# Usability of ATDs in Extended Use Positions

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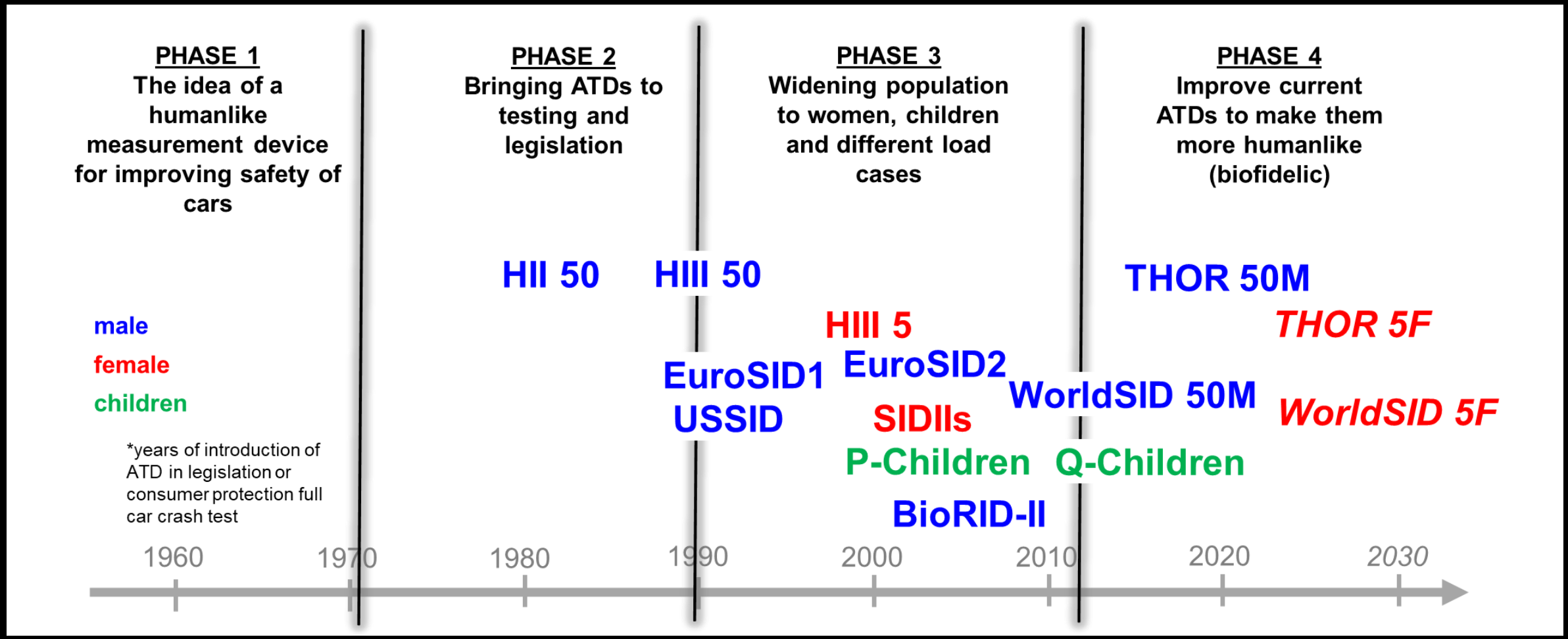
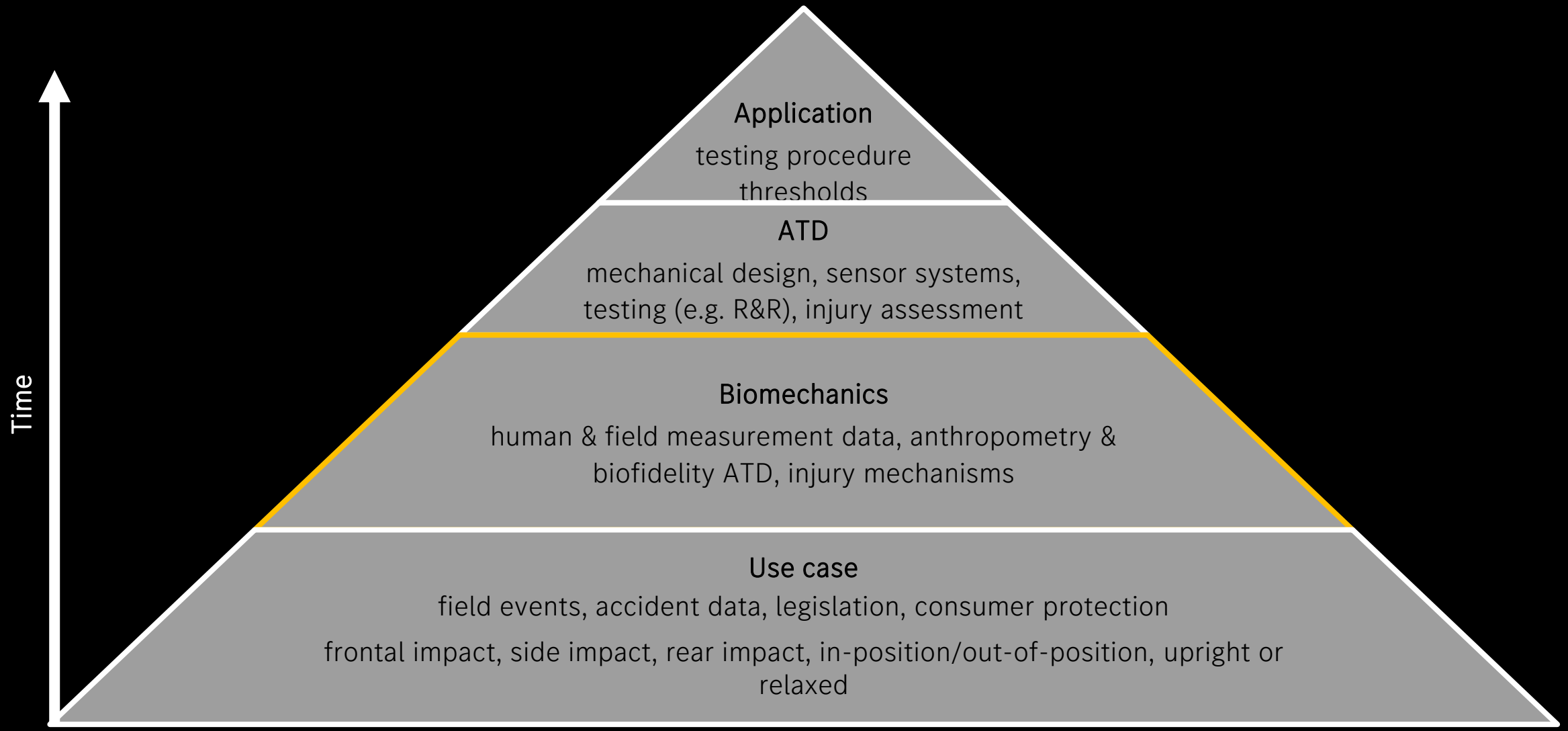
Mercedes-Benz

# Milestones of ATD Technology



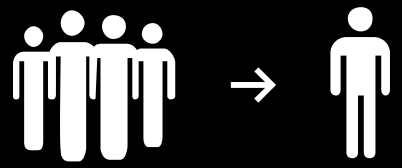

Paul H., Peschel I., Hohage B.: Gender discussion in vehicle safety - An overview of the consideration of subparts of the population in vehicle safety based on accident data analysis and current ATD development, VDI Conference Vehicle Safety, Berlin, 11/2023

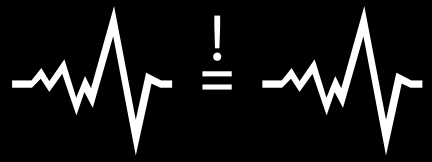
# ATD Development




Paul H., Peschel I., Hohage B.: Gender discussion in vehicle safety - An overview of the consideration of subparts of the population in vehicle safety based on accident data analysis and current ATD development, VDI Conference Vehicle Safety, Berlin, 11/2023

# ATD Development - Biomechanics





Background of ATDs:

**Anthropometry**

Objective: Mapping of a specific group by body measurements and weight

**Biofidelity (internal & external)**

Objective: Humanlike behavior (forces, moments, stiffness, damping)

**Injury prediction**

Objective: Link between measured loads to human injuries

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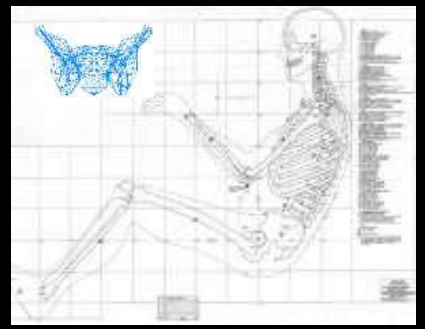
# Biomechanics - Anthropometry

What are the weight and size of the current ATDs based on?

- HIII 50%: Development in the 1970s. Geometry probably based on SAE J963 (invalid since 1979)
- HIII 5% and 95%: Development in the mid/late 1980s based on the UMTRI AMVO study
- THOR 5% & 50%: Development from mid-1990s based on the UMTRI AMVO study
- WorldSID5% & 50%: Development in the mid-2000s based on UMTRI AMVO study

➔ UMTRI AMVO study is the gold standard for geometries and masses of the current ATDs



Geometry of all ATDs is based on upright seated anthropometry evaluation !

Schneider et al. *Development of anthropometrically based design specification for an advanced adult anthropomorphic dummy family,* 1983

# Biomechanics - Biofidelity ~~~ = ~~~

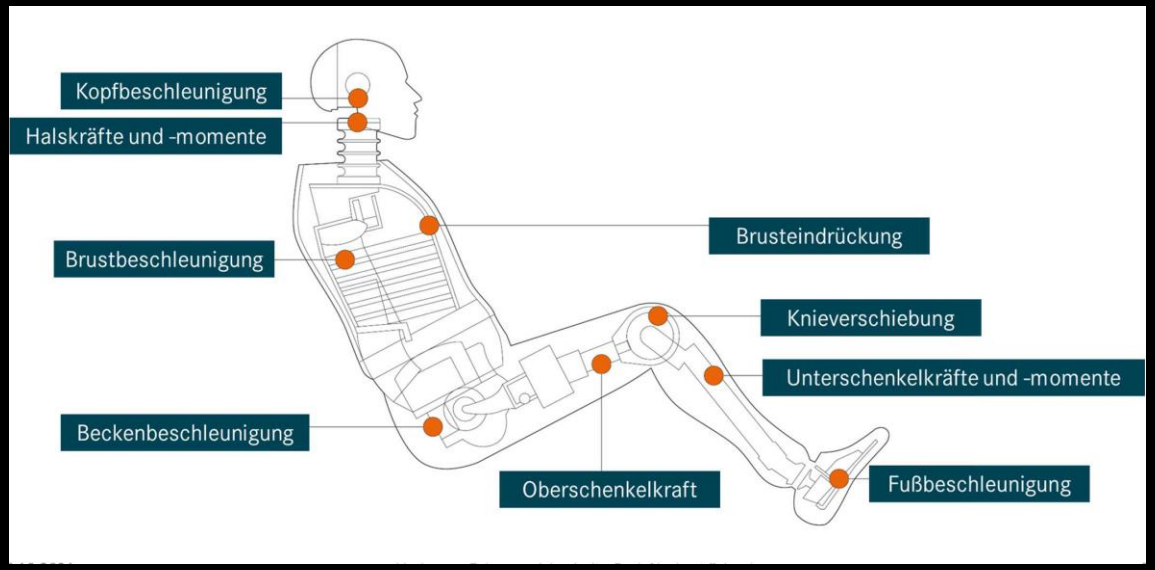



**Table 2.1. Biofidelity test matrix with test conditions appropriate for the THOR-05F**

| Body Region | Test | Impact Velocity | Impactor Mass | Impactor Face |
|---|---|---|---|---|
| Head | Head Impact | 2.0 m/s | 19.2 kg | 152.4 mm disk |
| | Rigid Bar Face Impact | 3.6 ± 0.1 m/s | 26.2 kg | Rigid Bar, Diameter 25 mm |
| | Rigid Disk Face Impact | 6.7 ± 0.1 m/s | 10.7 kg | 152.4 mm disk |
| Neck | Neck Frontal Flexion Response | 15G Sled Acceleration | | |
| | Neck Lateral Flexion Response | 7G Sled Acceleration | | |
| | Torsion | 500°/sec | | |
| Thorax | Upper Ribcage Central Impact | 4.3 ± 0.1 m/s | 14.0 kg | 152.4 mm disk |
| | Lower Ribcage Oblique Impact (L & R) | 4.3 ± 0.1 m/s | 14.0 kg | 152.4 mm disk w/pad |
| Shoulder | Range of Motion/Stiffness Test | - | - | - |
| Abdomen | Upper Abdomen Dynamic Impact | 6.7 ± 0.1 m/s | 9.0 kg | Steering Wheel, Diameter 26.7 mm |
| | Lower Abdomen Dynamic Impact | 6.1 ± 0.1 m/s | 16.0 kg | Rigid Bar, Diameter 25 mm |
| | Belt Loading | 4 m/s | - | - |
| Lumbar Spine | Flexion Pendulum Test | 2.0 m/s | - | - |
| Knee-Thigh-Hip | Knee-Thigh-Hip Impact (L & R) | 1.2 m/s | 250 kg ram | Molded knee interface w/pad |
| | Whole Body KTH Impact | 3.5 m/s | 255 kg ram | Padded knee interface |
| | Knee Slider Impact (L & R) | 2.15 m/s | 7.26 kg | 76.2 mm disk |
| Leg-Foot-Ankle | Axial Heel Impact (L & R) | 3.1 m/s | 28.4 kg | Padded Footplate |
| | Dynamic Dorsiflexion | 5.0 m/s | 3.0 kg | NHTSA Impactor |
| | Inversion/Eversion (L & R) | 1000°/sec | - | - |
| Full Body Sled Test | | 30 km/h with 2 kN force limiting belt | | |

Objective: Humanlike behavior (forces, moments, stiffness, damping)

Lee et al. *Biomechanical Response Manual: THOR 5th Percentile Female NHTSA Advanced Frontal Dummy, Revision 2*, 2018

➔ Development of ATD specific specifications for biofidelity assessment

- Biofidelity corridors for all relevant body regions (head, neck, thorax, lower extremities,..)
- Body region specific scaling of available data for all ATDs needed
- New in THOR Family – Validation via gold standard sled test in specific sex, size and weight

# Biomechanics - Injury prediction

- The ATD does NOT suffer or measure injuries; but physical loads (displacement, force, moment, acceleration).
- From the measured values, ATD specific injury criteria are determined, which are used to predict a possible risk of injury.
- There are different criteria for the different body regions.

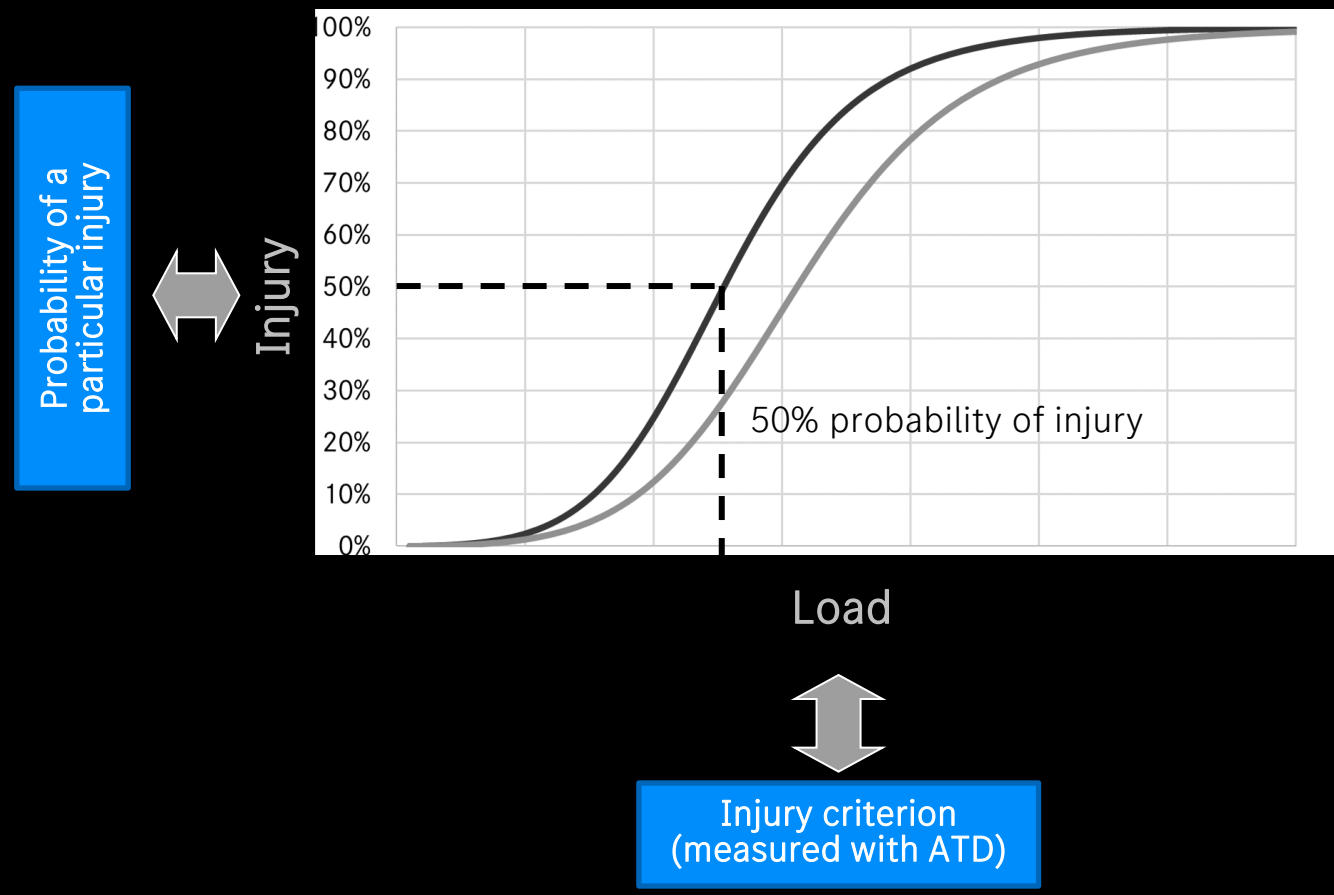
# Biomechanics - Injury prediction

The **Injury Risk Curve** describes the relationship between mechanical loads and risk of injury.

➔ What is the risk of suffering a particular injury under a given load?

Use of risk curve to identify threshold for injury prediction.

## Injury Risk Curve



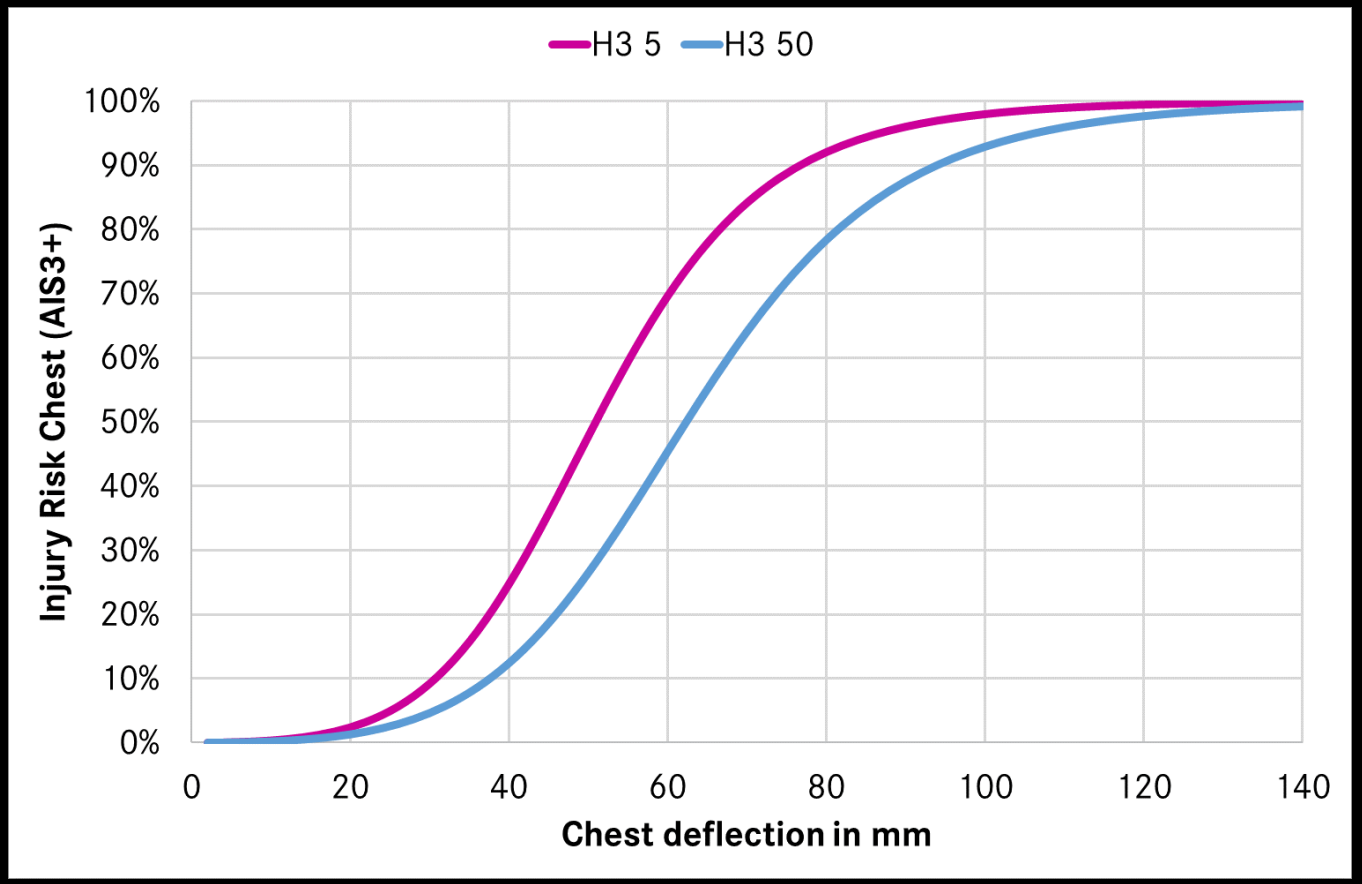
# Biomechanics - Injury Risk Curve

Example: Thorax Injury Assessment H3

- 185 data sets (67 female & 115 male PMHS, 17-86 years, average 64)

  ➔ Human data, not male or female

- First, development of a risk curve for the H3 50
- Scaling the H3 5 curve from the H3 50

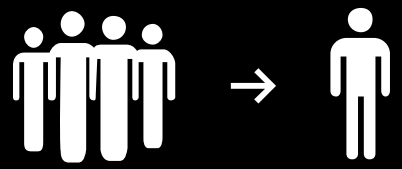



*Sources:*
*Laituri et al. 2005: Derivation and Evaluation of a Provisional, Age Dependent AIS 3+ Thoracic Risk Curve for Belted Adults in Frontal Impacts, SAE World Congress.*
*Mertz et al. 1989: Size, weight, and biomechanical impact response requirements for adult size small female and large male dummies; SAE International Congress and Exposition.*

Source Pictures: HIS

# ATDs in Extended Use Positions

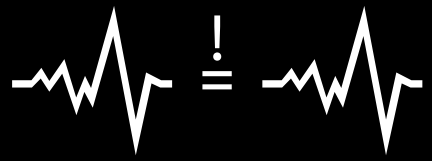
Background of ATDs:



**Anthropometry**

Objective: Mapping of a specific group by body measurements and weight

**Check positionability**



**Biofidelity (internal & external)**

Objective: Humanlike behavior (forces, moments, stiffness, damping)

**Check usability regarding the biofidelity**

**Injury prediction**

Objective: Link between measured loads to human injuries

**Check and develop injury prediction**

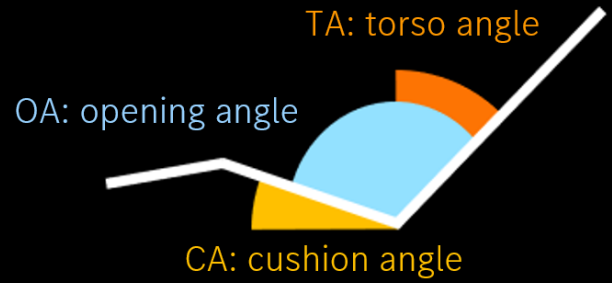
# ATDs in Extended Use Positions

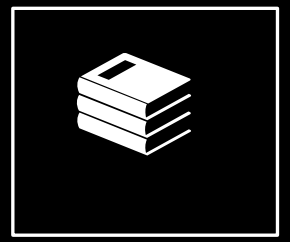
## Positionability

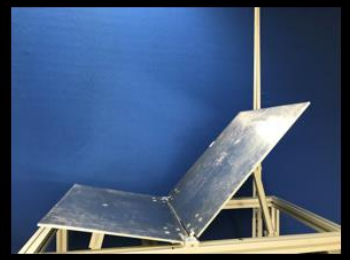
Literature research

Investigations on Generic Seat
up to
torso angle 65°
cushion angle 35°
opening angle 120°

Investigations on Driver Seat
up to
torso angle 60°
cushion angle 30°
opening angle 120°





NHTSA: ATD in Highly Reclined Seats, in SAE Government Industry Meeting, 2019

Forman, J, et al.: THOR-50M Modification for Reclined Seating – Initial Assessment, UVA, 2020

Reed, M et al.: Effects of Recline on Passenger Posture and Belt Fit, UMTRI, 2018

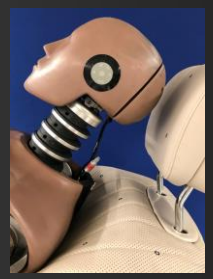
? geometrical boundaries of the dummies
? optical anomalies
? preloads
? compliance with the target-H-point by HPM I
? interaction with the seat (e.g. headrest)

# ATDs in Extended Use Positions - Positionability

## Hybrid III 50%

OA 110 ok

OA 120 not ok



Limitation: stiff spine (only lumbar spine as a „joint“) prevents further opening, torso or back of knee lose contact with the seat

## Hybrid III 5%

OA 110 ok

OA 120 not ok

Limitation: stiff spine (only lumbar spine as a „joint“) prevents further opening, torso or back of knee lose contact with the seat

## THOR-50M (slouched)

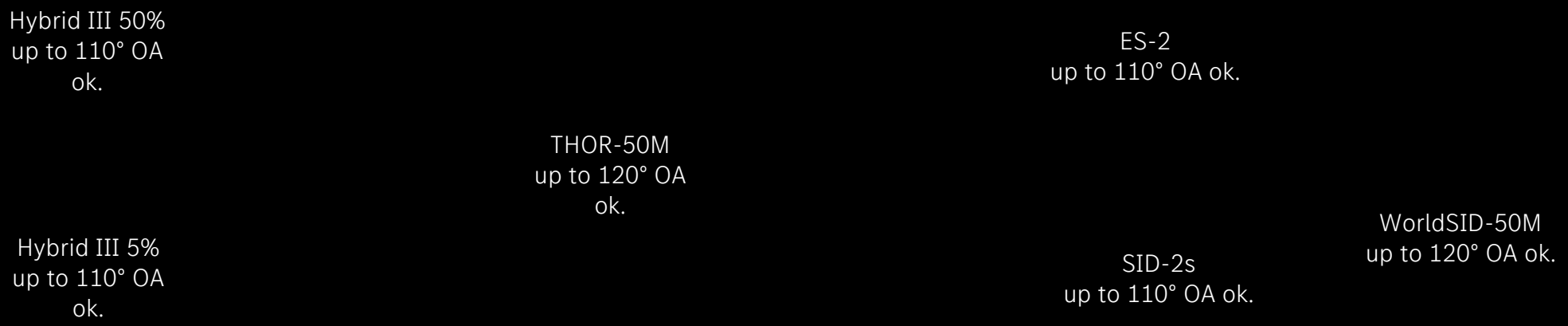
OA 110 ok

OA 120 ok

Limitation: increasing hollow back formation, which is considered to be unbiofidelic above 120° OA

# ATDs in Extended Use Positions - Positionability

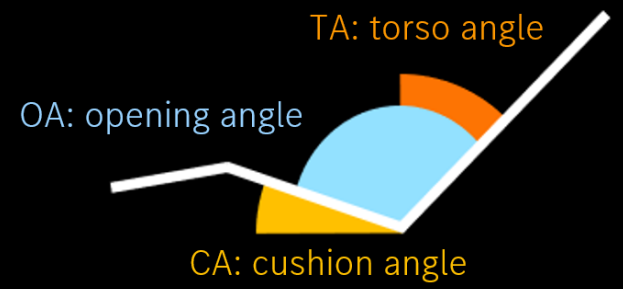
☞ **Maximum possible opening angle of ATD needs to be considered.**



# ATDs in Extended Use Positions

## 3 Stages

| Stage 1 | Stage 2 | Stage 3 |
|---|---|---|
| Opening angle up to ~110° | Opening angle up to ~120° | Bigger opening angles |



# ATDs in Extended Use Positions

## Alternative ATDs

THOR-50M

Standard THOR

THOR-RS-50M

Concept ➔ not change upright behaviour, just adapt for reclined usage

Forman et al., Update on Refinements to THOR, 2023 RCCADS

THOR-AV-50M

Big changes in upright behaviour (neck, abdomen, pelvis)

Kinsky et al., ATD Development – Status THOR-AV, 2021 RCCADS

# ATDs in Extended Use Positions - Alternative ATDs Positionability

## THOR-50M
(slouched)

OA 110 ok

OA 120 ok

Limitation: increasing hollow back formation, which is considered to be unbiofidelic above 120° OA

## THOR-RS-50M

OA 105 ok

OA 120 ok

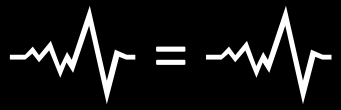
## THOR-RS-50M

Upright ok
OA 100

Limitation: Head more forward than THOR 50M

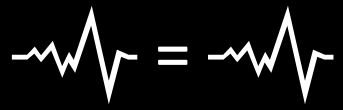
# ATDs in Extended Use Positions

## Alternative ATDs - Biofidelity and Injury Prediction

| | | THOR-50M | THOR-RS | THOR-AV-50M |
|---|---|---|---|---|
| Anthropometry  | Reclined | Limited to 120° opening angle | wide opening angle possible<br>(limits unkown) | wide opening angle possible<br>(limits unkown) |
| Biofidelity  | Upright | Comprehensive assessment | No change - development goal! | Significant changes |
| | Reclined | Observed issues in pelvis kinematics (submarining)<br>Evaluation of new injury patterns? | Biofidelity (Kinematics only) is checked currently<br>Evaluation of changed load paths in components?<br><br>R&R needs to be checked<br>Qualification stays the same<br>.. | Biofidelity (Kinematics only) shown by Humanetics<br>Evaluation of changed load paths in components?<br>No R&R investigations!<br>New qualification procedures needed!<br>... |
| Injury Prediction  | Upright | Initial Injury risk curves available | No change - development goal! | Big changes in the dummy (neck, abdomen, pelvis, )<br>New injury criteria for neck and abdomen needed |
| | Reclined | Investigations on validity of injury prediction necessary (e.g. chest) | Limited modifications<br>validity of others needs to be checked (chest) | Validity of new and remaining criteria in reclined need to be checked (chest) |

# ATDs in Extended Use Positions

## Alternative ATDs - Biofidelity and Injury Prediction

| | | THOR-50M | THOR-RS | THOR-AV-50M |
|---|---|---|---|---|
| Anthropometry  | Reclined | Limited to 120° opening angle | wide opening angle possible (limits unkown) | wide opening angle possible (limits unkown) |
| Biofidelity | Upright | Comprehensive assessment | change - d pment goal! | Significant changes |
|  | Reclined | Observed issues in pelvis kinematics (submarining)<br>Evaluation of new injury patterns? | Biofidelit atics only) is che tly<br>Eva n of changed load paths in co ents?<br><br>R&R needs to be checked ication stays the same<br>... | Biofidelity (Kinematics only) shown by Humanetics<br>Evaluation of changed load paths in components?<br>No R&R investigations!<br>New qualification procedures needed!<br>... |
| Injury Prediction  | Upright | Initial Injury risk curves available | No change - development goal! | Big changes in the dummy (neck, abdomen, pelvis, )<br>New injury criteria for neck and abdomen needed |
| | Reclined | Investigations on validity of injury prediction necessary (e.g. chest) | Limited modifications<br>validity of others needs to be checked (chest) | Validity of new and remaining criteria in reclined need to be checked (chest) |

# Summary

- In discussion different stages of opening angle need to be taken into account
- Current dummys (e.g. H3 Family) seem to be usable up to a certain opening angle
- Alternative ATDs like THOR 50M and prototypes for reclined are available

➔ more investigation on biofidelity on component level and injury prediction is needed for high opening angles

- Experience should be gathered with moderate opening and recline angles