EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

The use of the Hybrid III Dummy in Low-speed Rear Impact Testing

EEVC WG12 & 20 report
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The use of the Hybrid III Dummy in Low-speed Rear Impact Testing

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On behalf of European Enhanced Vehicle-safety Committee (EEVC) Working Group 12

Number of Pages (including Appendices)
43

CONTENTS

The use of the Hybrid III Dummy in Low-speed Rear Impact Testing

Summary

The poor biofidelity of the Hybrid III in low-speed rear impact conditions could send head restraint design in the wrong direction and reduce the level of whiplash protection offered to car occupants. The Hybrid III is therefore not appropriate for whiplash protection testing.

Issues

The main benefit of having an optional dynamic test of head restraint geometry (which as a whole vehicle sled test will be considerably more expensive than the static measurement of head restraint geometry), is that reactive head restraint systems can be fairly and adequately assessed. These restraints are actuated by the inertia of the occupant loading the seat back and pushing an arrangement of levers that move the head restraint forwards and, typically, upwards. This moves the head restraint from an unfavourable geometry to a favourable geometry before head contact occurs. In order for such a dynamic test to be meaningful, the dummy must load the seat back (and therefore load the reactive part of the head restraint mechanism) in an equivalent way as a human occupant. The relevant biofidelity studies *all* show that the interaction of the rigid thoracic spine of the Hybrid III with the seat back is *not* humanlike. As a result, there is a very real risk that a reactive head restraint would deploy less effectively for a human occupant than when tested with the Hybrid III, or even not deploy at all. For example, HR-06-07 shows very similar actuation of active head restraint A for both BioRID and Hybrid III, but for active head restraint B the actuation of the head restraint is very much more ‘efficient’ with the Hybrid III (a backset reduction of almost 90 mm) than with the more biofidelic BioRID dummy (a backset reduction of less than 40 mm).

There is evidence that it is possible to design a better seat using the Hybrid III - some seats that have been developed with the Hybrid III have been shown to reduce whiplash insurance claims. However, developing an effective seat using the Hybrid III requires an understanding of the limitations of the dummy in low-speed rear impact loading conditions and compensation for these limitations in the design process. It is not possible, in a regulatory test procedure, to ensure that appropriate compensation is made. It is therefore possible to design a seat that meets a given regulatory requirement based on the Hybrid III measurements that will have no real-world benefit for some or all occupants. In addition, the literature reviewed indicates that it would even be possible to develop an active head restraint that would be disbeneficial to a real-world occupant compared with a good static geometry. For instance, protection could rely on a reactive head restraint that is actuated quickly and moves forward and upwards by a large amount when loaded by the rigid spine of the Hybrid III dummy, but which may move to a lesser extent and later in the impact event when loaded by a human occupant with a flexible spine.

Background

A comprehensive review of the literature regarding the biofidelity of the Hybrid III dummy in low-speed rear impacts has been undertaken (EEVC WG12 Doc No. ###). This included comparison of the dummy with volunteer and PMHS test data at a range of impact severities, including sled tests that evaluate the response of the whole occupant to rear impact with and without a head restraint, and pendulum impactor tests that evaluate one specific aspect of rear impact response. The tests evaluated the head and neck kinematics of the Hybrid III compared with volunteers and PMHS, as well as the interaction with the seat back.

The evidence reviewed overwhelmingly shows that the Hybrid III is not biofidelic in low-speed rear impacts and should not be used to test seats in these conditions. The interaction between the dummy and the seat back was not humanlike for several reasons, for example:

- The stiff one-piece thoracic spine of the Hybrid III prevents rotation of the T1, so all head motion must be accommodated in the neck;
- The stiff shoulders interact with the side bolsters of narrow seat backs, preventing correct interaction with the seat back and altering the head-neck response;
- Ramping-up (movement of the occupant up the seat back during a rear impact) was almost absent in the Hybrid III, meaning that the interaction between the dummy and the seat and head restraint is lower down than for a human occupant of the same stature.

Review of Recommendations Regarding the use of Hybrid III in Low-speed Rear Impact ‘Whiplash’ Tests

Introduction

The Hybrid III dummy was developed by General Motors Corporation in the 1970s, and the development of the dummy is summarised in Backaitis and Mertz [1994]. It is a high-speed front impact dummy that has been used in front impact regulations (e.g. FMVSS 208 and ECE Reg 94) and consumer testing (e.g. NCAP) world-wide for many years. The neck design requirements for the Hybrid III included rear impact, with a torque-angle performance target for hyper extension [Mertz and Patrick, 1971]. The dummy has a flexible (steel cable and rubber) lumbar spine (the lower part of the back), a rigid steel thoracic spine (the main, upper part of the back) and a flexible neck. In an effort to improve the low-speed rear impact response of the Hybrid III several new necks were developed (the RID neck [Svensson and Lövsund, 1992] and the TRID neck [Thunnissen *et al.*, 1996]). The following sections summarise the published work that has evaluated the biofidelity (how humanlike the dummy is) of the Hybrid III for low-speed rear impact testing.

EEVC Research

EEVC WG12 (Biomechanics) have selected a suite of five biofidelity requirements chosen from a list of 19 candidate volunteer and PMHS data sets [Hynd and Van Ratingen, 2005], including four sets of volunteer data and one set of PMHS data. The WG has tested the Hybrid III, RID^{3D} and BioRID dummies in each of these biofidelity test conditions (as well as conducting separate tests on the repeatability and reproducibility of the dummies at higher severities) and is currently finalising its report. Most of the selected biofidelity test conditions have already been tested with the Hybrid III and the findings are included in the following sections of this report. However, the latest versions of the BioRID-2 and RID^{3D} had not been tested and so all three dummies were tested together by the EEVC to ensure comparable results. Whilst a final recommendation on a dummy for low-speed rear impact testing has not yet been made, it is clear from all of the EEVC biofidelity tests that the previous findings in the literature that the Hybrid III is not biofidelic in these conditions are confirmed.

EC Project Research

Cappon *et al.* [2000] and [2001] reported on the evaluation of the Hybrid III dummy in low-speed rear impacts within the EC Whiplash project. Biofidelity assessment was based on volunteer test [van den Kroonenberg *et al.*, 1998] and PMHS test [Bertholon *et al.*, 2000] results. The Hybrid III was found to be not sufficiently biofidelic for low-speed rear impact testing of seats. In particular, the interaction of the Hybrid III with the seat was not satisfactory, which the authors attributed to the stiff spine and neck of the Hybrid III. This led to the development and evaluation of the RID 2 rear impact dummy within the whiplash project. Both dummies showed some good kinematic biofidelity compared with volunteers in a real car seat, although the Hybrid III did not show any lower neck (T1) rotation, the S-shaped neck response or ramping up. In comparison with the PMHS tests in a rigid lab seat, the biofidelity of the Hybrid III was poor compared to the RID 2.

Other Research - Biofidelity

Svensson and Lövsund [1992] evaluated the biofidelity of isolated Hybrid III head-necks and the Hybrid III head with their newly developed RID neck. The authors approximated the lower neck input conditions from volunteer tests (pendulum rear impacts to the back at shoulder level) using the Hybrid III neck calibration pendulum. They found that the Hybrid III neck was too stiff in these test conditions and had too much resistance to horizontal translation motion (retraction) between the head and the torso. The RID neck was tuned to give a better performance in these test conditions, although further improvements were recommended.

The head and neck kinematics of the Hybrid III and Hybrid III RID in a standard car seat were compared with volunteers and PMHS by Geigl *et al.* [1995]. They found that the movement of the head and neck of the standard Hybrid III dummy was quite different to that of the volunteers and PMHS. With the RID neck, biofidelity was slightly improved. However, the authors reported that several degrees of freedom were still missing from the RID neck compared to the human neck and that further improvements could be made. They also found that rigid thoracic spine of the Hybrid III dummy was unable to reproduce the bending of the thoracic spine seen in both volunteers and PMHS, and that this lack of biofidelity contributed to the poor head-neck motion. The initial curvature of the neck was also absent in the dummy.

The Hybrid III and BioRID P3 dummies were evaluated against three sets of volunteer data at Δv's of 7 and 9 $km.hr^{-1}$ [Davidsson *et al.*, 1999a] and [Davidsson *et al.*, 1999b]. In all three sets of tests, the Hybrid III was not biofidelic for many of the parameters measured, including rearward and angular displacements, which were too small. This was in particular due to poor T1 rotations of the Hybrid III. In a later study by [Viano and Davidsson, 2002] it was concluded that both the BioRID P3 and the Hybrid III closely simulated the neck kinematics *relative to T1*. Given the poor T1 rotation biofidelity of the Hybrid III identified by Davidsson *et al.* [Davidsson *et al.*, 1999a; Davidsson *et al.*, 1999b], this implies that the overall biofidelity of the Hybrid III is inadequate when interaction with the seat is considered.

The Hybrid III and Hybrid III with TRID neck (Hybrid III TRID) were found by Prasad *et al.* [1997] to have similar performance and were considered to be biofidelic relative to the data [Mertz and Patrick, 1971] on which the original design targets for the Hybrid III neck were based (dynamic tests with one volunteer and with two PMHS at two speeds, plus quasi-static volunteer tests). However the biofidelity evaluation was limited to head rotations only, which is not an adequate measure for the neck kinematics themselves. No difference in performance between the standard Hybrid III and TRID necks was found. The RID neck was also tested and was reported to be biofidelic at lower speed used (Δv = 16 $km.hr^{-1}$), whilst it bottomed-out at the higher test speed (Δv = 24 $km.hr^{-1}$).

These dummies were subsequently evaluated with pendulum impacts to the middle of the back [Linder *et al.*, 2000; Linder *et al.*, 2002], replicating PMHS tests with eight subjects. The results showed that the BioRID P3 was more biofidelic than the Hybrid III in terms of the kinematics of the head and T1. This is an important result, as it suggests that the solid thoracic spine of the Hybrid III would not interact with seat backs in a human-like way.

Siegmund *et al.* [2001] found that in comparison with 11 male volunteers, the Hybrid III did not replicate many features of the human response to low-speed rear impacts with a Δv 4 and 8 $km.hr^{-1}$. The study indicated that the RID 2a was able to model the overall kinematic and kinetic responses.

The Hybrid III (with standard and TRID necks), THOR and BioRID-2 were compared with 10 volunteers in low-speed rear impacts with a relatively rigid laboratory seat [Roberts *et al.*, 2002; Roberts and Carroll, 2003]. The authors reported that no version of the Hybrid III dummy gave a satisfactory performance, which was attributed to the rigid thoracic spine. They also noted that, although it appears to be possible to compensate for a non-biofidelic rigid thorax, found in many dummies, by adjusting neck stiffness, this method will only produce reliable results in the loading condition for which the neck was adjusted.

Willinger *et al.* [2003] compared the frequency response of the head-neck system of volunteers and dummies using a pendulum impact to the forehead. The Hybrid III was found to be too stiff and to have only a bending mode, with no neck retraction as was observed for the volunteers. The TRID neck was a slight improvement in extension, but again no retraction was observed. The BioRID and RID2 had better extension performance than the Hybrid III and both rear impact dummies exhibited a retraction mode, although improvements in both were recommended.

Other Research - Seat Interaction

Shen *et al.* [1998] compared the pressure and load distribution of the Hybrid III with those of 12 volunteers in low-speed rear impacts whilst seated in a modified driver's seat. They found that the pressure distribution pattern was significantly different for the dummy and the volunteers. Similarly poor Hybrid III TRID pressure distribution was reported for a relatively rigid laboratory seat [Roberts *et al.*, 2002], with more biofidelic distribution for the BioRID 2 dummy.

The biofidelity of the Hybrid III and the BioRID P3 were evaluated by Gotou *et al.* [2001] in rear impacts with a Δv of 9.2 km.hr^{-1} and found that the BioRID P3 was more biofidelic in the test condition used. They also found that the differences between the two dummies were maintained at higher Δv's of 15 and 25 km.hr^{-1}, from which the authors inferred that the biofidelity of the Hybrid III was also poor at the higher velocities.

Zellmer *et al.* [2002] found that the Hybrid III TRID was very sensitive to seat design in a non-biofidelic way. In a seat with a narrow backrest and distinctive but thin padded side bolsters, the Hybrid III was supported by the bolsters at the shoulders (which are rigidly connected to the rigid spine). The kinematics of the dummy head and neck were governed by coupling between the bolster and shoulders, not by coupling between the spine and the seat back. It was the opinion of the authors that this was not realistic and that the results for this seat when tested with BioRID were more reliable. For other seats, they found that the rigid, one-piece spine box of the Hybrid III interacted with stiff structures in the seat back (e.g. the upper transverse support used in most seats) differently than spines with the correct number of segments (i.e. 12 for the thoracic spine). This produces differences in T1 accelerations and therefore in head-neck kinematics and injury assessment or seat performance measurements. The authors 'recommend not to use the HIII(TRID) further for low speed rear impact testing as it clearly deviates in kinematics from the two new dummies which have been developed to show more realistic human behaviour in such rear impacts'.

The thoracic spine is an important part of the dummy when aiming to reproduce a human-like motion and seat back interaction in low velocity rear impacts [Linder, 2001].

Conclusion

The evidence reviewed shows that the Hybrid III is not biofidelic in low-speed rear impacts and should not be used to test seats in these conditions. For some seat designs, some head-neck motion and force parameters are reasonably good compared with a human occupant, but this is dependent on the particular interaction between the Hybrid III back (the shoulders and/or the thoracic spine) and the seat back. All studies that have specifically examined the interaction between the Hybrid III and the seat back have found that the interaction is not at all human-like due to the rigid thoracic spine of the dummy. In order to ensure that the dummy interacts with the seat in the same way as a human in a low-speed rear impact, and thereby to ensure that the assessment of the seat is reliable and the prediction of injury savings is robust, the dummy used should have a more flexible spine than the Hybrid III.

Acknowledgements

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Annexes

Annex	Content	No. Pages
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Test of force controlled yielding seats to draft GTR head restraint dynamic test

Torbjorn Andersson
Ola Bostrom
Autoliv Research

Head Restraint Informal Working Group Meeting
January 23-26, 2006
BASt, Köln, Germany

Autoliv

GTR Draft

Either 55 mm* backset

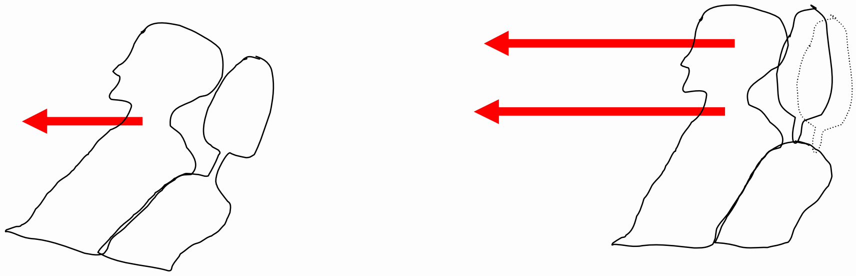
or

< 12 degree Hybrid III head-torso rotation in dynamic test

***IIWPG 70 mm**

Autoliv

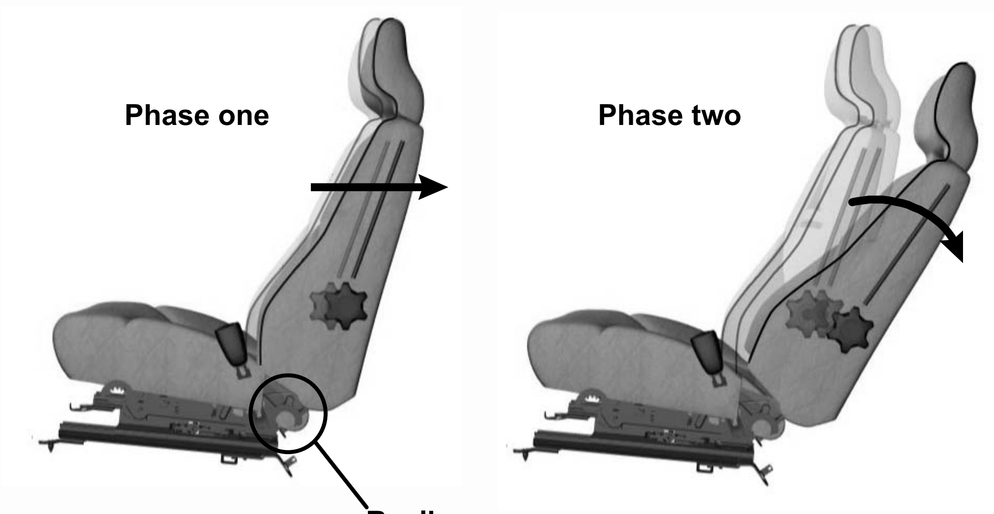
Two basic concepts of dynamic neck protection



Reduce elastic force
by force controlled yielding
(cf belt force limiter)

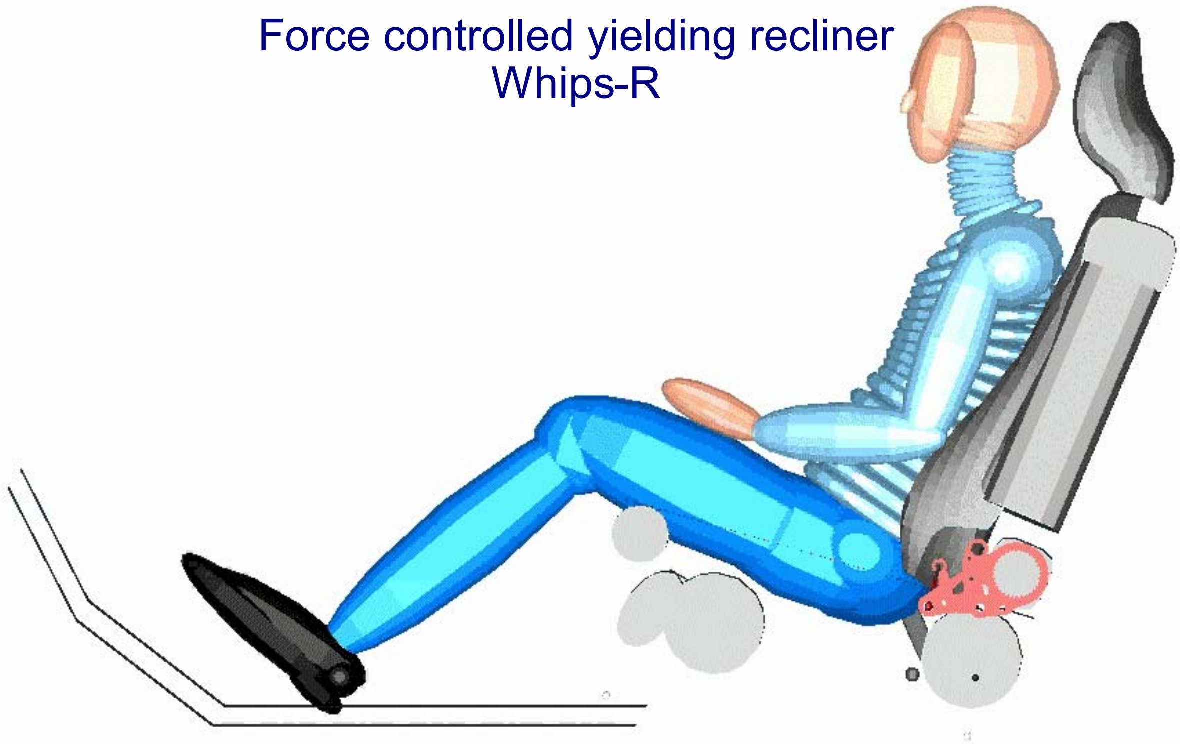
Reduce time of head-to-headrest contact by reduced backset or active headrest
(cf belt pretensioner)

Force controlled yielding recliner, named Whips-R



Whips-R in Volvo seats

Force controlled yielding recliner
Whips-R



Whips-R in Volvo seats

Real-life and rating facts
Whips-R

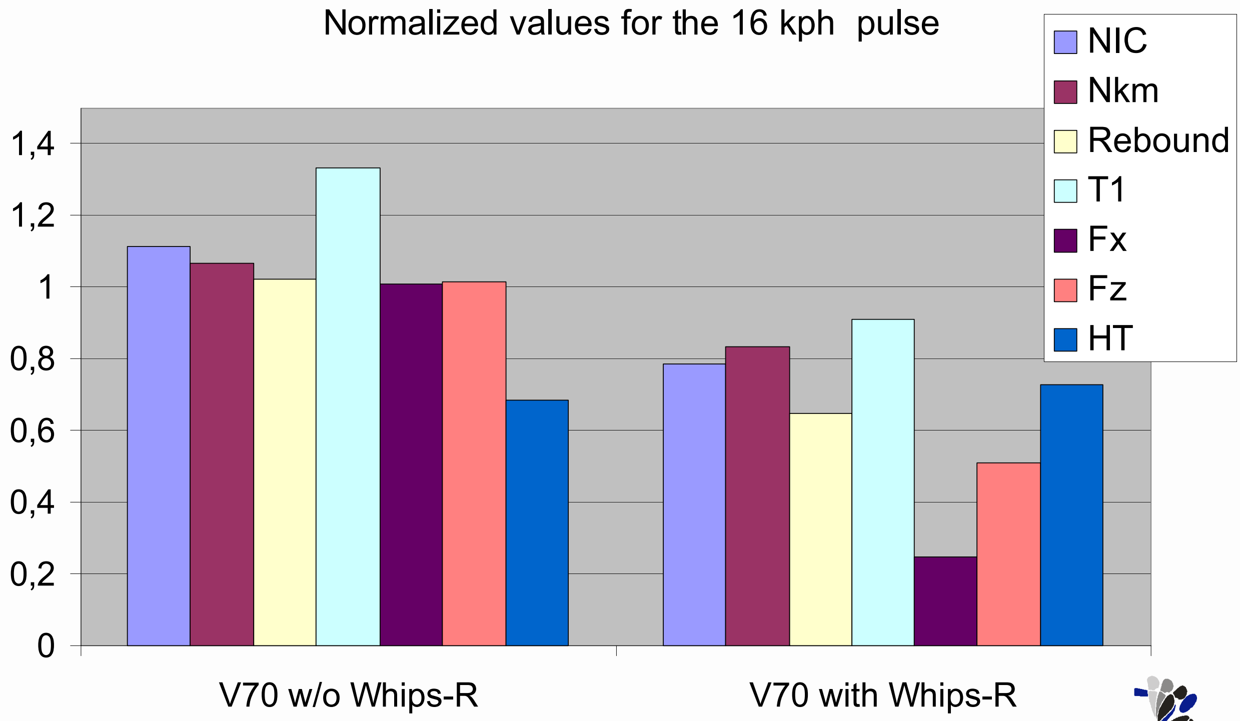
Volvo seats with force controlled yielding recliners reduce risk of short and long term soft tissue neck injuries in real life*

Volvo seats with force controlled yielding recliners are on the top of all consumer rating lists**

*Jakobsson "Field analysis of AIS1 neck injuries in rear-end car impacts- injury reducing effect of the WHIPS seat", J of Whiplash & Related Disorders Vol 3 No 2 2004.
Jakobsson & Norin "AIS1 neck injury reducing effect of WHIPS", Int IRCOBI Conf. 2005).
Farmer et al, "Effects of head restraint and seat redesign on neck injury risk in rear-end crashes", TIP Vol 4, 2003).
Krafft et al, "Assessment of whiplash protection in rear impacts – crash tests and real-life crashes" , Folksam and SRA Press release June 2004).
Krafft, "A comparison of short- and long-term consequences of AIS1 neck injuries, in rear impacts", Int. IRCOBI Conf. 1998).
**Folksam/SRA (criteria based on scientific facts) and IIWPG (IIHS/Thatcham/ADAC) (criteria based on best practice)

Autoliv

Combined IIWPG and Folksam&SNRA evaluation



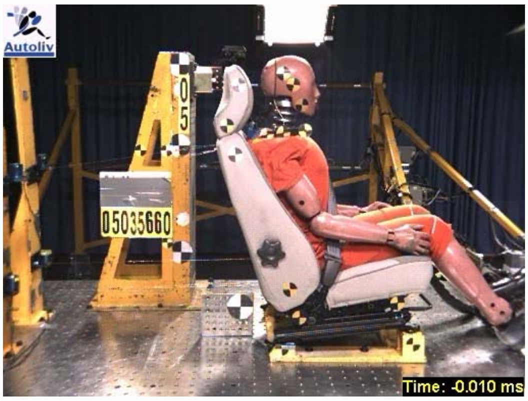
Autoliv draft GTR dynamic test evaluation

Hybrid III (draft GTR)

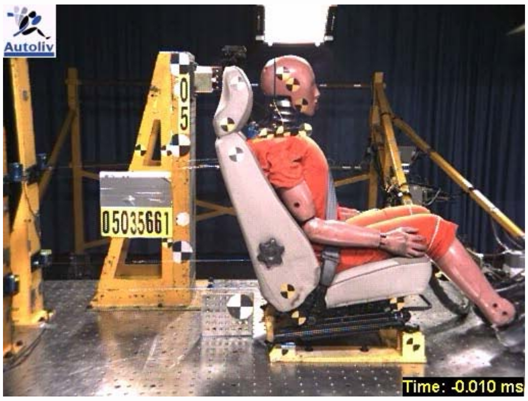
V70 w/o Whips-R
V70 with Whips-R

BioRID (sole deviation from draft GTR)

V70 with Whips-R



V70 with Whips-R

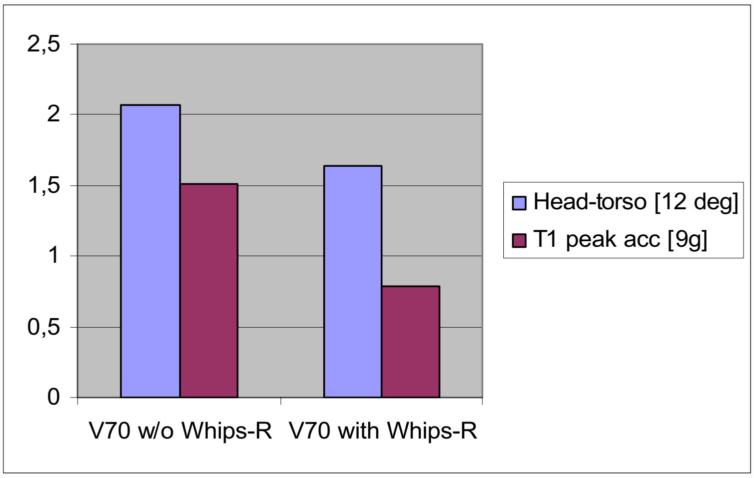


V70 w/o Whips-R

Test results draft GTR (Hybrid III)

	Volvo w/o Whips-R	Volvo with Whips-R
Head-torso angle [deg]	**24,8**	**19,6**
NIJ	0,14	0,11
T1 peak acc	13,6	7,1
Head angular velocity	1010	642
Head peak angle	29,7	32,7
Torso peak angle	8,2	20,7
Upper seat back disp.	74,7	172

Head-torso rotation and T1 acceleration normalized results



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Test results BioRID instead of HIII

Criteria	**Results**	***"Good Rating"***
NIC	10.4m/s^2	*15m/s^2*
Nkm	0,17	*0.3*
T1 acc	7.3g	*9.5g*
Head contact time	52ms	*70ms*
Upper neck Fx	32.4N	*130N*
Upper neck Fz	304N	*600N*

Remark: reflects highest possible rating (Folksam/SRA and IIWPG)

Autoliv

Summary test results

Volvo Whips-R test results are excellent when BioRID and BioRID performance criteria are used

When tested with Hybrid III, the head-torso rotation is reduced, but exceeds 12 degrees

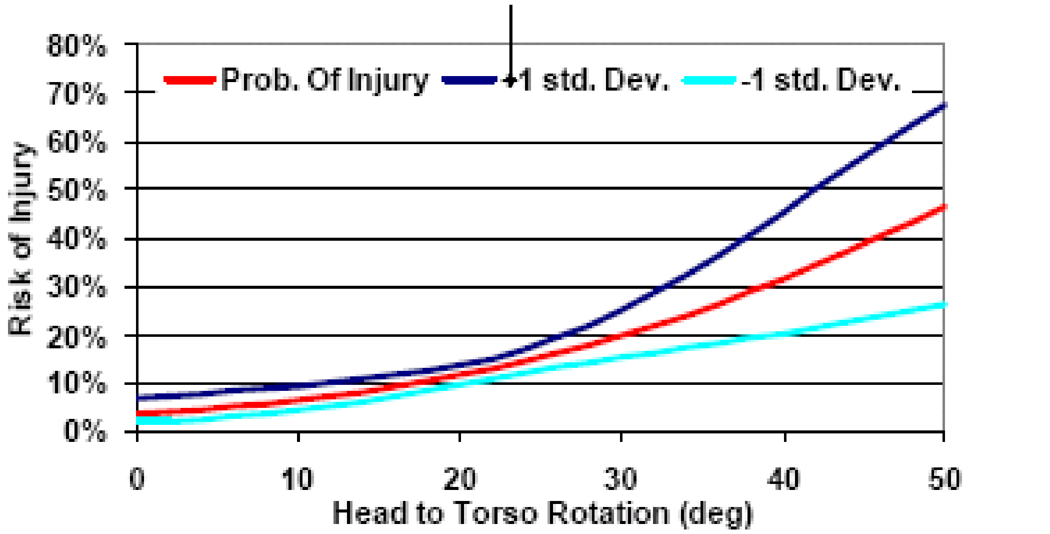
Remark: Volvo seats meet backset requirement of less than 55 mm, irrespective of Whips-R

Autoliv

Head-torso rotation risk curve

The FMVSS202 risc curve is based on two (2) observations.
No force controlled yielding systems were taken into account.

Seat	Field Data		Sled Tests (16 km/h) weighted	
	No. of occupants	No. with MT and LT whiplash injuries	Head to torso rotation (deg)	Head to torso x-translation (mm)
Saab 900	160	25	25.5	37
Saab 9-3	122	9	12.1	13



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Discussion

Proposed GTR head-torso rotation **risk curve** is based on only two observations of claim frequency where sample data-Δv median is only 10 km/h

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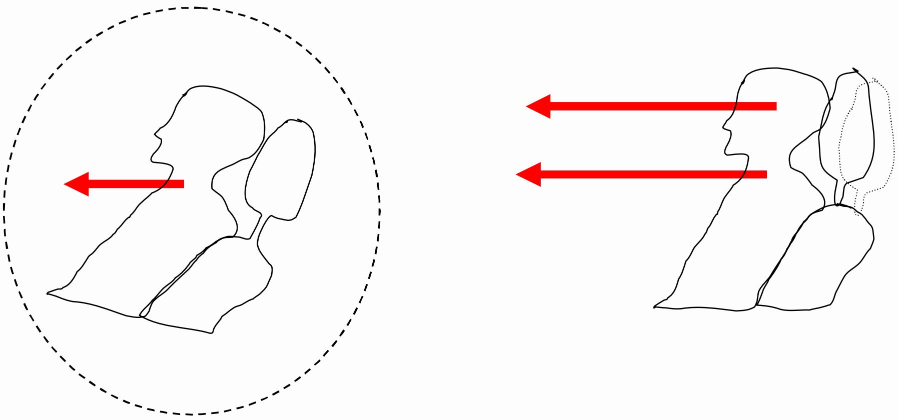
Conclusion

Proposed GTR dynamic test does not acknowledge force controlled yielding seats



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FMVSS 202a Alternative Dynamic Test

. Examine field performance of Volvo WHIPS seats versus performance in NHTSA's dynamic tests.

. Functional equivalency of the dynamic and static requirements.

. Suggested modifications of the dynamic requirements

Volvo WHIPS Seat: Real-World Performance

- Comparing Volvo seats with WHIPS to the previous-generation Volvo seats (Jakobsson and Norin, IRCOBI 2004).
  - There was an 18% reduction for initial soft tissue neck injuries.
  - For persistent soft tissue neck injuries (> 1 year), there was a 36% reduction.
- IIHS reported a 49% reduction in neck injury claim rates with WHIPS compared to previous generation seats (IIHS status report, 10/2002).

Volvo WHIPS Seat: Public Ratings

- IIHS/IIWPG (2005)
  - All tested models rated "Good"
    - S40, S60, S80, XC90
- Folksam/SRA (2005)
  - All tested models rated Green
    - S40, V50, S60, V70, S80, XC90

FMVSS 202a Alternative Dynamic Sled Test: Volvo S80

	Test 1	Test 2	Average	Requirement
Backset (mm)	55	50	52.5	55
Head-Torso Angle (Deg)	15.9	16.6	16.3	12
C7/T1 –My (Nm)	50	41	45.5	

FMVSS 202a Alternative Dynamic Test Concerns

- The head-torso rotation requirement may not be functionally equivalent to the static requirements.
  - Minimum height
  - Backset (Front outboard seating positions)
  - Gaps
  - Energy Absorption
  - Height Retention
  - Backset retention, displacement and strength
- The head-torso rotation requirement may be design/technology restrictive.

NHTSA Whiplash Injury Probability Curve: Basis

- Based on paired tests of Saab seats with and without the Self Aligning Head Restraint (SAHR)
  - The head-torso rotation was obtained via film analysis using "phantom" reference targets.
    - Not the method required by FMVSS 202a where instrumentation error is +/- 1.5 deg compared to film analysis (Voo et al., SAE 2003-01-0174).
- Viano 2002, "Role of the Seat in Rear Crash Safety"

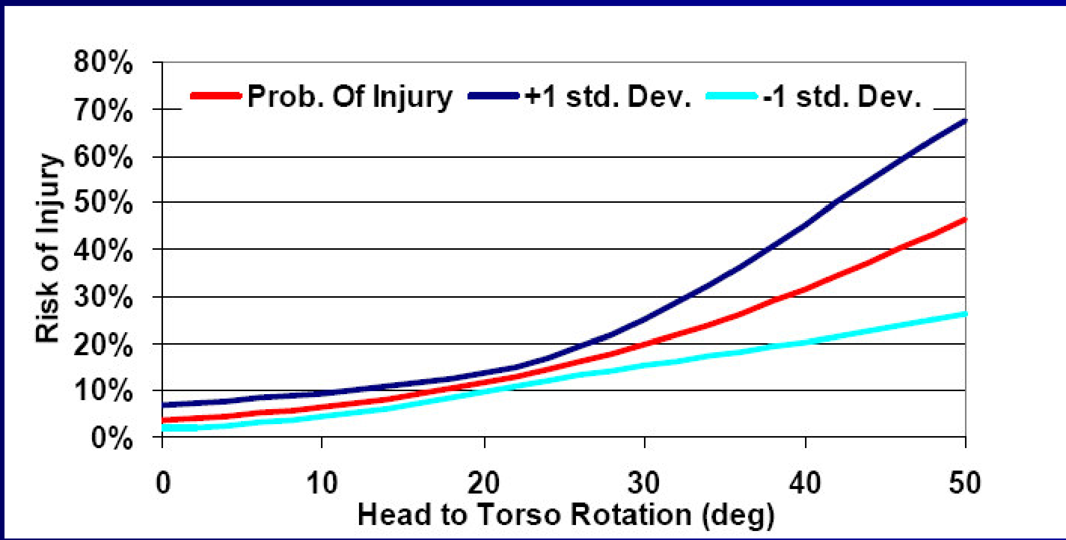
NHTSA Whiplash Injury Probability Curve: Basis

- The corresponding field data used consisted of a total of 282 occupant cases.
  - 160 Saab 900 occupants
  - 122 Saab 9-3 occupants
- The data are vehicle type specific.
  - The data was not normalized for vehicle mass.
  - Represents a specific vehicle architecture.
- The whiplash injury probability curve should be based on data representing the United States fleet.

Film Analysis: "Phantom" Reference Targets

• Viano, Role of the Seat in Rear Crash Safety, SAE 2002.

NHTSA Whiplash Injury Probability Curve



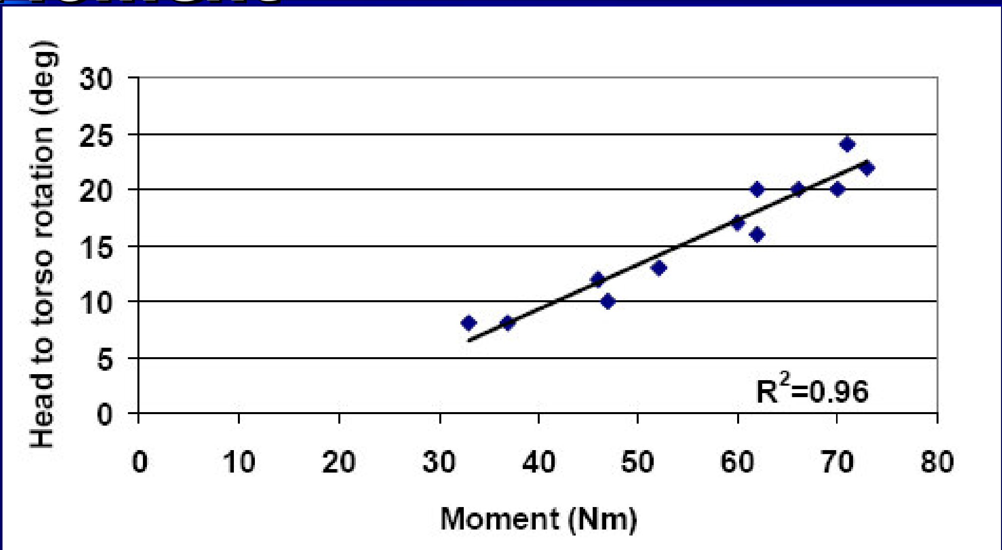
Proposal 1

- Increase the head-to-torso rotation limit to 20^{o} approximately 10% of risk
  - Approximately represents a 10% risk of whiplash injury (AIS 1) according to the NHTSA probability curve
  - Significantly lower than the 18.8% injury risk level allowed for moderate head injuries (AIS 2) by the HIC requirement of 500
  - Will be less design restrictive

Proposal 2

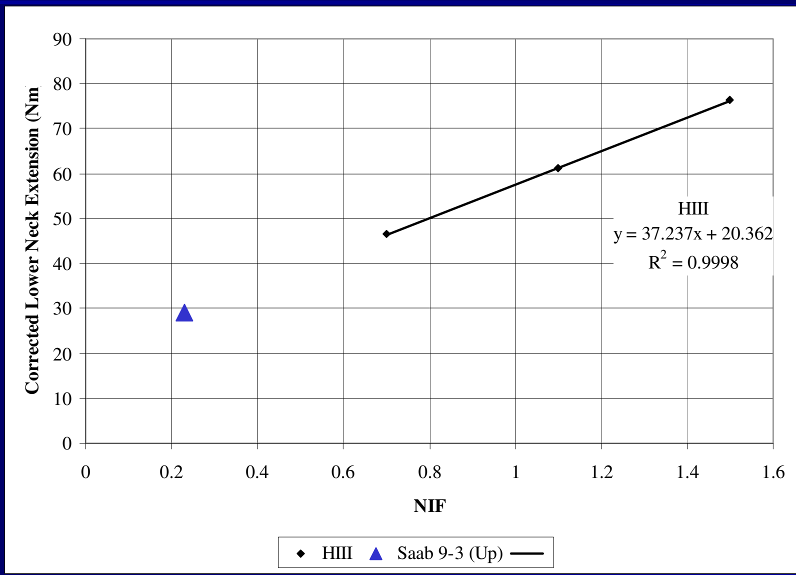
- Use the C7/T1 extension moment, -My
  - Uses direct measurements from lower neck load cell
  - Suggested value 65 Nm.
    - Corresponds to head-to-torso rotation of 20°.
  - Our studies indicate good correlation between C7/T1 moment reduction and and injury risk reduction.

50th% Hybrid III Head-to-Torso rotation versus C7/T1 Moment



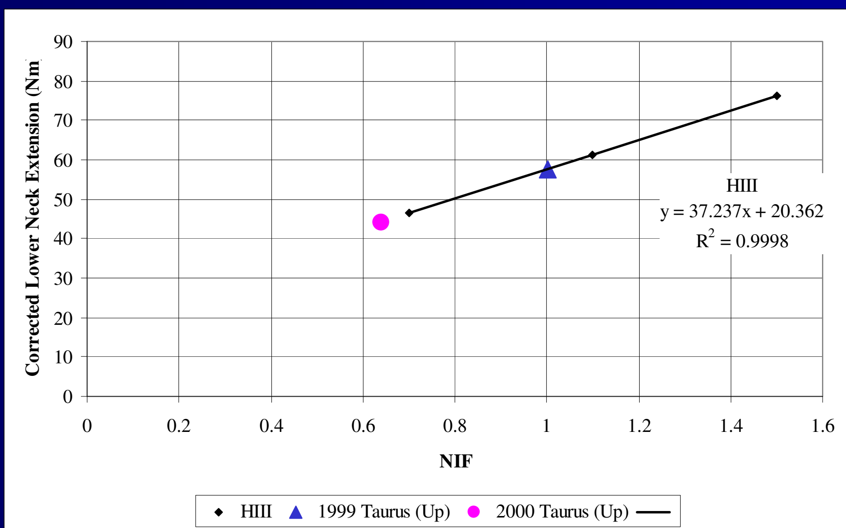
- Kuppa, Injury Criteria and Anthropomorphic Test Devices for Whiplash Assessment, NHTSA, 2004.
- Voo et al., Effect of Head Restraint Rigidity on Whiplash Injury Risk, SAE 2004-01-0332.

Real-world Prediction: Saab 9-3, 16 km/hr



% Reduction (Saab 9000, NIF ≅1.6) = 86%
- Viano's study documented a 75% improvement.

Real-world Prediction: Taurus, 16 km/hr



% Reduction (Taurus 1999 vs 2001) = 26%
- IIHS 2002 Study = 18%

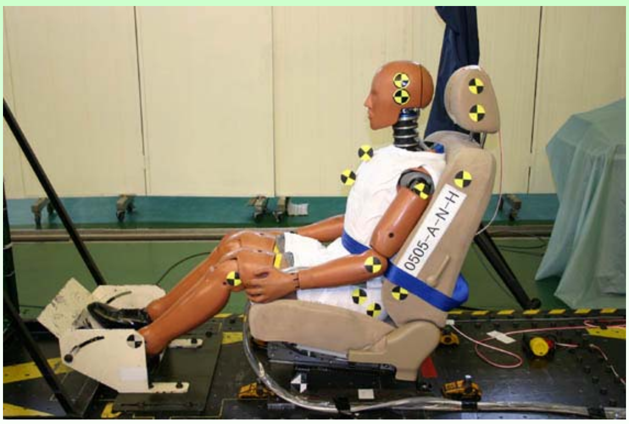
Correlation of Evaluation Results between FMVSS 202a (Hybrid III) and IIWPG (BioRID II) Tested in the Same Seat

January 2006

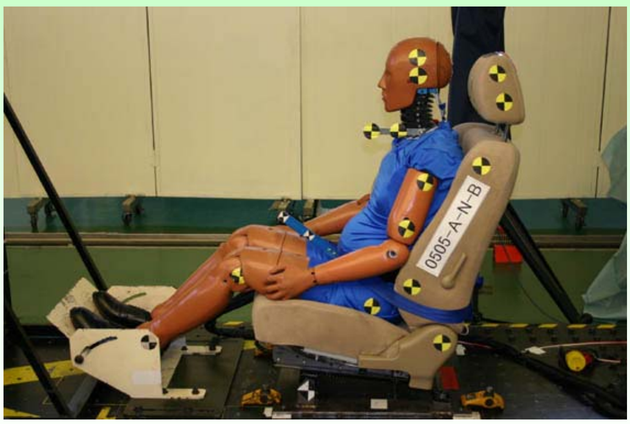
O I C A

Objective

To examine correlation
between <u>FMVSS 202a evaluation using a Hybrid III</u>
and <u>IIWPG evaluation using a BioRID II</u>.



Hybrid III



BioRID II

Test Conditions#1

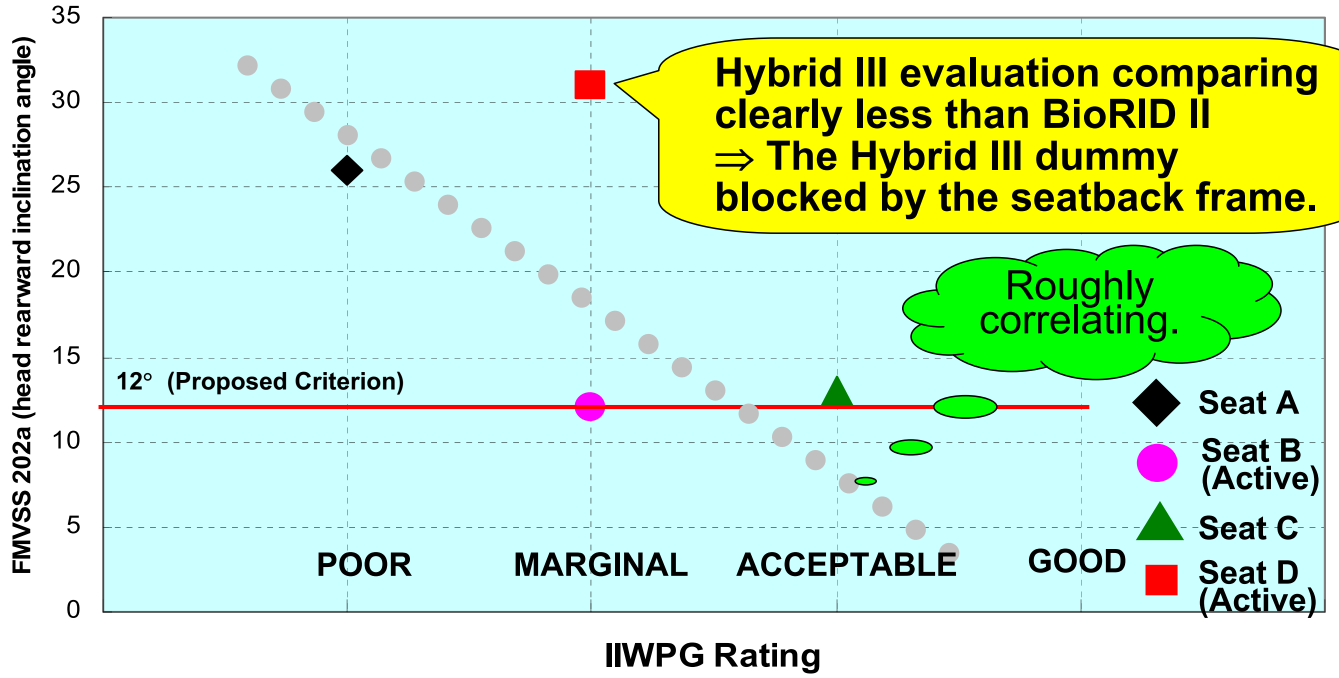
- Simulated rear-end impact tests using HYGE Sled
- Crash pulse : FMVSS 202a
- Measurements :
  - Sled acceleration
  - Head, T1, Chest, and Pelvis acceleration
  - Neck forces
- High speed video :
  - Kinematics
- Seat :
  - Normal HR - 2 types
  - Active HR - 2 types

Side View of Test

	Hybrid III	BioRID II
Normal Seat		
Active HR Seat		

Result

FMVSS 202a (Hybrid III) vs IIWPG (BioRID II) Evaluations



IIWPG Neck Injuries "GOOD" Criteria

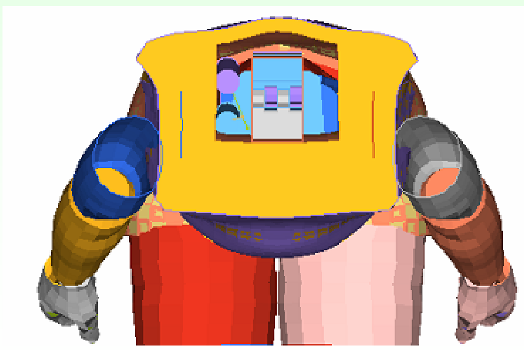
T1 x-acceleration	≤ 9.5 g	Or Time to HR contact	≤ 70 ms
* Neck Shear Fx	< 150N	* Neck Tension Fz	< 750N

HR-5-11

Differentiating Factors
Between FMVSS 202a (Hybrid III) and IIWPG (BioRID II)

- In the Hybrid III, the spine is encircled by rigid and mutually joined ribs and covered by a skin layer 10-15 mm thick.
- While the BioRID II has a thicker urethane skin layer. Combining a thicker skin layer and a flexible spine, BioRID II can more easily intrude into the seatback even when the vehicle is mini-sized and its seatback frame small -- thus, comparing better than Hybrid III.
- The same factors should be applicable to humans.

Hybrid III

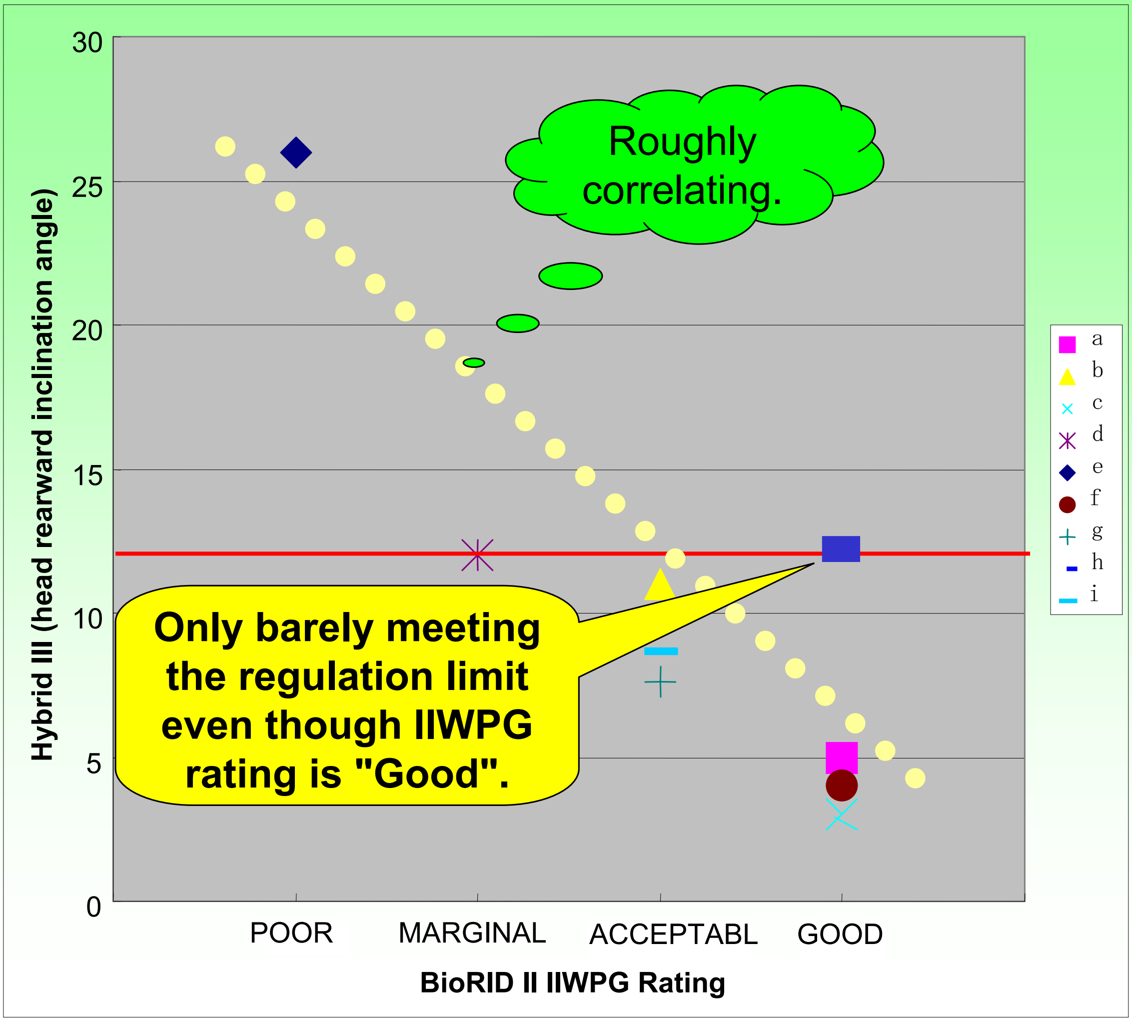


BioRID II

Test Conditions#2

- Simulated rear-end impact tests using HYGE Sled
- Crash pulse :
  - FMVSS 202a for Hybrid III
  - IIWPG for BioRID II
- Measurements :
  - Sled acceleration
  - Head, T1, Chest, and Pelvis acceleration
  - Neck forces
- High speed video :
  - Kinematics
- Seat :
  - Normal HR - 7 types
  - Active HR - 2 types

FMVSS 202a (Hybrid III) vs IIWPG (BioRID II) Evaluations



Conclusion

1. There is a certain correlation between Hybrid III head rearward inclination angle and BioRID II test results, but in some cases the angle shot up above the limit even though the BioRID II IIWPG rating is "Marginal".
   - ➢ The primary factor for angle rise in Hybrid III is likely its un- human like rigid ribs and spine, which make intrusion into the seat difficult when the seatback width is limited as in a mini car.
2. In some cases the head rearward inclination of Hybrid III barely satisfies the limit angle even though the BioRID II IIWPG rating is “Good”.
   - ➢ The FMVSS202a requirement is too strict.
3. The above findings suggest that Hybrid III gives poor results due to its unique factors absent in human bodies. Consequently, OICA has concern about the adoption of the Hybrid III to GTR.

Thank you

The T1G of Hybrid-III for Whiplash Injury Evaluation

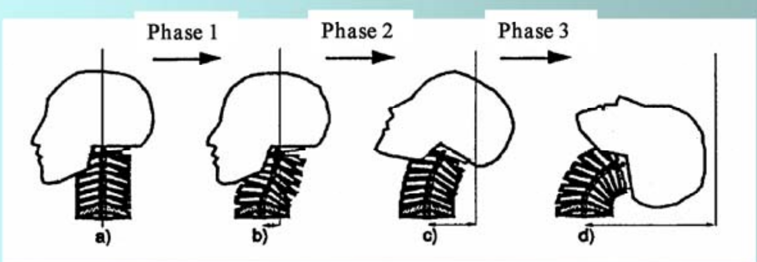
JAPAN/ MLIT
April 2006

Neck Injury Evaluation Criteria

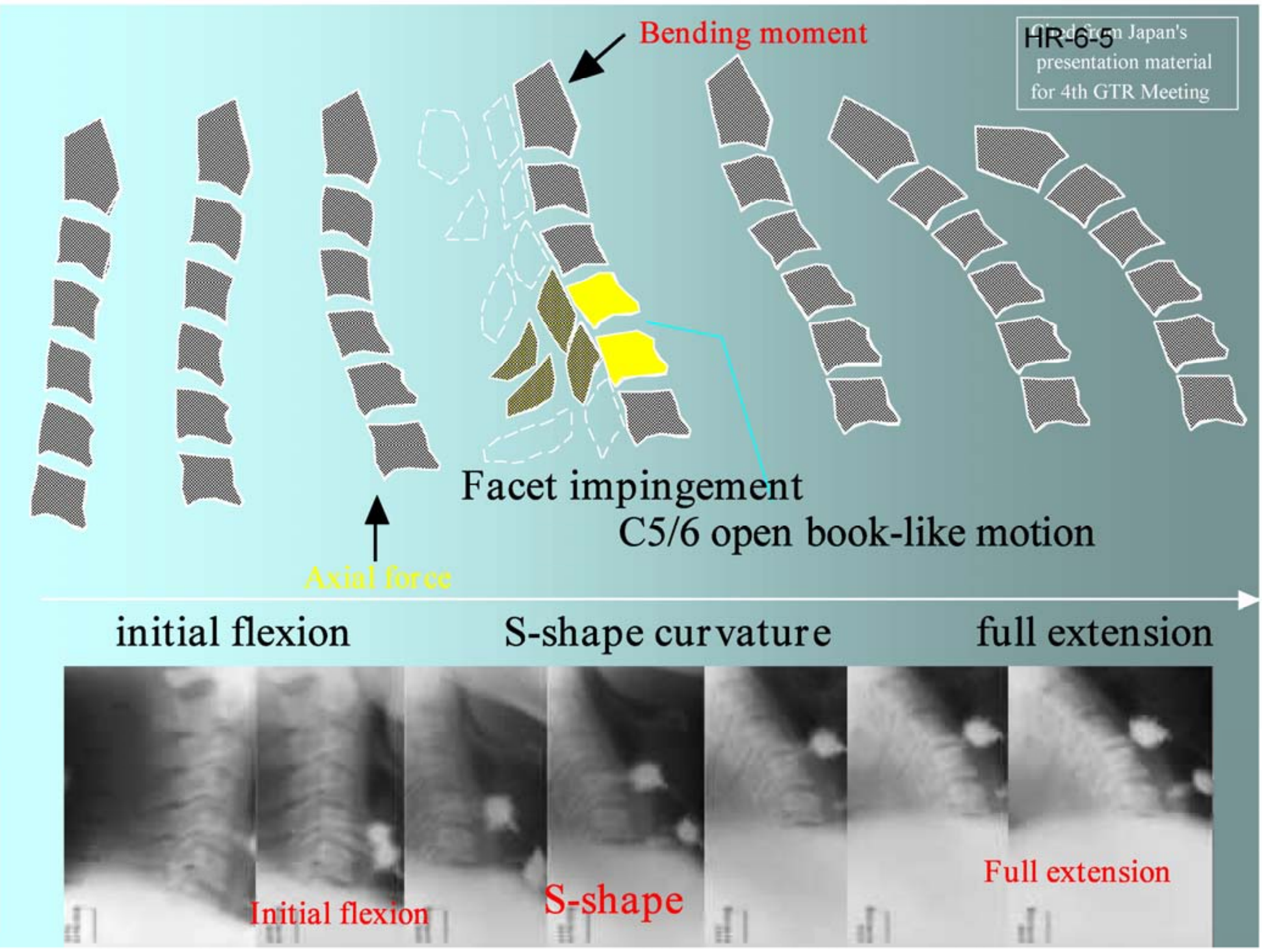
Cited from Japan's presentation material for 4th GTR Meeting

- For neck injury evaluation, the S-shape curving of the neck must be considered.

  ⇔ Conventional view



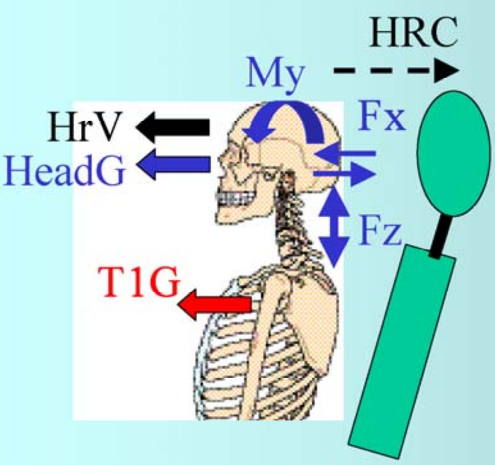
Bostrom et al, A New Neck Injury Criterion Candidate Based on Injury Findings in the Cervical Spinal Ganglia After Experimental Neck Exteision Trauma,1996 IRCOBI Conference



Existing Neck Injury Evaluation Methods

All the methods using upper and lower neck criteria

- IIWPG – T1G, HRC, Fx, Fz
- EuroNCAP – NIC, Nkm, Head rebound V,
  (draft) Fx, Fz, T1G, HRC



NIC: Calculated from acceleration/ velocity of the head and T1

Nkm: Calculated from neck moment and neck shear force

Biomechanical Responses of HY-III and BioRID II Part1

Cited from Japan's presentation material for 3rd GTR Meeting

To verify different biomechanical responses of HY-III and BioRID II

HY-III

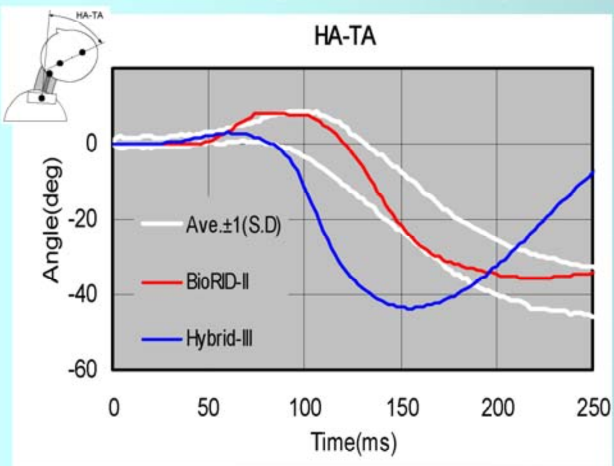
BioRID II

Kinematics

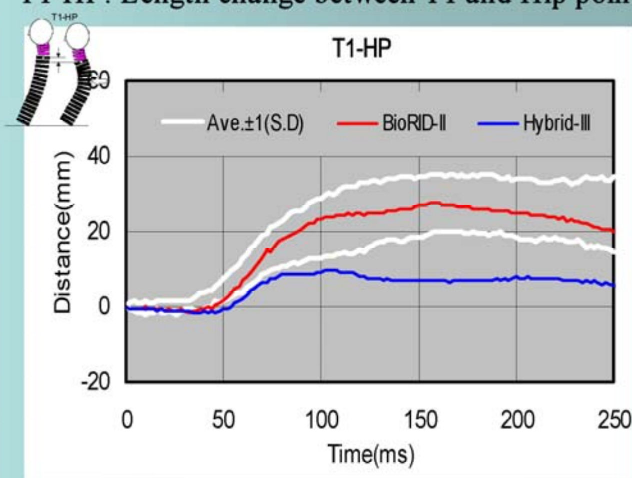
Cited from Japan's presentation material for 3rd GTR Meeting

•BioRID II is closer in terms of S-shape deformation pattern of the neck and the head/neck angle relative to T1 of human volunteer than HY-III.

HA: Head Angle,TA: Torso Angle



T1-HP: Length change between T1 and Hip point



↓

HY-IIIの挙動は人体と異なるが、ピークレベルは近い

↓

HY-IIIの挙動、ピークレベル共に人体と異なる

HR-6-5

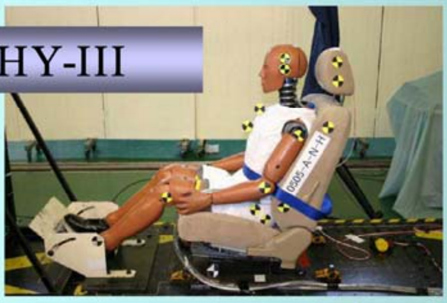
Biomechanical Responses of HY-III and BioRID II Part2

Cited from Japan's presentation material for 3rd GTR Meeting

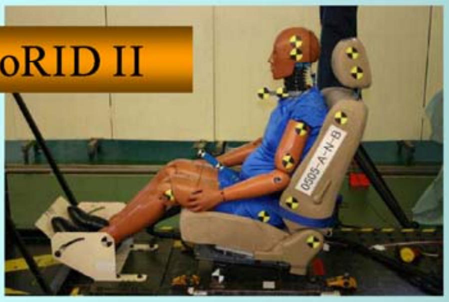
Hyge Sled Test

To verify the different biomechanical responses of HY-III and BioRID II due to different seat characteristics.

HY-III



BioRID II

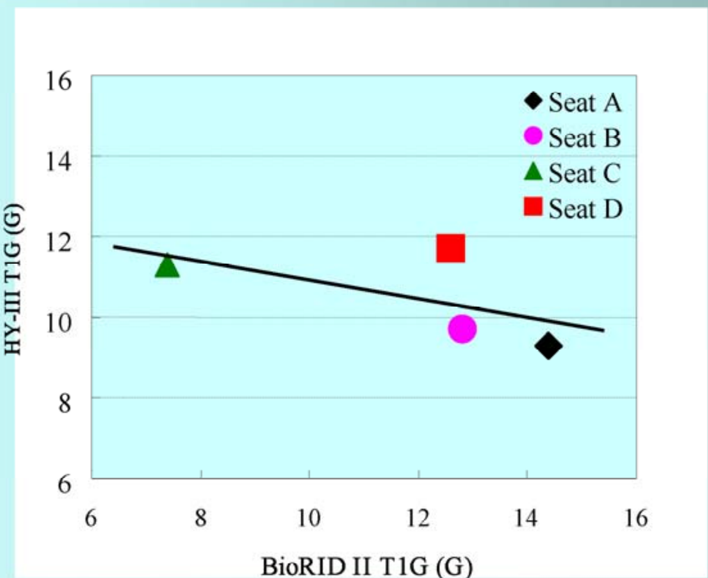


Types of Tests

- Seat A : Normal Head Rest
- Seat B : Active Head Rest
- Seat C : Normal Head Rest
- Seat D : Active Head Rest

HR-6-5

T1G Comparison between Hybrid-III and BioRID II

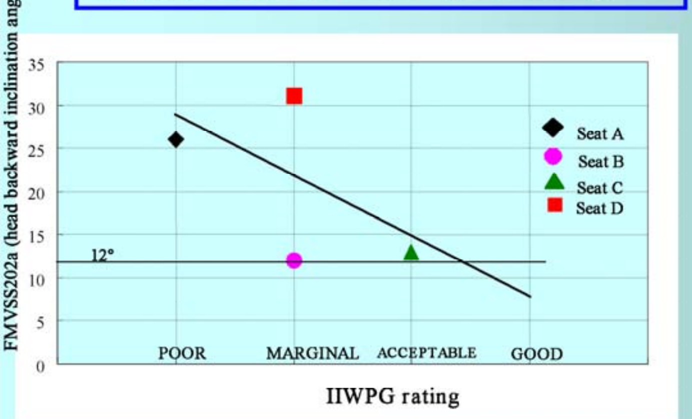


Because the T1G values of Hybrid-III and the more biofidelic BioRID II correlate inversely, the T1G of Hybrid-III is inappropriate as a neck injury evaluation criterion.

Hybrid-III's Head Backward Inclination/T1G vs BioRID-II's IIWPG Rating

Hybrid-III の場合、T1G加速度よりも頭部後傾角の方が生体忠実性のより良いBioRID IIの評価指標と相関がある。

Hybrid-III's head backward inclination angle vs BioRID-II's IIWPG rating



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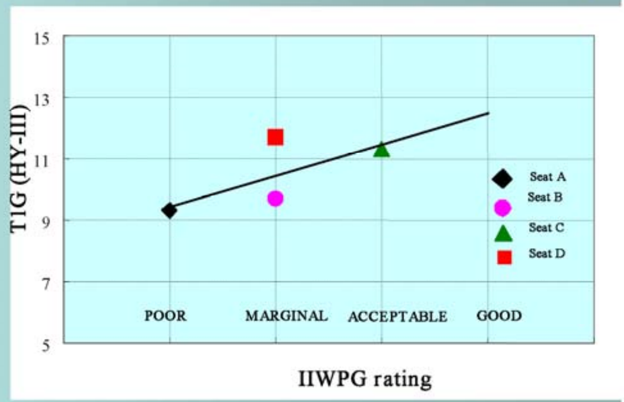
Roughly Fair correlation

Hybrid-III's T1G vs BioRID-II's IIWPG rating



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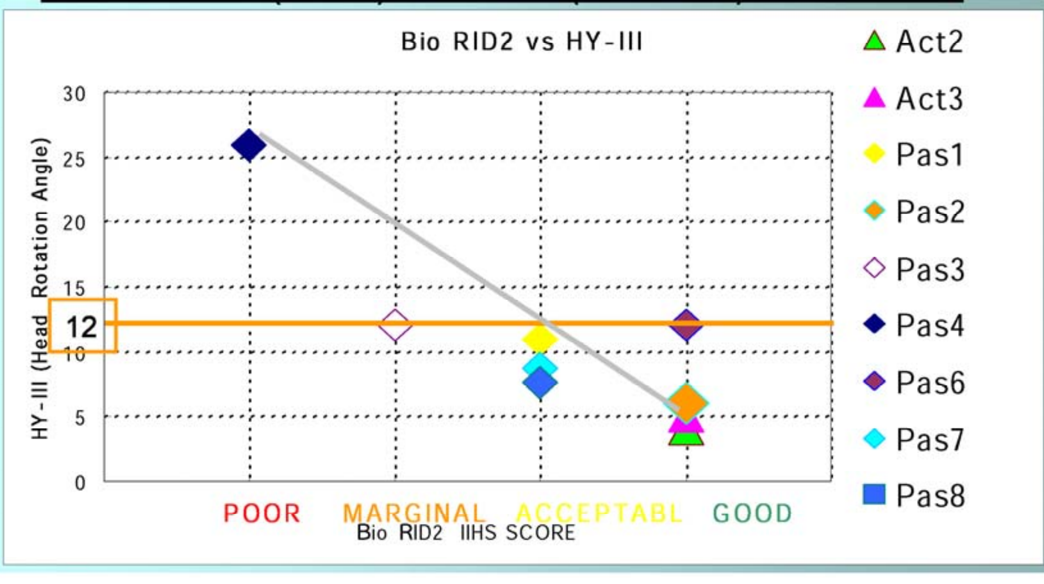
Inverse correlation

HY-III頭部後傾角要件の妥当性検証

頭部後傾角の要件は生体忠実性の低さから傷害低減効果を示す根拠が不十分であり、技術的実現性から決めるのが妥当と考えるが、現提案[頭部後傾角≦12°]は IIHSアセスメント実力との相関性検証結果から厳しすぎると考えられる。

FMVSS 202a (HY-III) vs IIWPG (BioRID-II) Evaluations



Conclusions

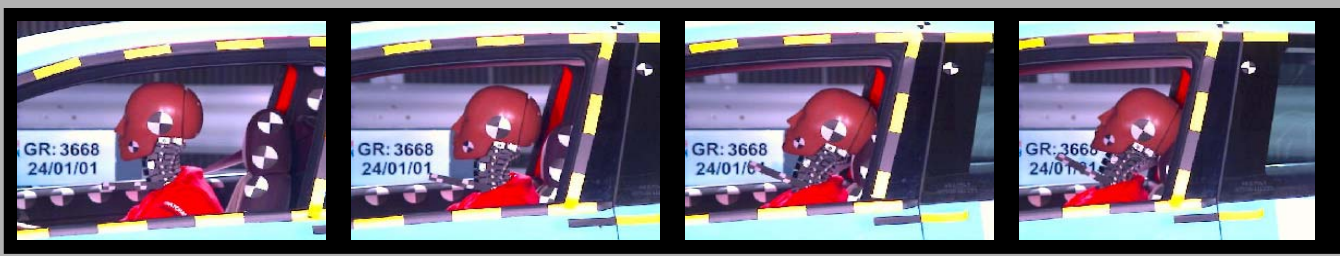
- S-shape curving of the neck is important.
  Desirable to measure both upper/lower neck criteria.
- Hybrid-III's T1G is an inappropriate criterion for the following reasons:
  - -生体忠実性が低い
  - - Inversely correlates with biofidelic BioRID-II's T1G.
  - - Inversely correlates with IIWPG rating.
- If Hybrid-III is to be used, head backward inclination angle is more reliable a neck injury evaluation criterion than T1G.
  しかしながら、現要件 案[12°以下]の妥当性はさらに検証要と考える。

Conclusions

- 将来的には、ダミーだけでなくスレッド波形も含めて、より市場の事故実態と相関性のある、（オプションではない）本来のダイナミック要件とすることが必要であり、その旨gtrプレアンブルにフェーズ２で検討すべき事項と記載することが望まれる。

BioRID ATD

Part of a Presentation from
Matthew Avery / Thatcham
for
an EEVC WG12/20 joint meeting



Why not Hybrid III?

Spine is not human-like

Human skeleton

Hybrid III

BioRID has more humanlike spine than Hybrid III

Human Skeleton

BioRID 2

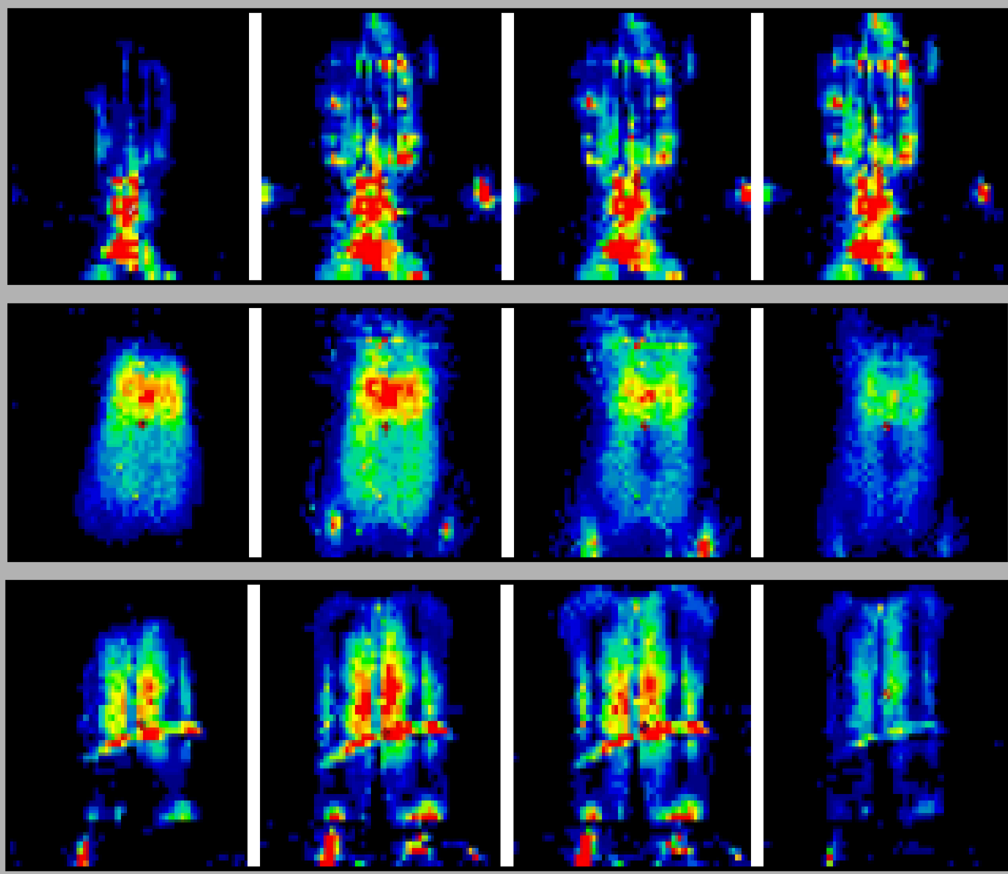
BioRID exhibits more humanlike motion than Hybrid III

BioRID exhibits more humanlike pressure distribution on seatback than Hybrid III

Hybrid III with TRID neck

Human Volunteer

BioRID



For further details see:

„Kinematics of the Human Spine in Rear Impact and the Biofidelity of Current Dummies“

Roberts AK, Hynd D et al.

IMechE Conference 2002, London

and

Project Report Whiplash II (not released yet)

GTR-HR

19-20-21 April 2006
London

Consideration of active HR

Needed consideration

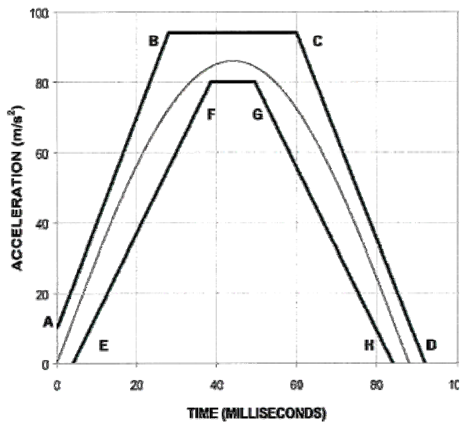
- Backset is the distance covered by the head during a rear impact before contacting the head restraint
- Backset should be measured when active system has been activated
- Anti-whiplash systems are motion of the HR or motion of the back of the dummy. They are reactive, active, using foam or structural deformations

Principles

- For active systems
  - Measurement of the backset after activation of the system. For non permanent system, need a camera to evaluate the displacement
- For reactive systems
  - Activation by applying load
    - Biofidelity of the backpan to apply the load ?
    - Angular deformation of the seatback difficult to manage
    - Inertia of the system is not considered
  - Dynamic tests to determine the cinematic backset

Dynamic tests done

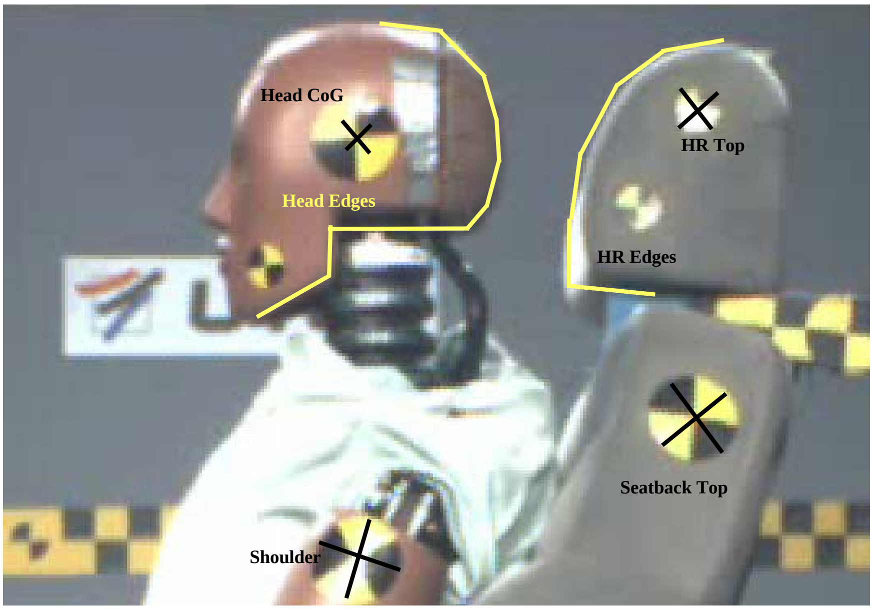
- Tests with H3 50% and BIORID
- FMVSS 202 Pulse
- Tests on 3 seats
  (2 reactives and 1 "passive")
- Two seats on same shot



- 17.3 ± 0.6 km/h ΔV
- 86 m/s^2 (8.8 g) peak acceleration
- 88 ms duration

proposal

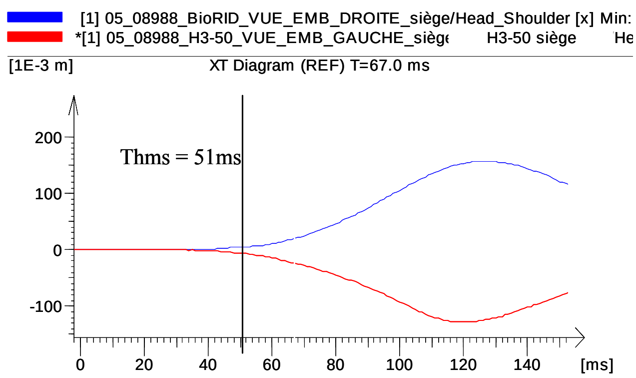
- Based on tracking

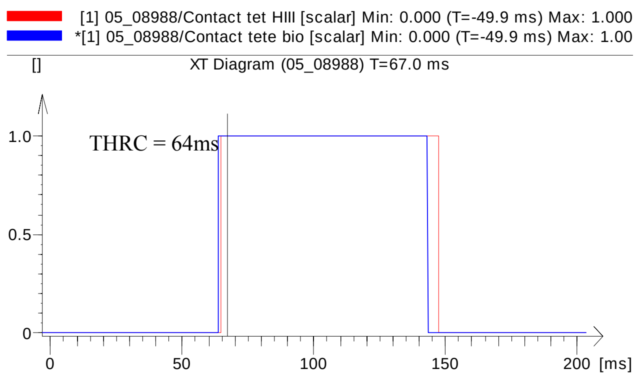


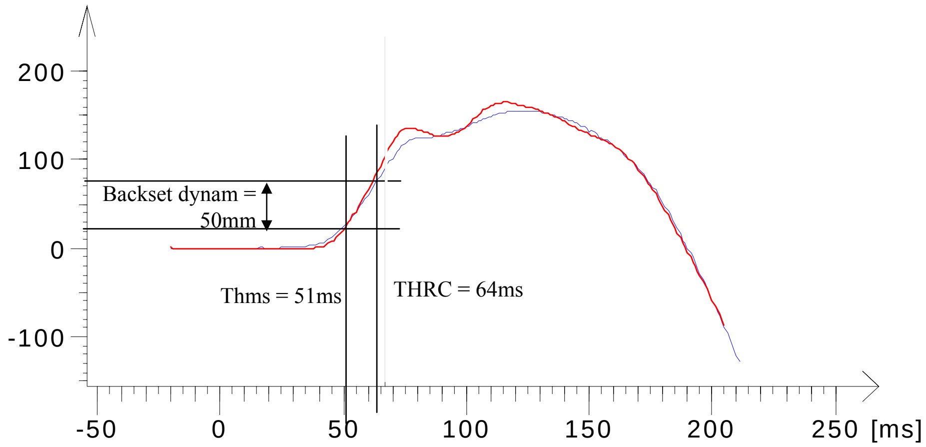
Values to measure

- Determine the Time of Head Motion relatively to the Shoulder (Thms). To consider only timing during which shearing of the neck occurred (considered to be dangerous) and to be incentive for foam deformation systems (toyota avensis) or structural one (whips)
- Determine the Time of contact of the Head with the Head Restraint (THRC)
- Measure the distance covered by the Head to the Head Restraint during that period.

Values to measure



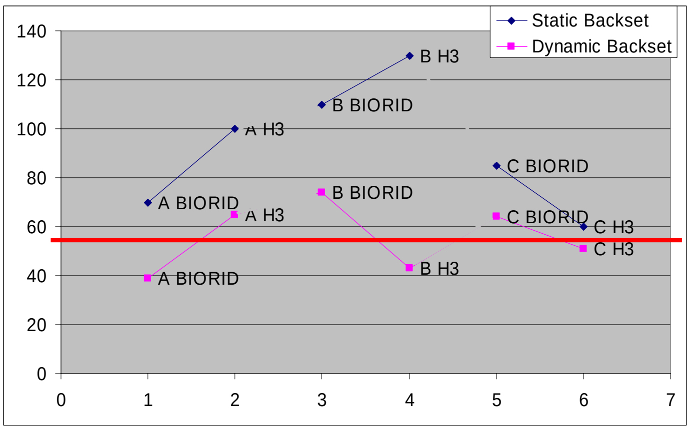




Timing analyses

	Dummy	Static Backset	Activation React HR	Thms	THRC	Dynamic Backset	HIC
Seat A	BIORID	70 mm	50 ms	53 ms	64 ms	39 mm	67
	H3	100 mm	50 ms	51 ms	65 ms	65 mm	48
Seat B	BIORID	110 mm	45 ms	55 ms	75 ms	74 mm	114
	H3	130 mm	30 ms	61 ms	68 ms	43 mm	61
Seat C	BIORID	85 mm	NA	55 ms	87 ms	64 mm	117
	H3	60 mm	NA	47 ms	63 ms	51 mm	58

- Dynamic backset always lower than static one
- On seat B H3 actuate really efficiently
- No rule for tendency. Different technologies tested



Conclusions

- Dynamic backset is coherent with technical solution used.
- Positioning of H3 is not define and should be if it has to be use (explanation of the behavior on seat B)
- Need to validate accuracy of the method
- Non-permanent shape system not considered