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Folksam

Evaluation of Seat Performance Criteria for Rear-end Impact Testing

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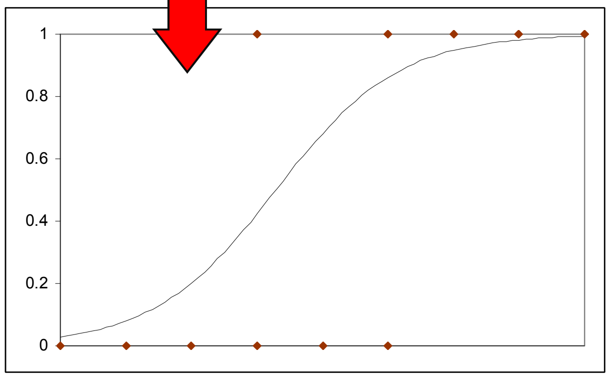
Objective

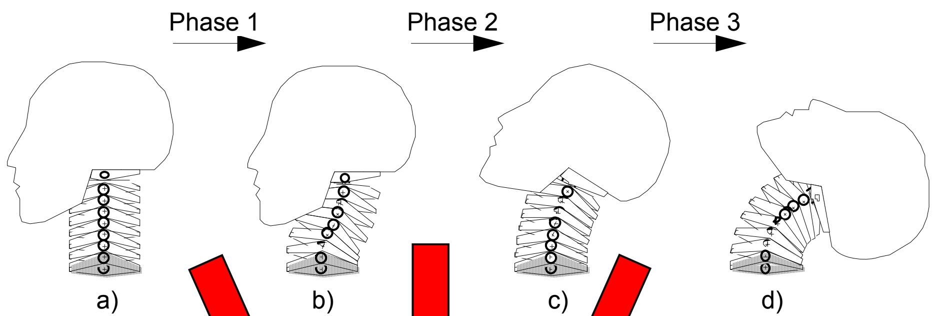
- Overall objective
  - Seat performance criteria to be used in rear-end impact seat tests with BioRID II.
- This presentation
  - Differences compared to interim report and ESV paper
  - Materials and Methods
  - Results
  - Discussion
  - Conclusions

Difficult to develop injury risk curves for WAD

- Traditional approach



- Whiplash Associated Disorders



Studies of injury thresholds for a dummy

- PMHS studies
  - Assessment of injuries and relate these to symptoms
  - PMHS parameter measurements to be related to dummy measurements
- Volunteer studies
  - Sub-injury level
  - Volunteer parameter measurements to be related to dummy measurements
- Reconstruction of accidents using Human Body Models
  - Injury thresholds for some tissues unknown
  - Initial posture of occupants unknown
  - Human Body Model parameter measurements to be related to dummy measurements
- Reconstructions of accidents using crash test dummy
  - Initial posture of occupants unknown
  - Large number of cases required

Principle method

- Find correlations between injury risks, as calculated from insurance data, and BioRID measurements

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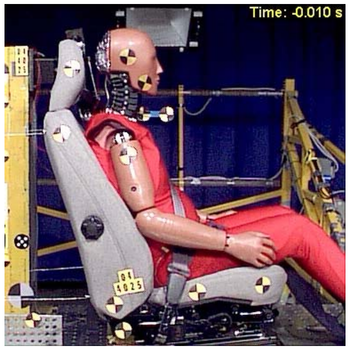
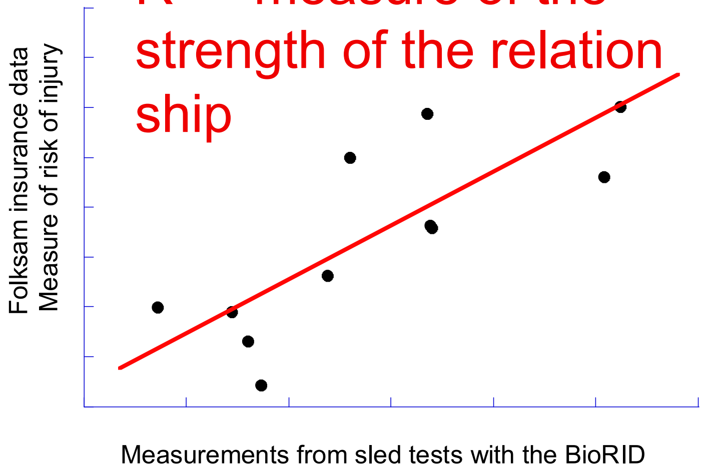
Injury Claim data from rear-end impacts



Correlation coefficient R^2 = measure of the strength of the relation ship



Methods: Data used

Insurance data

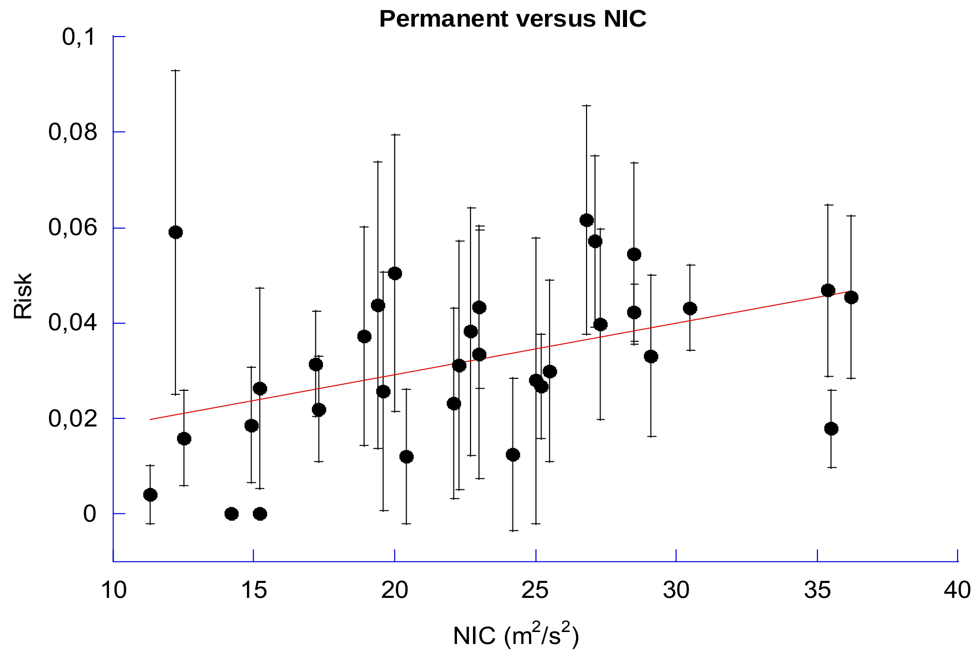
- Folksam insurance data; 1998 and 2011
  - Only drivers
  - Only neck related injuries
  - Only rear +/-30 deg.
  - Only data with complete records
- All with initial symptoms
- Risk of symptoms for more than one month (> 1 month)
- Risk of permanent medical impairment (Permanent)

Seat test data

- Test by
  - Autoliv, 2004, 2005 and 2006
  - Thatcham, 2004 and 2012
- BioRID II build level E or G
- H-point tool:
  - TechnoSports, Inc.,
  - Automotive Accessories, Ltd.,

Methods: Grouping insurance data

- ~~Individual vehicle models… Audi A3 ≠ VW Golf~~
- ~~Similar risk~~
- Seats from different vehicles in which the seat design was (about) the same



Methods: Insurance data

Ford with STD	
Focus	99-05
Mondeo	93-99
Hyundai with STD	
Accent	99-06
Atos	04-03
Atos	98-03
Elantra	04-
Elantra	96-03
Getz	03-
Matrix	01-
Santa Fe	00-05
Sonata	01-05
Mercedes with STD	
A-class	98-04
C-class	93-01
E-class	96-01
CLK	02-06
E-class	02-06
Opel with STD	
Astra	98-04
Corsa	00-06
Meriva	03-
Omega	94-03
Vectra	89-95
Vectra	96-98
Zafira	99-04
Peugeot with STD	
206	98-05
306	93-01
307	01-
406	96-04
605	90-98
607	99-
307	01-
Saab with STD older	
Saab 900	88-93
Saab 9000	85-97

Saab with STD newer	
Saab 900	94-98
Saab with SAHR	
Saab 9-3	98-02
Saab 9-5	98-09
Saab 9-3	03-11
Toyota with STD	
Avensis	98-02
Camry	97-01
Corolla	98-02
Picnic	97-01
Previa	00-05
RAV4	95-99
Starlet	97-99
Lexus IS 200/300	05-
Toyota with WIL	
Auris	07-
Avensis	03-08
Avensis Verso	01-05
Camry	01-03
Corolla	02-07
Corolla Verso	02-03
Corolla Verso	04-10
Prius	00-03
Prius	04-09
Rav4	00-04
Rav4	05-
Yaris and Yaris Verso	99-05
Yaris	05-
Volvo with STD older	
700	82-98
900	91-98
Volvo with STD	
S40/V40	96-99
850	91-97
V70	97-00

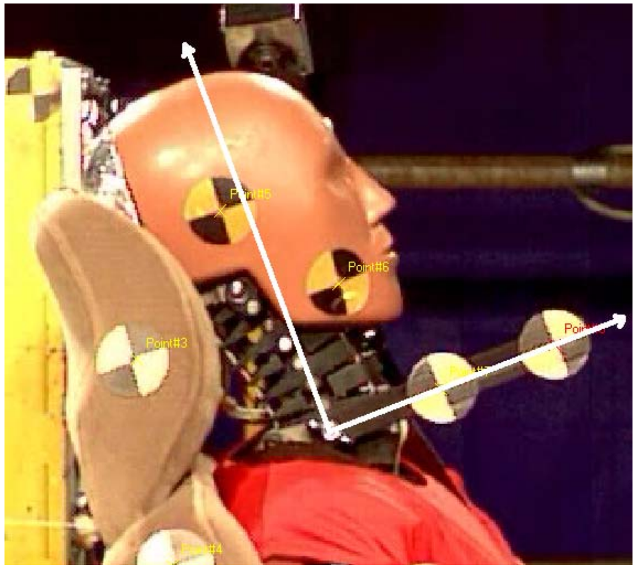
Volvo with WHIPS	
C30	06-
S40/V40	00-03
S40/V50	04-
S60	01-99
V70	00-06
V70	07-
S80	98-06
S80	07-
VW group with STD	
Seat Ibiza/Cordoba	99-02
Seat Ibiza	03-
Skoda Fabia	00-
VW Polo	02-
VW group with STD medium	
Audi A3	96-03
AUDI TT	98-02
Seat Toledo/Leon	99-04
Skoda Octavia	97-04
VW Bora	99-04
VW Golf	98-04
VW group with STD	
Audi A4	95-00
Audi A6	95-97
Audi A6	98-05
Skoda Superb	02-
VW Passat	97-05
VW group with RHR	
Audi A3	03-04
Audi A3	05-06
Audi A4	01-06
Audi A6	05-06
Audi TT	03-05
Seat Altea	05-
Seat Toledo/Leon	05-
Skoda Octavia	05-
VW Touran	03-
VW Golf/Jetta	04-
VW Passat	05-07

Methods: Seat test data

Groups	Model	Prod. year	Year tested	Test Facility	BioRID II version	H-point machine [2]	Backset (mm)
Hyundai	Santa Fe	00-05	2004	Thatcham	G	AA	61
Ford	Focus I	99-06	2004	Autoliv	E	TS	55
Mercedes	C-class	93-01	2004	Thatcham	G	AA	55
Opel	Astra	98-04	2004	Thatcham	G	AA	72
Peugeot	206	98-05	2004	Thatcham	G	AA	76
SAAB	900	94-98	2006	Autoliv	G	AA	30
	9000	85-97	2012	Thatcham	G	AA	48
	9-5	98-09	2004	Thatcham	G	AA	56
Toyota	Corolla	98-02	2005	Autoliv	E	TS	65
	Yaris	99-05	2004	Thatcham	G	AA	66
Volvo	700/900	82-98	2012	Thatcham	G	AA	17
	V70	97-00	2006	Autoliv	G	AA	74
	V/S70	00-06	2004	Thatcham	G	AA	32
VW small	VW Polo	02-	2004	Thatcham	G	AA	63
VW medium	Seat Altea	04-	2004	Thatcham	G	AA	65
VW large	Skoda Superb	02-	2004	Thatcham	G	AA	85
VW RHR	Audi A6	05-06	2005	Autoliv	E	TS	55

Note 2 TS refers to TechnoSports, Inc., USA and AA refers to Automotive Accessories, Ltd., UK

Methods: Studied parameters



- Maximum Neck Injury Criteria (NIC)
- Maximum Neck Force Criteria (N_{km})
- Maximum Lower Neck Loads Criteria (LNL)
- Maximum Head x- and z-acceleration
- Maximum C4 x- and z-acceleration
- Maximum T1 x- and z-acceleration
- Maximum T8 x- and z-acceleration
- Maximum L1 x- and z-acceleration
- Maximum Pelvis x- and z-acceleration
- Maximum and minimum Upper Neck Loads (F_x, F_z and M_y, before head contact stop)
- Maximum and minimum Lower Neck Loads (F_x, F_z and M_y, before head contact stop)
- Maximum Occipital condyle rel. T1 x- and z-displacement in the T1 frame (OC-x and OC-z)
- Maximum Head rel. T1 angular displacement
- Head Contact Time (HCT)
- Maximum Head Rebound Velocity (HRV)

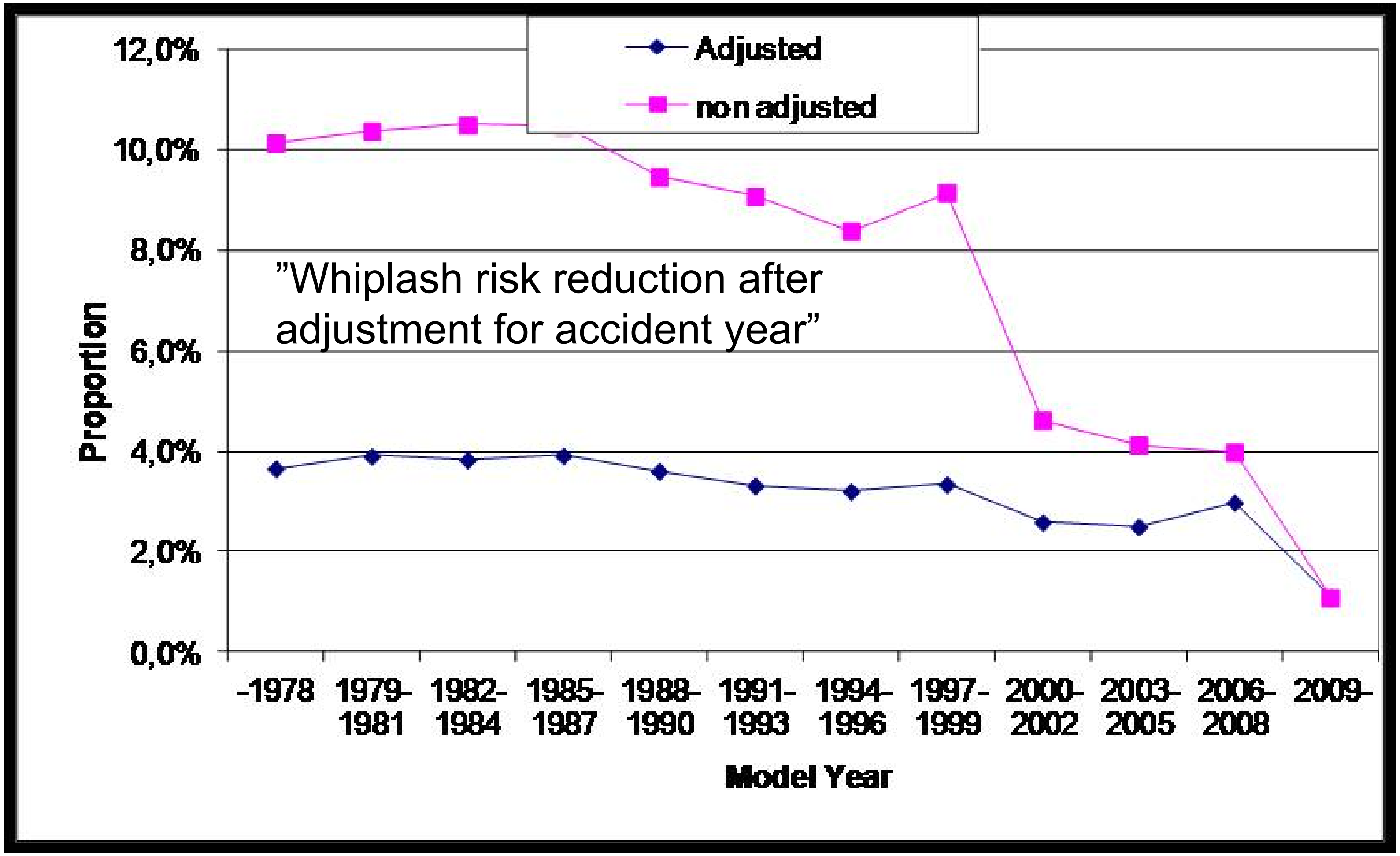
Methods: Compensation for classification over accident year

- This allowed for inclusion of cars popular towards the end of the sampling period.

	Accident year			
Model Year	-1999	2000-2002	2003-2005	2006-2008
-1978	17,1%	14,3%	11,3%	5,5%
1979-1981	17,2%	14,9%	9,6%	6,5%
1982-1984	19,2%	14,2%	9,9%	5,7%
1985-1987	18,0%	14,2%	10,0%	6,6%
1988-1990	14,5%	13,4%	9,9%	6,8%
1991-1993	16,8%	11,6%	8,6%	5,8%
1994-1996	12,4%	12,4%	8,8%	5,9%
1997-1999	16,9%	12,0%	8,7%	5,3%
2000-2002		2,6%	7,4%	5,9%
2003-2005			5,8%	4,7%
2006-2008				5,9%
All model years	16,5%	13,4%	9,6%	6,0%

% should be equal over the accident years

Differences compared to interim report and ESV paper



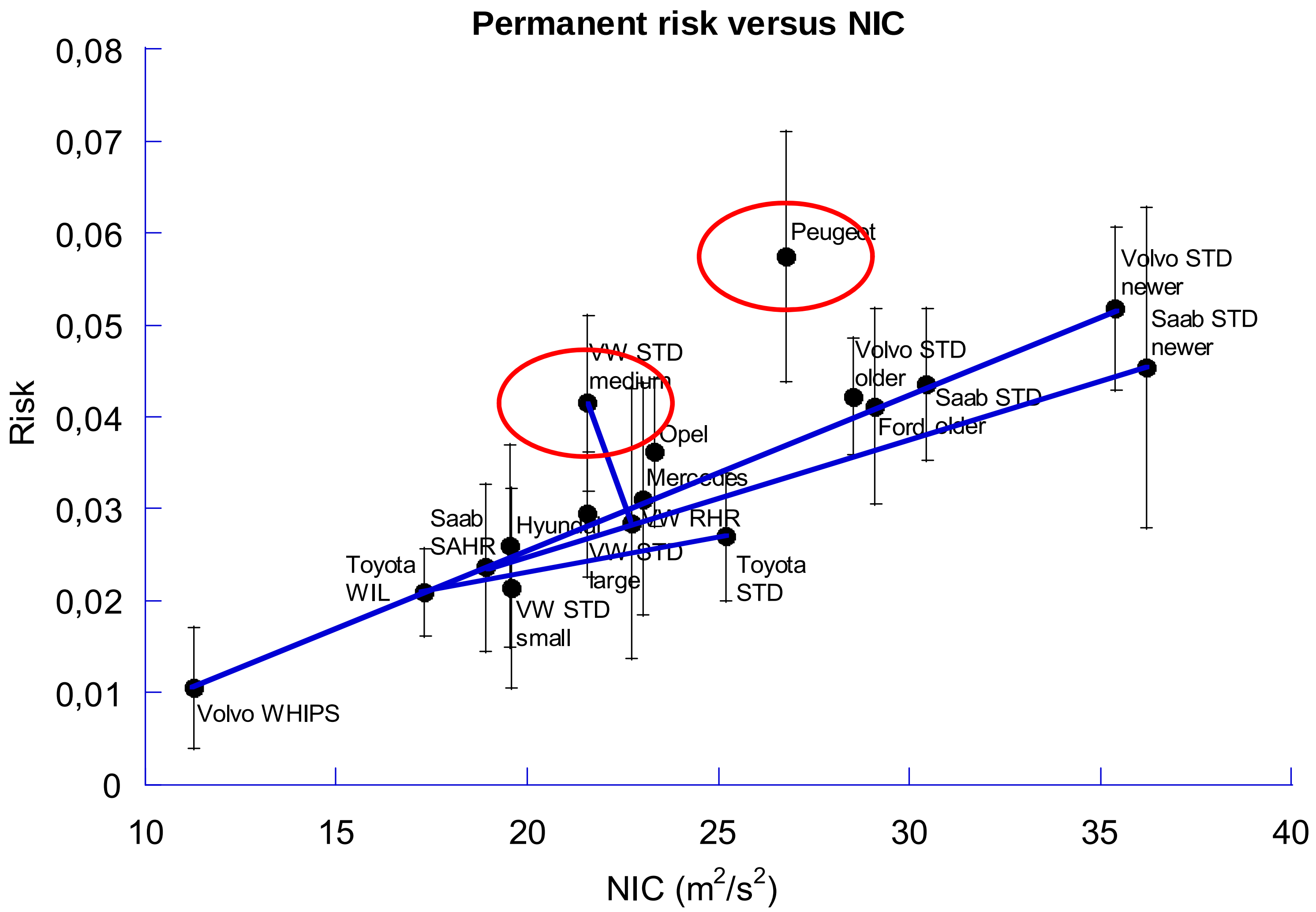
Results: Correlation R^2 values

Parameter	Permanent medical impairment	Symptoms < 1 month
NIC	0,70	0,73
OC rel. T1 x-displacement	0,46	0,57
L1 x-acceleration	0,40	0,44
Head rel. T1 y-rot. (extension)	0,39	0,57
Pelvis z-acceleration	0,33	0,22
L1 z-acceleration	0,30	0,24
N_{km}	0,27	0,44
T8 x-acceleration	0,27	0,38
L.N.F_x (head f.w.)	0,26	0,16
U.N.F_x (head r.w.)	0,22	0,39
T1 x-acceleration	0,19	0,39
T8 z-acceleration	0,19	0,10
L.N.M_y (negative)	0,18	0,34
T1 z-acceleration (upward)	0,12	0,27

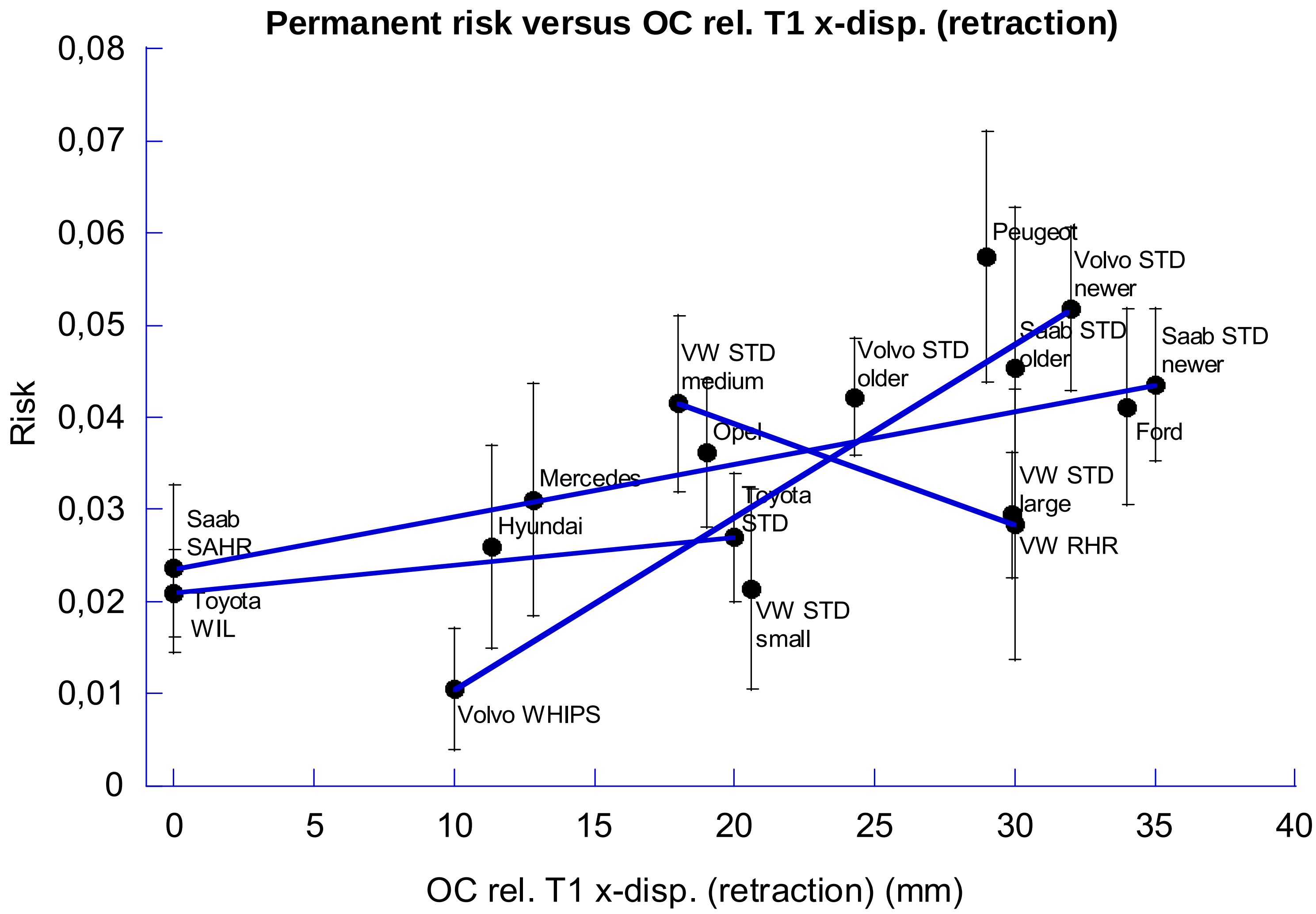
Results: Correlation R^2 values

Parameter	Permanent medical impairment			Symptoms < 1 month		
	Complete	Maximum	Minimum	Complete	Maximum	Minimum
NIC	0,70	0,83	0,62	0,73	0,79	0,68
OC rel. T1 x-displacement	0,46	0,52	0,42	0,57	0,69	0,52
L1 x-acceleration	0,40	0,55	0,34	0,44	0,51	0,39
Head rel. T1 y-rot. (extension)	0,39	0,45	0,37	0,57	0,61	0,53
Pelvis z-acceleration	0,33	0,46	0,13	0,22	0,30	0,11
L1 z-acceleration	0,30	0,61	0,18	0,24	0,49	0,16
N_{km}	0,27	0,37	0,14	0,44	0,62	0,32
T8 x-acceleration	0,27	0,41	0,21	0,38	0,55	0,23
L.N.F_x (head f.w.)	0,26	0,36	0,03	0,16	0,25	0,00
U.N.F_x (head r.w.)	0,22	0,34	0,10	0,39	0,47	0,26
T1 x-acceleration	0,19	0,33	0,08	0,39	0,66	0,11
T8 z-acceleration	0,19	0,32	0,10	0,10	0,39	0,03
L.N.M_y (negative)	0,18	0,26	0,08	0,34	0,40	0,23
T1 z-acceleration (upward)	0,12	0,28	0,07	0,27	0,42	0,19

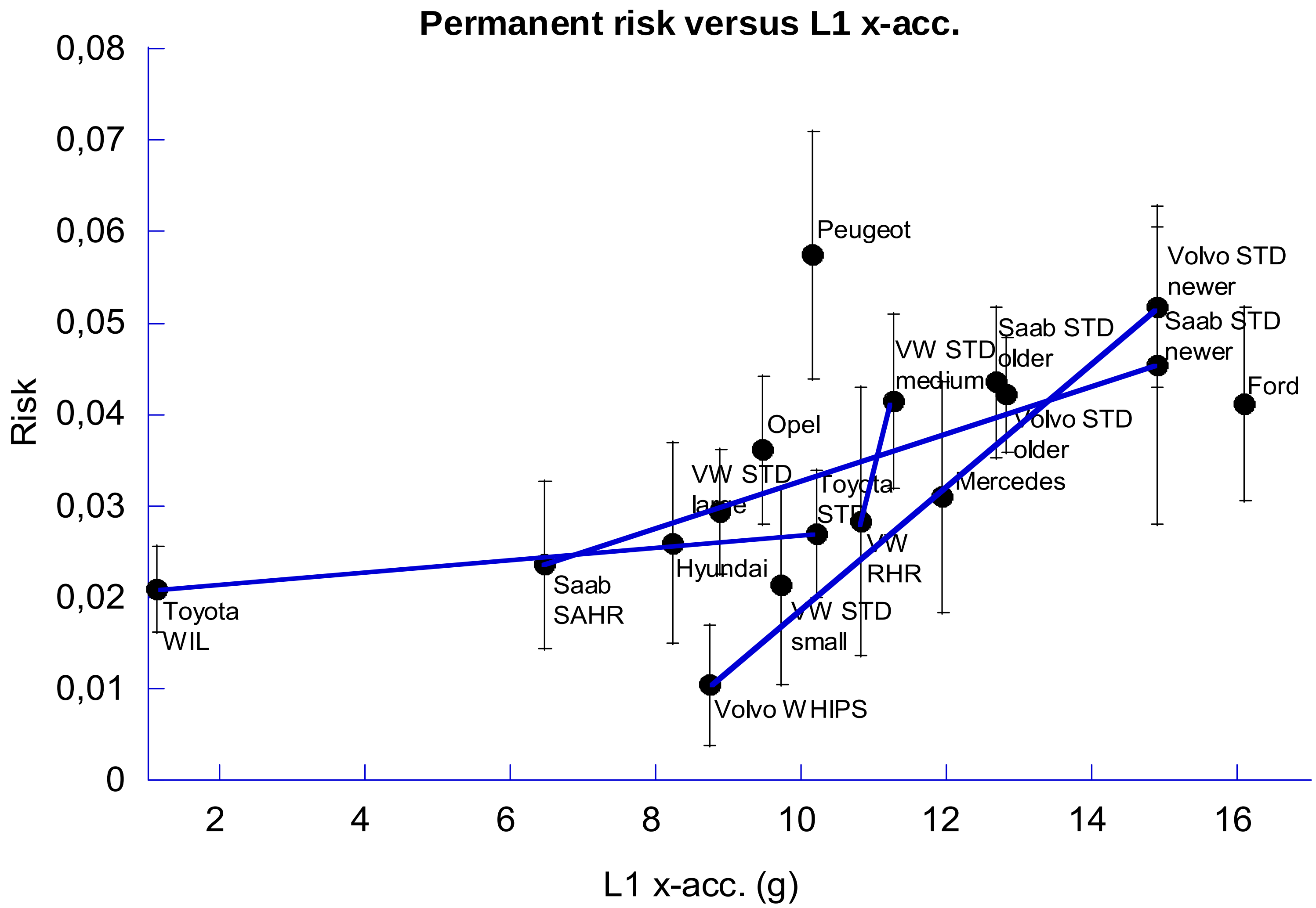
Results: NIC versus permanent medical impairment



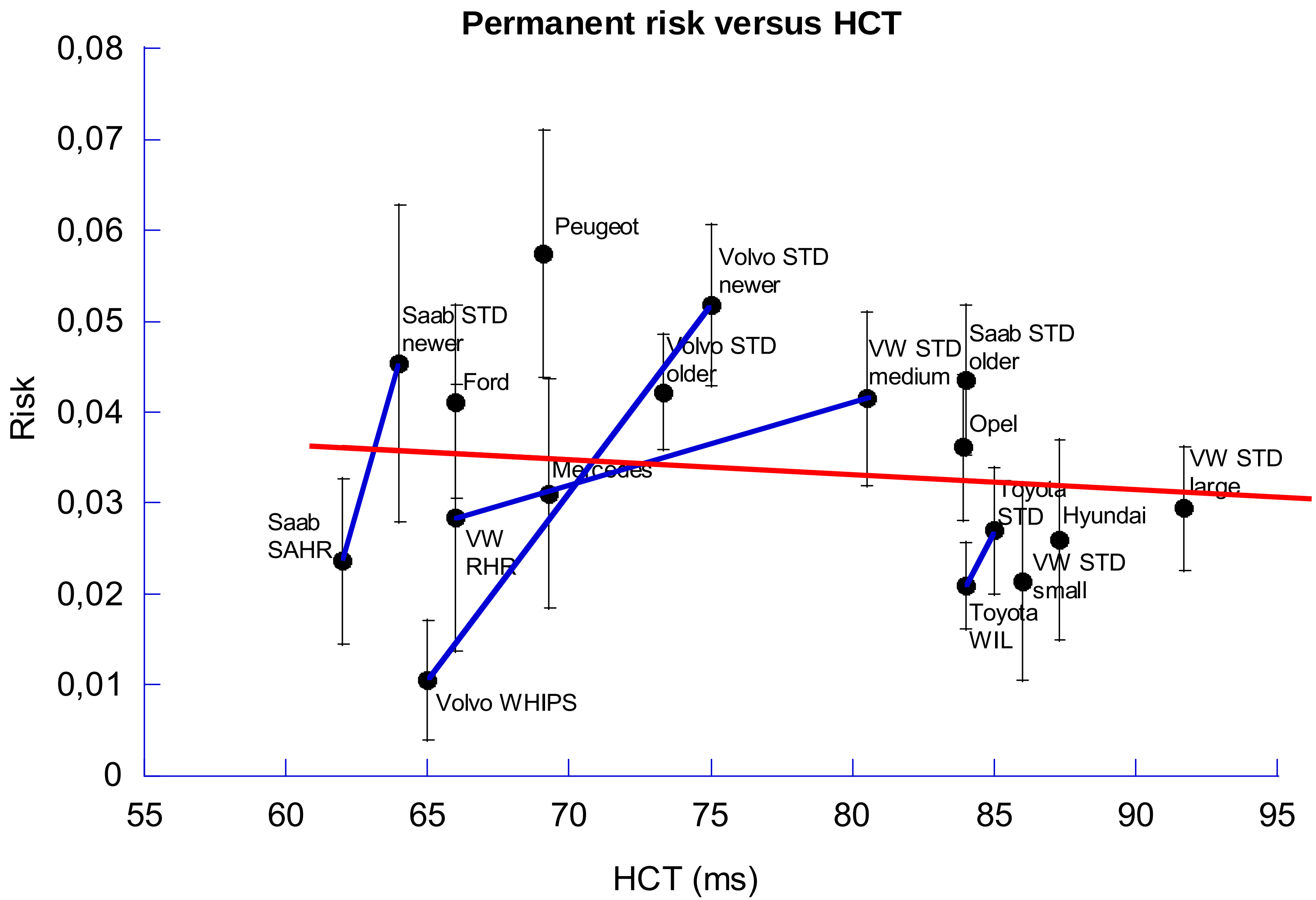
Results: Occipital rel. T1 x-disp. versus permanent medical impairment



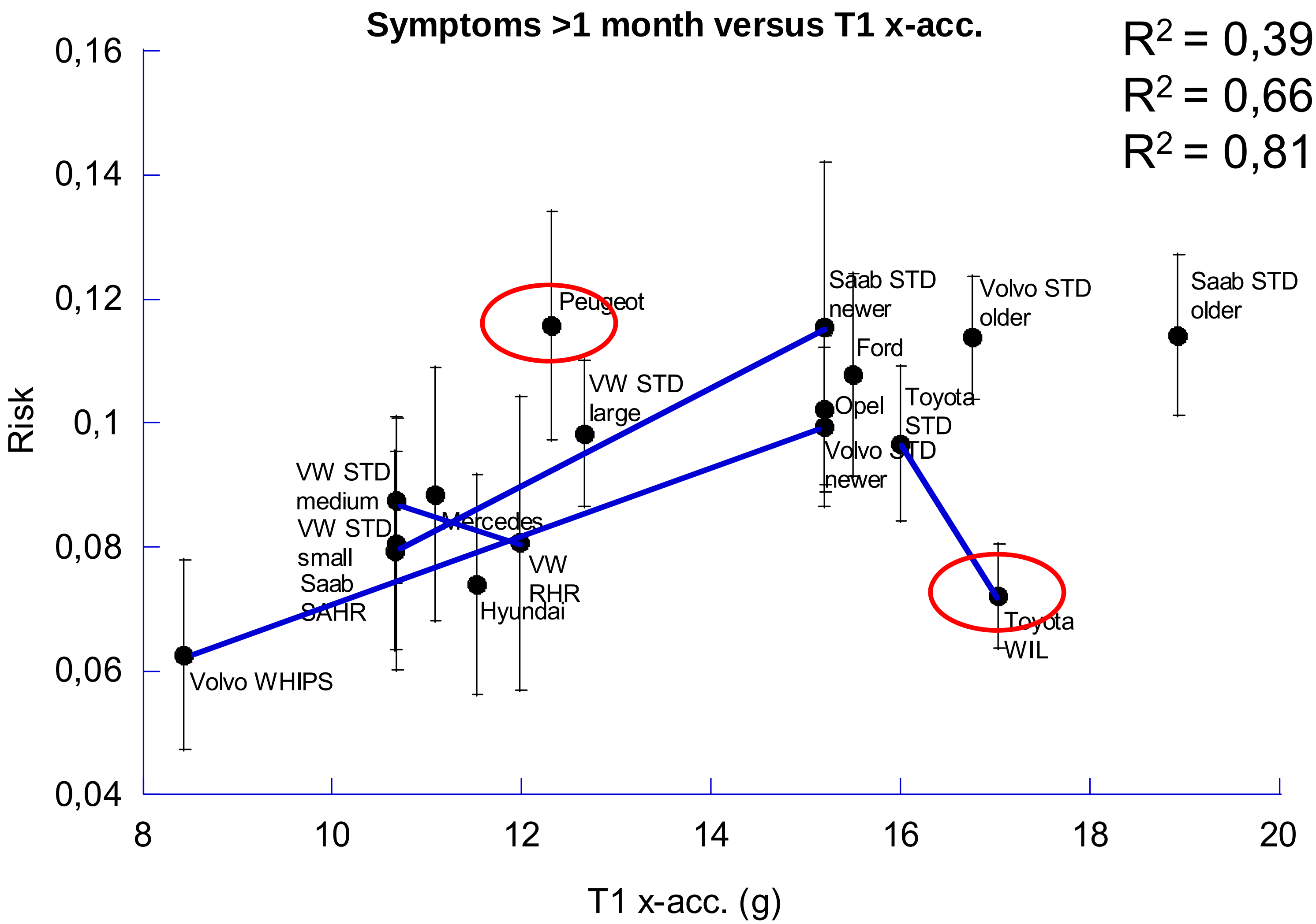
Results: L1x-acc. versus permanent medical impairment



Results: Head Contact Time versus permanent medical impairment

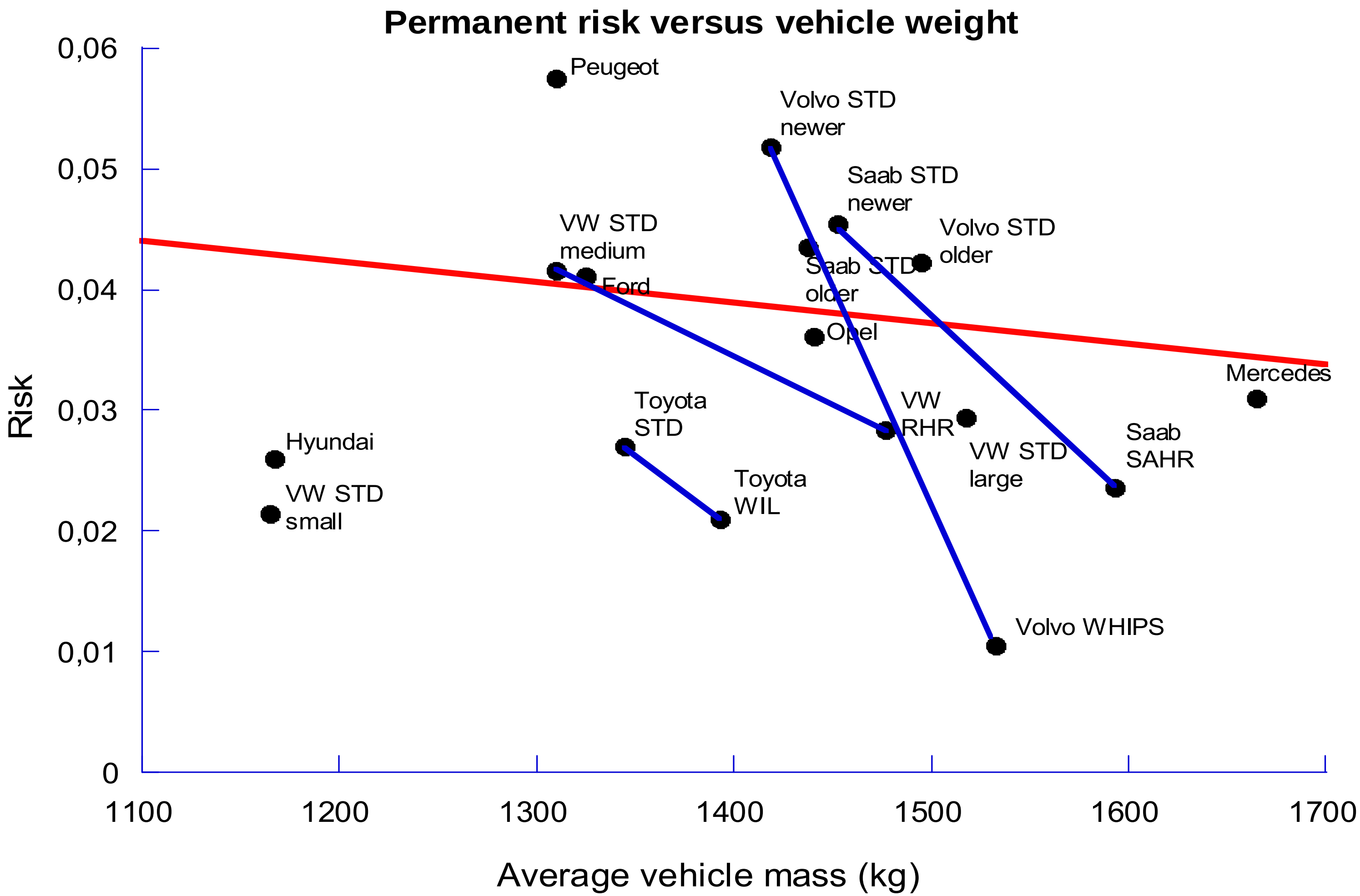


Discussion 1: Effect of outliers



R^2 = 0,39 for 17 datasets
R^2 = 0,66 for 16 datasets
R^2 = 0,81 for 15 datasets

Discussion 2: Is the risk reduction only due to vehicle mass increase?



Discussion 3: Differences compared to interim report and ESV paper

- Seat test selection criteria modified
  - 12 Thatcham tests and 5 Autoliv tests
- Number of insurance cases and seat tests included
  - 2976 cases and 11 vehicle groups in 2011 report
  - 6665 cases and 12 vehicle groups in the ESV paper
  - 7453 cases and 17 vehicle groups in this report
- Accident sampling period reduced due to lack of control of crash direction prior to 1998
- Seat groups now more homogeneous
  - Vehicle mass range from 1023 to 1533 kg
  - 44% to 67% were females

Discussion 4: Injury risk measures

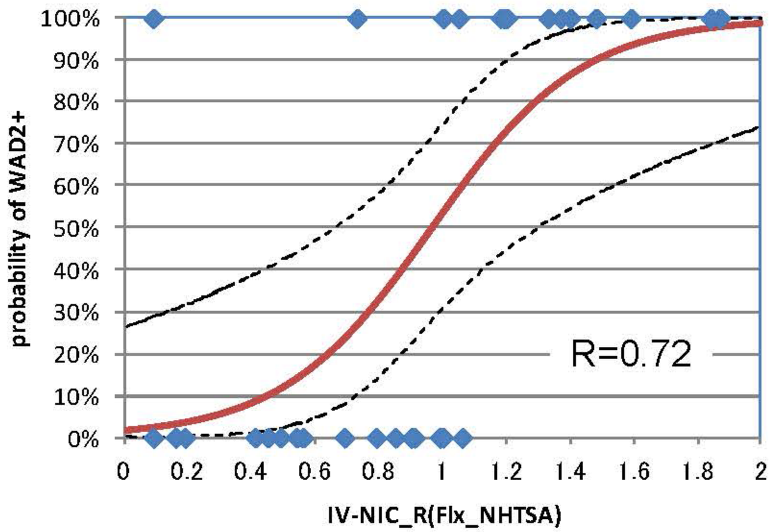
- About 35% of rear-end impacts in Sweden with modern cars results in initial symptoms

  3.5% risk in case you have initial symptoms =

  1,2% risk in case you are in a collision
- Risk of initial symptoms and long term symptoms proportional for most vehicle models

Discussion 5: Compared to GTR Phase II

- Risk Curves of IV-NIC(R) for Flexion:
  - The Risk Curve (R^2=0.49) from 20 cases accident simulation
  - The Risk Curve (R=0.72) from PMHS tests (17km/h and 24km/h) 4. Injury Parameters and Injury Criteria



Conclusions 1

- Grouping of seats is an important aspect of the methodology
- Issues with the reliability of some of the seat tests

Conclusions 2

- NIC, Occipital condyles relative T1 x-displacement and L1 x-acceleration correlate with long term injury risk.
- Initial recommendations for tolerance levels have been made (NIC, Occipital condyles relative T1 x-displacement and L1 x-acceleration)
- Neck extension, Nkm, Upper Neck Fx and T1 x-acceleration may be candidates but appear to be sensitive to set model inclusion
- Additional parameters may predict PMI and long term symptoms.

End!

Many thanks to Thatcham and Autoliv for providing BioRID seat test data!

Remarks during the meeting

- There were remarks on some of the assumptions that was made to facilitate this study.
  - Compensation for coding differences of injury risk over the years the accidents were collected
  - Grouped data was used
  - Data was used that originated from tests that were carried out according to state of the art procedures. These procedures, calibration routines and dummy build level have been updated since then.
  - Single delta V and single acceleration pulses were used that did not match the insurance data
  - Were also injuries to other body regions included
- In the following pages additional information related to these comments will be presented.

Compensation for coding differences of injury risk

- Background
  - A continuously more strict attitude to accept a final impairment degree by the Swedish social insurance agency could be identified during the sampling period.
- A method to compensate for this change have been developed that is independent of the introduction of improved seat systems or vehicle model updates.
  - Groups were established for which the year of first introduction was identical (grouped into 3 year periods)(a seat model change or similar results in a new year of introduction).
  - Average risks were calculated for these groups for 3 year intervals.
  - A trend line was calculated for each group.
  - These trend lines were found to be rather consistent among different groups (with identical year of first introduction).
  - An average trend line was calculated and used to compensate for injury impairment setting change.
- Text that explains how this was carried out (next page):

Medical expertise in Sweden has gradually been classifying whiplash associated symptoms more restrictively. Given that for vehicles with identical introduction year the risk of long term symptoms, given that you have initial symptoms, should not change over the sampling period a reduction factor in classification of symptoms can be calculated. This reduction in the likelihood of classifying an injury as a permanent medical impairment appears to be linear over the sampling period, from 1998 to 2011, and was found to be 15% per year for a large number of vehicle models and for a representative distribution of males and females. Identically, the reduction in classification of those with symptoms lasting for longer than 1 month was found to be 7% per year. These changes were used to compensate the insurance data used in this study to be valid for year 2010. By doing an adjustment for accident year for each crash injury outcomes from all cars could be compared with each other.

Grouped data was used

- For the included groups a thorough study to identify differences in seat design between vehicle models were carried out.
- Only groups with rather consistent seat designs were used in this study.

Data was used that originated from tests that were carried out according to state of the art procedures. These procedures, calibration routines and dummy build level have been updated since then.

- These routines are established mainly to reduce the scatter in responses and not to shift the responses.
- Carrying out this study with newest build level and calibration routines would most likely reduce scatter and improve the power of this study.
- Carrying out this study with second hand seats, of which a few would be rather old, is an option but also introduces uncertainties.

Single delta V and single acceleration pulses were used that did not match the insurance data

- The purpose with the study is to determine if a single test with the BioRID II can be used to assess risk of long-term symptoms following a rear-end impact.
- Hence a single representative pulse was used.
- A slightly higher delta-V would provide better match between the real life pulse and the test pulse.

Were also injuries to other body regions included

- Only neck related injuries that was cased in rear (+/-30 deg) end impacts were included.