Dummy Design and Issues

Introduction
Dummy terminology
Today’s dummy family
Frontal impact dummies
Hybrid III & THOR comparison
Dummy issues
Comparison of rear impact dummies
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Introduction to Dummies

What is a dummy?
Dummies are mechanical surrogates of the human body.
Thus, they are also called:
ANTHROPOMORPHIC TEST DEVICES

What uses do they have?
To measure the impact loading of different body parts
(By using a suite of instrumentation built into the Dummy)

To correctly load a vehicle to assess type and severity of injury by mimicking human dynamic impact responses
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Dummy Terminology

- Percentile
- Anthropometry
- Biofidelity
- Measuring capability
- Repeatability
- Reproducibility
- Durability
- Sensitivity
- Simplicity and ease of use
Sizes of adult dummies are expressed as ‘Percentiles’

Three percentile masses are used:

- 5th percentile
- 50th Percentile
- 95th Percentile

Example:
A 5th percentile indicates that 5% of the adult population is smaller than the Dummy
Percentile

Figure 1: Stature and mass distributions by gender based on the data of Gordon (1988) with inverted markers for standard dummy sizes (5th female (F5), 50th male (M50), 95th male (M95)).

Hybrid III percentiles on a stature and mass scale in comparison to the resp. distribution of the population


Anthropometry

Dummies should have and duplicate the following:

• Have similar mass distribution to that of a living human
• Have similar shape to that of a living human

I.E. ATTRIBUTED WITH HUMAN CHARACTERISTICS
Biofidelity

**DUMMIES SHOULD:**
Duplicate the biomechanical response behaviour of a living human exposed to the same impact conditions

**ACHIEVED BY:**
- Dummy matching the human cadaver test corridor response
Biofidelity: Human Corridors

- Force min/max envelope
- “Corridors”

Fig. 16 – Thoracic impact responses to blast impacts at 6.7 m/s are shown relative to the Nebraska 50th percentile male corridor

Measuring Capability

The dummy should be instrumented to provide the following measurements:

- Appropriate forces
- Deflections
- Accelerations
**Repeatability & Reproducibility**

Different Dummies of same design should:

- Receive the same response (output) to the same impact conditions (input)

Repeatability is assessed from responses to tests with the same dummy, and

Reproducibility from responses to tests with different dummies of the same design.

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**Durability**

**Durability implies that the Dummy should:**

- Be structurally sound (intact) following an impact
- Have responses that remain repeatable

**Durable Exceptions:**

- Deliberate designed replacement parts
Environmental Sensitivity

The dummy should not be sensitive to temperature and humidity. These factors may affect its biofidelity and repeatability.

Examples for calibration

A Hybrid II and US SID temperature limits between 18.9°C and 25.6°C
A Hybrid III, BIOSID temperature limits between 20.6°C and 22.2°C
The relative Humidity limits between 10% RH and 70% RH

Simplicity and Ease to Use

The Dummy should....

• Be easy to calibrate
• Require minimal external support equipment
• Be readily repairable
• Have parts that are easy to change and replace
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Today’s Dummy Family

Frontal Impact

Hybrid 2
50th, 3, 6 year old

Hybrid 3
5th, 50th, 95th

THOR
50th percentile male

Pregnant 5th% female

CRABI
3, 6, 12, 18 month

Hybrid 3
3, 6, 10 year old

TNO
P series (P0, P3/4, P3, P10)
Q series

Side Impact

US SID
BioSID
EuroSID
SIDIIs
WorldSID

Rear Impact

BioRID
RID2

Other

Pedestrian
Example of Frontal Impact Dummies

Hybrid III

50th%ile  95th%ile  5th%ile

Example of Frontal Impact Dummies

Hybrid III cutaway
Example of Side Impact Dummies

![Side Impact Dummies Image]

Adult Dummy Types Weights

<table>
<thead>
<tr>
<th>Dummy Type</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYBRID II (50TH%ILE)</td>
<td>74 kg</td>
</tr>
<tr>
<td>HYBRID III (5TH%ILE)</td>
<td>50 kg</td>
</tr>
<tr>
<td>HYBRID III (50TH%ILE)</td>
<td>78 kg</td>
</tr>
<tr>
<td>HYBRID III (95TH%ILE)</td>
<td>101 kg</td>
</tr>
<tr>
<td>FEDERAL OR US SID (50TH%ILE)</td>
<td>75 kg</td>
</tr>
<tr>
<td>EURO SID (50TH%ILE)</td>
<td>78 kg</td>
</tr>
<tr>
<td>BIO SID (50TH%ILE)</td>
<td>79 kg</td>
</tr>
<tr>
<td>TNO 10 (ECE 16 SEAT TESTING 50TH%ILE)</td>
<td>76 kg</td>
</tr>
</tbody>
</table>
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Evolution of Adult Frontal Impact Dummies:
TNO 10

Developed as test device for ECE regulation 16: “Approval of safety belts and restraint systems”
50th%ile male in weight/size
Consists of six parts:
Head
Neck
Torso
Upper legs
One lower leg
Parts connected by joints in mid-sagittal plane
Complies to:
EEC Directive 82/319
**Evolution of Adult Frontal Impact Dummies: Hybrid 1**

Developed in 1971 by GM and ARL (FTSS)

Modified Sierra Engineering Dummy/ VIP-50A Dummy Design

Head and chest accelerometers

Standardized design

Repeatability possible

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**Evolution of Adult Frontal Impact Dummies: Hybrid II**

Developed in 1971

NHTSA Contract to GM & ARL (FTSS)

Improved Biomechanical Response

Based on previous VIP designs

Measurements in Head, Chest and Knee

Repeatable, durable and serviceable

Used for airbag testing 1972 to 1973

1973 - Adopted into Code of Federal Regulations

Still in use for Aircraft Seat Testing - FAA
Evolution of Adult Frontal Impact Dummies: Hybrid III 50th-%ile

1976-78 Developed by General Motors & FTSS

New and improved design measurements in:

- Head
- Neck
- Chest acceleration
- Chest deflection
- Femur
- Knee
- Tibia
- Feet

Representative 1.75 m height

Improved biofidelity and range of motion

Complies to 49 CFR, Part 572, Subpart E

Approved for FMVSS 208 in 1986

Hybrid III 50th-%ile: Calibration Corridors

TEST SET-UP SPECIFICATIONS

HEAD dummy CRADLE

CONNECTING RING

DROP HEIGHT 376 mm (14.8 in.)

CHROME-PLATED STEEL BLOCK 5.9 x 6.10 mm (0.24 x 0.24 in.)

FMVSS head calibration tests
Hybrid III 50\textsuperscript{th}-\%ile: Calibration Corridors

Fig. 13 - Neck extension torque–angle responses are compared to the Mertz et al. biomechanical response corridor.

FMVSS neck calibration test

Hybrid III 50\textsuperscript{th}-\%ile: Calibration Corridors

Fig. 16 - Thoracic impact responses to blunt impacts at 6.7 m/s are shown relative to the Neathery 50\textsuperscript{th} percentile male corridor.

FMVSS thorax calibration tests
Hybrid III 50\textsuperscript{th}-\%-ile: Calibration Corridors

FMVSS knee calibration tests

Hybrid III 50\textsuperscript{th}-\%-ile: Instrumentation
### Hybrid III 50th-%ile: Instrumentation

<table>
<thead>
<tr>
<th>Part</th>
<th>Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Triaxial accelerometers</td>
</tr>
<tr>
<td>Neck</td>
<td>Neck shield</td>
</tr>
<tr>
<td></td>
<td>Six axis upper neck transducers</td>
</tr>
<tr>
<td></td>
<td>Six axis lower neck transducer</td>
</tr>
<tr>
<td></td>
<td>RID Neck (Rear Impact dummy)</td>
</tr>
<tr>
<td>Chest</td>
<td>Triaxial accelerometers at T4 Chest Deflection</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Triaxial accelerometers</td>
</tr>
<tr>
<td>Femur</td>
<td>Modified femur load cells</td>
</tr>
<tr>
<td></td>
<td>Uniaxial femur load cells</td>
</tr>
<tr>
<td>Knee</td>
<td>Knee sliders</td>
</tr>
<tr>
<td></td>
<td>Knee sliders (Ball Bearing - Space age)</td>
</tr>
<tr>
<td>Lower Extremities</td>
<td>Instrumented lower legs</td>
</tr>
</tbody>
</table>

### Evolution of Adult Frontal Impact Dummies: THOR

**Test Device for Human Occupant Restraint**

THOR 50th-%ile male originally developed by NHTSA 1994 – 2003, prototype Thor–α developed by GESAC.

The primary design objectives were as follows:

- Biofidelity in mass, size, surface geometry, and dynamic response
- Incorporation of specific instrumentation relevant to injury assessment
- Repeatability of performance
- Minimization of damage in severe test environments; i.e., overload protection
- Easy assembly and disassembly enabled by a modular user-friendly design
Evolution of Adult Frontal Impact Dummies: THOR

As problems occurred with durability and usability, FTSS developed THOR-FT (EU-financed), GESAC upgraded to THOR-NT (NHTSA financed). Now a joint working group is established to harmonize until 2011 (?)

THOR: Instrumentation

| Head | 9 Uniaxial Accelerometers  
| 1 Bi-axial Tilt Sensor |
| Face | 5 Uniaxial Load Cells |
| Neck | Upper Neck Load Cell (8 channels)  
| Lower Neck Load Cell (8 channels)  
| Front Neck Cable Load Cell  
| Rear Neck Cable Load Cell  
| Head Rotation Potentiometer |
| Thorax | 5 RMS Deflection Units - 3 Dimensional Displacement at each of Four Locations (UL, UR, LL, LR), 4 DRMS units @ 3 channels each  
| Two Uni-directional Displacement Ring Potentiometers at Mid/Center Location (optional)  
| 1 Triaxial Accelerometer at the C.G |
| Mid Torso | 1 Uniaxial Accelerometer |
| Upper Abdomen | Uni-directional Displacement String Potentiometer  
| Uniaxial Accelerometer |
| Lower Abdomen | DQSS Deflection Units - 3 Dimensional Displacement at L & R Locations (2 DQSS units @ 3 channels each) |
| Spine | 1 Triaxial Accelerometer at T1 Location  
| 1 Triaxial Accelerometer at L12 Location  
| 1 Q-Band Load Cell |
| Pelvis | Acetabular Load Cell (left and right, 3 channels each)  
| Iliac Crest Load Cells (1 each left and right)  
| 1 Triaxial Accelerometer at Pelvis C.G |
| Femur | Femur Load Cell (left and right, 6-axis each) |
| Knee | Knee Shear Displacement, L/R  
| Knee Rotation (L/R, optional) |
| Lower Extremities | Upper Tibia Load Cell (L/R, 4 channels each)  
| Lower Tibia Load Cell (L/R, 5 channels each)  
| Tibia Acceleration (X, Y, Z) each leg  
| Achilles Tendon Load Cell (each leg, optional)  
| Ankle Joint Rotation Potentiometers (C, Y, Z) each leg  
| Foot Acceleration (X, Y, Z) each leg |
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THOR – Hybrid III : Differences

same weight 78 kg
THOR – Hybrid III : Differences

1. Measurements
- spine angle
- load cells face
- additional acceleration sensors
- 4-point deflection measurement of the chest
- penetration measurement of the abdominal area

2. Design
- spine
- thorax
- abdomen

Seating position and handling
THOR: tilt sensors help during the dummy positioning.

Differences between distance of the thorax and IP.

Source: Burkhard Eickhoff, Autoliv
THOR – Hybrid III : Differences

Dynamic tests

Higher forward displacement with THOR (especial pelvis)

THOR: more biofidelic behaviour (especially dummy rotation z-axis)

Source: Burkhard Eickhoff, Autoliv
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Dummy Issues

Example: Hybrid III dummy

Temperature sensitivity
Belt path sensitivity
Chest deflection in test and calibration
Repeatability & reproducibility
Temperature Sensitivity

NHTSA report DOT HS 806 722 “State-of-the-art Dummy Selection”
Author: Saul, R.A. - December 1984

Chest deflection temperature sensitivity

- Hybrid II
  - 18.3°C: -6%
  - 22.2°C: reference 25mm
  - 26.7°C: +3%

- Hybrid III
  - 18.3°C: -15%
  - 22.2°C: reference 32mm
  - 26.7°C: +27%

Hybrid III chest deflection sensitivity 5%/ºC

Temperature Sensitivity

NHTSA report DOT HS 806 722 “State-of-the-art Dummy Selection”
Author: Saul, R.A. - December 1984

Chest acceleration temperature sensitivity

- Hybrid II
  - 18.3°C: +8%
  - 22.2°C: reference 35G
  - 26.7°C: -6%

- Hybrid III
  - 18.3°C: +19%
  - 22.2°C: reference 16G
  - 26.7°C: -16%

Hybrid III chest acceleration sensitivity -4%/ºC
Belt Path Sensitivity

- three different shoulder belt paths were realised this way (no changes in D-ring geometry)

**Upper position**

**Mid position**

**Lower position**

Result of static tests: lowest chest deflection for upper pos. belt path
**Belt Path Sensitivity**

Result of dynamic tests: lowest chest deflection for upper pos. belt path

<table>
<thead>
<tr>
<th>Position</th>
<th>Deflection (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>21</td>
</tr>
<tr>
<td>Mid</td>
<td>36</td>
</tr>
<tr>
<td>Lower</td>
<td>39</td>
</tr>
</tbody>
</table>

**Chest Deflection in Test and Calibration**

Calibration Corridor:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Temperature</td>
<td>°C</td>
<td>20.6 to 22.2</td>
</tr>
<tr>
<td>Laboratory Relative Humidity</td>
<td>%</td>
<td>10 to 70</td>
</tr>
<tr>
<td>Probe Velocity</td>
<td>m/s</td>
<td>6.58 to 8.82</td>
</tr>
<tr>
<td>Peak Probe Force</td>
<td>Newtons</td>
<td>5159 to 5893</td>
</tr>
<tr>
<td>Peak Sternal Displacement</td>
<td>CM</td>
<td>6.35 to 7.26</td>
</tr>
<tr>
<td>Internal Hysteresis</td>
<td>%</td>
<td>69 to 85</td>
</tr>
</tbody>
</table>

Typical chest deflections in NCAP tests are between 20 mm and 30 mm

-> A second test with less impact velocity is now introduced in EuroNCAP
Repeatability & Reproducibility

As a rule of thumb, reproducibility with the HIII is about ±10% for acceleration, forces and moments, and about ±20% for chest deflection and HIC.

By using always the same individual dummy and being precise in the seating procedure and the belt path, repeatability and reproducibility can be improved.

The best practice to rate repeatability and reproducibility today is the Objective Rating Method (ORM).

Literature you will find on the CD:


The Influence of the individual dummy to chest deflection in this crash test is +/- 4 mm at 30 mm i.e. +/- 15%.
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Performance Comparison of Rear Impact Dummies: Hybrid III (TRID), BioRID and RID2

Harald Zellmer1), Markus Muser 2), Michael Stamm1), Felix Walz2), Wolfram Hell3), Klaus Langwieder3), Mat Philippens4)

1) Autoliv GmbH, Elmshorn, Germany
2) Working Group on Accident Mechanics, University/ETH Zürich, Switzerland
3) GDV Institute for Vehicle Safety, Munich, Germany
4) TNO Automotive, Delft, The Netherlands

IRCOBI Conference 2002, Munich
Necks of Rear Impact Dummies

HIII(TRID)  BioRID  RID2
Low Speed Rear Impact Test Procedure

Direction of Travel

Deceleration Corridor

Test Set Up
Investigated Injury Criteria

\[ NIC(t) = a_{rel}(t) \cdot 0.2 + (v_{rel}(t))^2, \]

\[ N_{km}(t) = \frac{F_x(t)}{F_{int}} + \frac{M_y(t)}{M_{int}} \]

Head Rebound Speed

Scope

Determine the influence of the dummy on proposed injury criteria and on a possible rating of seats
Comparison HIII(TRID) / BioRID

13 seats, different designs

<table>
<thead>
<tr>
<th>Description</th>
<th>Seats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional seat, actual design</td>
<td>2, 6, 7, 8, 10, 13</td>
</tr>
<tr>
<td>Conventional seat, older design (produced mid 1990°)</td>
<td>11, 12</td>
</tr>
<tr>
<td>Seat with neck protection system</td>
<td>1, 4, 9</td>
</tr>
<tr>
<td>Sports car seat</td>
<td>5</td>
</tr>
<tr>
<td>Bucket seat</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1: Description of the seats used for the comparison tests.

Comparison HIII(TRID) / BioRID

Stiff Rubber

Solid

Multiple Joints
Comparison HIII(TRID) / BioRID

NIC

Comparison HIII(TRID) / BioRID

NIC HIII(TRID) vs. BioRID

NIC vs. NIC HIII(TRID)
Comparison HIII(TRID) / BioRID

Head acceleration

Comparison HIII(TRID) / BioRID

Extension
**Comparison HIII(TRID) / BioRID**

**T1 rebound speed**

![Graph showing T1 rebound speed comparison between HIII(TRID) and BioRID](image)

**Conclusions**

Results obtained with the TRID neck may be transferred to the BioRID and vice versa only with precise knowledge of details and even then, with considerable uncertainties.

In a test specification it cannot be left open which dummy is used.

We recommend not to use HIII(TRID) further in low speed rear impact tests.
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Useful Links

Governmental Information:


Dummy Manufacturers Pages:

www.gesacinc.com/
www.humaneticsatd.com