Informal document No. **GRSP-41-04**
(41st GRSP,7-11 May 2007,agenda item 3.1.1)

Proposal to Set Up the Head Restraints GTR Phase 2 Examination WG

MLIT, JAPAN

1. Proposal to set up a new ..

We propose to set up a “WG for the establishment of appropriate methods for testing and evaluating whiplash injury” as phase 2 and provide feedback to the Head Restraints GTR.

2. Background

- The head restraints GTR Phase 1 was limited to static requirements.
- As for appropriate dynamic tests, dummies with a high human-body fidelity are available, but it is still necessary to continue reviews including the improvement of reproducibility.
- Regarding assessment, the insurance industry groups such as IIWPG have already started dynamic tests. Also EuroNCAP plans to introduce dynamic tests starting 2007. However, the testing and evaluating methods vary among them.

3. Subjects of Review and Tasks

(1) Test conditions. Test conditions that reflect the realities of accidents on the market..

- Tests with actual vehicles or on sleds; the number and conditions of sled pulses

(2) Mechanism . Theories on the mechanism of whiplash injury vary. We do not know yet which one is the best.

- It is necessary to clarify the mechanism by analyzing accidents and performing volunteer tests and simulations with human body FE models.

(3) Evaluation dummies . We need dummies that reflect the above mechanism with a high fidelity to the human body and a high degree of perfection as a measuring instrument

- BioRID II is promising with its high fidelity to the human body, but still needs improvements in testing methods, structure, etc., because it has a problem in reproducibility.
- It is necessary to reduce the variation of results in initial sitting position of the dummy by improving the sitting method.

(4) Evaluation indicators . Indicators of human body injury that reflect the above mechanism

- According to what we have found so far, it is necessary to measure the relative movements between the upper and lower parts of the neck and the forces applied to each of these parts.

(5) Reference values. Should be based on the results of injury risk analysis and feasibility study.

(6) Effect evaluation . Evaluation of effects on reduction of injury and cost-effectiveness

4. Schedule

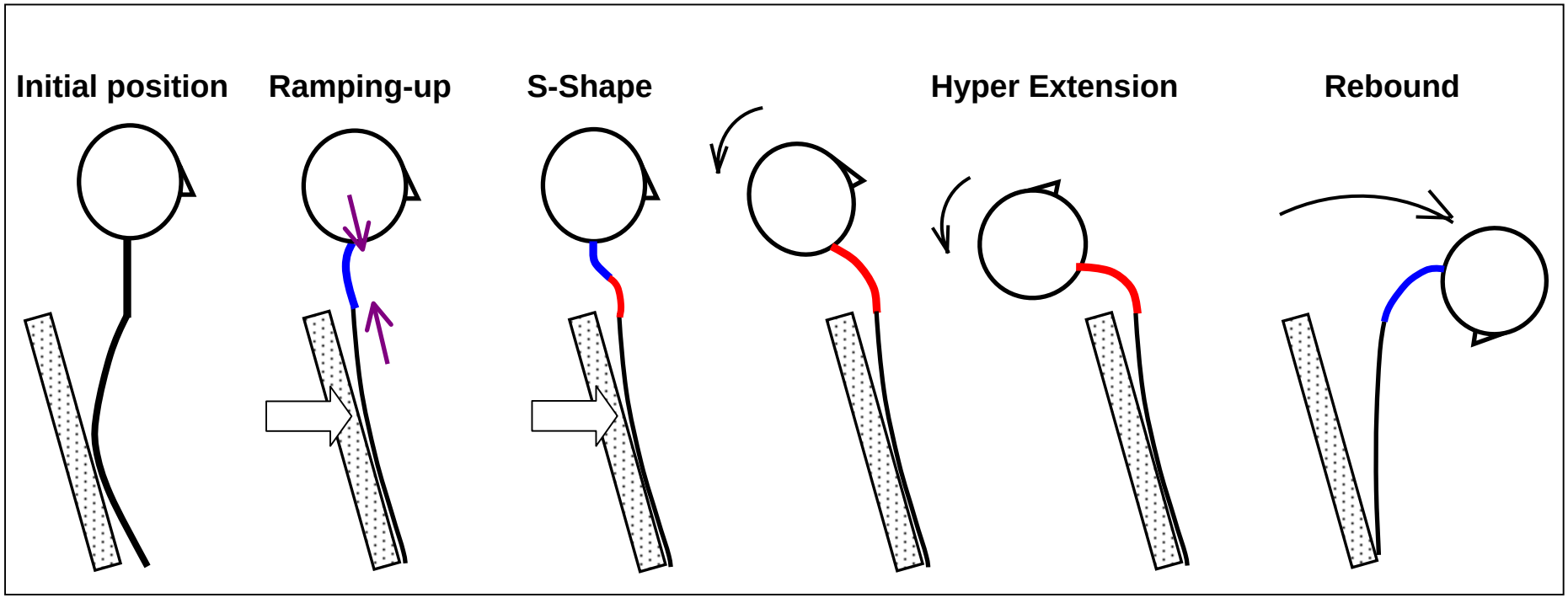
Subjects of review	Schedule
	'08 '09 '10
	Publication of GRSP WP29 Feedback to GTR as phase 2
(1) Test conditions Tests with actual vehicle or on sleds; the type and conditions of sled pulses	
(2) Mechanism Analysis of data on accidents on the market; Volunteer tests; FEM Simulations	
(3) Evaluation dummies Improvements in the structure of the dummy; assaying method; sitting method	
(4) Evaluation indicators Reflection of injury mechanism; Evaluation with injury values	
(5) Reference values Appropriate values based on injury risks feasibility studies	
(6) Effect evaluation Effect on the reduction of injury in accidents on the market; Cost effectiveness	

Thank You

Supplementary Information

1. Mechanism of production of neck injury

<Behavior of the passenger upon rear collision>



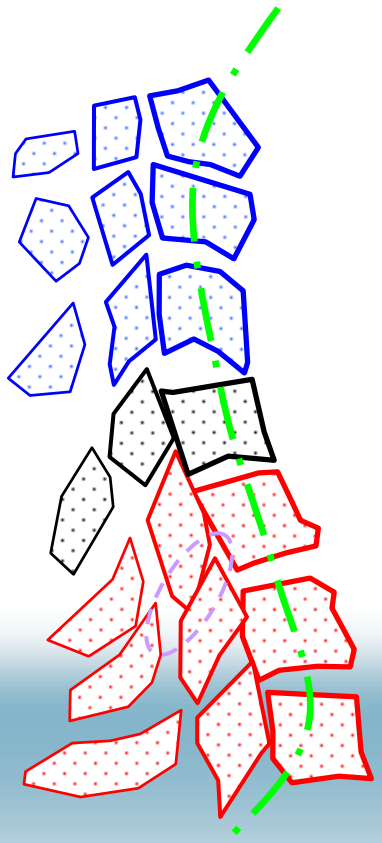
<Injury mechanism>

(1) Hyper extension of the neck.MacNab et al. 1964)

..Detachment of vertebral disks upon hyper extension in a situation without head restraints

Mechanism of Production of Neck Injury

S-Shape



(2) Pressure on the spinal neural ganglion due to a change of pressure in the spinal canal.Svensson et al. 1996)

The pressure and flow in the canal rapidly changes due to a change in the volume of the spinal canal, and this produces pressure on the spinal nerve.

(3) The synovial membrane folds of the facets are nipped as the turning center of the body of vertebra rises (Ono, Kaneoka..1998)

The partial rotation of the body of vertebra in the lower cervical vertebra causes pressure on the **facets** and ligaments.

(4) Injury due to facet sliding.(Yoganandan et al. 2001)

In the lower part of the cervical vertebra, the facets are locally compressed.

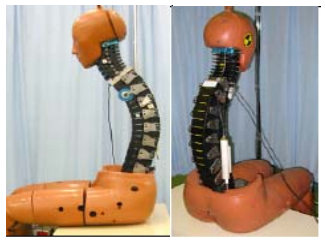
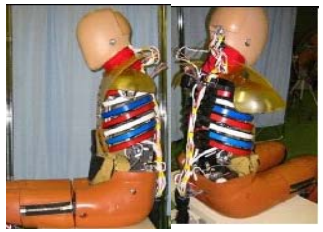
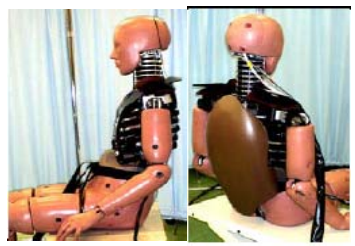
1. Injury indicators - Injury indicators according to shock response

Name	Proponent	Year	Source	Outline	Adoption as injury indicators			
					IIWPG	Folksam	ADAC	Euro NCAP
NIC	Bostrom (Autoliv)	'96	IRCOBI	Represents change in pressure in the cervical canal due to the change of the neck in S	Not adopted because it does not correspond to whiplash injury some cases.	○ Adopted as injury indicators before restriction with the head restraints	○ Adopted as injury indicators before restriction with the head restraints	○ Adopted as injury indicators before restriction with the head restraints
Nkm	Schmitt (ETH)	'01	ESV	Calculated by combining the shearing load and the bending moment applied on the upper part of the cervical vertebra		○ Adopted as injury indicators during restriction with the head restraints	○ Adopted as injury indicators during restriction with the head restraints	○ Adopted as injury indicators during restriction with the head restraints
LNL	Heitplatz (Ford)	'03	ESV	Calculated by combining the shearing load and the bending moment applied on the lower part of the cervical vertebra				
MIX	Kullgren (Folksam)	'03	ESV	Calculated by combining NIC and Nkm				
WIC	Muñoz (CIDAUT)	'05	ESV	Calculated by combining the bending moment on the upper and lower parts of the cervical vertebra				
T1G				Deceleration on the first thoracic vertebra	○ Adopted as reference for the determination of the seat dimensions		○ Adopted as reference for the determination of the seat dimensions	○ Adopted as reference for the determination of the seat dimensions
Fx (upper)				Shearing load on the upper part of the cervical vertebra	○ Adopted as injury indicators during restriction with the head restraints		○ Adopted as injury indicators during restriction with the head restraints	○ Adopted as injury indicators during restriction with the head restraints
Fz (upper)				Axial force on the upper part of the cervical vertebra	○ Adopted as injury indicators during restriction with the head restraints		○ Adopted as injury indicators during restriction with the head restraints	○ Adopted as injury indicators during restriction with the head restraints

2. Injury indicators - Injury indicators according to shock response

Name	Proponent	Year	Source	Outline	Adoption as injury indicators			
					IIWPG	Folksam	ADAC	Euro NCAP
IV-NIC	Panjabi (Yale Univ.)	'99	IRCOBI	Mobile range between vertebral bodies				
VT1	Muser (ETH)	'00	IRCOBI	Velocity of the head center of gravity relative to T1				
NDC	Viano (Saab)	'02	SAE	Mobile range of the head center of gravity relative to T1				
PWI	Mallory (NHTSA)	'05	ESV	Mobile range of the head relative to the torso				
Rebound Velocity				Rebound velocity of the head after the completion of restriction with the head restraints		○ Adopted as an injury indicator after the completion of restriction with the head restraints	○ Adopted as an injury indicator after the completion of restriction with the head restraints	○ Adopted as an injury indicator after the completion of restriction with the head restraints
THRC				Timing of contact between the head and the head restraints	○ Adopted as reference for the determination of the seat dimensions		○ Adopted as reference for the determination of the seat dimensions	○ Adopted as reference for the determination of the seat dimensions

3. Dummies for Whiplash Injury Evaluation

	Hy-III	Bio-RID	THOR	RID-3D
				
Advantages	The relative relationship with human body is good in terms of the rotation angle of the head relative to the torso (NHTSA). Reproducibility and repeatability are good.	The neck is designed as a flexible multi-joint structure and can reproduce behaviors close to the human body.	–	The neck is designed as a flexible multi-joint structure and can reproduce behaviors close to the human body.
Disadvantages	The neck is harder than the human body → Difference in passenger' behaviors (deformation in S-form; Straightening of the vertebra)	Repeatability in the same dummy; Reproducibility between dummies; Reproducibility of sitting position; Standardization of calibration	Originally developed for front collision evaluation; Results in smaller rotation angle due to the high bending rigidity of the neck.	The neck is too soft; the rotation angle of the neck is larger than that observed in volunteer tests (NHTSA).
Adoption	NHTSA (FMVSS202)	IIHS (US) Thatcham (UK) Folksam (Sweden) ADAC (Germany)	–	–

Problems in the Evaluation of Bio-RID

1. Repeatability and reproducibility

<Repeatability with the same dummy>

<Reproducibility among different dummies>

2 Reproduction of sitting position of the dummy

- Backset when setting the dummy and variation of H-Point

3. Standardization of calibration

- Influences the difference of response among dummies

Method and Criteria for Evaluation of Repeatability

Cited from presentation material for 5th GTR Meeting

■Method of evaluation

..Comparison of coefficient of variation .CV.

Repeatability $C.V = \frac{Sd}{\overline{X}} \quad 100\ (\%)$

$\overline{X}$ .. = *Mean value of each dummy*

Sd . *Standard deviation of each dummy*

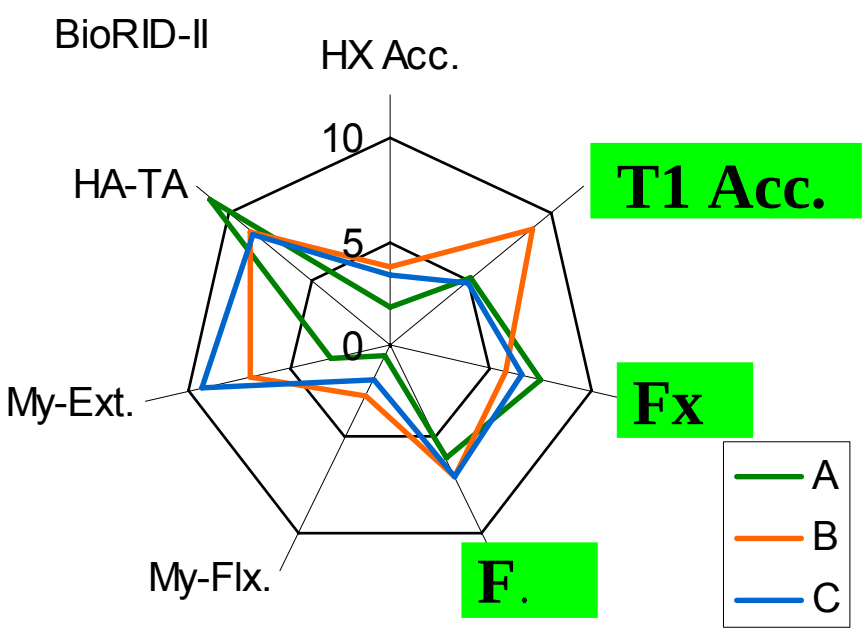
■Criteria ..Admissible level: CV.10

Summary of Evaluation of Repeatability Based on CV

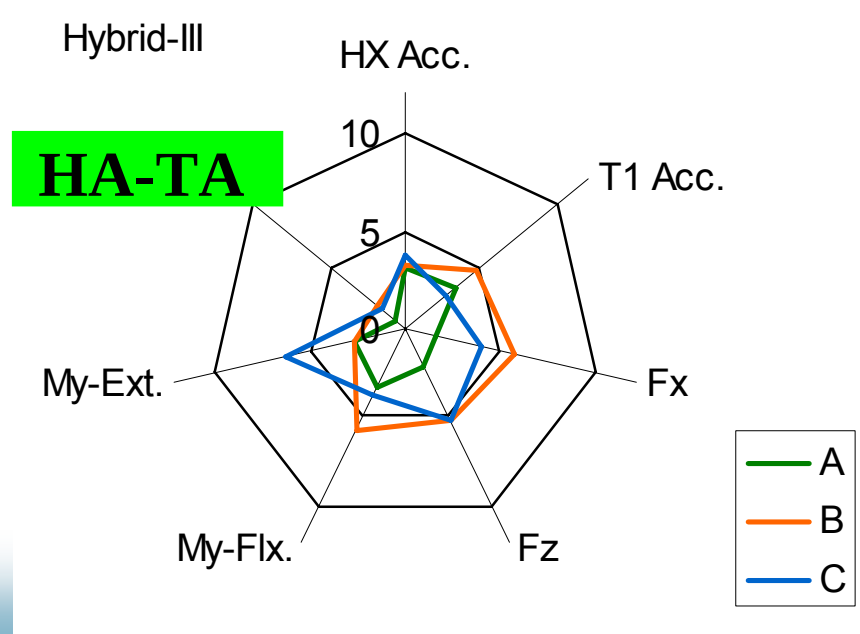
Cited from presentation material for 5th GTR Meeting

- For both of BioRID-II and Hybrid-III, the repeatability of the evaluation indicators was within the limit of tolerance.

BioRID-II



Hybrid-III



Method and Criteria for Evaluation of Reproducibility

Cited from presentation material for 5th GTR Meeting

■Method of evaluation

.Comparison of coefficient of variation .CV.

$$Reproducibility \quad C.V = \frac{S_B}{\bar{X}_G} \qquad 100\ (\%)$$

$$S_B = \left[\frac{MSB\text{-}MSW}{n}\right]^{1/2}$$

$\bar{X}_G$ = Mean value of 3 dummies

S_B

MSB : Mean square among groups (dummies)

MSW : Mean square in a group (each dummy)

n : Number of repetitions of test

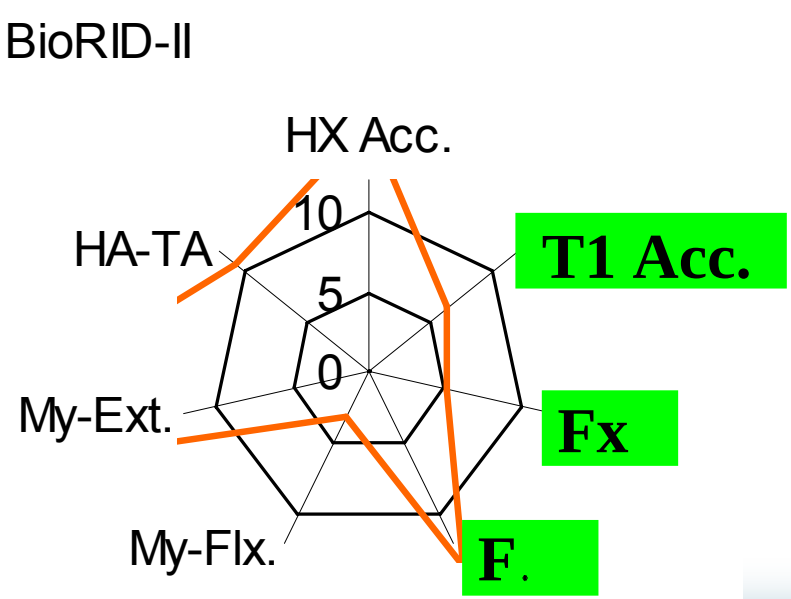
■ Criteria

.Admissible level: CV.10

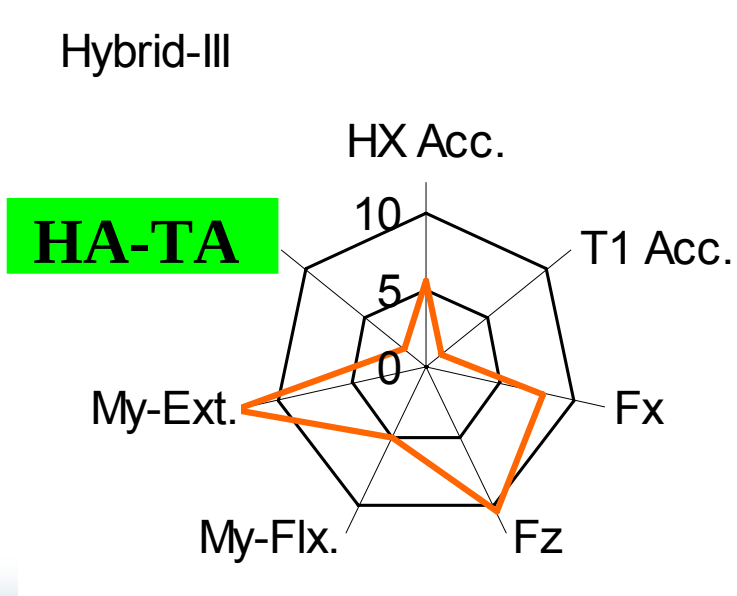
Summary of Evaluation of Reproducibility Based on CV

- **For Hybrid-III, the reproducibility of the evaluation indicators was within the limit of tolerance.**

BioRID-II



Hybrid-III



Standardization of Calibration

To improve repeatability and reproducibility, it is necessary to:

. Ensure the proper maintenance and check required of dummies and standardize setting position, etc.

. Establish standardized calibration tests because the response of dummies varies depending on production lot.

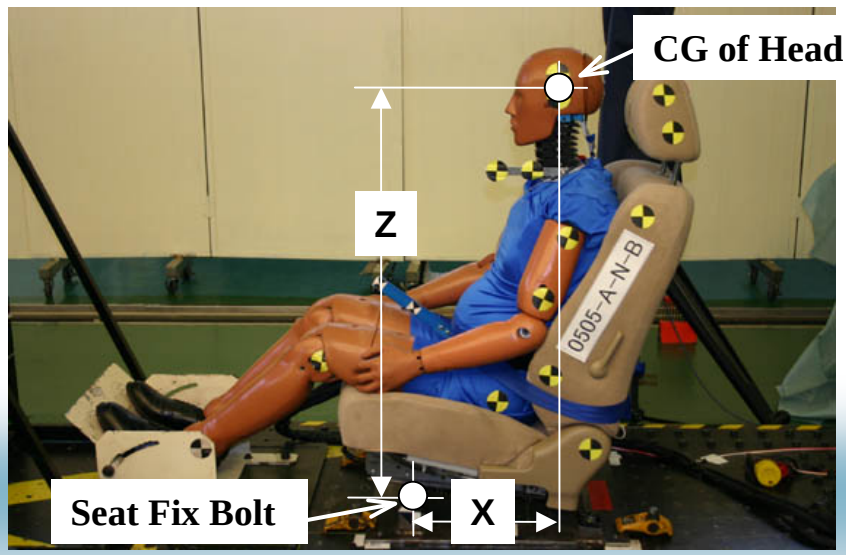
. Reduce the variation of measurements of HRMD, used as reference for the reproduction of sitting position when setting the dummy.

- Develop a (detail) regulation on the calibration of dummies.
- Establish testing methods enabling the maintenance of product performance
  - Clarify the design reference position to reduce the variations in setting position.

Issues on Dummy Setting

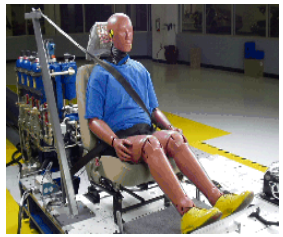
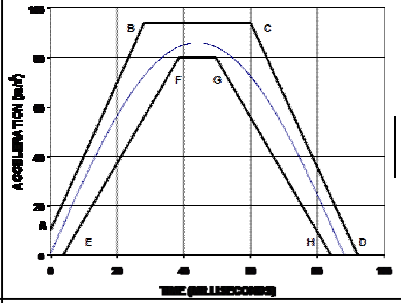
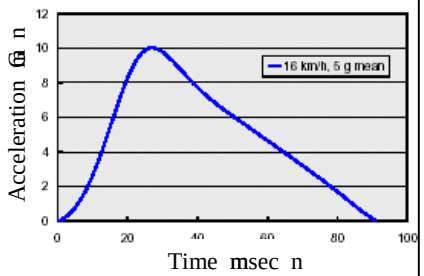
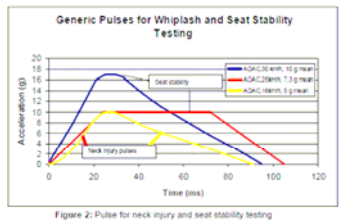
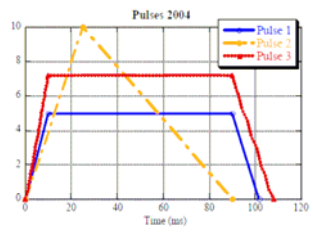
Large head position variations during dummy setting have been observed, depending heavily on testing personnel factors and seat design factors.

⇒ Need to introduce measures to reduce head position variations.



(Ex.)
Set dummy posture by using the Design HP and measure the x and z distance of CG of head from seat fix bolt.

4. Testing Method – Comparison of Dynamic Tests

	FMVSS202a	IIWPG	ADAC	FOLKSAM
Positioning	Legal test	Assessment		
Form of sled fixture	Fixed on the car 	Fixed on the seat anchor 		
Dummy used	AM50% HY-III	BioRID II		
Sled pulse	ΔV =17.3 km/h 	ΔV =16km/h 	ΔV=16 km/h 5 G ΔV=25 km/h 7.3 G ΔV=30 km/h 10 G 	ΔV=16 km/h 4.5G ΔV=16 km/h 5.5G ΔV=24 km/h 6.5G 
Evaluation indicators	(1)The backward rotation angle of the head relative to the torso ≤ 12° (2) HIC 15ms ≤ 500	(1)Seat Assessment Time of contact between the head and the head restraints ≤ 70 ms T1G (G produced on the upper torso) ≤ 9.5G (2)Neck Force Fx and Fz divided into three stages	**neck injury x 0.7** (1)NIC, (2)Nkm, (3)Head rebound velocity (4)Fx (5)Fz (6)T1G (7)HRC (8)Geometry + **Seat Stability x0.3** (1) Seatback angle Assessment in five grades	(1)NIC, (2)Nkm, (3)Head rebound velocity Assessment in three grades using the total of three indicators and three pulses