Designing for equity – example WHIPS

Lotta Jakobsson, PhD

Senior Technical Leader, Injury Prevention
Volvo Cars Safety Centre

Adjunct Professor, Vehicle Safety
Chalmers University of Technology

L. Jakobsson et al. / Accident Analysis and Prevention 32 (2000) 307–319

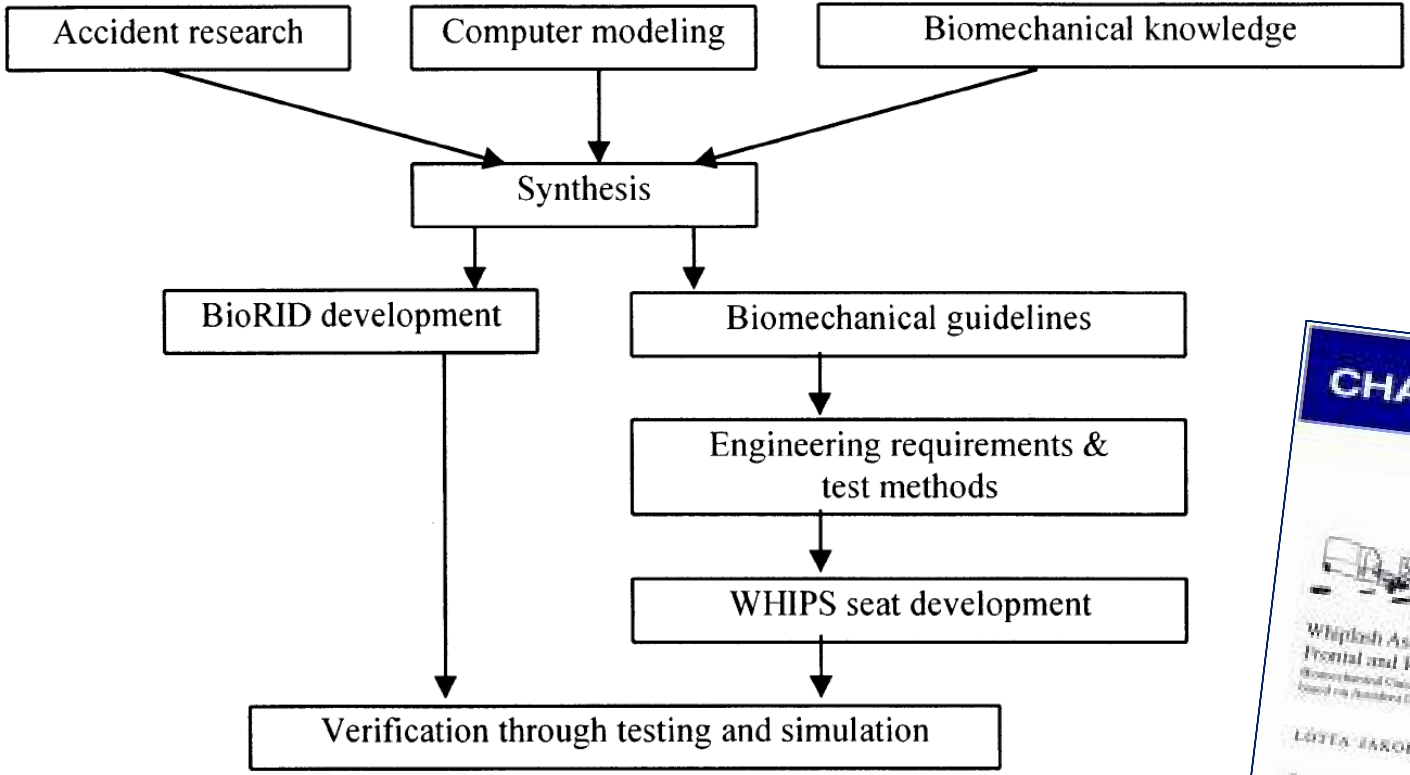
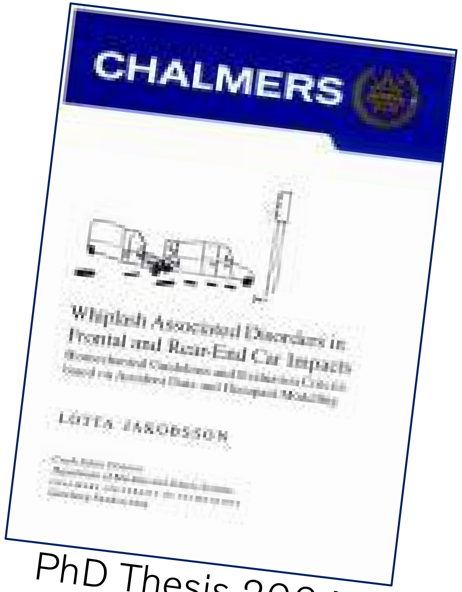


Fig. 1. Volvo's whiplash protection study (WHIPS).

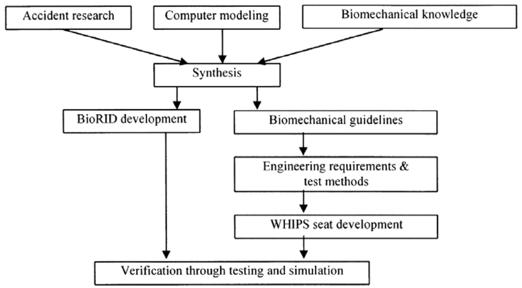


PhD Thesis 2004

Whiplash injuries in rear-end impacts

VOLVO

L. Jakobsson et al. / Accident Analysis and Prevention 32 (2000) 307–319



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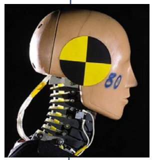
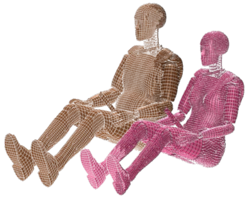
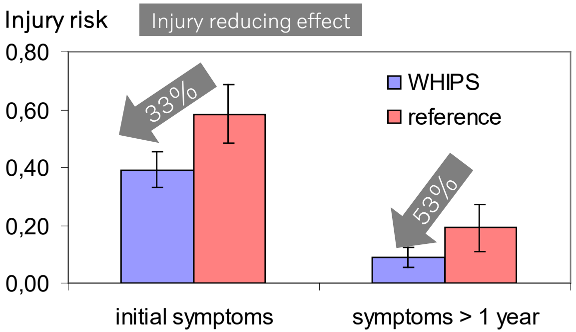
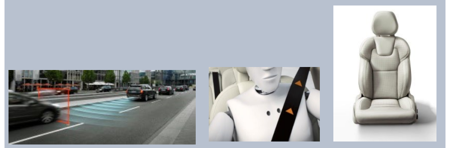


WHIPS

WHIPS was used as benchmark for BioRID's injury assessment measures in rating methods, e.g., IIHS and EuroNCAP







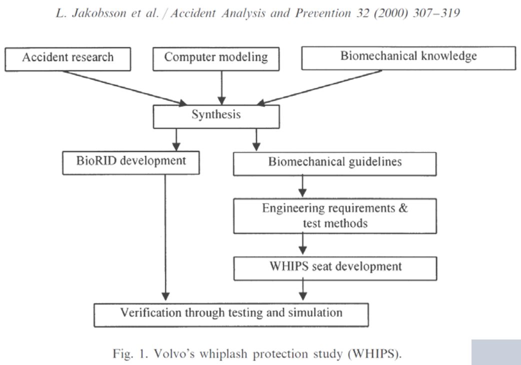
"WHIPS II"

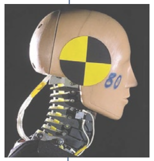
1990 2000 2010 2020

VOLVO

Whiplash injuries in rear-end impacts, **the content of the presentation**

Way of working, examples of assessment methods used

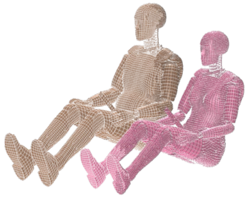


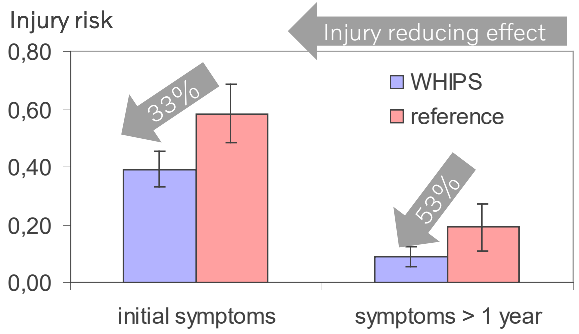


Real-world data and protection principles

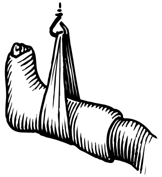
☆☆☆☆☆

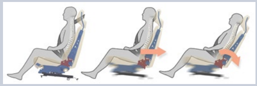
WHIPS was used as benchmark for BioRID's injury assessment measures in rating methods, e.g., IIHS and EuroNCAP



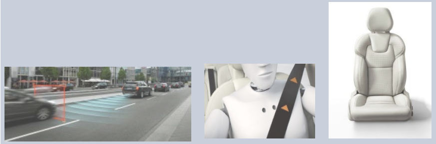


Additional examples





WHIPS

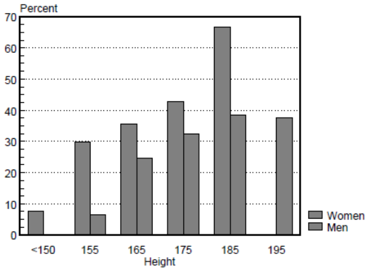


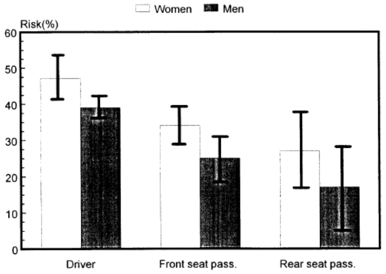
"WHIPS II"

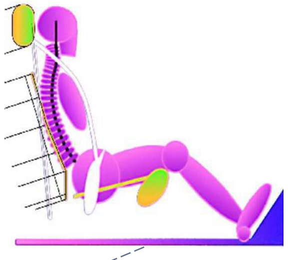
1990 2000 2010 2020

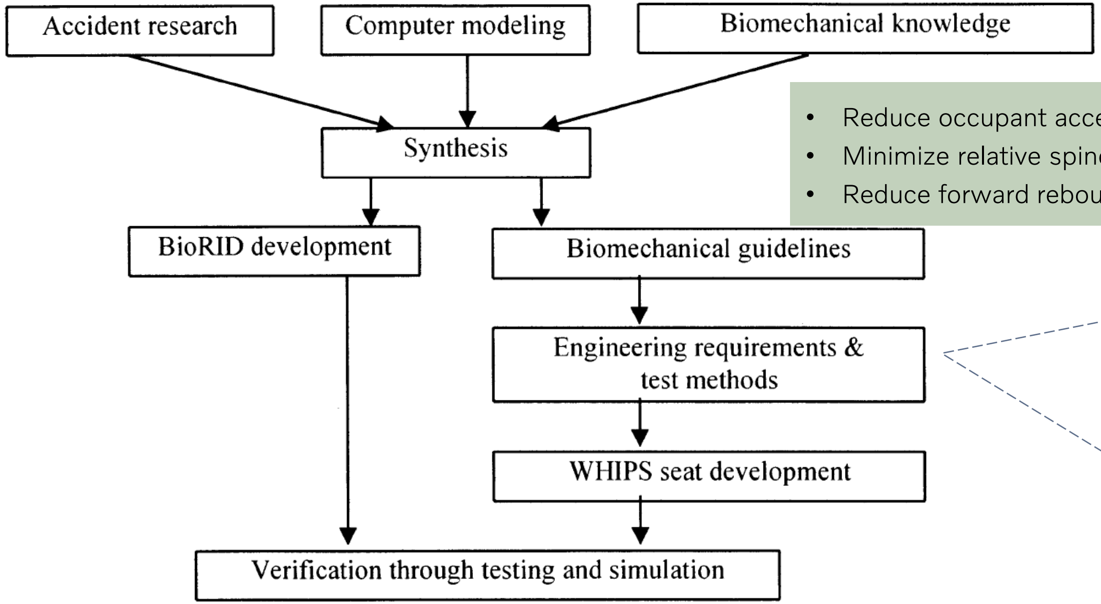
V O L V O

References:
Jakobsson et al. IRCOBI 1994, Lundell et al. ESV 1998, Lundell et al. SAE 1998, Jakobsson et al. AAP 2000









- Reduce occupant acceleration
- Minimize relative spine movements
- Reduce forward rebound

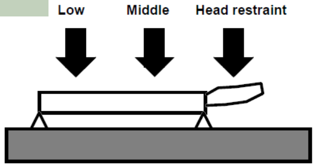


Figure 7. Backrest sub-system drop test

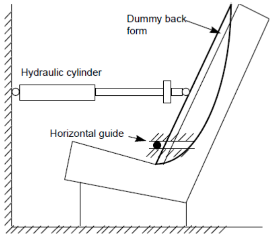


Figure 9. Energy Absorption Test Set-up

References:
Jakobsson et al. IRCOBI 1994, Lundell et al. ESV 1998, Lundell et al. SAE 1998, Jakobsson et al. AAP 2000

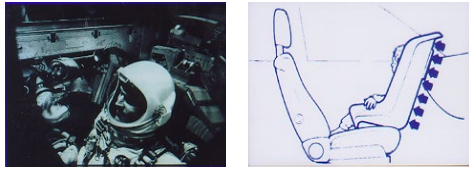
Biomechanical guidelines

Reduce occupant acceleration

- Accident data
- Basic crash dynamic knowledge

Minimize relative spine movements

- Occupant simulation
- Injury mechanism research



Minimize forward rebound

- Seat belt interaction during forward rebound suggested as injury-producing
- Accident data

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Guidelines for and the Design of a Car Seat Concept for Improved Protection against Neck Injuries in Rear End Car Impacts

Björn Lundell, Lotta Jakobsson, Bo Alfredsson and Clas Jernström
Volvo Car Corp.

Irene Isaksson-Hellman
Volvo Data Corp.

Example of assessment methods developed and used

Sub-system drop test

Assessing evenness of seatback, addressing *Minimize relative spine movements*

The seat backrest was exposed to drop tests with an impact speed of 5 m/s. Two different impactors were used, one for the backrest having a mass of 10 kg, simulating impact by part of the occupant's torso. The impactor's acceleration as well as the dynamic deflection were recorded. Even though it can be argued that different sections of the torso and pelvis have different masses, only one mass was used. The real differences in mass was considered in the analysis.

The other impactor, applied to the head restraint, is the headform form used for vehicle interior testing, with a mass of 6.8 kg (ECE 1993).

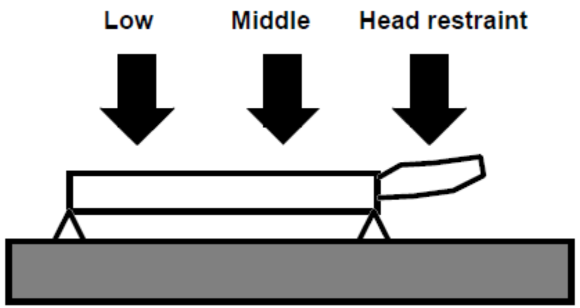

Figure 7. Backrest sub-system drop test

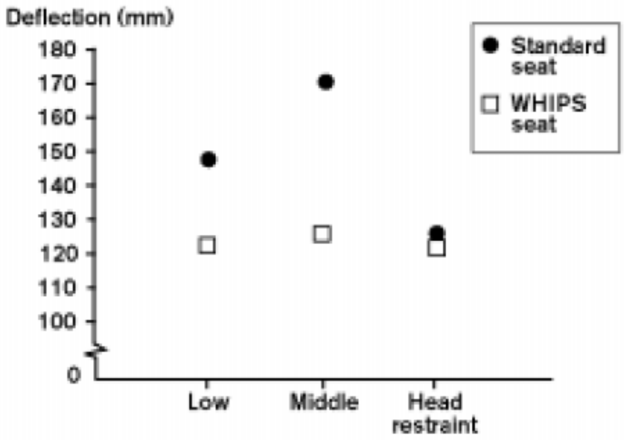

Figure 8. Results from Sub-System Drop Test

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Example of assessment methods developed and used

Guidelines for and the Design of a Car Seat Concept for Improved Protection against Neck Injuries in Rear End Car Impacts

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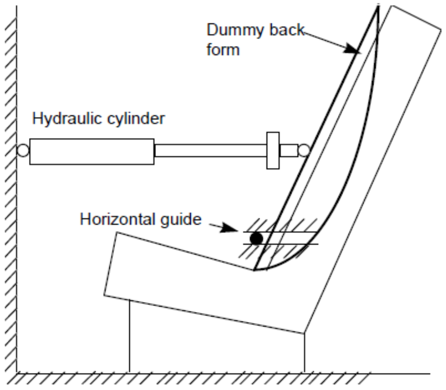
Volvo Car Corp.
Irene Isaksson-Hellman
Volvo Data Corp.

Sub-system energy absorption test

Assessing energy absorption, addressing
Minimize forward rebound

SUB-SYSTEM ENERGY ABSORPTION TEST – This sub-system energy absorption test was designed to measure energy absorption characteristics of the seat backrest. It uses a hydraulic cylinder to press a stiff form, representing the back of a dummy, into the backrest of the seat (ISO 6549) The force-deflection of the form is recorded while loading to different force levels, and also while releasing the load. Doing so, it is possible to calculate the hysteresis for the different load levels, and subsequently the total efficiency of the seat backrest in absorbing energy.



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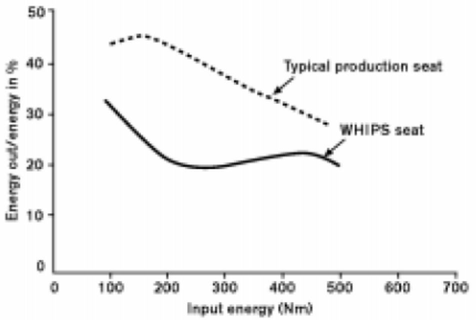


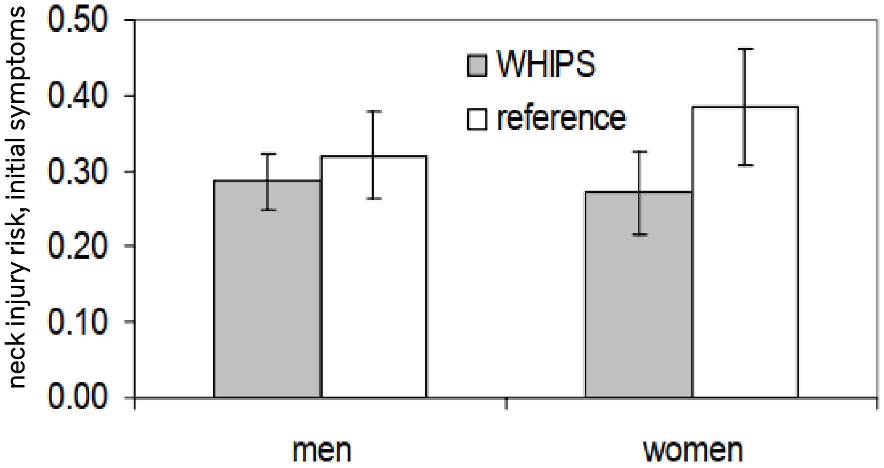
Figure 10. Energy Absorption Test Results

WHIPS real-world benefit

Compared to the prior Volvo seat:

31% reduction of initial symptoms and

51% reduction of long-term symptoms



AIS1 NECK INJURY REDUCING EFFECT OF WHIPS (WHIPLASH PROTECTION SYSTEM)

Lotta Jakobsson and Hans Norin
Volvo Car Corporation, Göteborg, Sweden

ABSTRACT

Rear-end impacts involving Volvo cars from 1999-2002, including 1221 front seat occupants (above 14 years of age and without prior neck problems), are investigated with respect to AIS1 neck injury rate differences between those in WHIPS seats as compared to those in previous Volvo seats. The differences with respect to gender is explored.

The AIS1 neck injury reducing effect of WHIPS as compared to previous Volvo seats is 31% for initial neck symptoms and 51% for neck symptoms lasting longer than one year. The injury reducing effect is higher for women than for men. No clear explanation for the gender differences was found with respect to occupant size.

IRCOBI Conference – Graz (Austria) September 2004

Higher injury risk reduction for women than men

- *Equal risk for men and women in WHIPS seat*

References:
Lundell et al. ESV 1998, Jakobsson et al. AAP 2000, Jakobsson et al. IRCOBI 2015

VOLVO

WHIPS (1998)

Head restraint geometry

Backrest characteristics

Add-on recliner mechanism for energy absorption

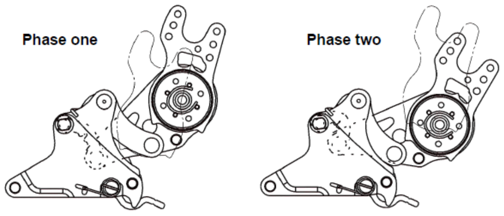


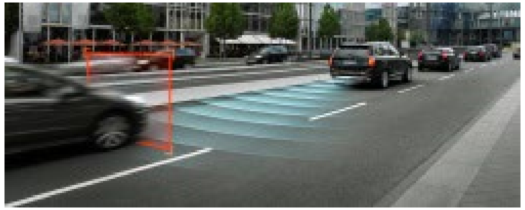
Figure 7. WHIPS recliner schematic motion.

WHIPS II (2015)

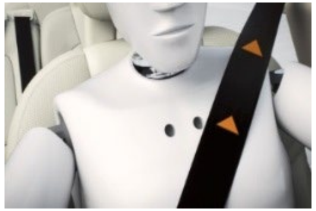
+ Adapted seat frame design

+ Integrated energy absorption

+ Pre crash warning



+ Occupant positioning



VOLVO

Factors potentially influencing whiplash injury risks in rear-end impacts, examples

- Seat position in car
- Stature
- BMI
- Sex
- Crash severity and characteristics
- Head to head restraint distance
- Head rotation at impact
- Seat adjustments
- Prior neck problems
- Neck constitution
- Spine curvature
- Posture at crash
- Muscle tension
- Activities
- and more

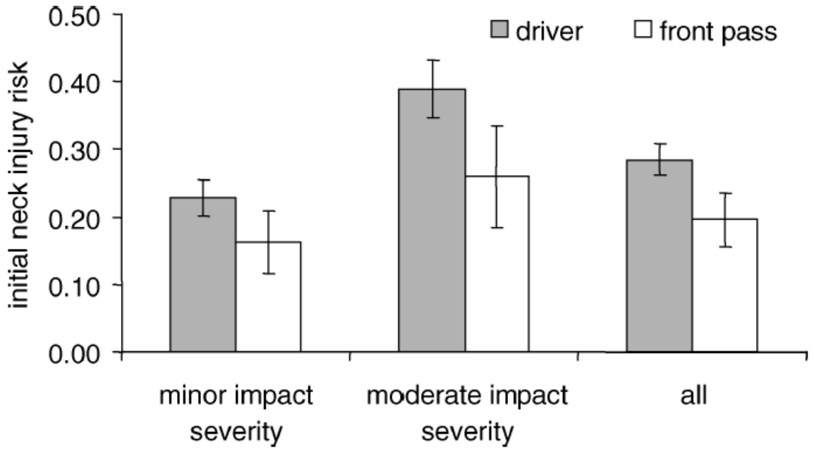


Figure 1 Initial neck injury risks comparing drivers and front-seat passengers in WHIPS.

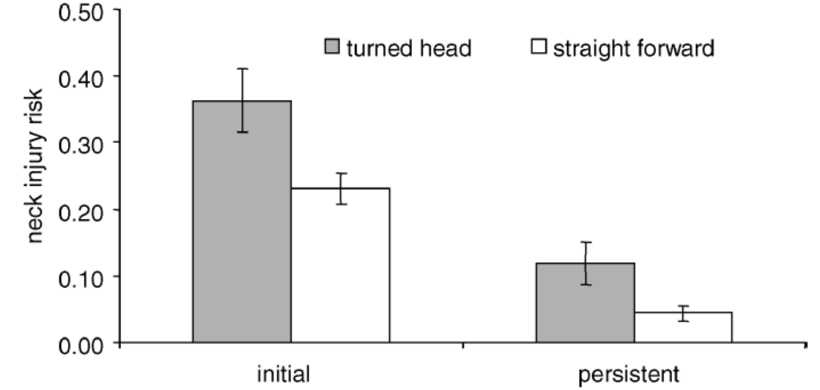


Figure 2 Soft tissue neck injury risk vs. head rotated posture at impact, all impact severity.

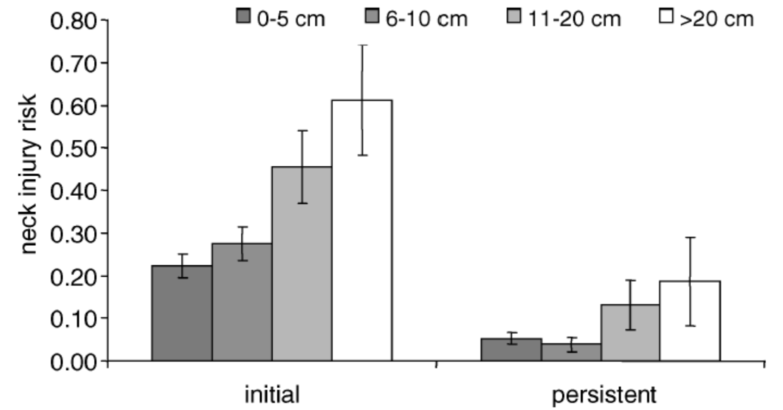
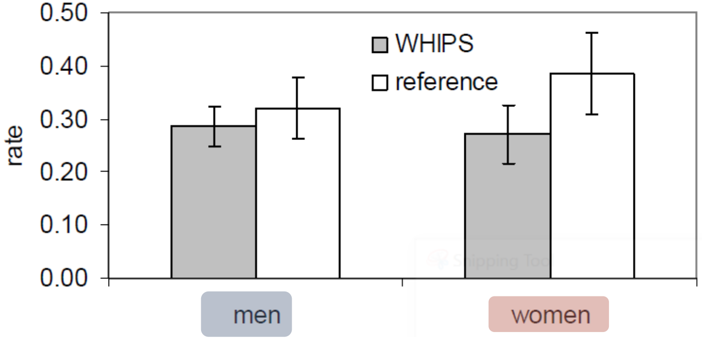


Figure 3 Soft tissue neck injury risk for different backsets, all impact severity.

Reference:, Jakobsson and Norin, IRCOBI 2004



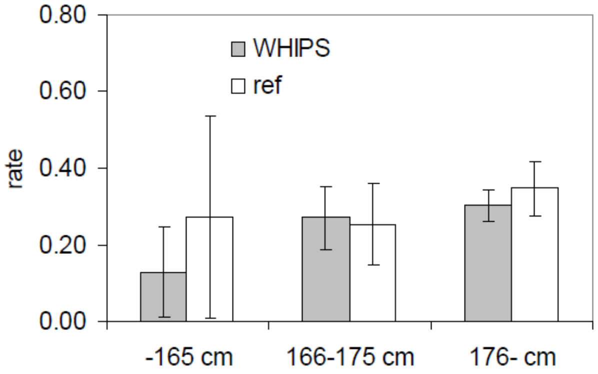


Figure 5a. Initial AIS1 neck injury rates with respect to stature for men, all impact severity impacts.

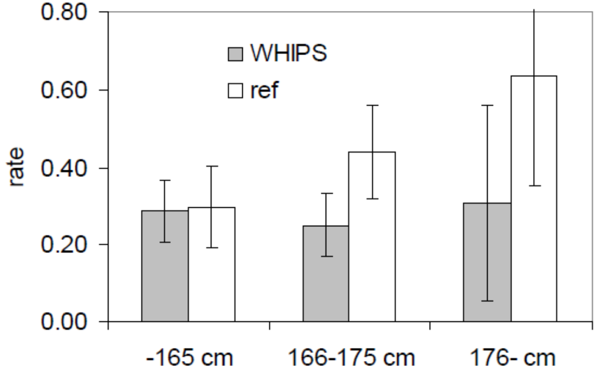


Figure 5b. Initial AIS1 neck injury rates with respect to stature for women, all impact severity impacts.

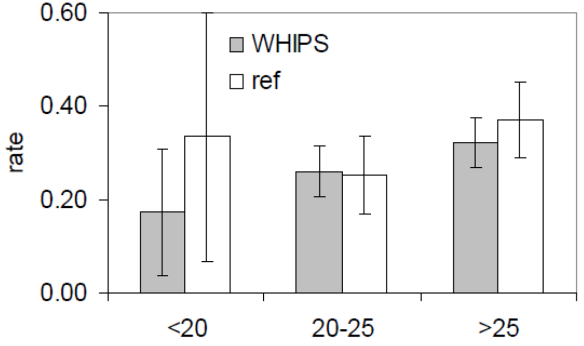


Figure 6a. Initial AIS1 neck injury rates with respect to BMI for men, all impact severity impacts.

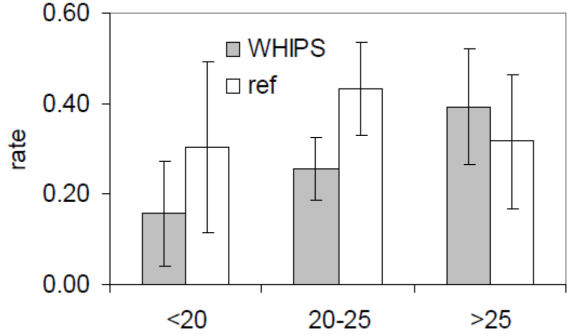


Figure 6b. Initial AIS1 neck injury rates with respect to BMI for women, all impact severity impacts.

Rear-End Impact – Crash Prevention and Occupant Protection

Lotta Jakobsson, Magdalena Lindman, Magnus Björklund, Trent Victor

VOLVO

Occupant pre-positioning, forward leaning (backset 275 mm)

Fig. 3a. Initial occupant position at start of test.

Fig. 3b. Occupant position after activation of electrical reversible pretension.

Rear-End Impact Assessment expanded with Pre-Impact Posture Variations

Lotta Jakobsson, Jonas Östh, Katarina Bohman

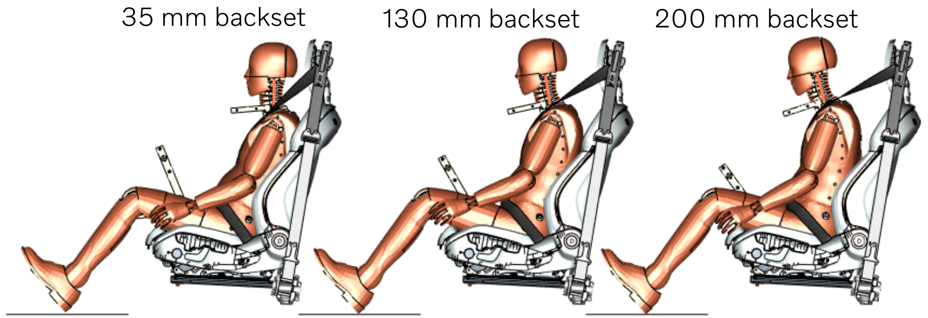
Is virtual whiplash assessment an enabler for the real world needs for occupant protection in rear-end impacts?

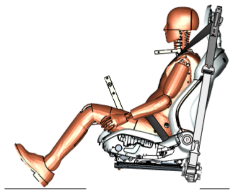
Explore if the current ATD (BioRID) can be used to cover a larger scope of the real-world context

Investigate virtual testing of braking followed by a rear-end impact, and alternative pre-impact positioned sitting postures, to

- explore two strategies to include variation of backset in virtual seat testing
- explore inclusion of pre-impact means of intervention, exemplified by seatbelt pretensioning, called ERR (Electrical Reversible Restraint)
- assess the BioRID model's ability to predict car occupant kinematics during braking interventions

Pre-impact positioning





Whole sequence simulation:

Pre-impact braking + rear-end impact

Brake pulses:

- Medium – 0.5g
- Harsh – 1.1g

ERR settings:

- Force of 150N, 300N and 600N
- No ERR activation

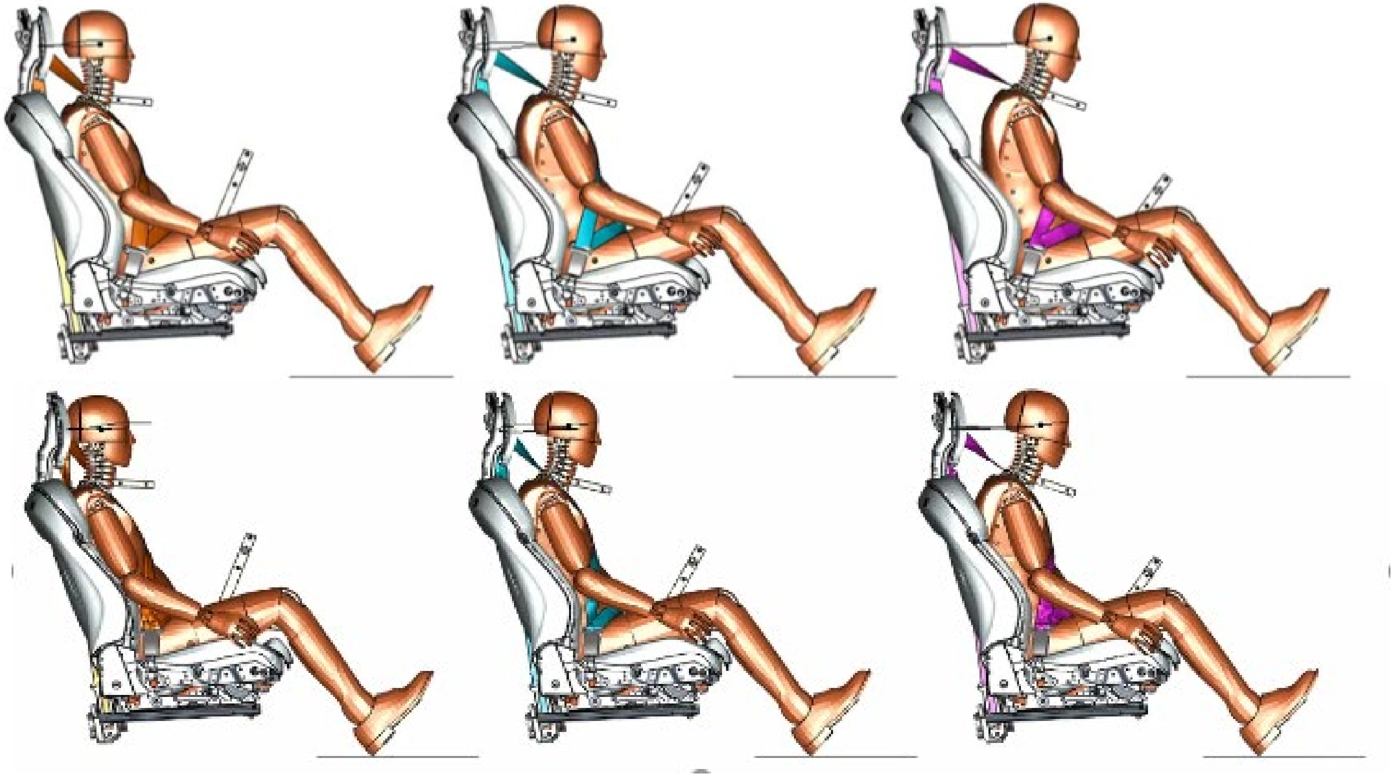
Lotta Jakobsson, Jonas Östh, Katarina Bohman

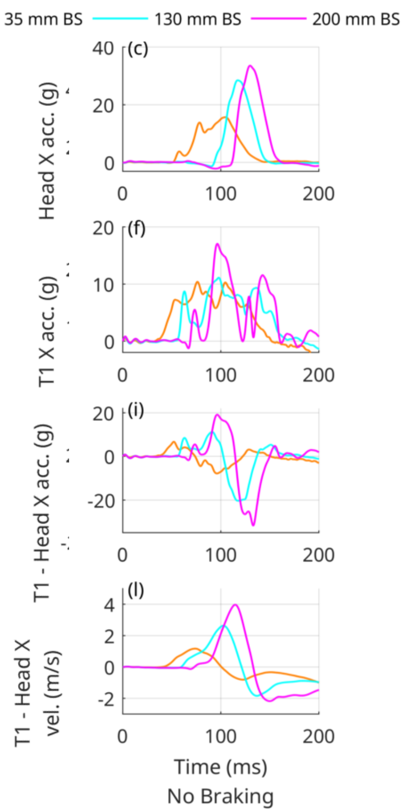
VOLVO

Variation in sitting posture

Rear-end impacts with pre-impact positioned occupant

Backsets (BS) of 35mm, 130mm and 200mm





IRC-15-90 IRCOBI Conference 2015

Rear-End Impact – Crash Prevention and Occupant Protection

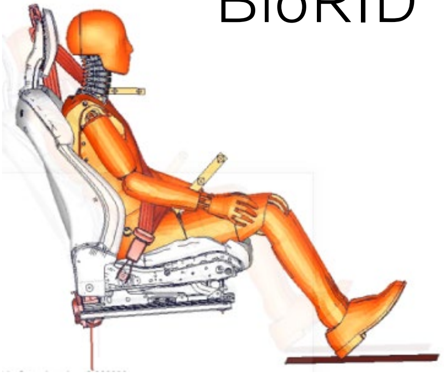
Lotta Jakobsson, Magdalena Lindman, Magnus Björklund, Trent Victor

WHIPS II (2015)

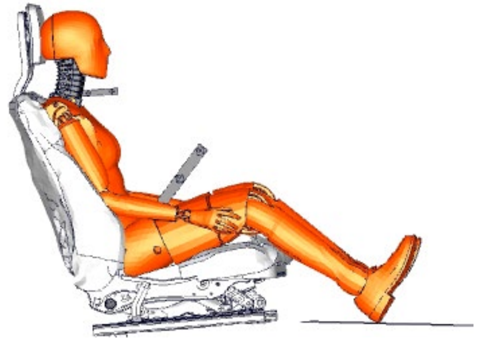
Variation in occupants

EvaRID

BioRID



Initial position



Most rearward position

Variation in occupants


virtual

Open access
virtual testing protocols
for enhanced
road user safety

Virtual Testing, Occupant Protection in Future Vehicles
WP number: 3
Deliverable: D3.2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768960.

https://projectvirtual.eu/dissemination/deliverables/


Figure 3-2 The three seats used in the study; Chalmers lab seat (left), Toyota seat (mid) and Volvo seat (right)

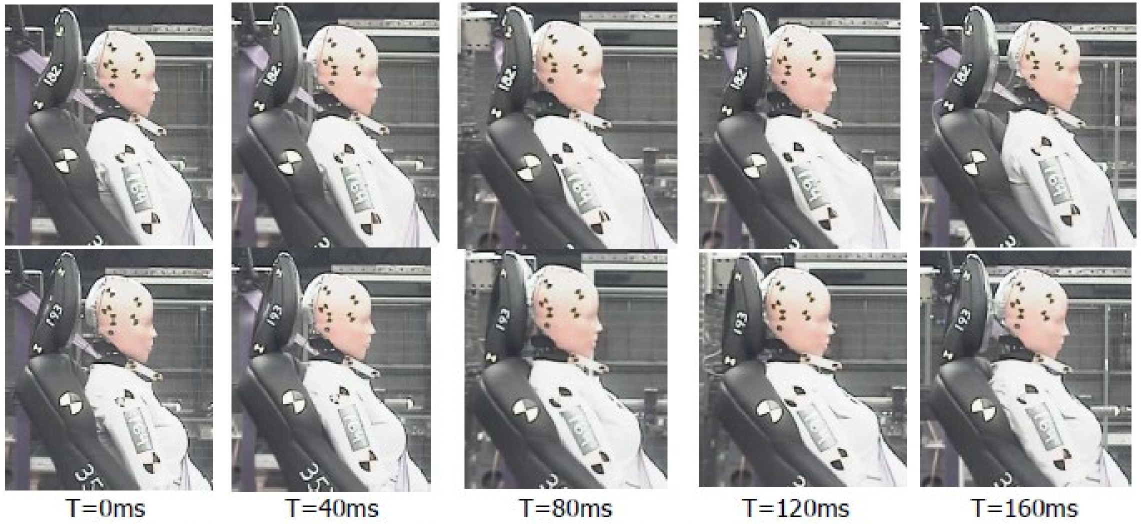


Figure 3-3 SET 50F in Volvo seat at mid (top) and high (bottom) crash pulses. Tests No. V3 and V4.

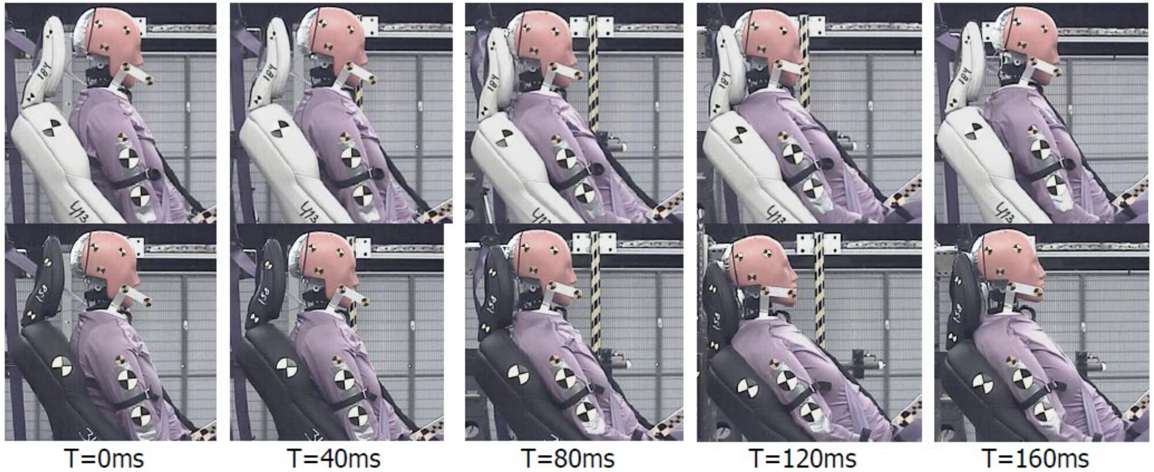


Figure D11. **SET 50M** in **Volvo seat** at mid (top) and high (bottom) pulses. Tests No. V7 and V8 virtual

VOLVO

The SETs are sensitive for different types of seat interaction

For the Volvo seat, the accelerations provide evidence of balanced support over the head and torso throughout the event

SET 50F in Volvo seat

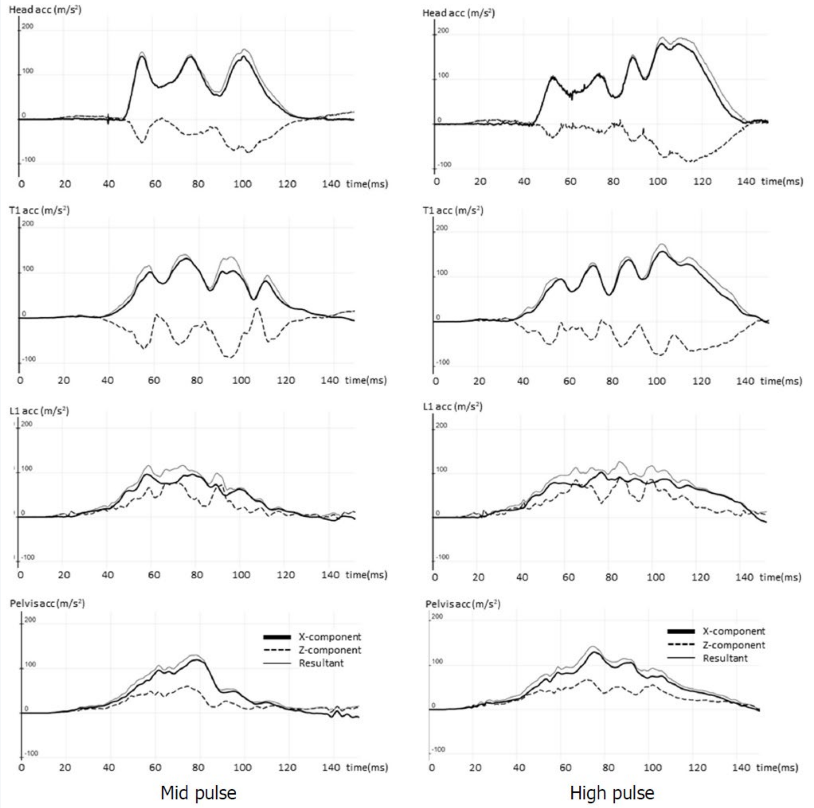


Fig D19. **SET 50F** in **Volvo seat**. Head, T1, L1 and pelvis accelerations (x, z and resultant) for mid pulse (left) and high pulse (right). Tests No. V3 and V4.

Head acc

T1 acc

L1 acc

Pelvis acc

SET 50M in Volvo seat

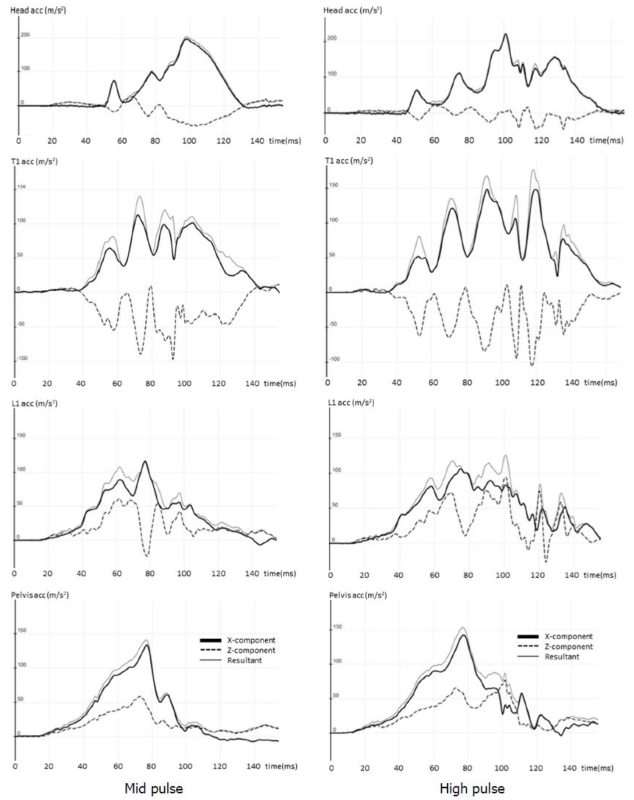


Fig D21. **SET 50M** in **Volvo seat**. Head, T1, L1 and pelvis accelerations (x, z and resultant) for mid pulse (left) and high pulse (right). Tests No. V7 and V8

Biomechanical guidelines

Examples of assessment

Reduce occupant acceleration

- Accident data
- Basic crash dynamic knowledge

→ Crash test dummy acceleration

Minimize relative spine movements

- Occupant simulation
- Injury mechanism research

→ Dynamic sub-system tests
Geometrical requirements
Advanced occupant models/ATD

Minimize forward rebound

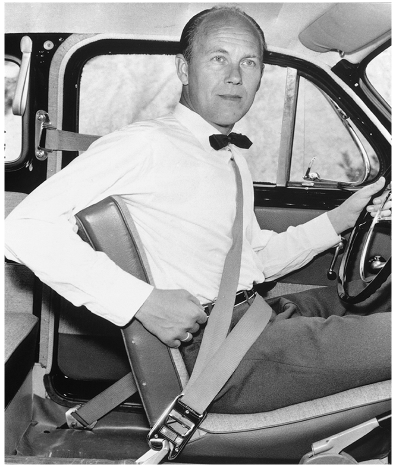
- Seat belt interaction during forward rebound suggested as injury-producing
- Accident data

→ Energy absorption seat test; quasistatic sub-system or dynamic using ATD

Nils Bohlin’s solution – simple perfection

Guiding principles

- Easy to use – put on using one hand
- Restrain the lower and the upper part of the body - lap and diagonal belt
- Well positioned from a physiological point of view - the ”V-shape” with low anchorage points beside the seat
- The belt stays in position - should not move under load



Refs:

Bohlin IAATM 1977 *https://group.volvocars.com/media/ccs/company/vision/research/the_adult_belt__a_hazard_to_the_child_norin_h_andersson_b_1977_melbourne.pdf*

Bohlin AAAM symposium 1981

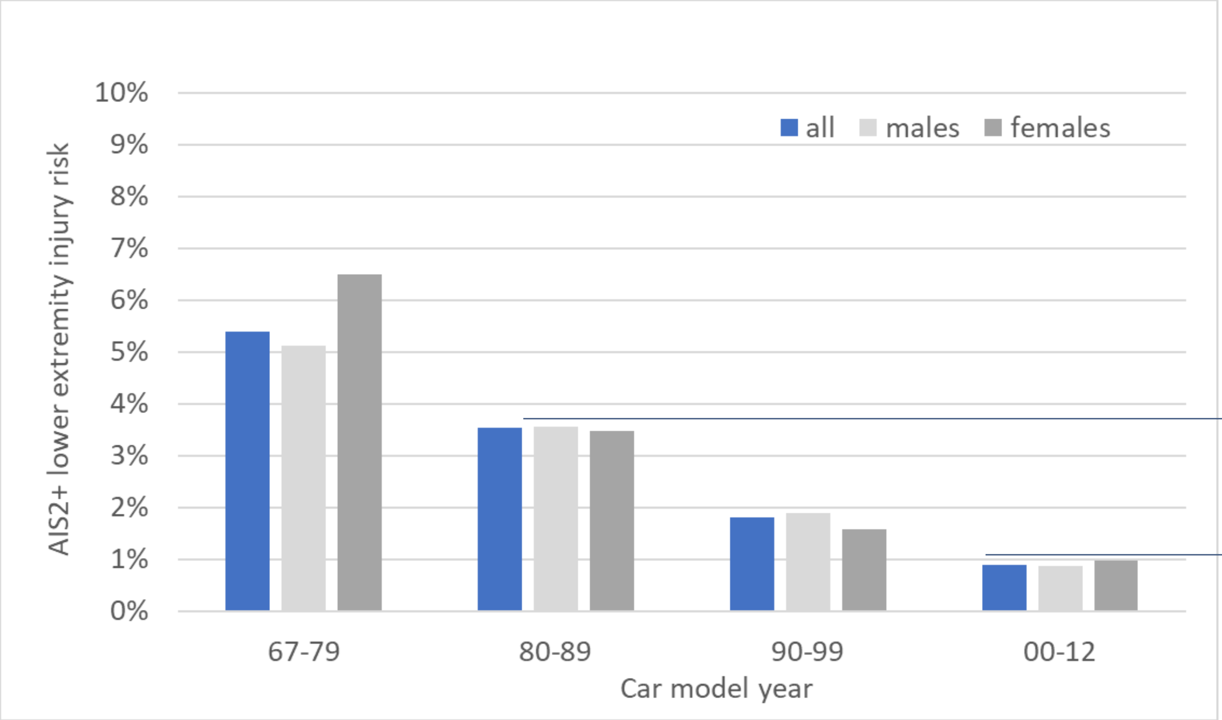
https://group.volvocars.com/media/ccs/company/vision/research/refinementsofrestraintsystemdesignaprimarycontributiontoseatbelteffectivenessinswedenbohlinn1981toro.pdf

VOLVO

Lower extremities, restrained drivers in frontal impacts

Volvo Cars Traffic Accident Database

N=13 100



ESV 1996

FOOT AND LEG INJURIES IN FRONTAL CAR COLLISIONS

Jonas Forssell
Lotta Jakobsson
Åse Lund
Emma Tivesten
Volvo Car Corporation
Sweden

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Preventing injuries

In order to reduce the risk of a leg injury, it is important that all factors are taken into consideration. Regarding each factor, the following general design guidelines are suggested:

Geometry
- Attempt to make the footwell as smooth and flat as possible. Avoid having local differences in height and width.
- Place pedals as close to the footwell as possible. Ultimately, remove the pedals.

Acceleration
- Avoid placing solid objects in front of the footwell, which may cause increased stiffness of firewall when intruded.
- Design the footwell so that it will be shock absorbing, in order to reduce foot acceleration at impact.
- Allow for the feet to be placed close to the firewall in order to limit the delta V at impact.

Pedals
- Place the pedals as close to the firewall as possible.
- Design the pedals so that the brake booster intrusion will have limited effect on pedal intrusion.

Intrusion
- Limit intrusion
- When intrusion occurs, the footwell area should stay flat in order to avoid trapping the feet.
- Instrument panel and knee bars should be designed in such a way that the possibility of jamming the leg during impact, is reduced.

In summary

Robust protection is based on an understanding of the mechanisms.

Breaking down essential mechanisms and including influence of occupant heterogeneity – defining guidelines - have proven successful for injury risk reduction.

Crash test dummies provide a whole-body interaction but cannot alone provide enough details for safe vehicle designs.

Virtual whiplash assessment opens for including the influence of:

- additional vehicle countermeasures, e.g., seatbelt technologies and ADAS, in addition to car body design influence on crash pulse
- a variety of occupant sitting postures, characteristics, and kinematics

Although many issues need to be solved before becoming standardized methods.

Real world data is a good source of knowledge, however the most important parameters may be difficult to collect. Analyses only provide insights into the parameters collected.