Full Width Test – ECE-R 94

Evaluation of test data
Proposal for injury criteria
Way forward

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BASt Project on Frontal Impact:
Evaluation of European Vehicles

Objective:

- Analyse safety performance of European vehicles in the proposed full width rigid barrier test

- Investigate the benefit of a restraint system test

- Three "European" super mini class vehicle models were selected
  - Budget: vehicle v1
  - Popular: vehicle v2
  - Small, new design: vehicle v3

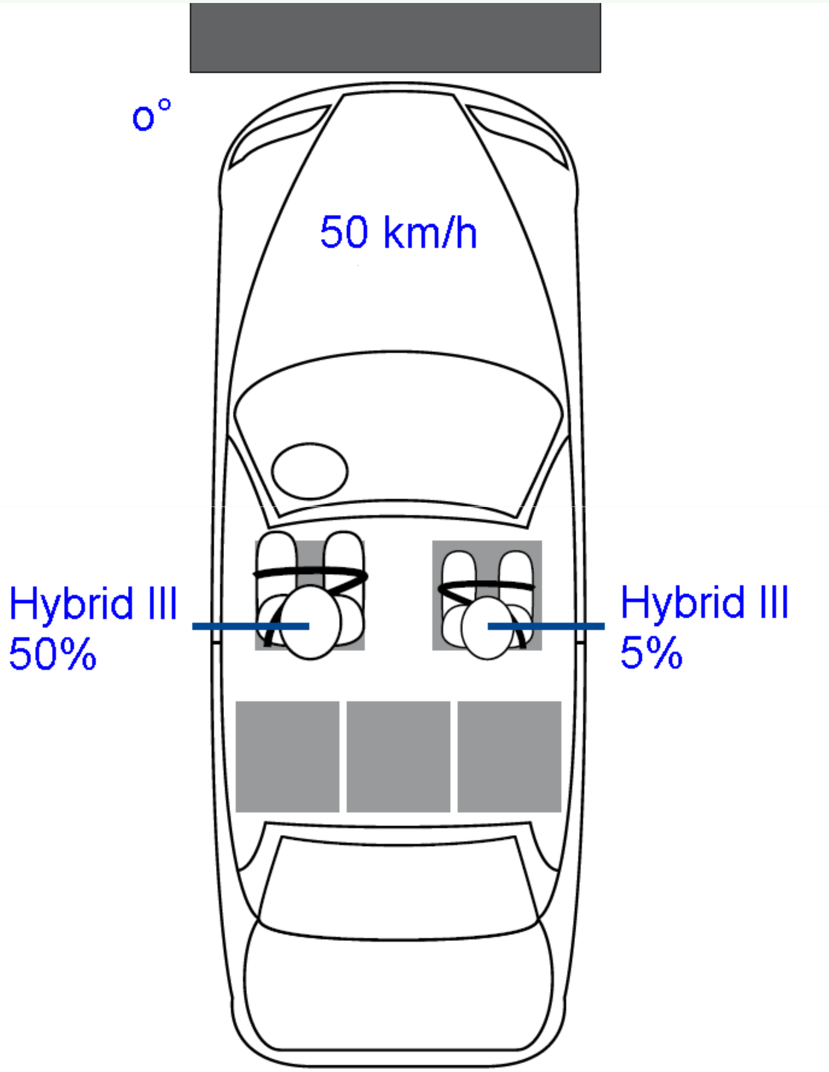
Test Configuration

Full Width Rigid Barrier Test

- Driver’s side dummy:
  Hybrid III 50th percentile male
  Mid seat position

- Passenger’s side dummy:
  Hybrid III 5th percentile female
  25% seat position

- Vehicle & dummy preparation according to ECE – R94



References for IARV
(Injury Assessment Reference Value)

- Eppinger R, Sun E, Kuppa S, Saul R. Supplement: Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems-II, 2000
- Mertz HJ, Irwin AL, Prasad P, Biomechanical and Scaling Bases for Frontal and Side Impact, Stapp Car Crash Journal 47 (October 2003) 155-188
- Laituri TR, Prasad P, Sullivan K, Frankstein M, Thomas RS. Derivation and Evaluation of a Provisional, Age-Dependent, AIS3+ Thoracic Risk Curve for Belted Adults in Frontal Impacts. Society of Automotive Engineers. 2005 Paper Number 2005-01-0297
- Kramer et al. Evaluation of Protection Criteria by Combining Results of Computer and Experimental Simulation with Results of Accident Investigation. IRCOBI Conference. Birmingham. 1980
- ECE-R 94, Uniform Provisions concerning the approval of vehicls with regard to the protection of the occupants in the event of a frontal collision, 2009

Thorax Acceleration / Thorax Deflection

- Chest deflection is sensitive to seat belt routing
- High seat belt routing reduces chest deflection but corresponding reduction of injury risk is uncertain
- Thorax acceleration is less depended to the seat belt routing compared to the chest deflection
- Mertz 2003:
  - “It (chest acceleration) does provide a measure of how well the restraint loads are balanced between various body regions. If the restraint loads are balanced so that the body regions are decelerated without significant distortion between adjacent segments, then the internal forces acting on the thoracic spine will be low and its acceleration will also be low.”
- Thorax acceleration may help to compensate the disadvantages of single point chest deflection measurement

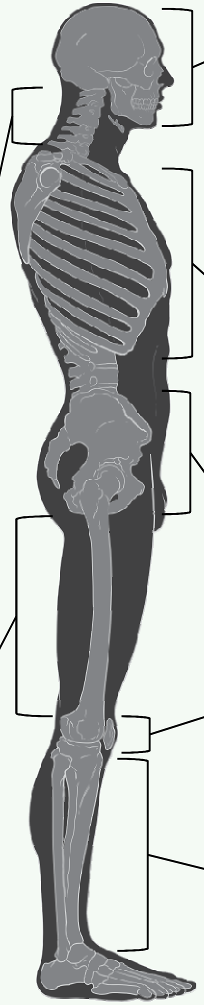
Outcome of Research Projects Regarding Thorax Injuries

- FP 7 Project: THORAX
  - Of the body regions in the accidents analysed, the thorax was the most frequently injured region for all killed and seriously injured occupants in front al impact accidents.
  - Passenger side / Female / Elderly
- FP 7 Project: COVER
  - The most frequently occurring injuries to the torso, of moderate or greater severity (AIS 2+), were: 1. Rib fractures and 2. Sternum fractures
  - The most frequently occurring visceral injuries to the torso, of serious or greater severity (AIS 3+), were: a. Lung injuries and b. Heart injuries

- Assuming that current 40% overlap tests are maintained to ensure occupant compartment integrity, the next target for improving occupant protection in frontal impacts would involve collisions with:
  - Distributed loading of the vehicle's front structure.
  - A male driver and female front seat passenger.
  - Injury risk functions targeted to the over 50 age group.
- In addition, the typical collision severity for serious thorax injuries was well below current R94 and Euro NCAP test velocities. The modal speed for MAIS ≥ 3 thorax only injuries was 20 to 29 $km \cdot h^{-1}$.

Test Method - HIII 50th Male

Proposal for injury criteria



NIC Tensile: (ECE R-94)	3,3 kN @ 0 ms 2,9 kN @ 35 ms 1,1 kN @ ≥ 60 ms
NIC Shear: (ECE –R94)	3,1 kN @ 0 ms 1,5 kN @ 25-35 ms 1,1 kN @ ≥ 45 ms
M_y (-) : (ECE R-94)	57 Nm

FFC: 9,07 kN @ 0 ms
7,58 kN @ ≥ 10 ms
(ECE R-94)

HIC_{36}: 1000 (ECE R-94)
HPC_{15}: 700 (Eppinger et al. 2000)
a_{3ms}: 80 g (ECE R-94)

ThCC: 42 mm (Mertz 2003)

VC: 1.0 m/s (ECE R-94)

Thorax peak acc: 60 g (Mertz et al. 2003)

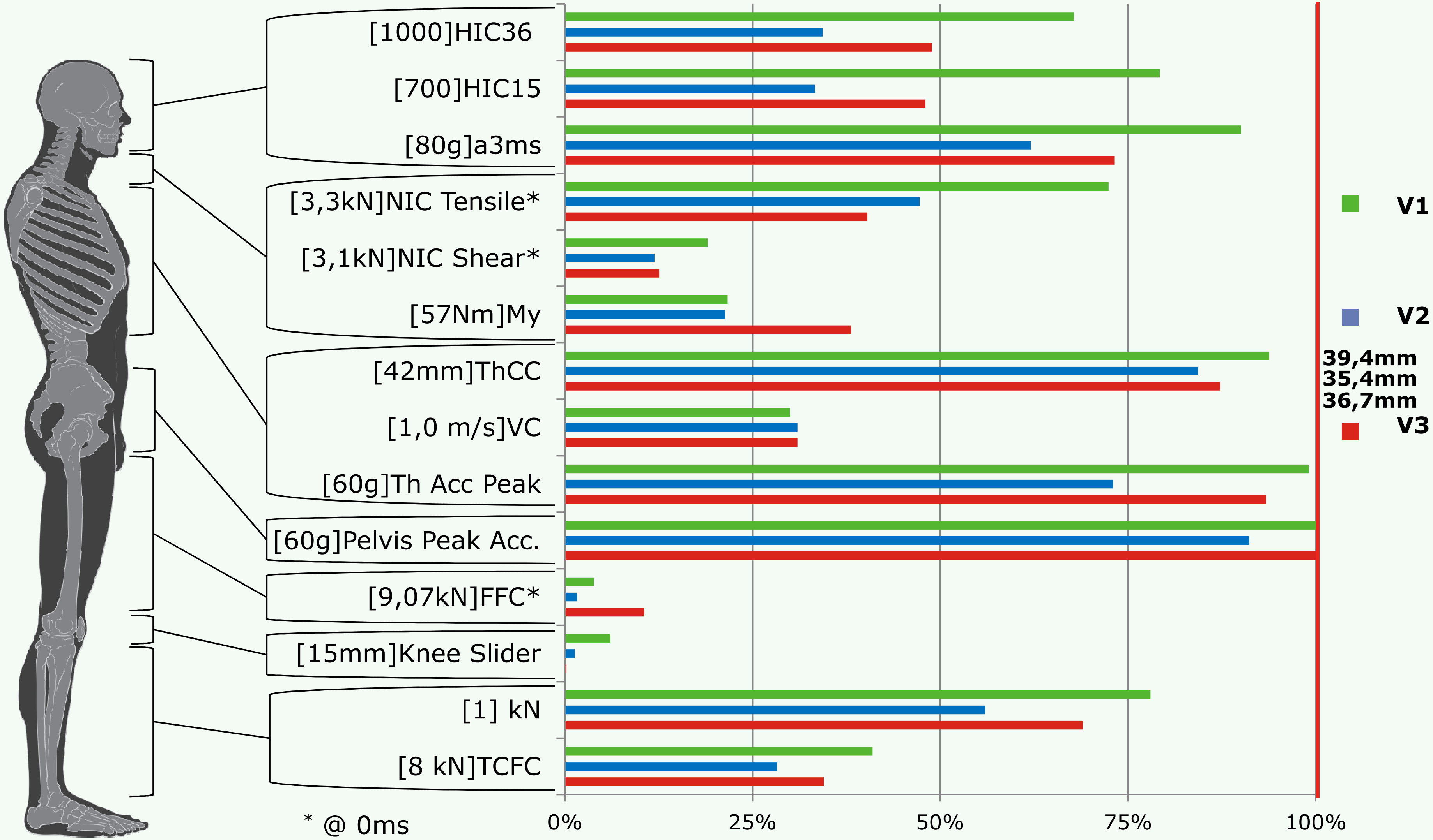
Pelvis peak acc.: 60g (Kramer 1980)

Knee Slider: 15 mm (ECE R-94)

TI: 1 $(M_C)_R$225 Nm and $(F_C)_Z$35,9N (Mertz, 2003)

TCFC: 8 kN (ECE R-94)

Test Results – Driver (HIII 50th Male)



Test Method - HIII 5th Female

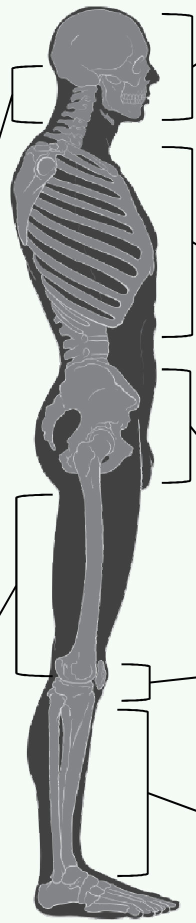
Proposal for injury criteria

NIC* tension (upper): 2,01 kN @ 0ms
(scaled based on Mertz et al. 2003) 1,83 kN @ 28ms
0,7 kN @ ≥ 48ms

NIC* Shear (peak): 1,95 kN
(Mertz et al. 2003)

$M_y(-)$*: 29 Nm
(scaled based on Mertz et al. 2003)

FFC: 6,16 kN @ 0 ms
(Mertz et al. 2003) 5,13 kN @ ≥ 9 ms



HPC36: 1000 (ECE-R 94)
HPC_{15}: 700 (Eppinger et al. 2000)
a_{3ms}: 80 g (ECE R-94)

ThCC: 34 mm
(scaled to chest depth, Mertz 2003)

VC*: 1.0 m/s (ECE R-94)

Thorax Acc Peak: 60g
(Mertz et al. 2003)

Pelvis Acc Peak.: 60g
(Kramer et al. 1980)

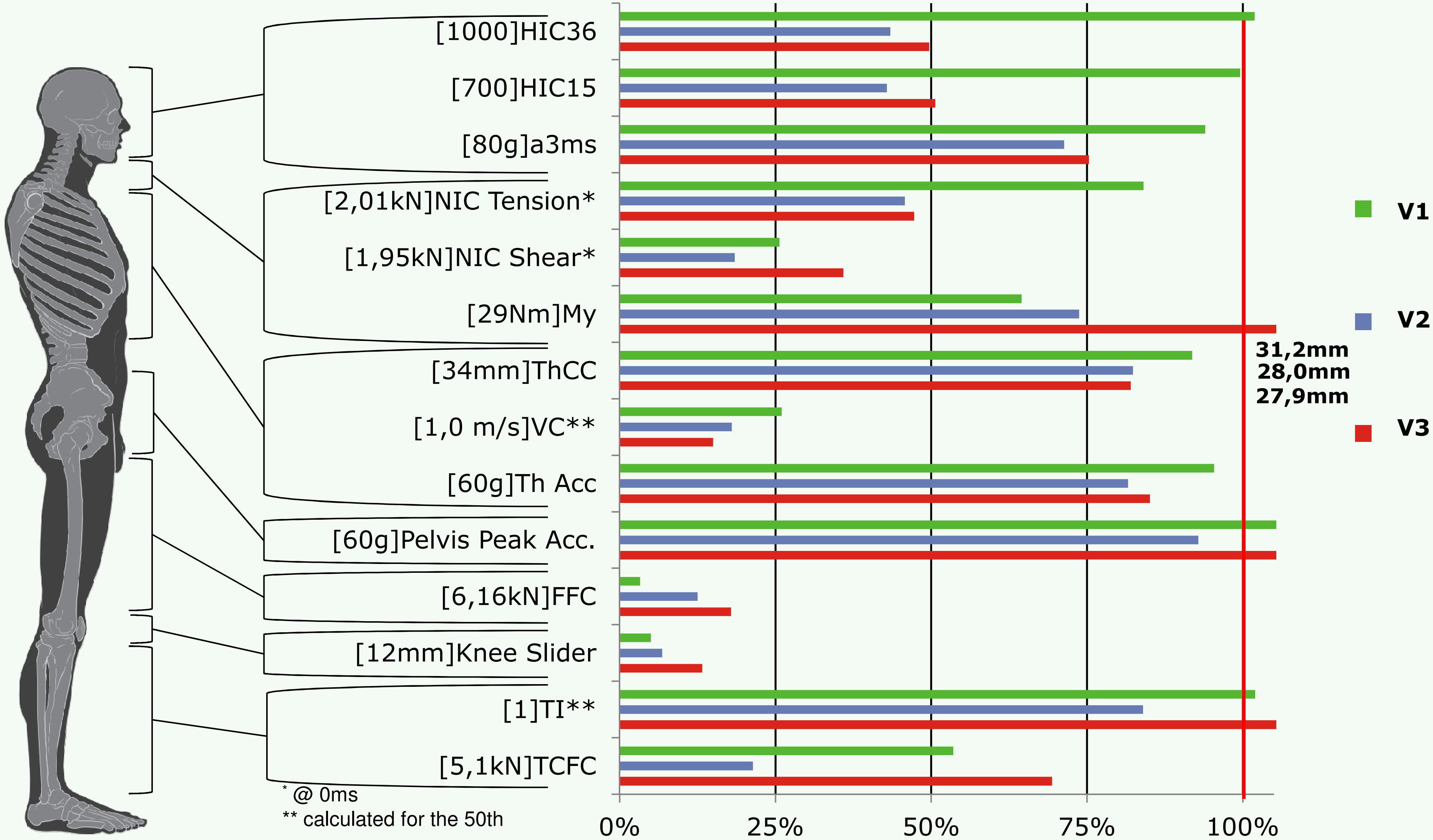
Knee Slider: 12mm (Mertz et al. 2003)

TI: 1 $(M_C)_R$114 Nm and $(F_C)_Z$22,9N
(Mertz et al. 2003)

TCFC: 5,1 kN
(Tibia Compr., F_z; Mertz et al. 2003)

*details for scaling of the HIII 5th is in the annex

Test Results – Passenger (HIII 5th Female)



* @ 0ms
** calculated for the 50th

Further Findings: Vehicle 1

- Intrusions to the footwell
- High head accelerations, in particular for the passenger dummy
- Thorax accelerations up to 60g
- Belt path close to the neck
- Upper seat belt load of 7kN for driver and passenger (no seat belt pretensioner, load limiter existent)
- Pelvis acceleration
  - Driver 70g
  - Passenger 77g

Further Findings: Vehicle 2

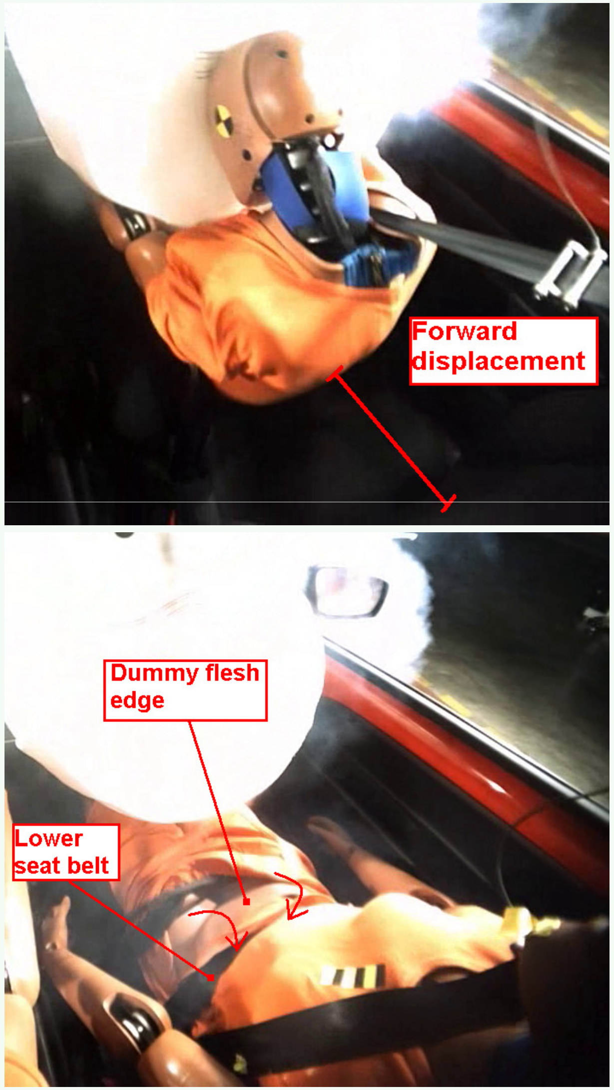
- Vehicle 2 passes all ECE- R 94 occupant injury criteria (Vehicle is developed and designed in the early 2000s)

- Relative low values for the head impact
  - Driver HIC_{36}=343; Passenger HIC_{36}=434

- Relative low chest values
  - Driver chest deflection = 35 mm, a_{3ms}=42g
  - Passenger chest deflection = 28 mm, a_{3ms}=46g

Further Findings: Vehicle 3

- Dummy kinematic and seat belt routing not ideal
- Possibly submarining on the front passenger seat
- Pelvis peak acceleration
  - 73g driver
  - 78g passenger
- Tibia Index up to 1,2 (passenger)
- Neck moment 43Nm (passenger)
- Lap belt forces
  - Driver 8,3
  - passenger 7,3 kN



Results (1)

- Driver side:
  - All vehicles pass the limits proposed in FI 20 and also the proposed BASt limits
    - Thorax deflection: 35 - 40 mm
- Front passenger side:
  - All vehicles pass the limits proposed in FI 20, except: one vehicle with HIC_{36} of 1024
    - Thorax deflection: 27 - 32 mm
  - Vehicles do not pass the BASt limits in HIC, neck moment, tibia index and pelvis acceleration

Results (2)

- Other findings
  - Thorax peak acceleration up to 59 g
  - Pelvis peak acceleration up to 80 g
  - One vehicle with very high shoulder belt force (7 kN)
  - Dummy kinematic and seat belt routing not ideal

Conclusions (1)

- Phase 1: Changes to ECE-R 94
  - Dummy configuration
    - ODB Test: driver HIII 5th; passenger HIII 50th
    - FW Test: driver HIII 50th; passenger HIII 5th
    - Seat longitudinal position:
      HIII 50th = mid track; HIII 5th = 25% from front
  - Injury Criteria: As proposed in slide 5 and 7
    - Thorax Deflection: 42mm HIII 50th; 34mm HIII 5th
    - Thorax Acceleration: 60g
    - Pelvis Acceleration: 60g
    - Lower leg evaluation for HIII 50th and HIII 5th
    - Head, neck and upper leg were scaled for the HIII 5th

Conclusions (2)

According to the terms of references at GRSP 2012 the following is **NOT** addressed in phase 1:

- Optimization of vehicles' structural interaction
- Use of results of existing research programs (THORAX; FIMCAR)
- Thorax injury prediction tools

Due to this and based on the test results it is likely that phase 1 will not significantly improve current situation.

Thus, a phase 2 should be implemented on a mid term basis as proposed in the 14th GRSP IWG FI Meeting.

- Phase 2
  - Implementation of new frontal impact dummies
  - Modification of the test configuration including compatibility requirements

Full Width Test Series - ECE-R 94
Test data
Injury Criteria
Way forward

Thank you for your attention

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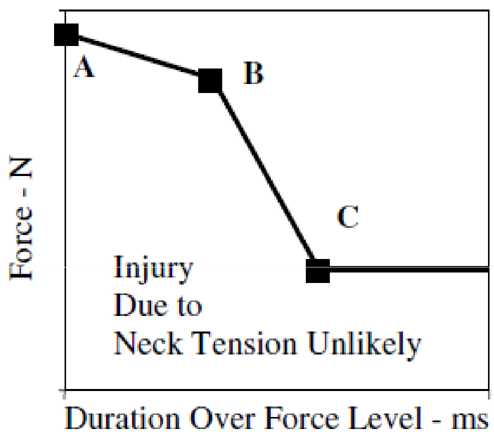
Scaling NIC Tension (Upper) for the HIII 5th



Size & Age	λ_F (1)	λ_t (2)	Point A Force (N)	Point A Time (ms)	Point B Force (N)	Point B Time (ms)	Point C Force (N)	Point C Time (ms)
6 Month	0.648	0.577	930	0	820	20	250	35
12 Month	0.691	0.585	990	0	870	20	260	35
18 Month	0.755	0.590	1080	0	950	21	290	35
3 Year	1.000	0.637	1430	0	1260	22	380	38
6 Year	1.323	0.689	1890	0	1670	24	500	41
10Year	1.590	0.749	2290	0	2000	26	600	45
S. Female	1.832	0.794	2620	0	2310	28	700	48
Mid Male	2.909	1.000	4170	0	3670	35	1100	60
L. Male	3.511	1.099	5030	0	4420	38	1330	66

Notes: 1. $\lambda_F = \lambda_\sigma \lambda_C^2$ 2. $\lambda_{time} = \lambda_z = \lambda_C$

FIGURE A1. Neck Tension Time-Dependent Criterion for In-Position Testing.

NIC Tensile:
(HIII 50th ECE R-94)

3,3 kN @ 0 ms
2,9 kN @ 35 ms
1,1 kN @ ≥ 60 ms

Scaled with λ_F 0,63
and
Scaled with λ_t 0,794
(Pk. Tension, +Fz (N),
Mertz et al. 2003)

NIC tension (upper):
HIII 5th ECE R-94

2,01 kN @ 0ms
1,83 kN @ 28ms
0,7 kN @ ≥ 48ms

Scaling NIC Shear for the HIII 5th

Body Region	Injury Assessment Criteria	Infants			Children			Adults		
		6 Month	12 Month	18 Month	3 Year	6 Year	10 Year	Small Female	Mid Male	Large Male
Upper Neck (OC/C1)	Pk. Flexion Moment, $+M_y$ (Nm)	25	27	29	42	60	78	95	190	252
In-Position & OOP	Pk. Compression, $-F_z$ (N)*	890	960	1040	1380	1820	2200	2520	4000	4830
	Pk. Shear, F_x & F_y (N)	690	740	810	1070	1410	1710	1950	3100	3740

NIC Shear: 3,1 kN @ 0 ms
HIII 50th ECE –R94 1,5 kN @ 25-35 ms
1,1 kN @ ≥ 45 ms

NIC tension (upper): 1,95
HIII 5th ECE R-94

Scaling Neck Moment (Extension) HIII 5th

Body Region	Injury Assessment Criteria	Infants			Children			Adults		
		6 Month	12 Month	18 Month	3 Year	6 Year	10 Year	Small Female	Mid Male	Large Male
Upper Neck	Pk. Extension Moment, $-M_y$ (Nm)	13	14	15	21	30	40	49	96	128

M_y (-) : 57 Nm
HIII 50th ECE R-94

Scaled with 0,51
(Pk. Extension
Moment $-M_y$ (Nm)
Mertz et al. 2003)

M_y(-): 29 Nm
HIII 5th

Scaling VC Criterion for the HIII 5th

$$C_{(t)} = \frac{D_{(t)}}{0.229}$$

$$V_{(t)} = \frac{8\left(D_{(t+1)} - D_{(t-1)}\right) - \left(D_{(t+2)} - D_{(t-2)}\right)}{12\delta t}$$

VC: 1.0 m/s
HIII 50th ECE R-94

Chest depth for the HIII 50th is **0,229**

Scale factor **0,817**

Chest depth for the HIII 5th is **0,187**

$$C_{(t)} = \frac{D_{(t)}}{0.187}$$

$$V_{(t)} = \frac{8\left(D_{(t+1)} - D_{(t-1)}\right) - \left(D_{(t+2)} - D_{(t-2)}\right)}{12\sigma t}$$

VC: 1.0 m/s
HIII 5th