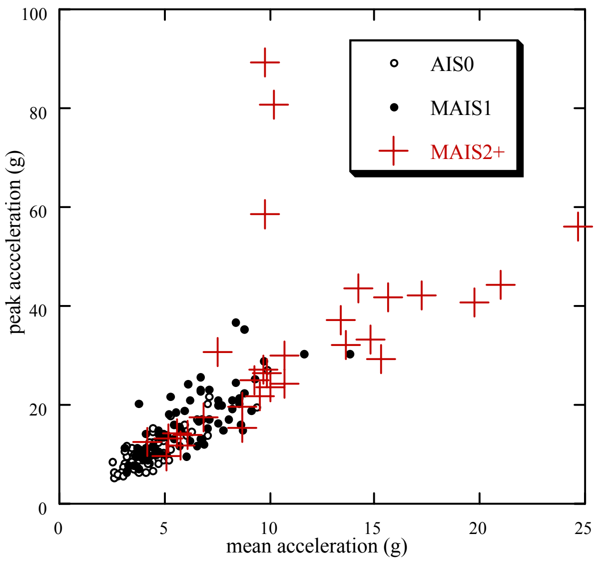


Figure 7 - Correlation between mean and peak acceleration for AIS0, MAIS1 and MAIS2+ injuries. n=178

Figures 8 and 9 shows that the injury risk for females and males differ. At a delta-v above 10 km/h the MAIS1+ injury risk increase more rapidly for females than for males. For mean acceleration the risk of MAIS1+ injuries was found to be higher for females than males over the whole severity span. Correspondingly for MAIS2+ injuries, the risk was found to be higher for females at a delta-v above 30 km/h and at a mean acceleration above 7 g. The risk to sustain an MAIS1+ injury approaches 100% at a Delta-v of 35 km/h for females compared with 45 km/h for males and at a mean acceleration of 11 g for females compared with 15 g for males. The risk to sustain an MAIS2+ injury approaches 100% at a delta-v of 45 km/h for females compared with 75 km/h for males. The corresponding figures for MAIS2+ injuries are 15 and 19 g.

Figure 10 and 11 shows the risk for MAIS1+ and MAIS2+ divided for two age groups of front seat occupants, below and above 50 years age. No apparent difference in risk of an MAIS1+ injury for the two age groups could be seen for either delta-v or mean acceleration. In Figure 10 it can be seen that the MAIS2+ risk separates at a delta-v above 25 km/h for the two age groups. At higher severity the MAIS2+ risk increase more rapidly for the age group above 50 years of age.

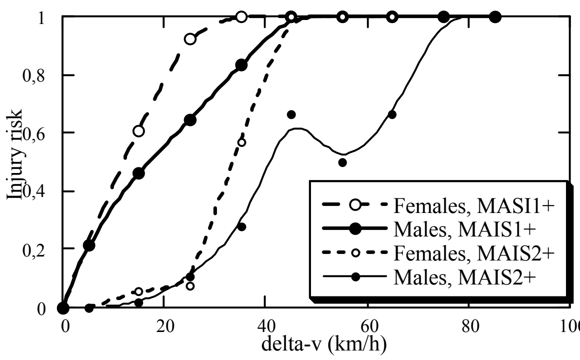


Figure 8 - Injury risk, MAIS1+ and MAIS2+, for female and male drivers versus delta-v.
n=176

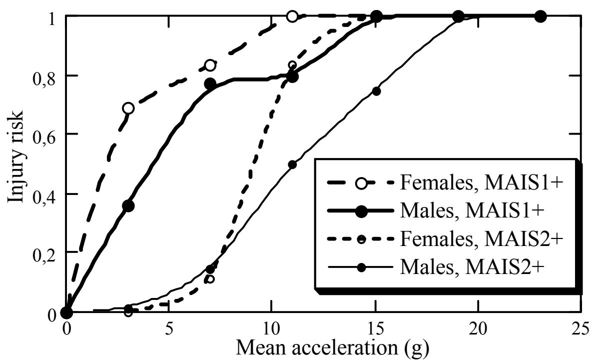
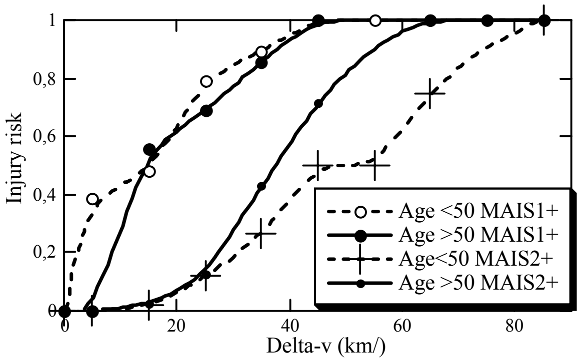


Figure 9 - Injury risk, MAIS1+ and MAIS2+, for female and male drivers versus mean acceleration.
n=175



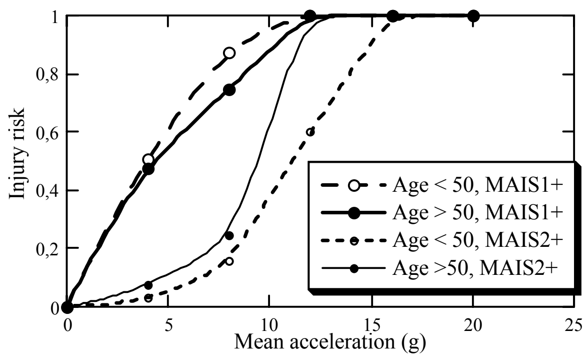
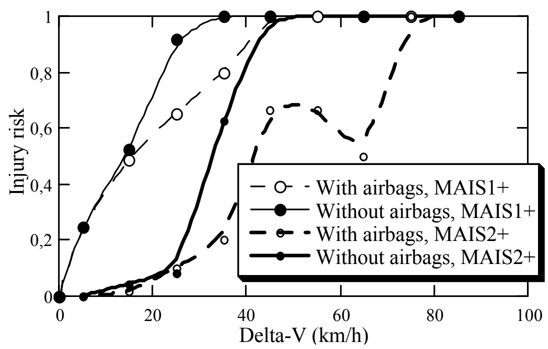


Figure 10 - Injury risk, MAIS1+ and MAIS2+, for front seat occupants below and above 50 years age versus delta-v. n=216

Figure 11 - Injury risk, MAIS1+ and MAIS2+, for front seat occupants below and above 50 years age versus mean acceleration. n=216

At ΔVs above 15 km/h the risk of an MAIS1+ injury was found to be lower for airbag fitted cars compared to non-airbag cars, see Figure 12. For MAIS2+ injuries the risk was lower at ΔVs above 25 km/h in airbag fitted cars compared to non-airbag cars, see Figure 12. The corresponding numbers for mean acceleration was approximately 5 g and 10 g respectively, see Figure 13.



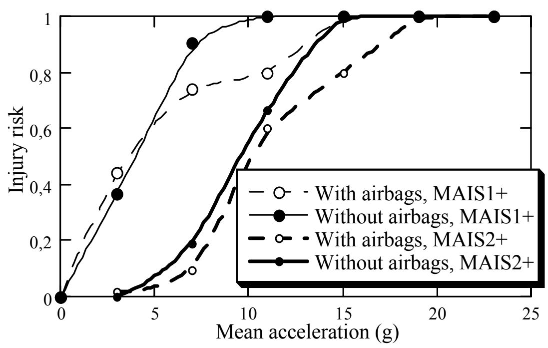
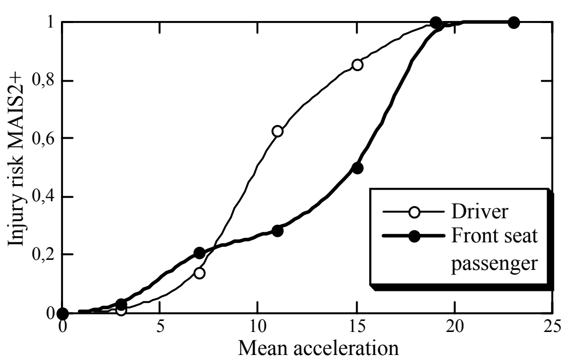


Figure 12 - Driver injury risk, MAIS1+ and MAIS2+, for cars with and without airbags versus delta-v. n=168

Figure 13 -Driver injury risk, MAIS1+ MAIS2, for cars with and without airbags versus mean acceleration. n=168

Drivers were found to have higher injury risk than the front seat passengers at mean accelerations above 8 g, see Figure 14. Approximately 10 percentage units difference in risk of an MAIS1+ injury was found between a car model and its successor over the whole span of mean acceleration.



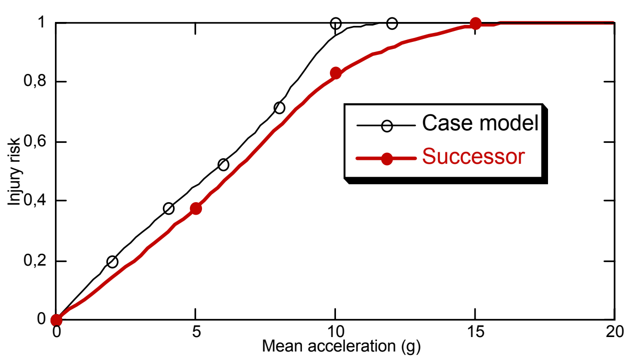


Figure 14 - Risk of MAIS2+ injuries for drivers and Front seat passengers versus meanacceleration

Figure 15 - Injury risk, MAIS1+, for case car model and its successor.

DISCUSSION

Traditionally it has only been possible to estimate impact severity parameters, such as ΔV, in real life collisions using various crash reconstruction programs. The use of crash pulse recorders in accident reconstruction's means that the accuracy of impact severity parameters will increase. The influence of acceleration-based measurements on injury risk in real life impacts has so far only to a limited extent been possible to determine, as such studies require on-board measurement techniques.

With help of the unique data material used in this study, it was possible to estimate the levels for impact severity likely to produce an injury. This can be used to estimate criteria for construction of cars and roadside objects. Moreover, with the correlation between the parameters shown, it is possible to estimate the conditions in which injuries are likely to occur, as well as limits with a combination of mean and peak accelerations describing risk of injury. Such limits are important in injury preventive actions and could be used as criteria in the construction of a crashworthy road transport system.

One of the inclusion criteria for this study was a repair cost of at least 5000 US$. This limit excludes most of the crashes at ΔVs below 10 km/h. Studying the injury risk in frontal impacts presented in this study, the risk was found to be very low at such impact severity levels, especially regarding AIS2+ injuries, indicating that the inclusion criterion should not influence the findings in this study.

In this study AIS 85 was used. Using AIS 90 instead of AIS 85 would not mean any major changes in the risk curves or conclusions in this study depending on differences in injury classification between the two versions.

The risk curves for the correlation between impact severity and injury should be handled with some care as they only apply to a limited number of car models. As injury risk curves depend on the passive safety level of car models, comparisons between risk curves calculated from different data sources with different car models included is difficult to conduct. The number of frontal impacts at high crash severity was relatively low. This fact makes the statistical significance of the results at high severity low. The shape of the injury risk curves plotted, especially at high crash severity, were influenced by the number of observations in each interval, see Figures 3, 8 and 12. A relatively limited number of makes and models were included in this research project. Further studies with more severe crashes and preferably with more car models are necessary. Also studies with disabling injuries and not only classified in AIS levels, would be desirable.

It is also important to further study injury risk functions for injuries to different body regions. Previous studies have shown large differences in injury risk for injuries to different body regions, but with the same AIS level (see for example JPL 2001, Krafft et al. 2000). It could also be useful to analyse the correlation between ISS levels and injury risk, to analyse also polytrauma aspects.

An important next step is to apply analytical functions to the injury risk observations, to allow in-depth statistical analysis.

The risk curves may differ from others seen in the literature (see for example Mertz et al. 1996). Such differences may depend on several factors. The methods used to calculate risk functions are often different (see for example Versace 1971, Mertz and Weber 1982 Nakahira et al. 2000). In this study no risk functions were calculated, only smooth curve fits were used to connect the observations in each impact severity interval. Due to the number of observations in each interval, the shape may alter when more data is collected. Furthermore, the accuracy of impact severity may differ between the data sources used. Usually, delta-V calculated in accident reconstruction programs, such as Crash III, Edcrash etc, underestimates Delta-V (Nolan et al 1998, Stucki and Fessahaie 1998, Lenard et al. 1998, Kullgren 1998). Generally, risk curves calculated from data sources such as NASS, have been calculated from data where delta-V has relatively large errors (Nolan et al 1998, Stucki and Fessahaie 1998). Errors in the data may dramatically change the risk function (Kullgren and Lie 1998). At lower Delta-V the risk will be overestimated and at higher Delta-V the risk will be underestimated (Kullgren and Lie 1998). The effect is larger the lower accuracy of the data.

Results such as those presented in Table 2 could be useful as guidelines in the design of a crashworthy road transport system. With the car models included in this study it was found that at a change of velocity of 40 km/h or at a mean acceleration of 11 g or at a peak acceleration of 35 g, there was a 50% risk of an MAIS2+ injury. To be below 25% in injury risk, delta-v should be below 30 km/h, mean acceleration should be below 8 g and peak acceleration should be below 26 g. The results shown in Figures 6 and 7 indicate that delta-v do not explain the MAIS 2+ injury risk as good as mean and peak acceleration. A relatively large change of velocity might exist, despite a low mean acceleration. In some crashes, see Figures 6, only MAIS1 injuries can be seen at relatively large delta-v's, while the mean acceleration was relatively small. In this situation, with no MAIS2+ injury observed, the risk decreases at these delta-v's, see Figure 3. Earlier findings by Kullgren (1998) also indicated that acceleration better explained the risk of injury than did change of velocity. A high delta-v combined with low accelerations might not lead to a high risk of MAIS2+ injury. This indication should be further analysed. If this is the case, it means that the focus should be set on guidelines in mean and peak accelerations, rather than in change in velocity.

The better discrimination between MAIS1+ and MAIS2+ injuries found for peak acceleration is also interesting. If this is a true difference it is very important in the design of a crashworthy road transport system. An explanation could be that there exists a correlation between intrusion and peak acceleration. A slight indication in the data used in this study shows that crashes with large intrusion more often has higher peak accelerations. This has to be further investigated, also including intrusion as a parameter.

An interesting finding was that no significant difference in risk of an MAIS1+ injury was found between occupants above and below 50 years age, while a difference was found for MAIS2+ injuries above 30 km/h and 7 g in mean acceleration. It indicates that there is no difference in risk of AIS1+ injuries, while the risk of AIS2+ injuries, such as fractures, varies a lot between the age groups. This is not surprising, as research has shown a difference in biomechanical tolerance levels for different age groups.

The difference in MAIS1+ injury risk between cars with and without airbags is probably mainly depending on the reduction of AIS1 neck injuries. Kullgren et al. (2000) have shown a large influence of airbags on the AIS1 neck injury risk in frontal impacts in a study where injury risks for identical car models except from the presence of an airbag was compared. Results from Australia also show the benefits of airbags on the risk of AIS1 neck injuries (Morris et al. 2000). The difference in MAIS2+ injuries was mainly found in the severe impacts, above 30 km/h and 10 g in mean acceleration.

Drivers were found to have higher risk of MAIS2+ injury than the front seat passengers had. The relation between female and male front seat passengers was much higher (see Table 1) than was the relation for drivers. This indicates together with the results showed in Figure 8 and 9, that the difference in risk between drivers and front seat passengers is even larger than the presented difference in Figure 14.

Injury risk functions for different vehicle generations could be useful to evaluate the potential in passive safety of new car models in relation to older models. In Figure 15 it could be seen that there were a rather moderate reduction of risk for MAIS1+ injuries. The absence of more severe injury data did not aloud a risk calculation for MAIS2+ injuries. For MASI2+ it is expected to see a greater difference in injury risk. Research has shown only a small or no difference in risk of minor injuries between modern car models, while a large difference in risk has been observed for severe or fatal injuries (Lie and Tingvall 2000, Lie et al. 2001).

Information of differences in injury risk between car models together with information of the influence of airbags, differences in age and sex, is helpful in the evaluation of guidelines and design criteria to be used in the design of a crashworthy road transport system. To be able to find such guidelines or criteria, best possible passive safety of cars should be expected, while human injury tolerance levels for the occupants with lowest tolerance levels must be used. It was found that females had higher injury risks as well as older occupants. It could also be seen that modern cars with airbags had lower injury risks. The differences in injury risks found are quite large and it demonstrates the importance of further studies to evaluate criteria to be used as guidelines in the design of a crashworthy road transport system. The results found in this study could be used as a first step.

CONCLUSIONS

Data from real-life crashes is necessary to evaluate injury tolerance levels to be used as design criteria in the design of a crashworthy road transport system.

Regarding all front seat occupants, in cars with and without airbags, the following results were found;

- At a change of velocity of 40 km/h or at a mean acceleration of 11 g or at a peak acceleration of 35 g, a 50% risk of an MAIS2+ injury was found.
- To be below 25% in injury risk, delta-v should be below 30 km/h, mean acceleration should be below 8 g and peak acceleration should be below 26 g.

Females were found to have higher risk of both MAIS1+ and MAIS2+ injuries than males.

Front seat occupants above 50-year age were found to have higher risk of MAIS2+ injuries than had occupants below 50 years. The risk of MAIS1+ injuries was found to be equal for both age groups tested.

Airbags was found to reduce the risk of MAIS1+ at delta-v’s above 15 km/h and at mean accelerations above 5 g, and the risk of MAIS2+ injuries at delta-v’s above 25 km/h and regarding mean accelerations primarily above 10 g.

At a mean acceleration between 10 and 15 g, the risk of an MAIS2+ injury was found to be approximately 80% higher for drivers compared with front seat passengers. Drivers were found to have higher risk of MAIS2+ injuries than front seat passengers at mean accelerations above 7 g.

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APPENDIX

Table 1 - Data for injury risk, MAIS1+ and MAIS2+, for all front seat occupants versus delta-v.

Delta-V (km/h)	n=242	MAIS1+	MAIS2+	Risk MAIS1+	Risk MAIS2+
5	23	6	0	0,26	0,00
15	106	49	3	0,46	0,03
25	52	38	7	0,73	0,13
35	35	31	11	0,89	0,31
45	11	11	7	1,00	0,64
55	4	4	2	1,00	0,50
65	6	6	5	1,00	0,83
75	2	2	2	1,00	1,00
85	3	3	3	1,00	1,00

Table 2 - Data for injury risk, MAIS1+ and MAIS2+, for all front seat occupants versus mean acceleration.

Mean acc. (g)	n=240	MAIS1+	MAIS2+	Risk MAIS1+	Risk MAIS2+
3	118	46	2	0.38	0.01
7	84	67	13	0.79	0.15
11	23	21	12	0.91	0.52
15	9	9	7	1.00	0.77
19	3	3	3	1.00	1.00
23	3	3	3	1.00	1.00

Table 3 - Data for injury risk, MAIS1+ and MAIS2+, for all front seat occupants versus peak acceleration.

Peak acc. (g)	n=242	MAIS1+	MAIS2+	Risk MAIS1+	Risk MAIS2+
5	78	28	2	0.36	0.03
15	100	63	12	0.63	0.12
25	40	35	9	0.88	0.22
35	11	11	5	1.00	0.45
45	7	7	7	1.00	1.00
55	3	3	3	1.00	1.00
65	0	0	0		
75	0	0	0		
85	(3)	(3)	(2)		
95	0	0	0		

Table 4 - Data for injury risk, MAIS1+ and MAIS2+, for female and male drivers versus delta-v.

Delta-v (km/h)	Female all	Female MAIS1+	Female MAIS2+	Male all	Male MAIS1+	Male MAIS2+	Risk MAIS1+ female	Risk MAIS2+ female	Risk MAIS1+ male	Risk MAIS2+ male
5	(1)	(1)	0	14	3	0		0.00	0.21	0.00
15	18	11	1	58	27	1	0.61	0.06	0.46	0.02
25	13	12	1	28	18	3	0.92	0.08	0.64	0.11
35	7	7	4	18	15	5	1.00	0.57	0.83	0.28
45	2	2	2	6	6	4	1.00	1.00	1.00	0.67
55	1	1	1	2	2	1	1.00	1.00	1.00	0.50
65	1	1	1	3	3	2	1.00	1.00	1.00	0.67
75	0	0	0	2	2	2			1.00	1.00
85	0	0	0	2	2	2			1.00	1.00
95	0	0	0	0	0	0				

Table 5 - Data for injury risk, MAIS1+ and MAIS2+, for female and male drivers versus mean acceleration.

Mean acc. (g)	**All females**	**Females MAIS1+**	**Females MAIS2+**	**All males**	**Males MAIS1+**	**Males MAIS2+**	**Risk MAIS1+ females**	**Risk MAIS2+ females**	**Risk MAIS1+ males**	**Risk MAIS2+ males**
3	16	11	0	66	24	1	0.69	0.00	0.02	0.36
7	18	15	2	48	37	7	0.83	0.11	0.15	0.77
11	6	6	5	10	8	5	1.00	0.83	0.50	0.80
15	3	3	3	4	4	3	1.00	1.00	0.75	1.00
19	0	0	0	2	2	2			1.00	1.00
23	0	0	0	2	2	2			1.00	1.00

Table 6 - Data for injury risk, MAIS1+ and MAIS2+, for drivers below and above 50 years age versus delta-v.

Delta-v (km/h)	**All age<50**	**<50 MAIS1+**	**<50 MAIS2+**	**All age>50**	**Age>50 MAIS1+**	**Age>50 MAIS2+**	**Risk MAIS1+ <50**	**Risk MAIS2+ <50**	**Risk MAIS1+ >50**	**Risk MAIS2+ >50**
5.0000	13	5	0	6	0	0	0.38	0.00	0.00	0.00
15.000	52	25	1	36	20	1	0.48	0.019	0.55	0.028
25.000	34	27	4	16	11	2	0.79	0.12	0.69	0.12
35.000	19	17	5	14	12	6	0.89	0.26	0.86	0.49
45.000	4	4	2	7	7	5	1.00	0.50	1.00	0.71
55.000	4	4	2	0	0	0	1.00	0.50		
65.000	4	4	3	2	2	2	1.00	0.75	1.00	1.00
75.000	0	0	0	2	2	2			1.00	1.00
85.000	2	2	2	1	1	1	1.00	1.00	1.00	1.00
95.000	0	0	0	0	0	0				

Table 7 - Data for injury risk, MAIS1+ and MAIS2+, for drivers below and above 50 years age versus mean acceleration.

Mean acceleration (g)	**All <50**	**All >50**	**MAIS1+ <50**	**MAIS1+ >50**	**MAIS2+ <50**	**MAIS2+ >50**	**Risk MAIS1+ <50**	**Risk MAIS2+ <50**	**Risk MAIS1+ >50**	**Risk MAIS2+ >50**
4	65	38	33	18	2	3	0,51	0,03	0,47	0,08
8	31	24	27	18	5	6	0,87	0,16	0,75	0,25
12	5	3	5	3	3	3	1,00	0,60	1,00	1,00
16	3	2	3	2	3	2	1,00	1,00	1,00	1,00
20	1	1	1	1	1	1	1,00	1,00	1,00	1,00
24		1	0	1		1			1,00	1,00

Table 8 - Data for injury risk, MAIS1+ and MAIS2+, for cars with and without airbags versus delta-v.

Delta-v (km/h)	**All with airbag**	**All without airbag**	**With airbag MAIS1+**	**Without airbag MAIS1+**	**With airbag MAIS2+**	**Without airbag MAIS2+**	**Risk MAIS1+ without airbag**	**Risk MAIS1+ with airbag**	**Risk MAIS2+ without airbag**	**Risk MAIS2+ with airbag**
5	8	4	2	1	0	0	0.00	0.00	0.00	0.00
15	53	21	26	11	1	1	0.25	0.25	0.00	0.00
25	29	12	19	11	3	1	0.52	0.49	0.047	0.02
35	15	8	12	8	3	5	0.92	0.66	0.08	0.10
45	6	1	6	1	4	1	1.00	0.80	0.62	0.20
55	3	0	3	0	2	0	1.00	1.00	1.00	0.67
65	2	2	2	2	1	2		1.00		0.67
75	2	0	2	0	2	0	1.00	1.00	1.00	0.50
85	1	1	1	1	1	1		1.00		1.00
95	0	0	0	0	0	0	1.00	1.00	1.00	1.00

Table 9 - Data for injury risk, MAIS1+ and MAIS2+, for cars with and without airbags versus mean acceleration.

Mean acc. (g)	**All with airbag**	**All without airbag**	**Without airbag MAIS1+**	**With airbag MAIS1+**	**Without airbag MAIS2+**	**With airbag MAIS2+**	**Risk MAIS1+ without airbag**	**Risk MAIS1+ with airbag**	**Risk MAIS2+ without airbag**	**Risk MAIS2+ with airbag**
3	59	19	7	26	0	1	0.37	0.44	0.00	0.017
7	42	21	19	31	4	4	0.90	0.74	0.19	0.09
11	10	6	6	8	4	6	1.00	0.80	0.66	0.60
15	5	1	1	5	1	4	1.00	1.00	1.00	0.80
19	1	1	1	1	1	1	1.00	1.00	1.00	1.00
23	1	1	1	1	1	1	1.00	1.00	1.00	1.00

Table 10 - Data for injury risk MAIS2+ for drivers versus front seat passengers with mean acceleration as severity parameter.

Mean acc. (g)	**All drivers**	**Drivers MAIS2+**	**All front seat passengers**	**Front seat passengers MAIS2+**	**Risk MAIS2+ drivers**	**Risk MAIS2+ front seat passengers**
3	85	1	33	1	0.01	0.03
7	65	9	19	4	0.14	0.21
11	16	10	7	2	0.62	0.29
15	7	6	2	1	0.86	0.50
19	2	2	1	1	1.00	1.00
23	2	2	1	1	1.00	1.00