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CORRELATION OF ACCIDENT STATISTICS TO WHIPLASH PERFORMANCE PARAMETERS USING THE RID^{3D} AND BIORID DUMMY

H. Cappon[1], W. Hell[2], H. Hoschopf[3], M. Muser[4], E. Song[5], J. Wismans[1]
TNO Automotive[1], Ludwig Maximilian University Munich[2], Graz University of Technology[3], ETH Zurich[4], LAB PSA Peugeot Citroën Renault[5]

ABSTRACT

Injury criteria are crucial in whiplash protection evaluations. Therefore, the real-life rear impact performance of eight car seats was compared with various injury criteria using linear correlation techniques. Two dummies, BioRID and RID^{3D}, and two types of pulses were used: generic and car specific. This evaluation showed an acceptable correlation of the lower neck shear force measured in the RID^{3D} dummy with the real accident data. A reasonable amount of correlation was found also for the NIC measured in BioRID with a car specific pulse. When the injury risk figures were compensated for real-life car exposure, no correlations were found for any dummy using the generic pulse.

Keywords: whiplash, injury criteria, seats, dummies.

WHIPLASH INJURIES commonly result in large personal and societal costs (60-80% of all costs for personal injury in insurance claims). Currently increasing incidence of whiplash is reported due to stiffer cars and other contributing factors. This type of injury is mainly caused by low severity rear-end impacts (Hell et al, 1999; Temming and Zobel, 2000). Therefore, large efforts are being spent on reducing the whiplash occurrence, by evaluating cars and seats with respect to their rear impact behaviour. Several consumer testing groups like EuroNCAP, IIWPG (Insurance Institute Whiplash Prevention Group) and SRA (Swedish Road Administration) are active in this field, while on the other hand regulatory procedures are being developed by EEVC and ISO. FMVSS has recently adopted the 202a Final Rule, which includes an optional dynamic sled test for the evaluation of the combined seat and head restraint geometry.

However, most of these groups have come to the conclusion that a very vital piece of information for the adequate evaluation of seats is still missing: the injury criteria or parameters to adequately assess seat protection. Various studies have confirmed that seat and head restraint design changes have been effective in reducing whiplash injuries (Jakobsson & Norin, 2004; Viano & Olsen, 2001), but it is not clear how these improvements can be properly quantified before introducing a new system to the market. The car and seat manufacturer have only been able to show the product's effectiveness by exposure to real world, as in the references stated.

There are mainly two ways to solve the problem of injury criteria. The first one is based on detailed biomechanical studies, using for instance clinical data, accident statistics, volunteer and PMHS tests and mathematical simulations. This biomechanical approach has thus far not reached sufficient results and research is still continuing. Once an injury criterion is found, it must be translated into a parameter, measurable on e.g. a crash test dummy. The translation from the human response to the dummy is most straightforward when the dummy is biofidelic i.e. able to replicate the human behaviour in a rear impact situation with sufficient accuracy. For rear impact dummies available, biofidelity is quite reasonable for the aspects currently considered important, as shown in several publications on this subject in recent years (Zellmer et al 2002; Philippens et al, 2002; Roberts et al, 2002; Cappon et al, 2001; Davidsson et al, 1999; Scott et al, 1993), while the correct injury criteria remain to be a problem.

The second approach is to find a clear statistical relation between accident data of a certain car seat and dummy measurements using a similar seat, as performed for a large series of similar seats by Linder et al (2004) and for a limited set of different seats by Muser et al (2003) and Heitplatz et al

(2003). By using a large set of different seats, with a large real life exposure, a relation between dummy measurements and whiplash injury outcome can be established. This approach, using a limited set of 8 car seats, from medium class cars for which sufficient accident data is available, is the subject of this paper. We wish to clarify the procedure of such a method and its advantages and disadvantages, which were encountered during the process. First the accident data and seat selection will be discussed, followed by dummy experiments and associated measurements and results.

ACCIDENT DATA AND STATISTICAL PERFORMANCE

The data for accident analysis were obtained from insurance claim data of a large car insurance company in Germany with a 10% market share of all German car insurers. To these data the following inclusion criteria and restrictions apply:

- To limit the amount, only data of the year 2000 were used.
- The lower limit of total damage was 1534 € (3.000 German Marks). Inclusion occurs only with costs above this threshold.
- Only single rear-end impacts, multiple collisions were excluded.
- The age of the claimant car was less than 10 years.

All injury data are based on statements of the treating physician and the patient to the insurance company, which is a subjective measure. Regarding this aspect, it seems important to analyse the statements carefully concerning any compensation advantage of the victim. Due to the large number of cases, such enquiries have not been performed. Data analysis was performed by GDV in Germany.

Using the above inclusion criteria, a sub-database was obtained. It includes a total of 13652 cars involved in a rear-end accident, of which 4175 car accidents were reported with personal damage. The duration of treatment is divided into three classes : up to 10 days, up to 6 weeks and more than 6 weeks. The short term cases used here are of the second category (less than 6 weeks). From these cases a series of medium class car models of approximately similar mass were extracted, resulting in 8 remaining car models coded A-H. In fact, a significant amount of data were obtained for 6 cars only (more than 170 cases), excluding cars B and H having a relatively large confidence interval for estimated injury risk. In Table 1 the data for each of these cars are shown: the accident rates, the short term injury cases, the calculated short term injury risk and 95% confidence intervals for this risk. Figure 1 presents an overview of the risk for each car model.

Car code	Accident cases	Short term injury cases	Lower limit 95% confidence [%]	Average injury risk [%]	Upper limit 95% confidence [%]
A	268	49	13.7	18.3	22.9
B	78	12	7.4	15.4	23.4
C	201	43	15.7	21.4	27.1
D	399	96	19.9	24.1	28.3
E	170	44	19.3	25.9	32.5
F	211	54	19.7	25.6	31.5
G	204	83	33.9	40.7	47.4
H	83	33	29.2	39.8	50.3
Total	1614	414			

Table 1 - Accident rates and short term injuries for eight cars A to H

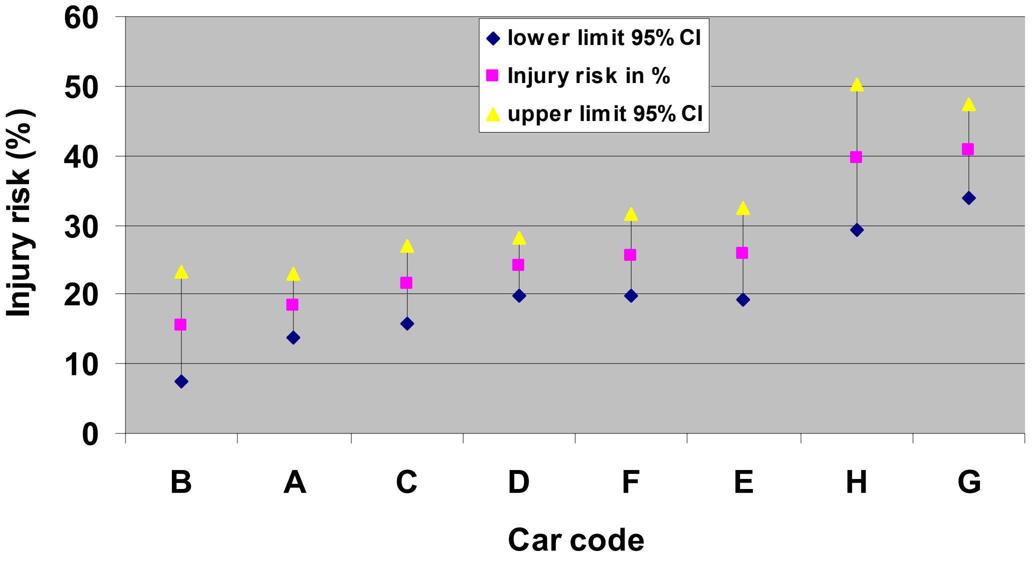


Figure 1 - Cars A-H with varying injury risk, including 95% confidence intervals. Note that there is no risk overlap between cars A-B on one hand and G-H on the other.

Given the inclusion criteria for the insurance database, specifically repair cost, it can be expected that the real injury risk for each car is different than shown in Figure 1. There is a way to compensate for this inclusion criterion using the exposure of each car model. This exposure compensation is based on the following assumptions:

- The risk to be subjected to a rear-end impact is similar for all cars on the road
- Yearly mileage and road use is independent of the car model (only medium class cars were used here, no city cars, no executive limousines)
- The amount of injury claims remains the same. This means cases with no insurance claim did not produce whiplash injury.

Table 2 compares the exposures of the cars in the database. It shows that car model G has a high representation on the road, 28% of all cars considered in the analysis. Model G accounts only for 13% of the accidents in the database, thus it is under represented (low repair cost). A more realistic amount of accidents for this car would be 446, so that it also accounts for 28% of the accident cases. Maintaining the amount of 83 short term injuries shows that the risk of 40.7% (Table 1) goes down to 18.6%. In a similar way the other figures are compensated for.

Car code	Exposure in Germany	Relative exposure [%]	Number of Accidents	Relative number of accidents [%]	Short term injury cases	Compensated number of accidents	Compensated short term injury risk [%]
A	370040	12	268	17	49	194	23.4
B	97943	3	78	5	12	51	25.2
C	528957	17	201	12	43	278	15.5
D	461352	15	399	25	96	242	39.7
E	317127	10	170	11	44	166	26.4
F	132699	4	211	13	54	70	77.6
G	851000	28	204	13	83	446	18.6
H	317105	10	83	5	33	166	19.8
Total	3076223	100	1614	100	414	1614	

Table 2 - Accident rates and short term injury risk with compensation for car exposure

This method of compensation entirely changes the injury risk figures. It should be noted that the truth will be somewhere in between. In other words: there will be injury cases which are not included due to low repair cost, but there is no way of telling exacly how many of them are excluded. As long as inclusion criteria are applied to a database, this will always be a drawback of the current method.

Using the risk tables as presented in Table 1 and Table 2 a comparison with dummy measurements in a dynamically tested car seat can be made. The test methods are described in the next section.

TEST METHOD

SLED SETUP. A car seat of similar make and model as in the accident database was mounted on an accelerated sled, according to the ISO draft whiplash procedure (ISO TC22/SC10/Wg1 N544 WD17373). The seat back angle was set to manufacturer specification or, if not available, 25 degrees, and the head restraint was positioned in the optimal position (top of dummy head aligned with upper edge of the head restraint or the highest position possible if this could not be done). A three point belt was applied only to restrain the dummy from severe rebound (Figure 3). Rebound parameters were not measured in this evaluation.

CRASH PULSES. The sled with seat and dummy was accelerated with two different pulses:

1. An early peak triangular pulse as used by IIWPG and proposed in ISO whiplash regulation. This is a 10 G max, 16 km/h pulse, as shown in Figure 2.
2. A car specific pulse, since it exposes the seat to a type of pulse it may encounter in the real world situation. This pulse was derived from a measured pulse in a barrier-to-car insurance reparability test. The test uses a moving barrier to impact the rear of a car with 40% overlap on the driver side. The impact speed is 15 km/h ± 1 km/h and resulting delta V is about 10 km/h, depending on car rear elasticity and car mass. The pulse measured was scaled to represent a 16 km/h delta V rear impact for this specific car. Pulse scaling may not be the best method to obtain a specific pulse, but the pulse shape is more likely to reflect the car characteristics than an average generic pulse.

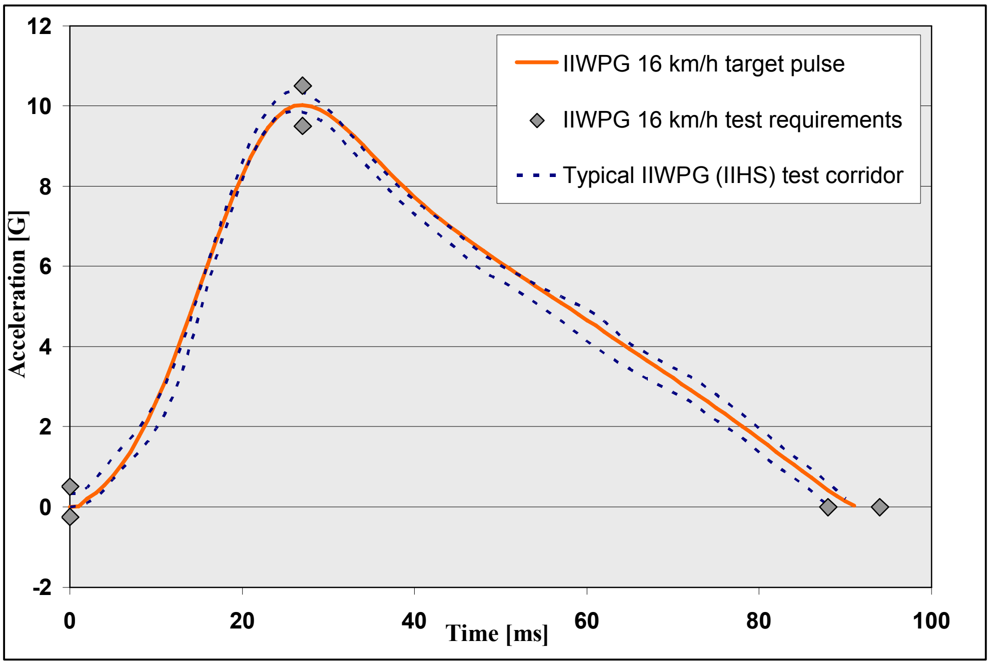


Figure 2 - IIWPG pulse used in the current evaluation as the generic pulse

DUMMIES. Two dummies were applied in this evaluation. The RID^{3D} dummy and the BioRID dummy, version II G. RID^{3D} is a dedicated 3D whiplash dummy developed in an earlier stage of this Whiplash2 project. Earlier evaluations of various dummies showed that RID2 had the best possibilities to be extended to a 3D whiplash dummy (Cappon et al. 2003). Therefore, RID2 was upgraded to a so called RID^{3D}, in order to handle frontal and frontal-oblique impacts as well, for which it was successfully evaluated. An smaller rear-end rebound response was also required for RID^{3D}, since the RID2 rebound was too large (Cappon et al. 2003). RID^{3D} has similar rear impact biofidelity as RID2, but the rebound displacement was indeed found to be smaller.

Figure 3 – Test setup with BioRID on seat E

RESPONSE PARAMETERS. Using these two dummies and the two crash pulses sled tests with 8 seat models were performed (32 tests, one test for each configuration), in which various parameters were measured. The parameters given in Table 3 were evaluated.

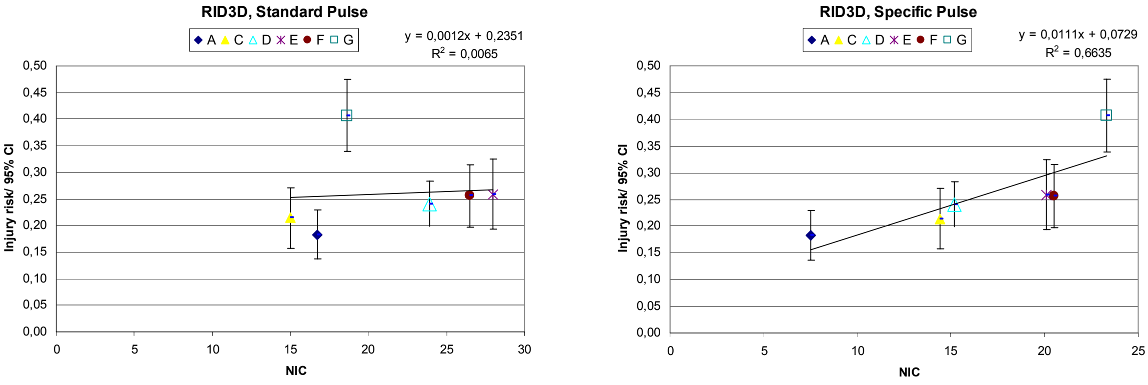
Parameter	*Specific focus or remark*
NIC	Focus on S-shape of the neck. Boström et al. (1998)
Nkm	Combined criterion of shear and axial forces and bending moments. Focus on all neck shapes, including rebound phase. Schmitt et al. (2001)
LNL	Maximum of lower neck load index, using bending moments, axial forces and shear forces. See SAE J1727 and Heitplatz et al. (2003)
LMy	Lower neck maximum flexion/extension moment
UFx	Upper neck maximum shear force
LFx	Lower neck maximum shear force
UFz	Upper neck maximum compression/tension force
Nij	Combined criterion like Nkm, but replacing shear forces by axial forces and using different intersect values. See FMVSS 208
G_T1	Average acceleration of T1 in x-direction (forward-rearward)
G_sled	Average sled acceleration

Table 3 – Injury criteria evaluated in relation to injury risk

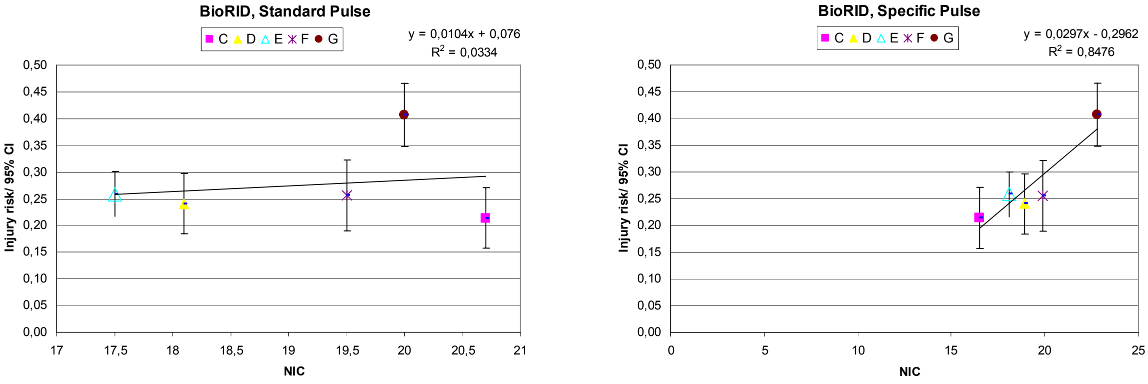
RESULTS

Injury risks were established from one accident database by two distinct methods and sled tests were performed with two dummies using two different pulse shapes. This section tries to identify the relation between the injury risk on one hand and the dummy measurements on the other. A straightforward method of linear correlation was applied. The maximum of a response parameter with a given seat is plotted against the injury risk of this seat and correlation coefficients were calculated.

Figure 4 shows an example for NIC measured in four tests (2 pulses and 2 dummies). A summary of the results for all measured response parameters is given in Table 4. In these plots and correlation calculations, cars B and H were excluded, due to the large confidence intervals associated with these cars. Corresponding plots are shown in Appendix A for the parameters with reasonable correlation. For this reason and in order to limit the amount of figures, plots for UFz and Nij are not presented.



NIC with RID^{3D}, standard pulse NIC with RID^{3D}, specific pulse



NIC with BioRID, standard pulse NIC with BioRID, specific pulse

Figure 4 - Example of linear correlation between injury risk and NIC, using RID^{3D} and BioRID both with a car specific and a generic pulse.

Table 4 shows the squared correlation coefficients (r^2) for the relation between dummy measurement and injury risk. An r^2 below 0.49 ($r < 0.7$) means that there is no correlation, a value between 0.49 and 0.81 ($r < 0.9$) indicates a possible relationship between the parameters and r^2 above 0.81 means a clear trend between the data was observed. The highest values above 0.81 are in bold. Figure 5 presents the same data in a bar diagram.

Table 4 indicates high coefficients for NIC in BioRID using a specific pulse and high values for T1 and sled accelerations in RID^{3D} using a specific pulse. However, the high NIC correlation in BioRID seems dependent on the result of one seat type (outlier G) as Figure 4 shows. This means that the correlation values should be considered with some extra care. A reasonable correlation was found for the lower neck shear force (LFx) in RID^{3D} and remarkably, this does not seem to be very dependent on the pulse applied. The sensitivity to the pulse type used is more profound in BioRID that in RID^{3D}. BioRID shows larger changes in correlation dependent on the pulse type.

	Squared correlation coefficient r^2			
Injury criterion	RID^{3D}		BioRID	
	Standard Pulse	Specific pulse	Standard Pulse	Specific pulse
NIC	0.01	*0.66*	0.03	**0.85**
Nkm	*0.70*	*0.55*	0.27	0.14
LNL	*0.59*	*0.76*	0.00	0.02
LMy	0.44	*0.71*	0.23	0.08
UFx	0.40	0.47	0.24	0.06
LFx	*0.79*	*0.80*	0.02	0.09
UFz	0.01	0.02	0.04	0.15
Nij	*0.63*	0.46	0.26	0.03
T1 acc	*0.65*	**0.94**	*0.63*	0.31
Sled acc	0.56	**0.83**	0.04	*0.61*

Table 4 - Squared correlation coefficients (r^2) of the linear relation between dummy measurement and injury risk. No exposure compensation was applied for this table. Values between 0.49 and 0.81 are in italics and above 0.81 are highlighted in bold.

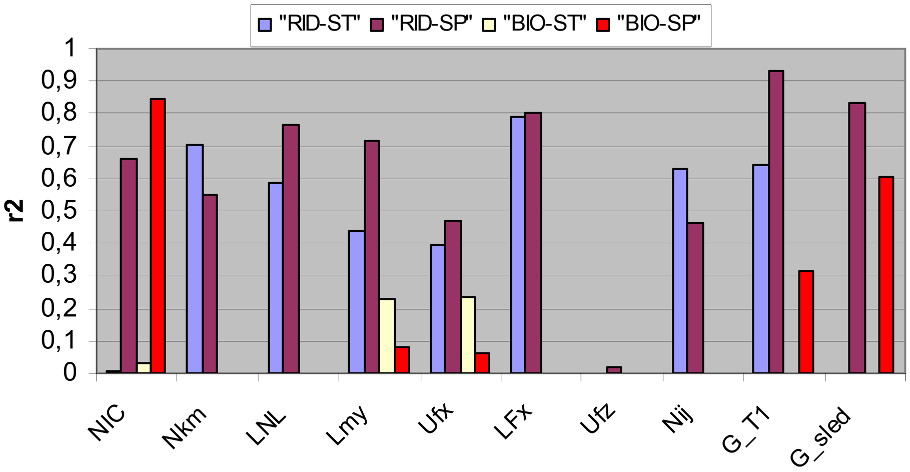


Figure 5 –Bar diagram of the squared correlation (r^2) between injury risk and injury criteria. Non-compensated risk figures, excluding cars B and H. 'ST' means standard pulse, 'SP' specific pulse

When the injury risk figures are compensated for real life exposure, the results of this evaluation change entirely. Table 5 and Figure 6 show the squared correlation coefficients for the exposure compensated risk versus injury criteria. Corresponding figures are presented in Appendix B. Nkm in BioRID using a generic pulse is the only variable with a high correlation coefficient (noting that average sled acceleration is a non-sense parameter when using a generic pulse). No conclusions can be drawn for the other parameters.

	Squared correlation coefficient r^2			
Injury criterion	RID^{3D}		BioRID	
	Standard Pulse	Specific pulse	Standard Pulse	Specific pulse
NIC	0.39	0.05	0.02	0.02
Nkm	0.11	0.25	0.13	**0.88**
LNL	0.25	0.09	0.00	0.43
LMy	0.35	0.18	0.08	*0.63*
UFx	0.45	0.41	0.12	*0.76*
LFx	0.05	0.03	0.00	0.24
UFz	0.02	0.00	0.02	0.08
Nij	0.01	0.10	0.02	0.00
T1 acc	0.01	0.09	0.01	0.09
Sled acc	0.08	0.05	0.82	0.00

Table 5 - Squared correlation coefficients (r^2) of the linear relation between dummy measurement and injury risk. Exposure compensation was applied for this table. Values between 0.49 and 0.81 are in italics and above 0.81 are highlighted in bold.

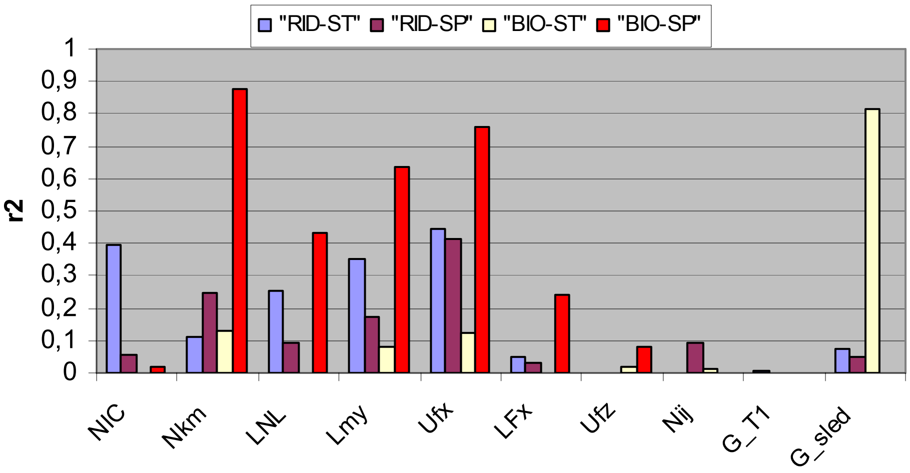


Figure 6 – Bar diagram of the squared correlation between injury risk and injury criteria. Exposure compensated risk figures, excluding cars B and H. 'ST' means standard pulse, 'SP' specific pulse

DISCUSSION

With the current knowledge on whiplash injury criteria, it is not possible to accurately determine the whiplash protection of a car seat. On the short term biomechanical studies will probably not find the appropriate injury criteria for proper indications of seat protection. Therefore, a more practical approach was presented in this paper. This method is extremely valuable for backing up biomechanical studies. With the increasing detail in accident data analysis, like crash recorder data becoming more and more available, a statistically significant comparison between accident data and dummy readings can be made, thus determining the relevant injury criteria for the dummy. It is a matter of time until enough accident cases have been acquired to establish this relationship for a large amount of seat models.

ACCIDENT DATA. Results of the relation between whiplash accident rates and dummy readings is highly dependent on the inclusion criteria of the accident databases, which are usually based on insurance claims or police reports. Accidents with minor damage may result in injury, but not in inclusion, which will thus pollute the injury statistics. Care should be taken in using a given database for these types of research.

From accident analysis data collected during the past years (Temming and Zobel, 2000) it has become clear that crash pulses of about 16 km/h delta V result in a high risk of whiplash injury. However, this pulse and its shape are highly dependent on several factors, like the front structure of the impacting vehicle, the rear structure of the struck vehicle, the impact speed and car mass. This means that 16 kph delta V in a light weight vehicle is much more easily acquired than in a heavy vehicle. It is therefore likely that light vehicles will have a higher whiplash risk when equal exposure is assumed. For this reason cars of approximately similar weight were used in this evaluation, so that injury risk is related rather to the seat than to the car mass. Even then a wide range of crash pulse shapes can be expected, as also indicated by Linder et al. (2001), justifying the use of a car specific pulse in this type of evaluation. The scaling method applied certainly does have limitations, yet it was thought to be more realistic than using generic pulses only. The differences in results show that the pulse shape is a relevant factor in whiplash testing.

It should be noted that the 95% confidence intervals for the accident data presented have a certain amount of overlap. There are clear differences between car A and car G, but not between the intermediate models, causing uncertainty in the actual injury risk. Thus in the present study only certain trends may be observed and no clear conclusion can be drawn. This confidence interval becomes smaller as the amount of cases increases. The amount of accident cases of one car type increases as the car gets older, but in the mean while these data become less relevant. It also means that statistically significant amounts will not be available for new cars with new protection systems. The current approach assumes that the injury mechanisms will remain the same in the near future, independent of the protection system used, otherwise the injury criteria found will be irrelevant for future systems.

The accident statistics usually have limited information on the head restraint position during the crash. It is known that head restraints may decrease the chance of whiplash injury considerably, as long as the vertical position is adapted to the occupant size. The head restraint position in the experimental reconstruction is set to an optimal location, but the real-life situation may not have been that optimal, resulting in more injuries than expected from a geometrical point of view. The seat back angle was set as close as possible to a 25 degree inclination or manufacturer specification. Here also, the real life position may have been different, but a seat should be tested in the way it is meant to be used, so that misuse is not tested.

This whiplash rating was performed using 50th percentile male dummies. Many studies indicate that women are higher at risk considering whiplash injuries (Ydenius, 2002; Temming and Zobel, 2000). This is even the case when several injured occupants in one car are observed (Krafft et al, 2002), so it is not just car dependent. The males, however, still have a larger exposure on the road (Temming and Zobel, 2000), partly justifying the use of current dummies.

DUMMY TESTS AND INJURY CRITERIA. Measured dummy parameters are obviously limited to the possibilities of the dummy used. All sensors which were thought to be relevant were included in the current study in order to obtain the injury criteria covering most of the (proposed) injury mechanisms in rear impact loading, like neck shear, tension, bending and accelerations, measured at the upper and lower end of the dummy neck.

Like in the studies of Muser et al (2003) and Heitplatz et al (2003) no real firm conclusions could be drawn on relevant injury criteria in this study. The indications found are even different between these studies: Muser suggests NIC_{max}, Heitplatz proposes lower neck My or LNL and this study sees a potential candidate in the lower neck shear force. One of the reasons for these differences might be that different seats expose the occupant and dummy to different loading mechanisms, so that different injury mechanisms and different criteria apply for the various seats. There is no easy way of finding a solution to this problem when comparing dummy measurements to accident data.

It should be noted that in some respects there are also clear differences between the dummies used, considering the criteria which were evaluated in this study. BioRID and RID^{3D} have a different way of measuring lower neck loads. In BioRID the shape of the spine is more human like than in RID^{3D} so that lower neck loads should represent the loading in the human spine better. However, only the shear forces in the neck are measured directly, while the measurement of lower neck axial force and neck bending moments do not take into account the cables in the BioRID spine. Since the introduction of the lower neck load cell in BioRID was only done quite recently, the biofidelity of lower neck readings has not yet been examined. In RID2 and RID^{3D} the load cell was integrated in the design from the beginning, ensuring a strict load path through the load cell. The orientation, however, it not similar to BioRID and the directions of force cannot be transferred to the human spine without corrections for orientation.

Repeatability tests were not performed in the current study, due to the limited amount of seats available. Obtaining good seats of each car type, usually second hand, will always remain to be a difficulty in this type of retrospective studies.

STATISTICS. The method applied here uses linear correlation in order to find a relation between injury criteria and injury risk, similar to the approach used by Muser et al (2003). In reality more complex relations will certainly apply. The assumption of linearity is just a first step in the process of understanding dummy measurements in relation to real injuries.

CONCLUSIONS

Additional to research on biomechanical injury criteria, the study of the relationship between injury statistics and measured dummy responses will help in the understanding of whiplash protection in car seats. Such use of reconstructed crashes will certainly contribute to the confidence in dummies being able to rate whiplash protection of car seats, although many limitations have to be considered.

Uncertainty relative to the SPL (Statistical Performance List) data, which is a car ranking method in terms of injury risk according to field accident data, and the repeatability and reproducibility of sled tests performed makes it difficult to draw any firm conclusions on injury criteria. However, the following trends were observed with the data produced in this study:

- Looking into non exposure compensated data, the best correlation was obtained, using RID^{3D} and a specific pulse, with peak T1 acceleration, LFx (lower neck shear force) and LNL (Lower Neck Load index). A similar result was found for LFx using the generic pulse;
- Considering exposure compensated SPL data, the best correlation was obtained using BioRID with Nkm and UFx (upper neck shear force) using a car specific pulse. However, this level of correlation was largely dependent on the results of one seat (car F);
- On average RID^{3D} results correlated better with non exposure compensated SPL data and BioRID with exposure compensated SPL data;
- Measured injury criteria were highly dependent on the crash pulse applied, even though cars of similar class (mass) were used. Given the wide range of vehicles on the road, the evaluation of a seat using a car specific pulse will reflect the real world situation better.

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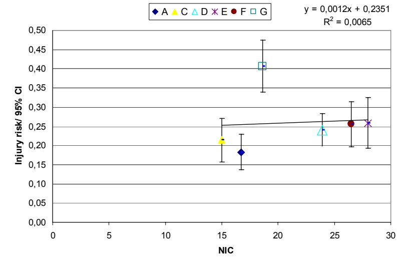
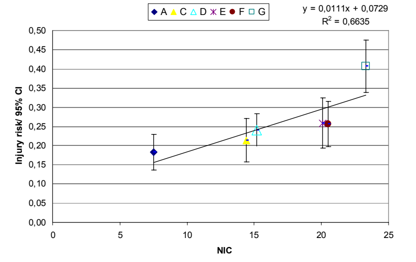
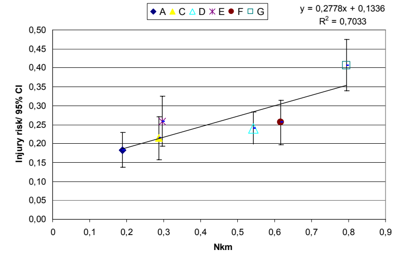
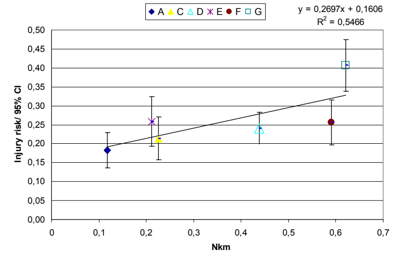
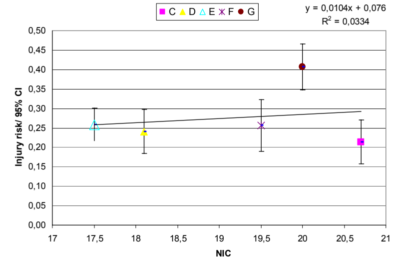
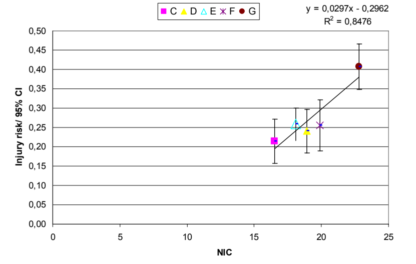
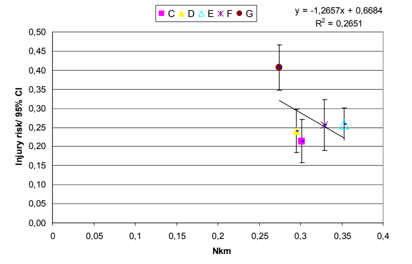
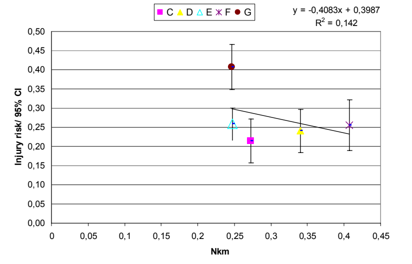
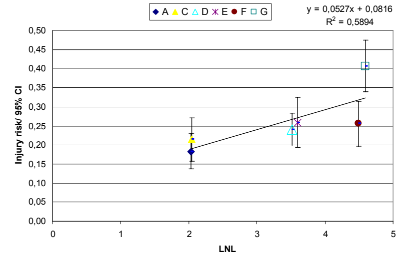
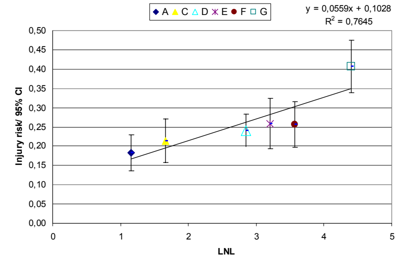
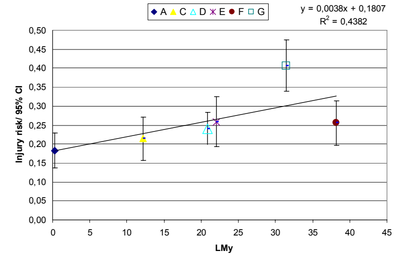
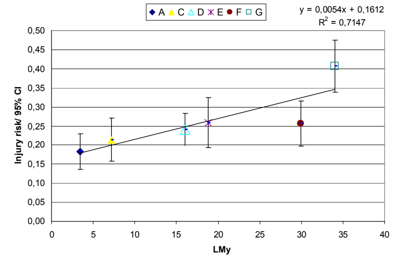
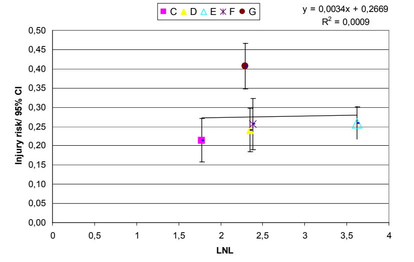
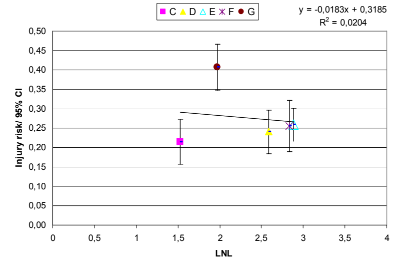
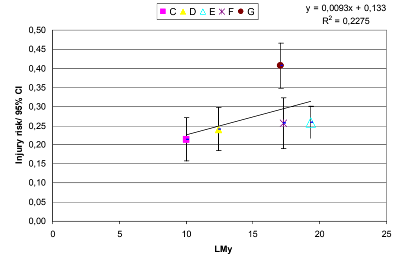
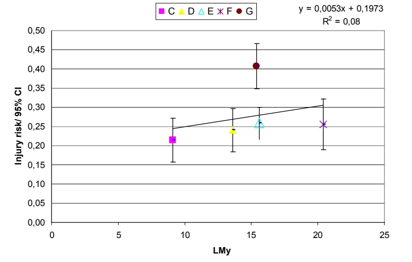
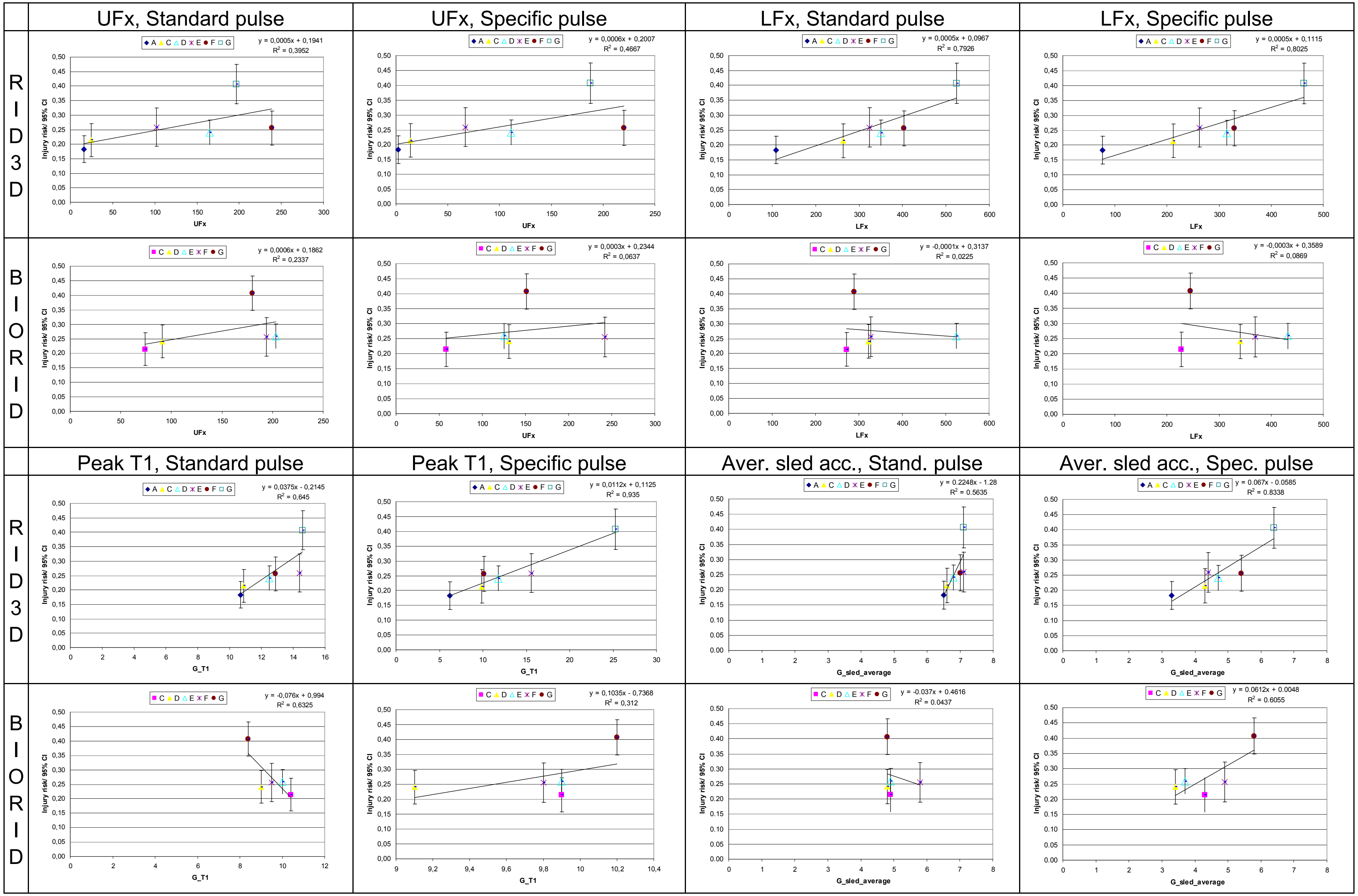
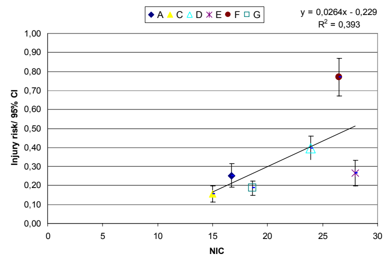
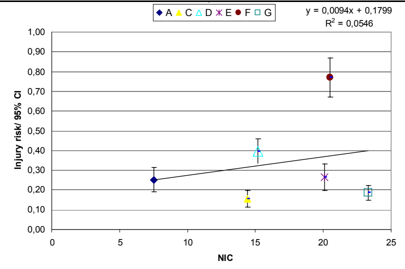
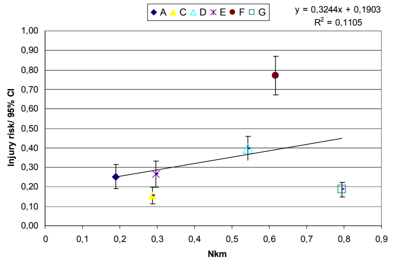
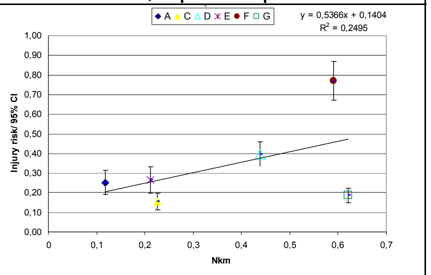
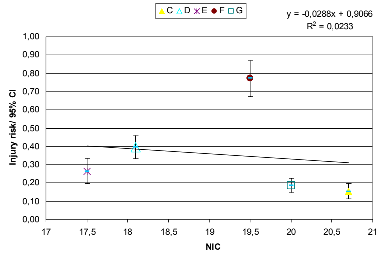
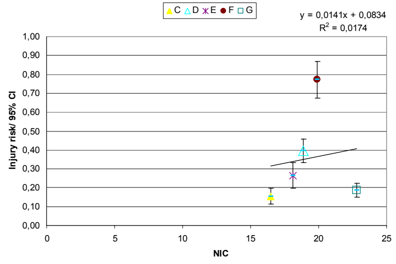
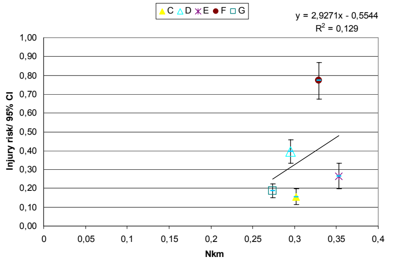
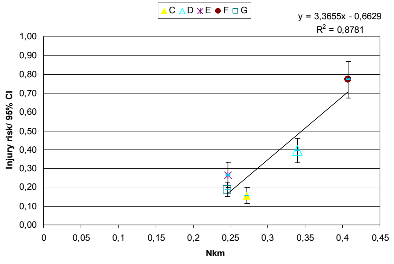
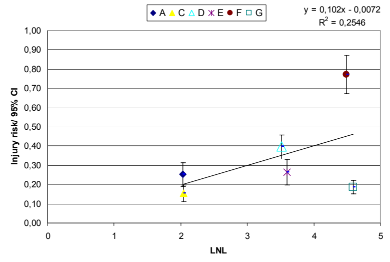
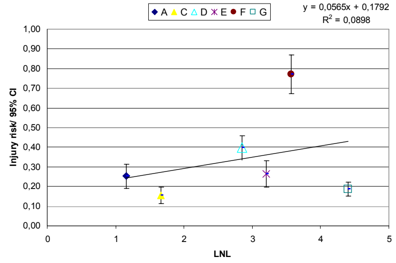
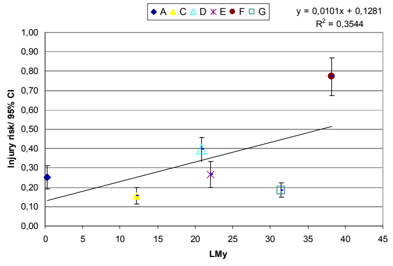
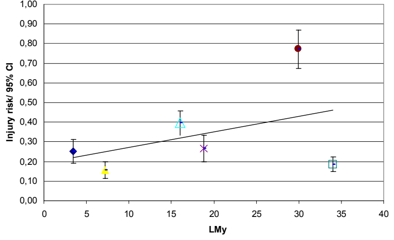
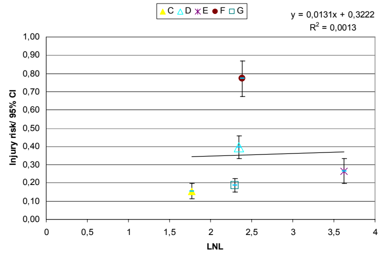
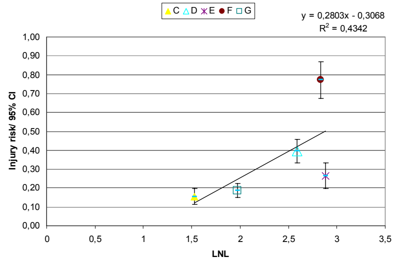
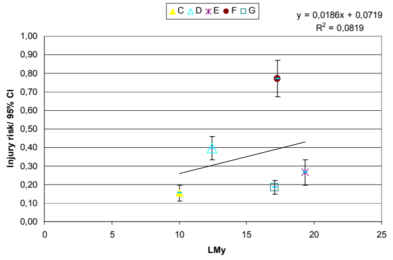
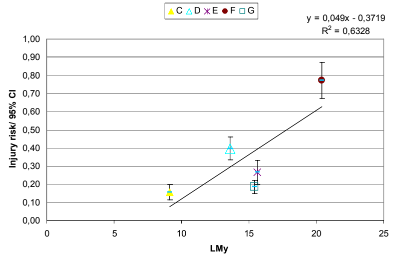
Appedix A: Injury risk versus injury criteria. Non-compensated, plain insurance data.

	NIC, Standard pulse	NIC, Specific pulse	Nkm, Standard pulse	Nkm, Specific pulse
RID3D				
BIORID				
	LNL, Standard pulse	**LNL, Specific pulse**	**LMy, Standard pulse**	**LMy, Specific pulse**
RID3D				
BIORID				

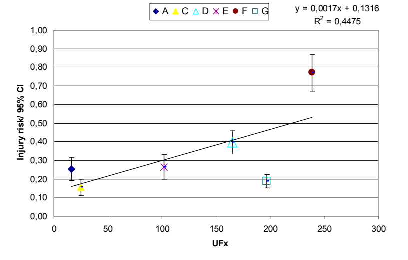

UFx, Standard pulse
UFx, Specific pulse
LFx, Standard pulse
LFx, Specific pulse
RID3D
◆ A ▲ C △ D ✕ E ● F □ G
y = 0,0005x + 0,1941
R² = 0,3952
y = 0,0006x + 0,2007
R² = 0,4667
y = 0,0005x + 0,0967
R² = 0,7926
y = 0,0005x + 0,1115
R² = 0,8025
BIORID
■ C ▲ D △ E ✕ F ● G
y = 0,0006x + 0,1862
R² = 0,2337
y = 0,0003x + 0,2344
R² = 0,0637
y = -0,0001x + 0,3137
R² = 0,0225
y = -0,0003x + 0,3589
R² = 0,0869
Injury risk/ 95% CI
UFx
LFx
Peak T1, Standard pulse
Peak T1, Specific pulse
Aver. sled acc., Stand. pulse
Aver. sled acc., Spec. pulse
RID3D
◆ A ▲ C △ D ✕ E ● F □ G
y = 0,0375x - 0,2145
R² = 0,645
y = 0,0112x + 0,1125
R² = 0,935
y = 0.2248x - 1.28
R² = 0.5635
y = 0.067x - 0.0585
R² = 0.8338
BIORID
■ C ▲ D △ E ✕ F ● G
y = -0,076x + 0,994
R² = 0,6325
y = 0,1035x - 0,7368
R² = 0,312
y = -0.037x + 0.4616
R² = 0.0437
y = 0.0612x + 0.0048
R² = 0.6055
G_T1
G_sled_average

Appedix B: Injury risk versus injury criteria. Injury risk is compensated real life exposure.

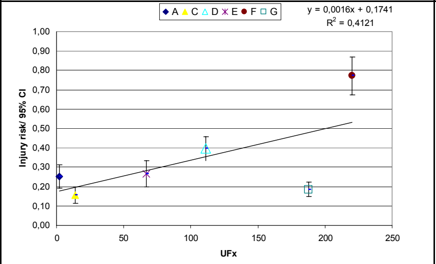
	NIC, Standard pulse	NIC, Specific pulse	Nkm, Standard pulse	Nkm, Specific pulse
RID3D				
BIORID				
	LNL, Standard pulse	**LNL, Specific pulse**	**LMy, Standard pulse**	**LMy, Standard pulse**
RID3D				
BIORID				

RID3D

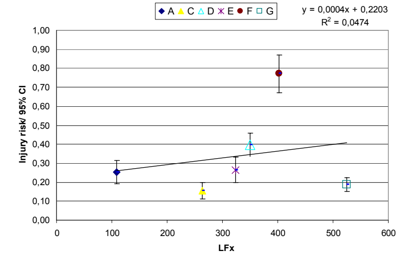
UFx, Standard pulse



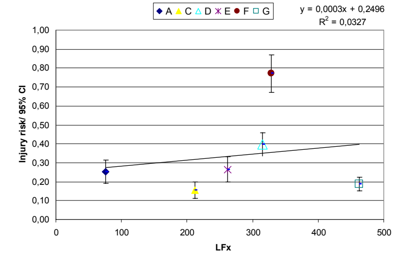
UFx, Specific pulse



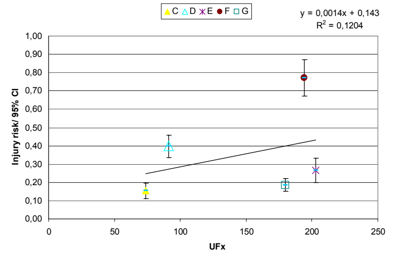
LFx, Standard pulse

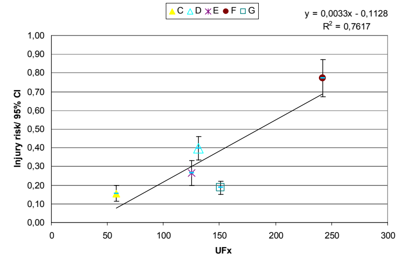


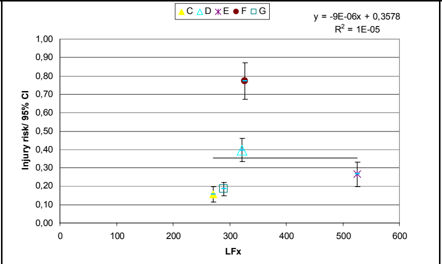
LFx, Specific pulse

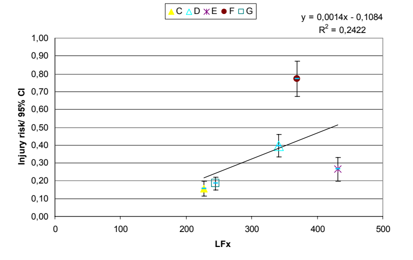


BIORID



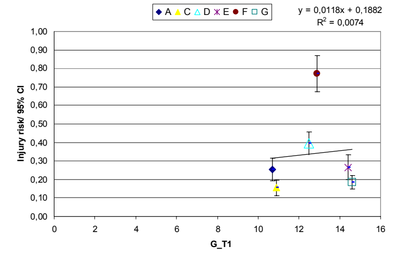




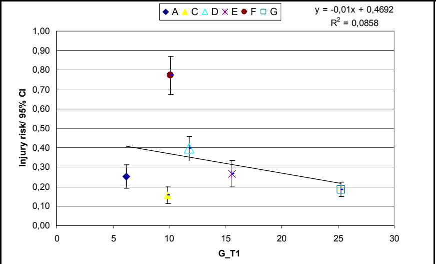


RID3D

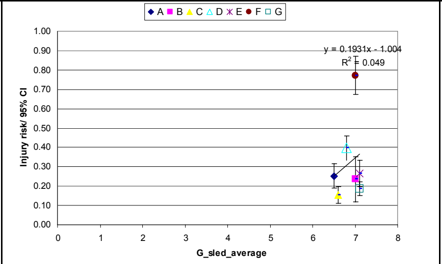
Peak T1, Standard pulse



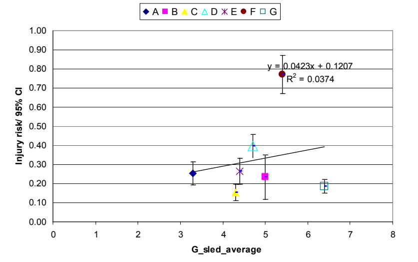
Peak T1, Specific pulse



Aver. sled acc., Stand. pulse



Aver. sled acc., Spec. pulse



BIORID