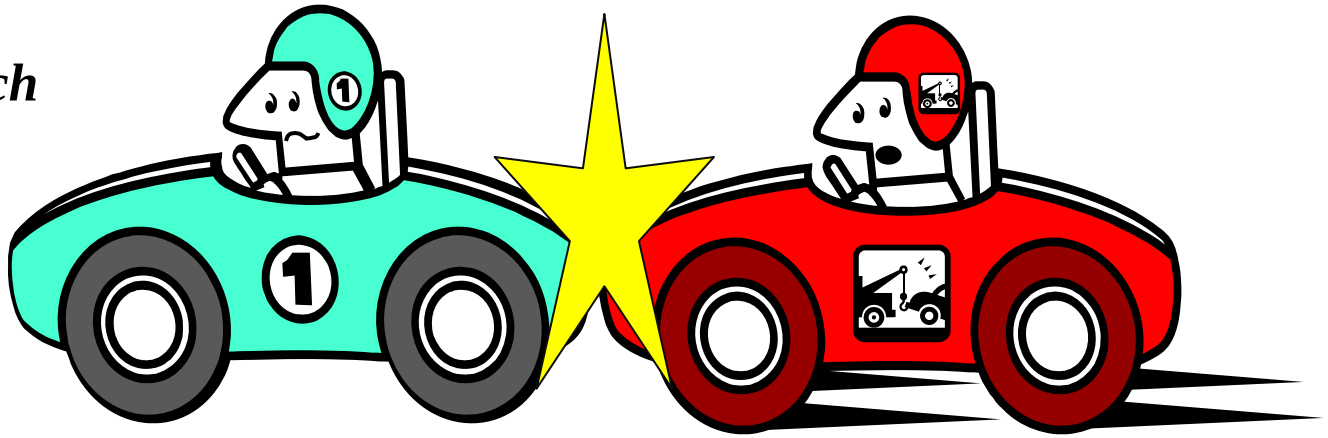
GTR7-06-09

Evaluation of Seat Performance Criteria for Rear-end Impact Testing

Johan Davidsson
Chalmers University of Technology

Anders Kullgren
Folksam Research



What is needed in a GTR?

Crash test dummy with acceptable:

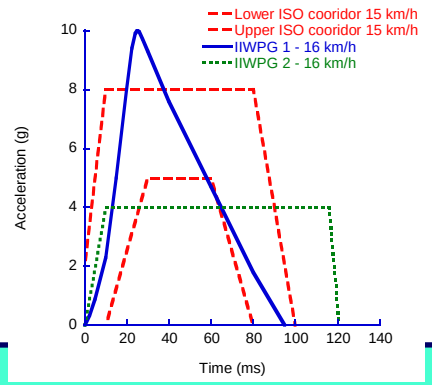
- Biofidelity
- R&R
- Robustness
- User friendliness, etc

Drawing package and material specification

Calibration routines

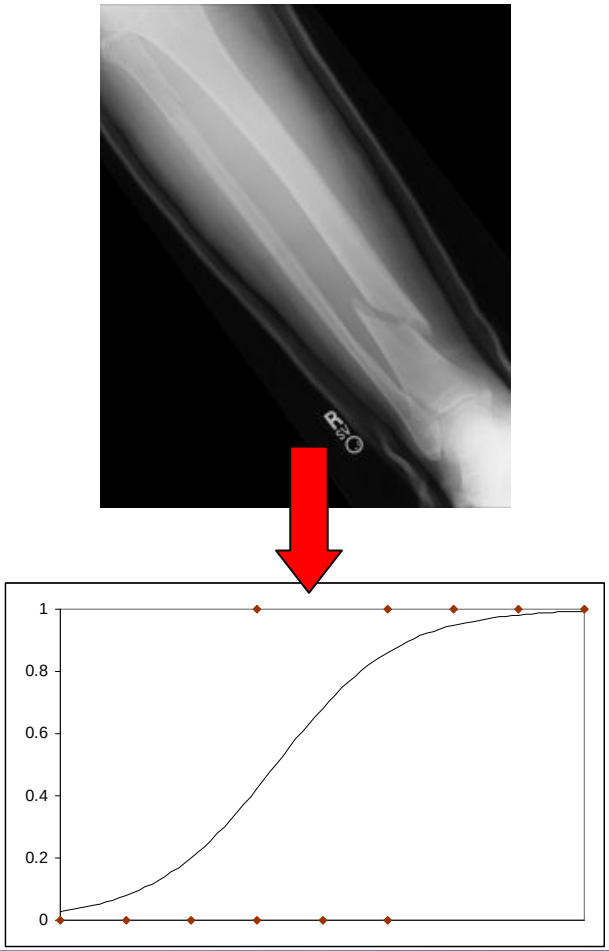
Seating routines for all types of seats on the market

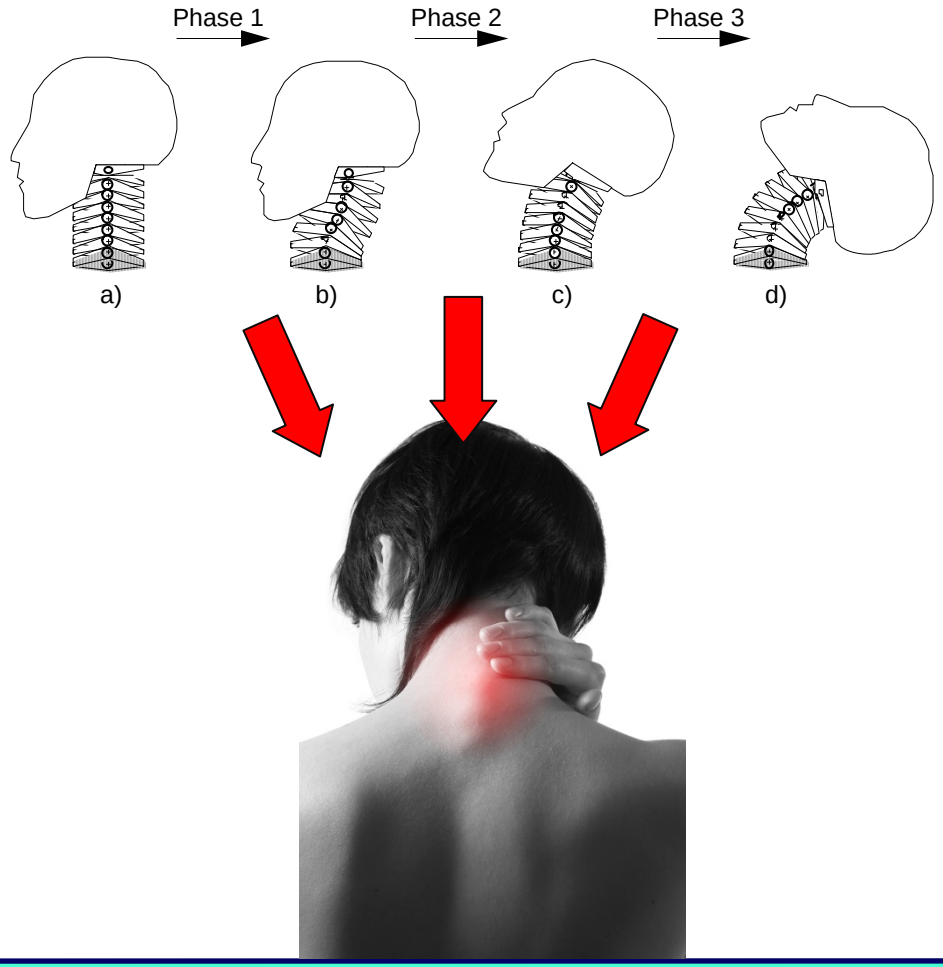
Test protocol incl. seat installation, sled pulse, etc



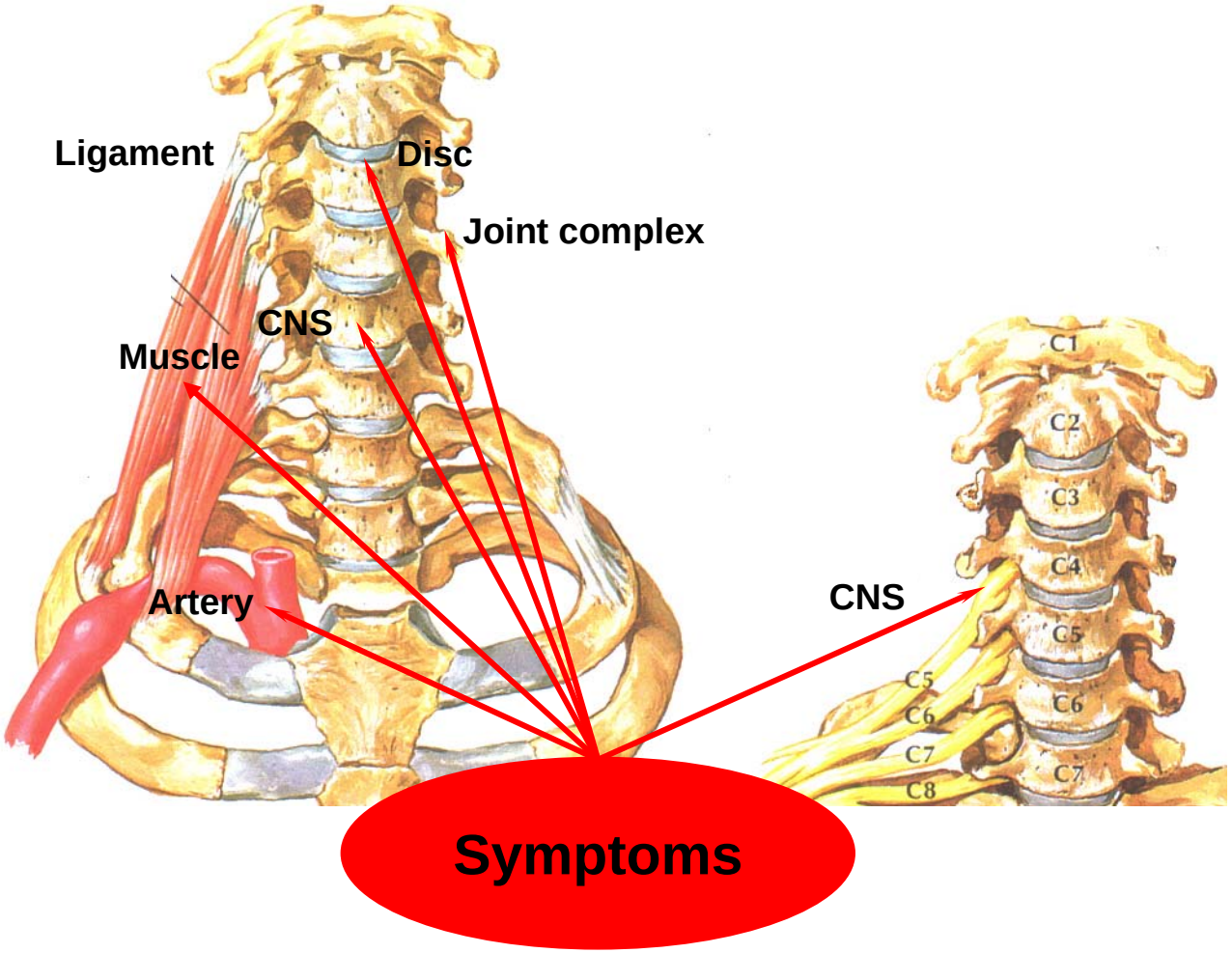
Injury criteria and reference value:

Relate measured load to risk of injury

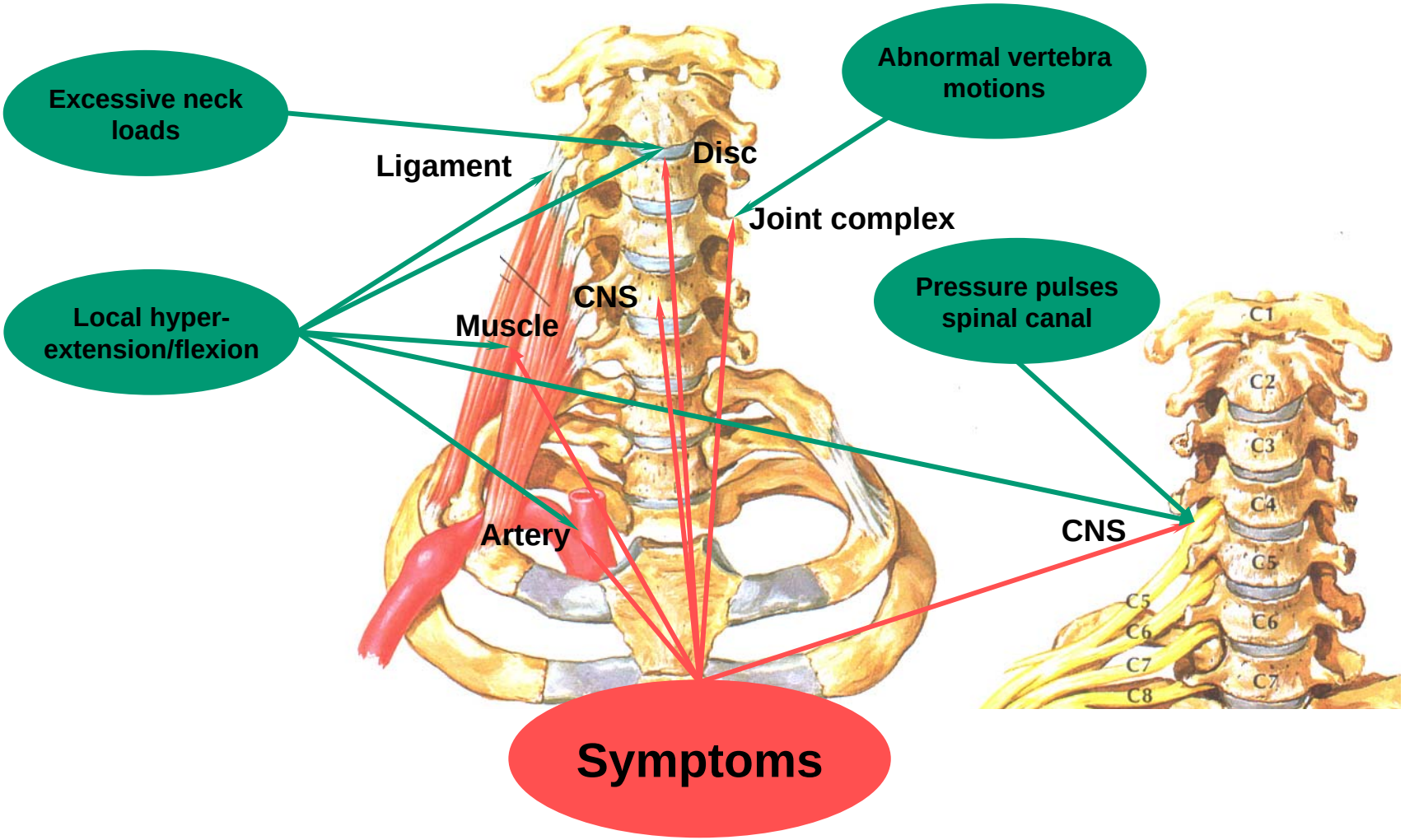




Injury location

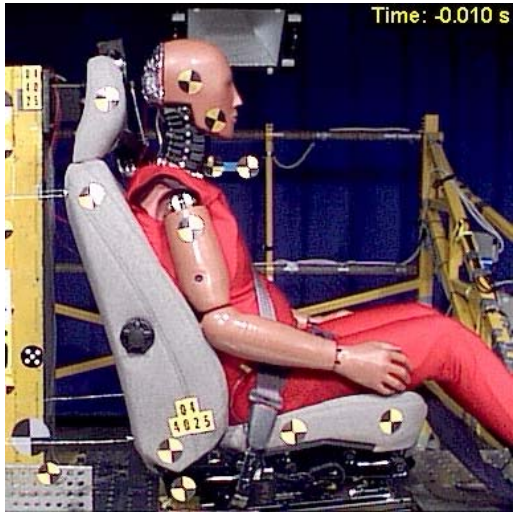


Injury mechanisms



Method

Investigate the correlation between whiplash injury risks, as calculated from real real-life insurance data, and between crash test dummy values



Data used

Insurance data

Folksam insurance data incl. collision that occurred between 1995 and 2008

Medical journals, +/-30 deg. from straight rear-end

Risk of symptoms for more than one month (> 1 month)

Risk of permanent medical impairment (Permanent)

Seat test data

Test by Autoliv and Thatcham between 2003 and 2006

BioRID II build level E or G

H-point tool:
TechnoSports, Inc.,
Automotive Accessories, Ltd.,

Grouping insurance injury claim data

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

Volvo w/o WHIPS, n=254, 1497 kg	
S40/V40	96-99
850	91-97
V70	97-00

Volvo with WHIPS, n=308, 1510 kg	
S40/V40	00-04
S40/V50	04-
V70	00-06
S60	01-99
S80	98-06

Saab w/o SAHR, n=308, 1460 kg	
Saab 900	94-98
Saab 9000	85-97

Saab with SAHR, n=165, 1578 kg	
Saab 9-3	98-02
Saab 9-5	98-09

Toyota w/o WIL, n=294, 1342 kg	
Avensis	98-02
Camry	92-96
Camry	97-01
Corolla	98-02
RAV4	95-99
Starlet	97-99

Toyota with WIL , n=466, 1320 kg	
Auris	07-
Avensis	03-08
Camry	01-03
Corolla	02-07
Corolla Verso	04-10
Prius	04-09
Rav4	00-04
Rav4	05-
Yaris and Yarsi Versio	99-05
Yaris	05-

European Enhanced Vehicle-safety Committee

VW group w/o RHR, n=698, 1386 kg	
Audi A2	99-05
Audi A3	96-03
Audi A4	95-00
Audi A6	95-97
Audi A6	98-05
Seat Ibiza	03-
Seat Ibiza/Cordoba	99-02
Seat Toledo/Leon	99-04
Skoda Octavia	97-04
Skoda Fabia	00-
VW Bora	99-04
VW Golf	98-04
VW Passat	97-05
VW Polo	02-

Hyundai STD, n=128, 1123 kg	
Accent	99-06
Atos	99-03
Atos	04-
Elantra	04-
Getz	03-
Matrix	01-
Santa Fe	00-05
Sonata	01-05

VW group with RHR, n=56, 1472 kg	
Audi A3	03-04
Audi A3	05-06
Audi A4	01-06
Audi A6	05-06
Seat Ibiza	03-
Seat Altea	04-
Skoda Octavia	05-
VW Touran	03-
VW Golf/Jetta	04-
VW Passat	05-

Peugeot STD, n=176, 1289 kg	
206	98-05
306	93-01
307	01-
406	96-04

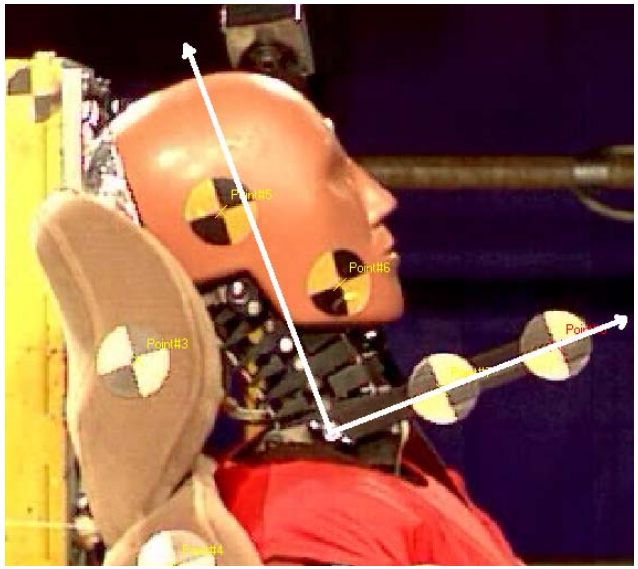
Opel STD, n=270, 1271 kg	
Astra	92-97
Astra	98-04
Corsa	00-06
Vectra	96-01
Vectra	02-08

European Enhanced Vehicle-safety Committee

Groups	Model	Prod. year	WAD mitigation system[2]	Year tested[3]	Test facility	BioRID II version	H-point tool [4]	Backset (mm)
Hyundai	Accent	99-06	None	2004	Thatcham	G	AA	68
Opel	Meriva	02-10	None	2004	Autoliv	E	TS	105
Peugeot	206	98-05	None	2004	Thatcham	G	AA	76
	307 [1]	01-	None	2003	Autoliv	E	TS	70
SAAB	900	94-97	None	2006	Autoliv	G	AA	30
	9-5	98-09	SAHR	2004	Autoliv	E	AA	40
Toyota	Corolla	98-02	None	2005	Autoliv	E	AA	65
	Corolla Versio	04-10	WIL	2005	Autoliv	E	AA	95
	Avensis [1]	03-08	WIL	2004	Autoliv	E	AA	75
Volvo	V70	97-00	None	2006	Autoliv	G	AA	74
	850 [1]	91-97	None	2003	Autoliv	E	TS	60
	V/S70	00-06	WHIPS	2006	Autoliv	G	AA	40
VW	VW Golf	98-04	None	2003	Thatcham	E?	AA	-
	VW Polo [1]	02-	None	2003	Autoliv	E	TS	65
	Audi A6	05-06	RHR	2005	Autoliv	E	TS	55

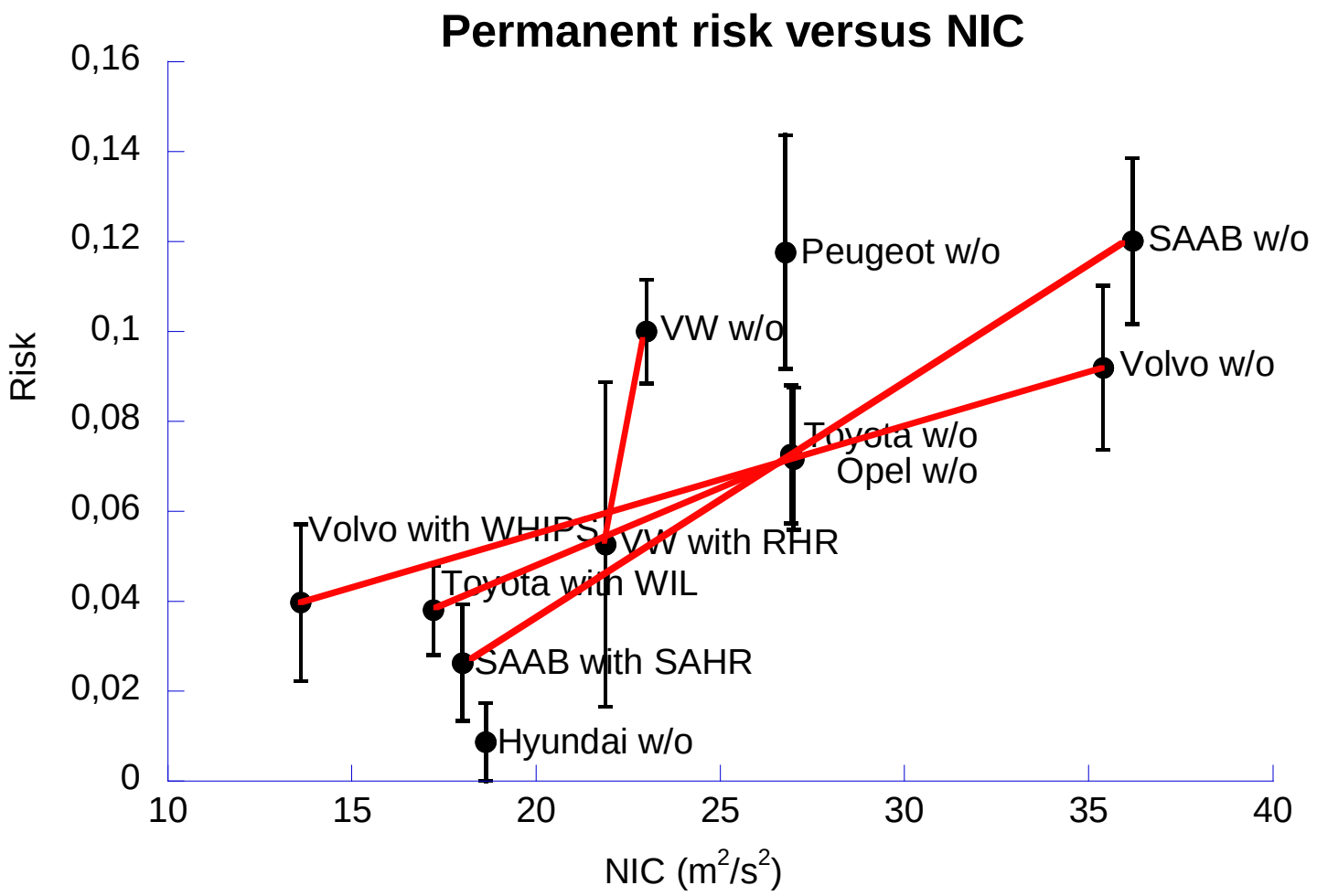
Note 1 From this test only film data was used to complement the other seat test in the same group
Note 2 No system is activated before or during the impact
Note 3 When the test was conducted at Autoliv in 2003 a trapezoid 16 km/h shaped sled pulse was used.
Note 4 TS refers to TechnoSports, Inc., USA and AA refers to Automotive Accessories, Ltd., UK

Studied parameters

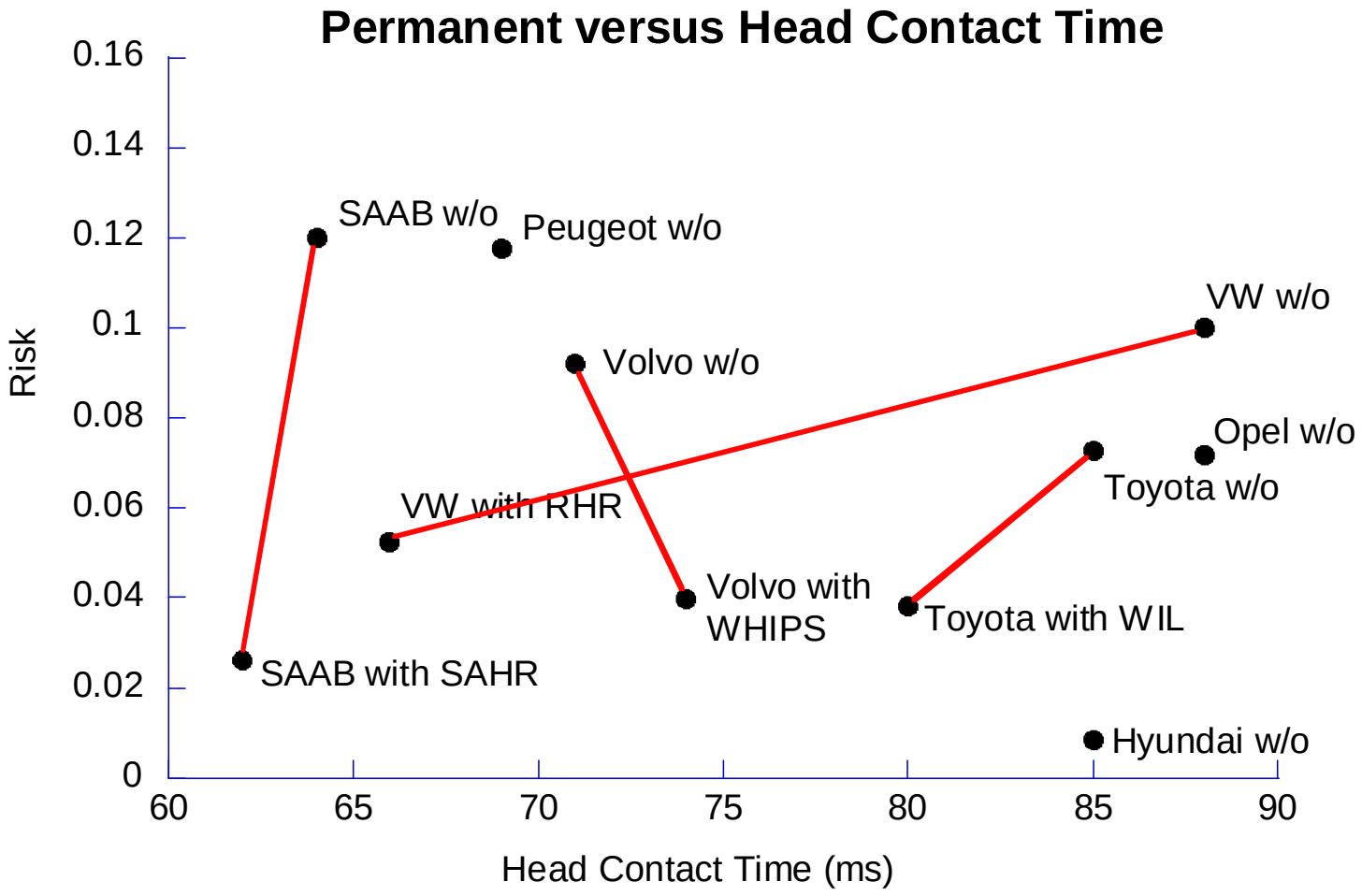


Maximum Neck Injury Criteria (NIC)
Maximum Neck Force Criteria (N_{km})
Maximum Lower Neck Loads Criteria (LNL)
Maximum Head x- and z-acceleration
Maximum C4 x- and z-acceleration
Maximum T1 x- and z-acceleration
Maximum T8 x- and z-acceleration
Maximum L1 x- and z-acceleration
Maximum Pelvis x- and 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)

Results


Permanent risk versus NIC
Risk
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
10
15
20
25
30
35
40
NIC (m²/s²)
Peugeot w/o
SAAB w/o
VW w/o
Volvo w/o
Toyota w/o
Opel w/o
Volvo with WHIPS
VW with RHR
Toyota with WIL
SAAB with SAHR
Hyundai w/o

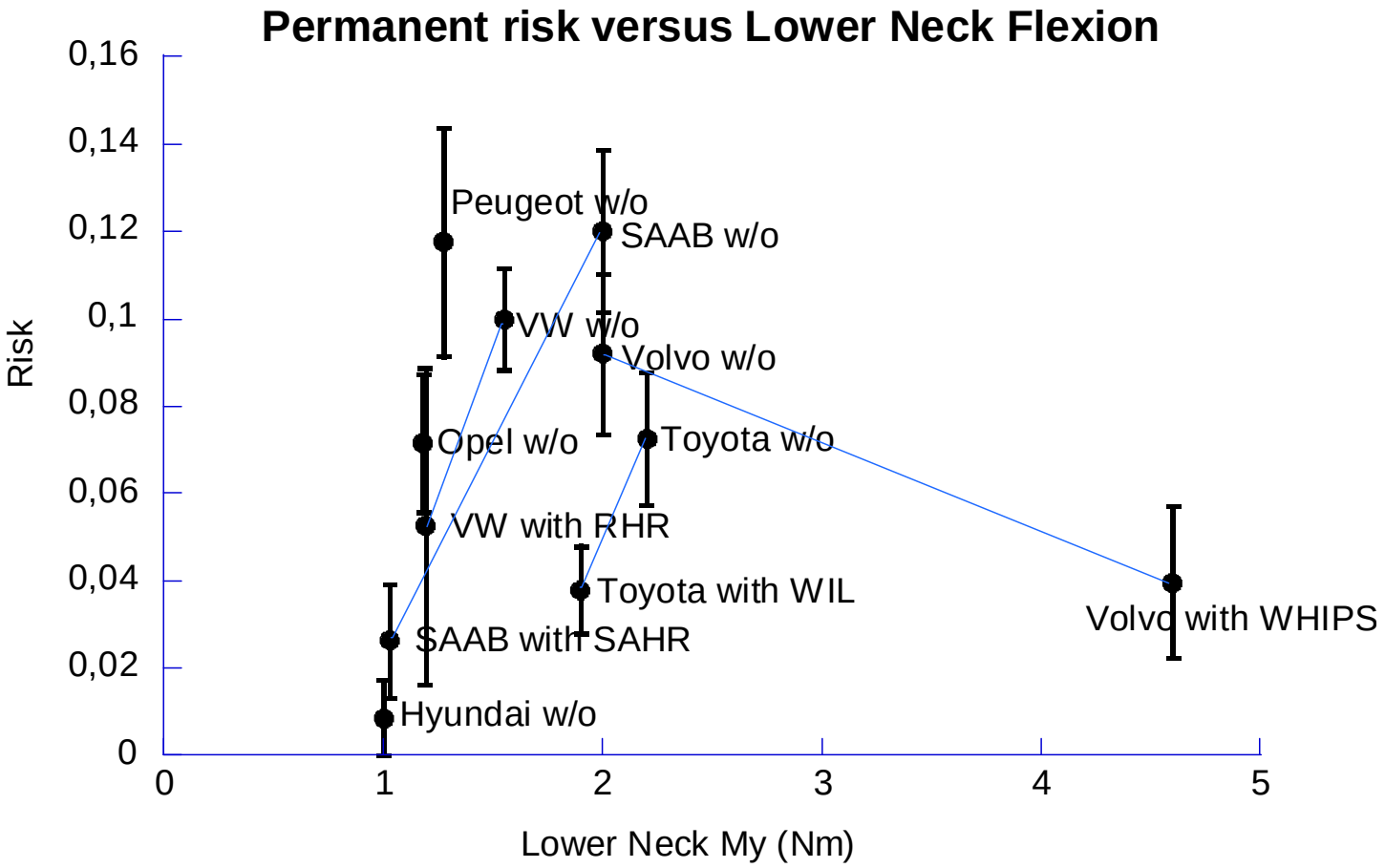
Results


Permanent versus Head Contact Time
Risk
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
60
65
70
75
80
85
90
Head Contact Time (ms)
SAAB w/o
Peugeot w/o
VW w/o
Volvo w/o
Opel w/o
Toyota w/o
VW with RHR
Volvo with WHIPS
Toyota with WIL
SAAB with SAHR
Hyundai w/o

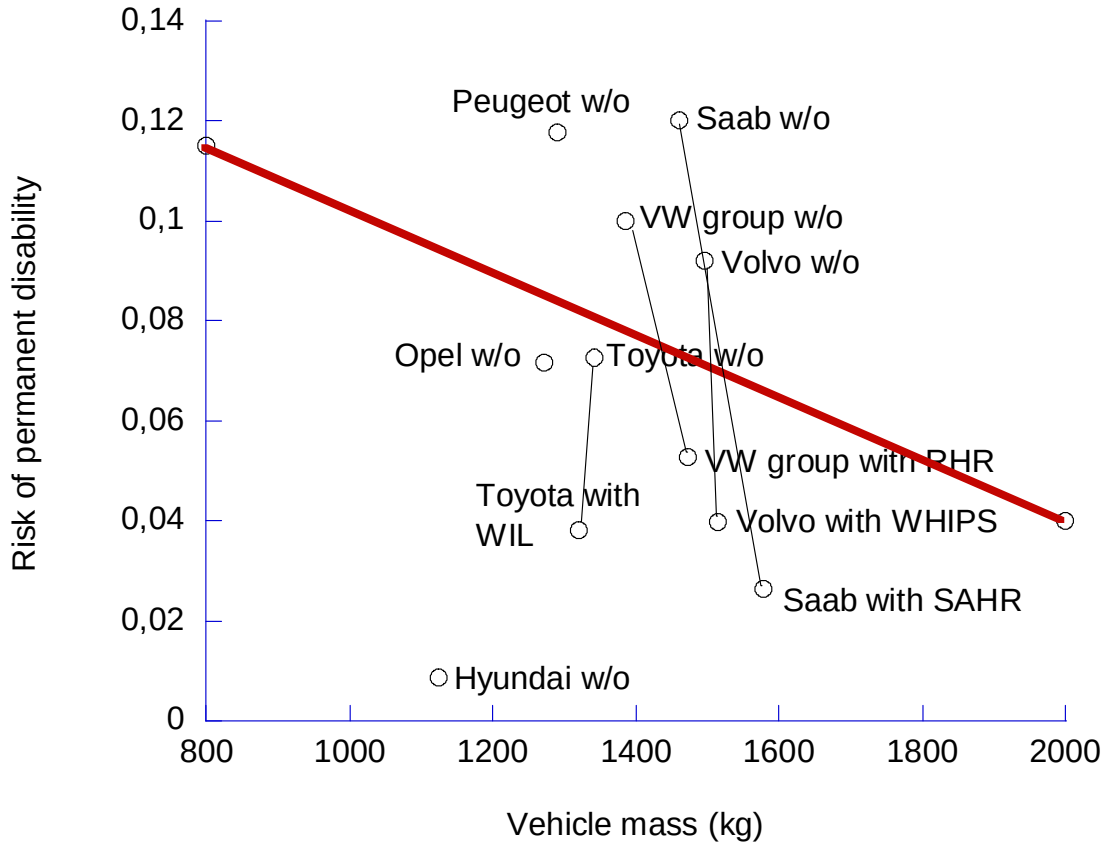
Results - Regression

Parameter	r^2 (permanent injury)
NIC	**0.62**
Upper Neck Shear Force (Fx, head rearward)	**0,60**
Head relative T1 angular displacement	0,57
L1 x-acceleration	0,53
N_{km}	0,50
Lower Neck Compression Force ($-F_z$)	0,36
Occipital condyles x-displacement (OC-x)	0,30
Head Contact Time	-
Head Rebound x-velocity	-

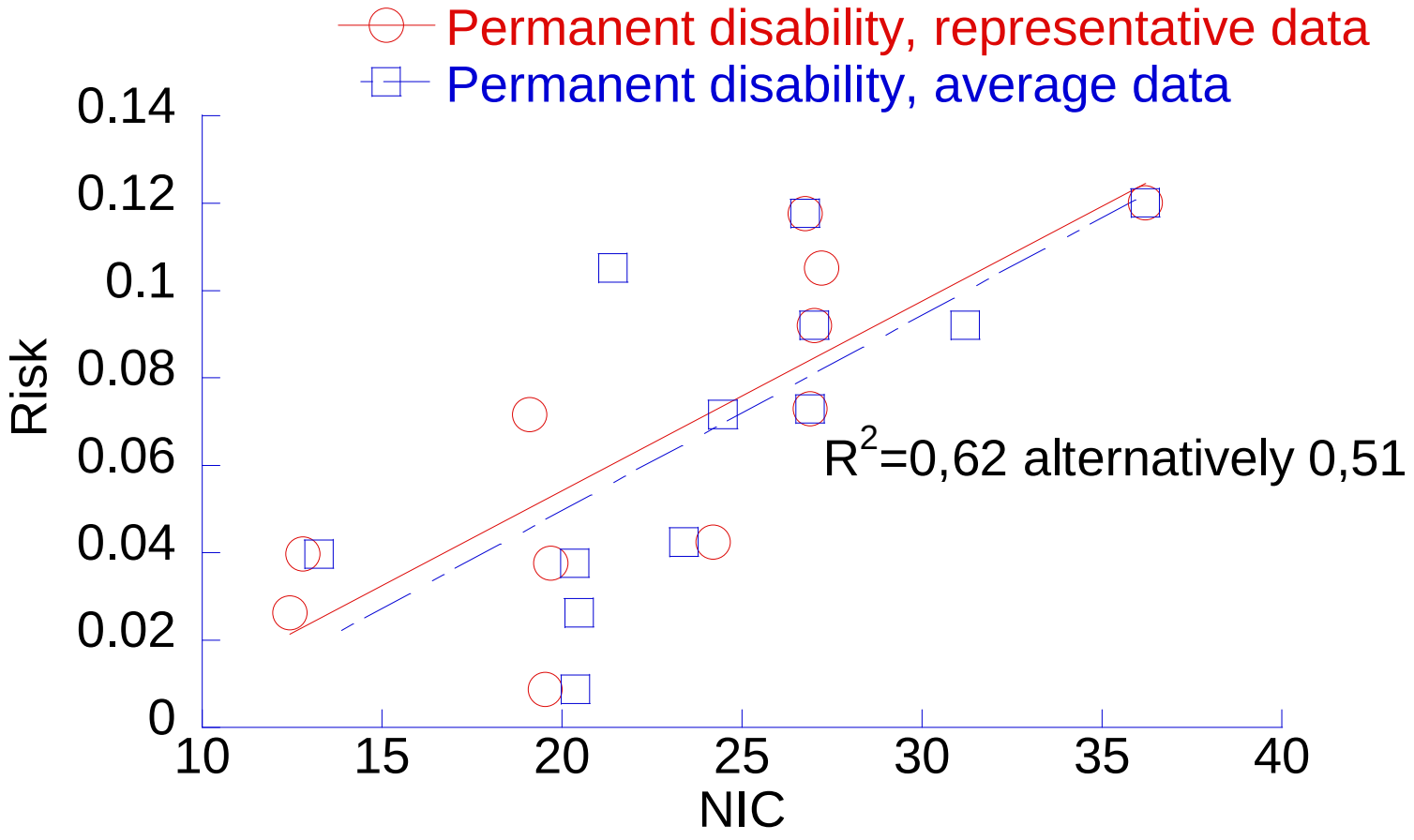
Discussion 1: Effect of outliers



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

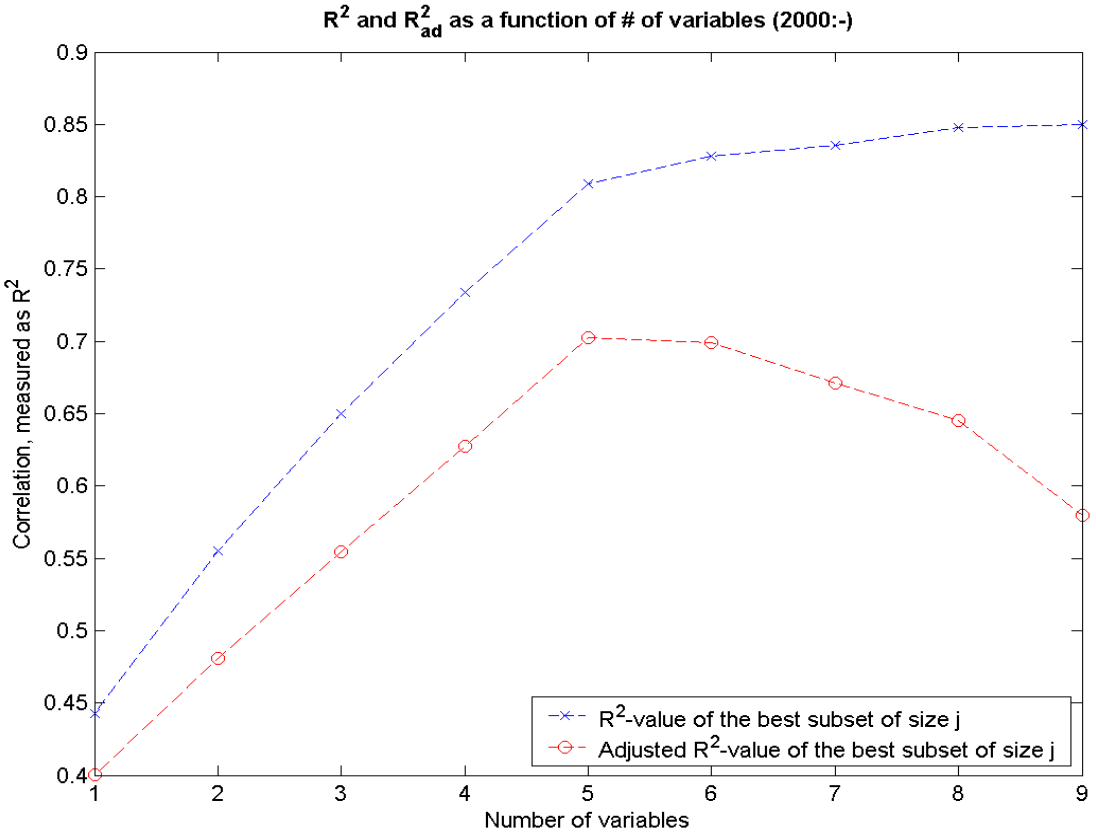


Discussion 3: Correlation sensitivity



Discussion 4: Multiple Injury Mechanism

Multiple injury mechanisms call for multiple parameter regression



Future 1

Additional insurance data (3 times more cases)

Additional seat tests

Evaluate the use of an alternative statistical approach:

- Predictability
- Failure analysis

Develop injury risk functions

Gender issues

Conclusions 1

Grouping of seats is an important aspect of the methodology

Issues with the reliability of some of the seat tests

Limitation of a single sled pulse

Recommendation for future work including new statistical method and extension of database

Conclusions 2

NIC and Upper Neck Shear Force correlate with long term injury risk (in agreement with other studies).

Initial recommendations for tolerance levels have been made (NIC, Nkm and Upper Neck Shear Force)

These findings are supported by other studies:

Boström and Kullgren 2007

Ono et al. 2009

Cappon et al 2005