

More Lives Saved



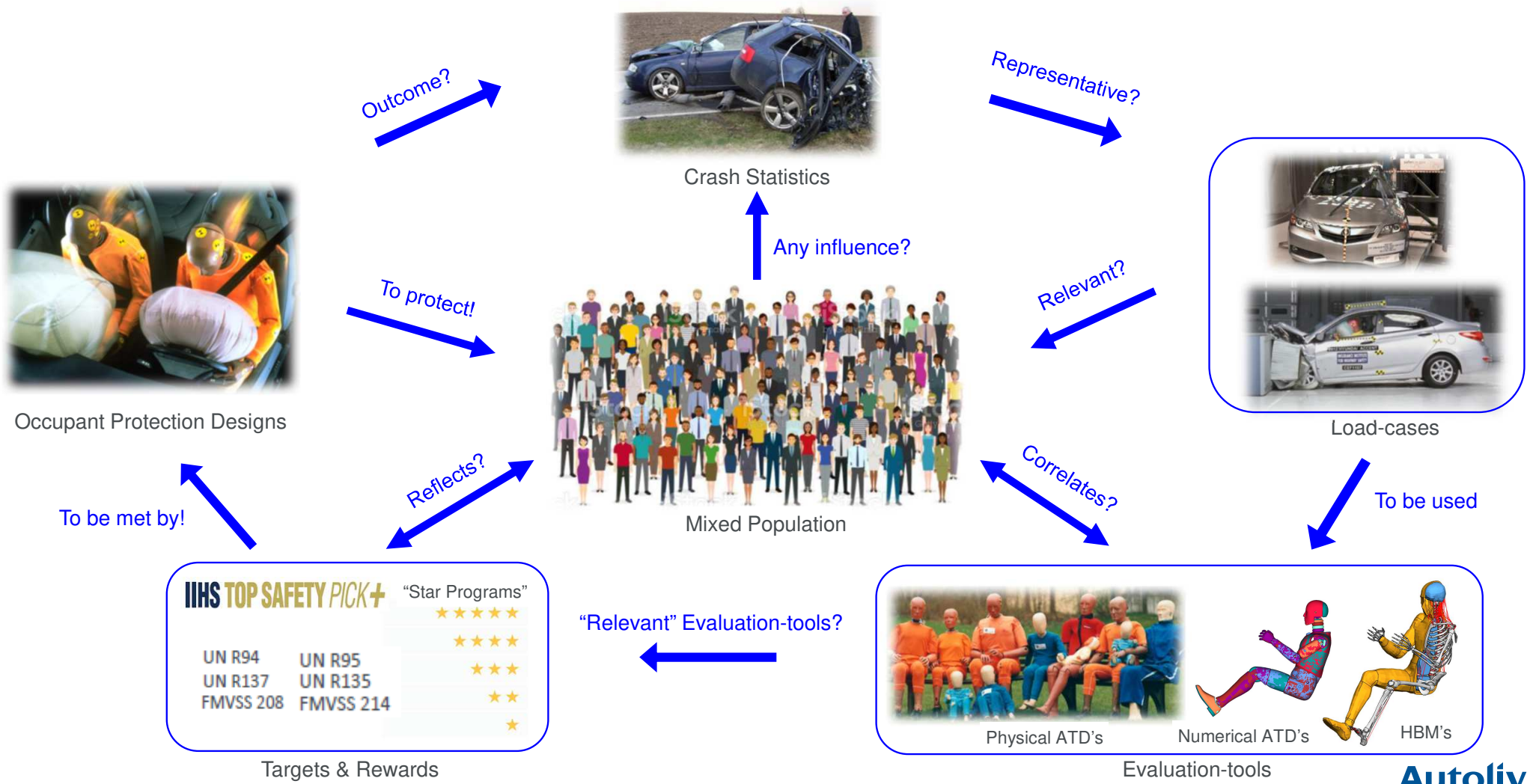
More Life Lived

# Data on Equitable Occupant Protection

Review of Occupant Protection Evaluation and Requirement

Torbjörn Andersson & Håkan Sundmark

# Data on Equitable Occupant Protection





# Crash Statistics.

We need to understand if different occupant-categories are protected equally or not



**IIHS HLDI**  
Insurance Institute for Highway Safety  
Highway Loss Data Institute

## Differences in injury risk between male and female vehicle occupants

Data on Equitable Occupant Protection UNECE ad hoc group  
31 Mar 2022

Jessica Jermakian  
Vice President, Vehicle Research

Matt Brumbelow  
Senior Research Scientist

[iihs.org](http://iihs.org)




## Developments in car crash safety since the 1980s

- divided for gender and age groups

Anders Kullgren Head of research Folksam, Professor Chalmers University of Technology

Slide 3-7 results published at IRCOBI 2020 (IRC-20-14)  
Slide 8-9 results published at Transportforum (Swedish conf.) Jan 2020


Folksam



Can a male size dummy represent the female population?  
– Experience from rear impact tests, including a female size prototype dummy

Mats Y Svensson, Chalmers [mats.svensson@chalmers.se](mailto:mats.svensson@chalmers.se)  
Anna Carlsson, CIT [anna.carlsson@chalmersindustriteknik.se](mailto:anna.carlsson@chalmersindustriteknik.se)  
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[www.chalmers.se/am](http://www.chalmers.se/am)



## Understanding Why Gender Matters in Standardization

Michelle Parkouda, Ph.D., Manager, Research  
2022-03-31

Standards Council of Canada  
Open a world of possibilities.

Canada



## Restraint systems – for all occupants?

Accident analysis and crash tests

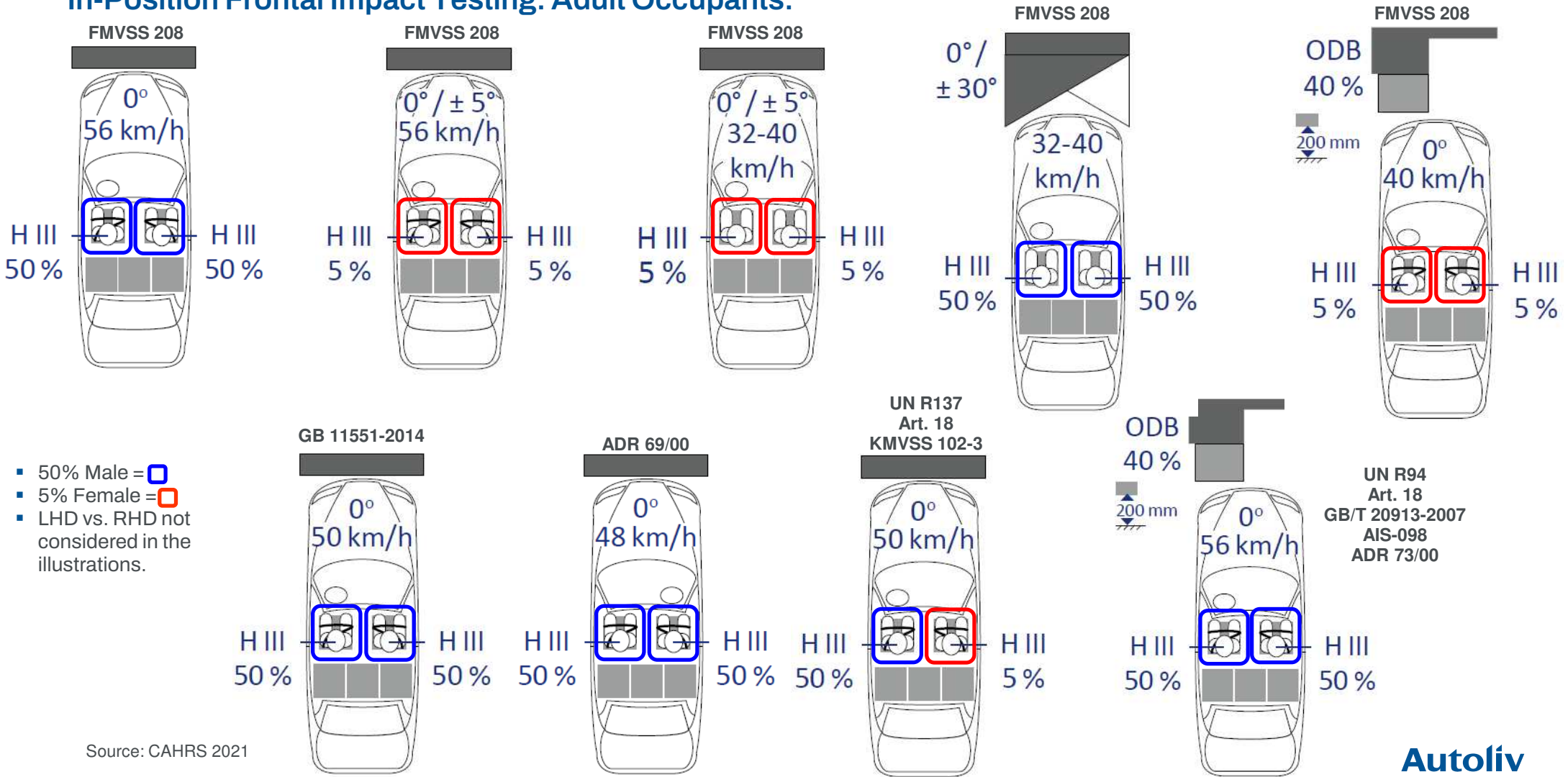


Isabella Ostermaier, ADAC e.V. | January 26, 2022

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# Load Cases. Regulatory Test Setup.

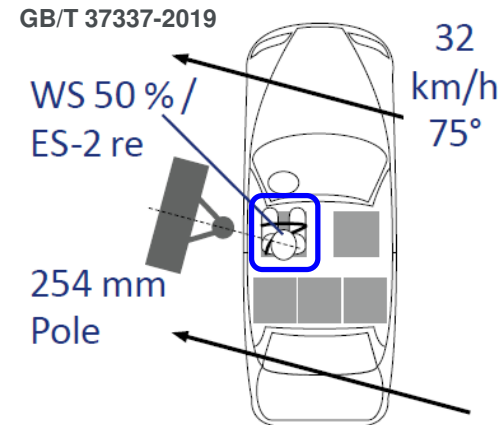
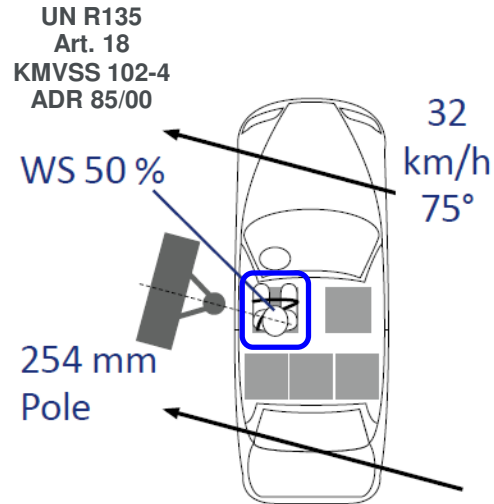
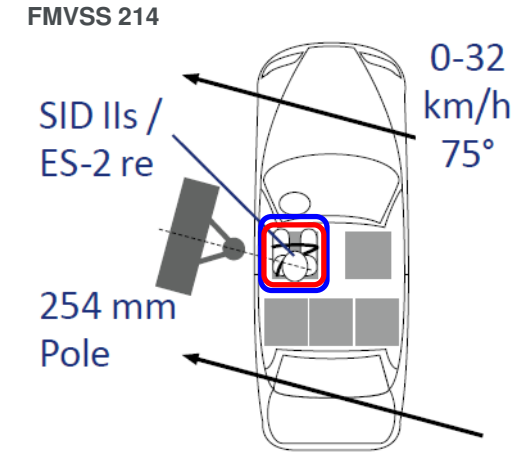
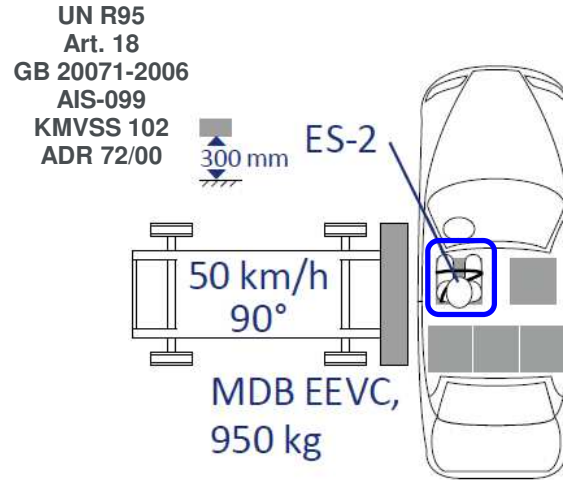
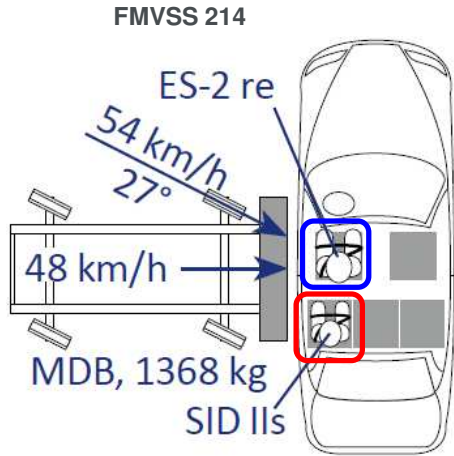
## In-Position Frontal Impact Testing. Adult Occupants.



Source: CAHRS 2021

# Load Cases. Regulatory Test Setup.

## In-Position Rear Impact Testing. Adult Occupants.



- 50% Male =
- 5% Female =
- LHD vs. RHD not considered in the illustrations.

Source: CAHRS 2021

# Load Cases. Dummy Mapping.

Dummies		Frontal Impact				Side Impact				Rear Impact		
		HIII 50%	HIII 5%	HIII 95%	THOR 50%	ES-2	ES-2re	SID-IIs	World SID	HIII 50%	BioRID II	Eva- RID
Europe	UN R94	•										
	UN R95					•						
	UN R44											
	UN R129											
	UN R135								•			
	UN R137	•	•									
	Euro NCAP	•	•	(•)	•				•		•	
America	FMVSS 208	•	•									
	FMVSS 214						•	•	○			
	FMVSS 213											
	FMVSS 202a									•		
	FMVSS xxx (OMDB)				○							
	U.S. NCAP	•	•		○		•	•	○			
	IIHS	•	•					•			•	
	Latin NCAP	•					•					
Asia	Japan Regulations	•	•			•			•			
	JNCAP	•	•						•		•	
	China Regulations	•				•	•		•			
	C-NCAP	•	•		•	•		•	•		•	
	KNCAP	•	•		•				•		•	
	ASEAN NCAP	•				•						
AUS	ADR (Frontal, Side)	•				•			•			
	ANCAP	•	•	(•)	•				•		•	
GTR	GTR 7 (Head Restr.)	•									•	
	GTR 14 (Pole Side)								•			

- Male ATD's (50%) used in 18 (plus 2 "pending") different regulatory tests.
- Female ATD's (5%) used in 9 different regulatory tests.

= NCAP's  
 = Male ATD's  
 = Female ATD's

Source: CAHRS 2021

# Evaluation-tools.

## Frontal Impact Testing ATD's. Sitting Heights and Buttock-to-Knee Length.



- H-III 95M:**
- Sitting Height = 920 mm
  - Buttock to Knee Length = 648 mm



- H-III 50M:**
- Sitting Height = 884 mm
  - Buttock to Knee Length = 592 mm



- THOR 50M (Metric\_v.1.3.2):**
- Sitting Height  $\approx$  939 mm
  - Buttock to Knee Length  $\approx$  640 mm



- THOR 5F (THOR\_5F\_v0.2):**
- Sitting Height  $\approx$  788 mm
  - Buttock to Knee Length  $\approx$  570 mm



- H-III 5F:**
- Sitting Height = 787 mm
  - Buttock to Knee Length = 533 mm



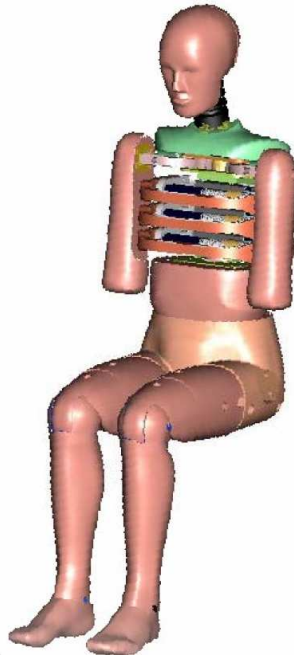
# Evaluation-tools.

## Side Impact Testing ATD's. Sitting Heights and Buttock-to-Knee Length.



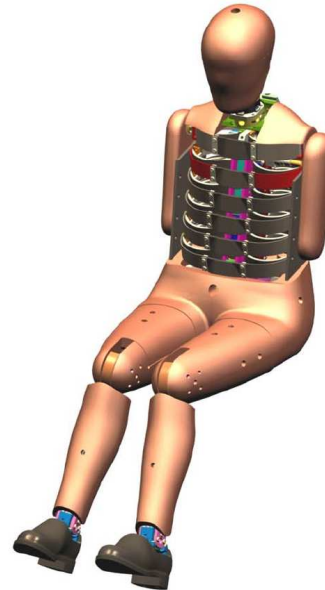
### WorldSID 50M:

- Sitting Height = 877 mm
- Buttock to Knee Length = 670 mm



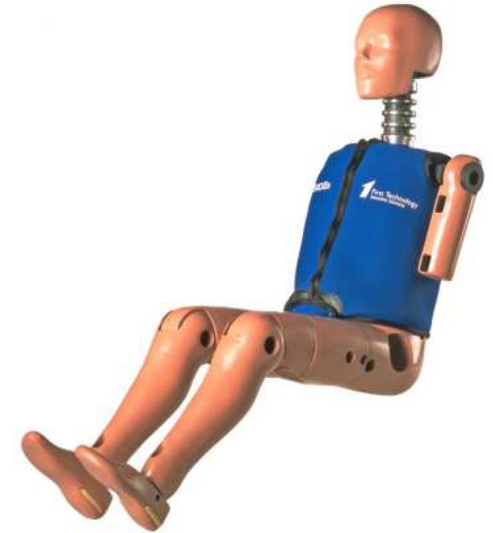
### ES-2:

- Sitting Height = 909 mm
- Buttock to Knee Length = 606 mm



### WorldSID 5F:

- Sitting Height = 761 mm
- Buttock to Knee Length = Not known



### SID-IIs:

- Sitting Height = 787 mm
- Buttock to Knee Length = 527 mm



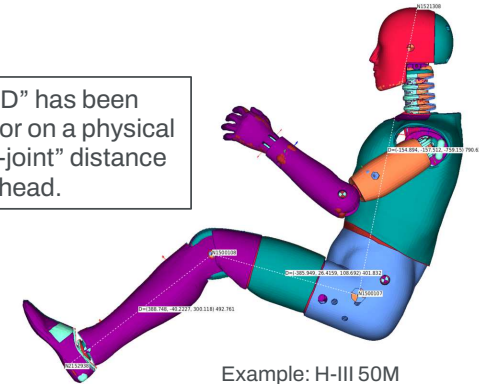
# Evaluation-tools.

## Anthropomorphic Data (example). Female Standing Height.

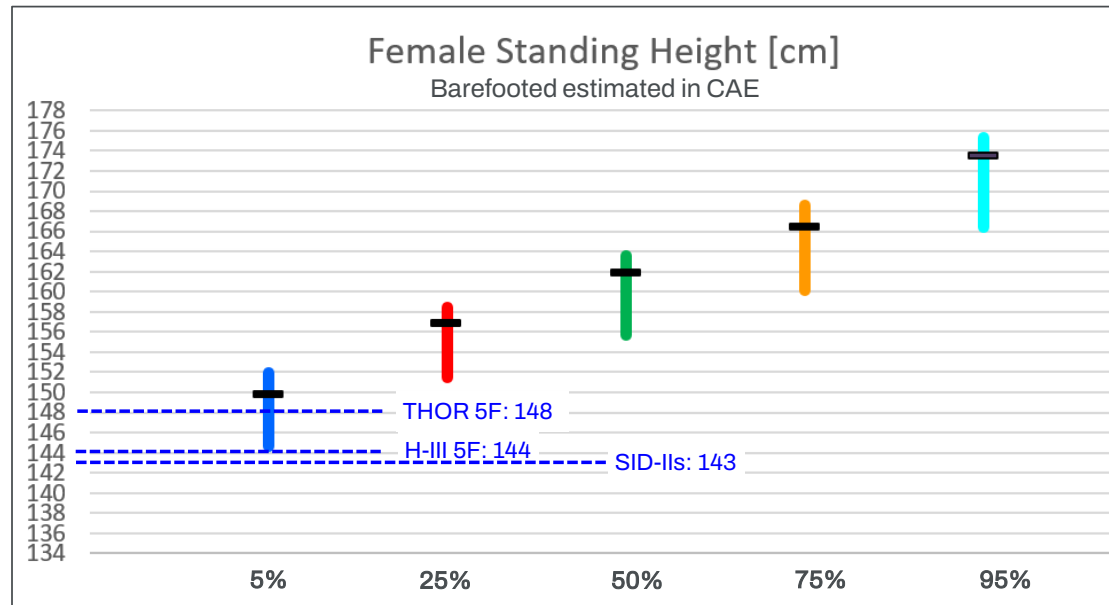
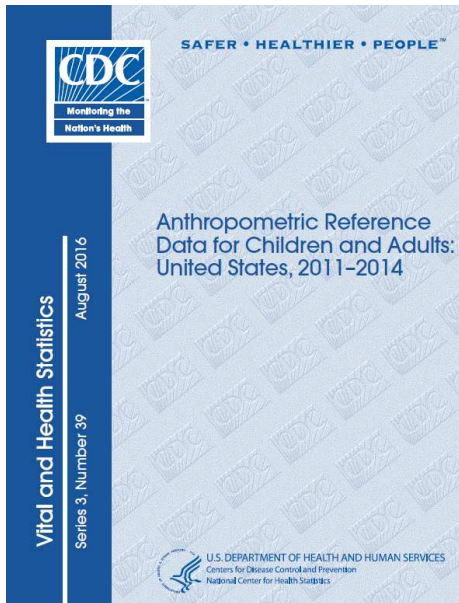
Table 9. Height in centimeters for females aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and Hispanic origin and age: United States, 2011–2014

Race and Hispanic origin and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and Hispanic-origin groups <sup>1</sup>												
Centimeters												
20 years and over	5,547	161.8	0.21	149.8	152.7	154.3	156.8	161.9	166.4	169.0	170.7	173.5
20–29 years	928	162.9	0.30	151.9	154.4	156.0	158.4	162.9	167.2	169.1	171.1	174.2
30–39 years	957	163.4	0.30	151.2	153.8	155.6	158.3	163.6	168.6	170.9	172.5	175.3
40–49 years	987	162.9	0.31	150.9	153.7	155.4	158.1	163.0	167.3	169.8	171.7	174.4
50–59 years	924	161.9	0.37	150.9	152.9	154.7	156.9	162.2	165.9	168.5	170.5	173.2
60–69 years	888	160.5	0.37	149.9	152.5	153.6	156.1	160.5	164.7	167.0	168.8	171.9
70–79 years	527	159.3	0.35	147.5	150.3	152.0	154.5	160.0	163.8	166.0	167.9	170.3
80 years and over	336	155.6	0.37	144.6	146.4	148.1	151.5	155.7	160.2	161.8	163.4	166.4

The standing height for a “sitting ATD” has been defined by measuring (by CAE and/or on a physical ATD) and summarizing the “joint-to-joint” distance from under the foot to the top of the head.



Example: H-III 50M



Legends:

- Colored bars = 20 years and over for each %-ile.
- Black line = Mean for each %-ile.

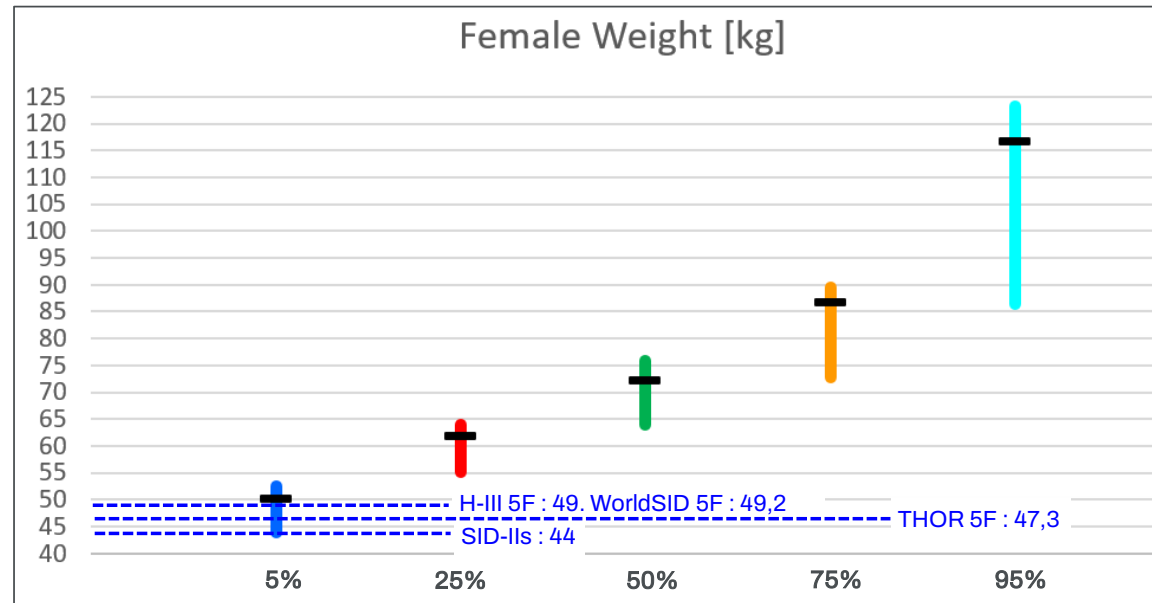
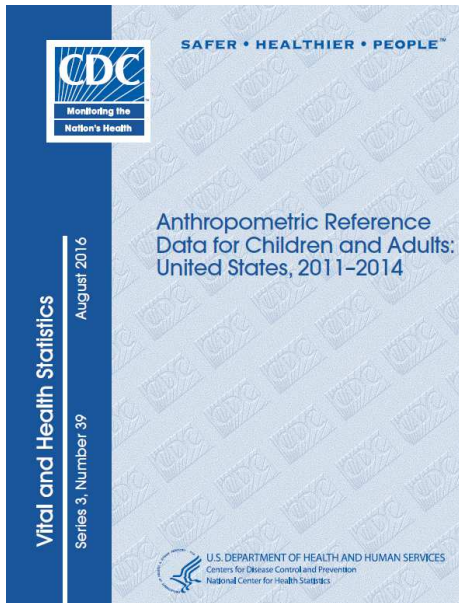


# Evaluation-tools.

## Anthropomorphic Data (example). Female Weight.

Table 3. Weight in kilograms for females aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and Hispanic origin and age: United States, 2011–2014

Race and Hispanic origin and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and Hispanic-origin groups <sup>1</sup>												
Kilograms												
20 years and over	5,425	76.4	0.42	50.1	54.3	57.5	61.7	72.1	86.7	96.2	104.0	116.5
20–29 years	853	73.4	0.85	48.6	51.7	54.3	58.4	67.9	83.7	96.5	103.7	115.8
30–39 years	915	78.4	0.87	52.1	56.3	58.4	62.5	72.8	88.9	98.9	107.8	122.1
40–49 years	979	78.5	1.00	52.5	56.6	59.3	63.0	74.4	89.3	98.8	107.6	118.5
50–59 years	923	79.1	1.05	52.3	56.6	58.6	64.0	75.9	89.5	99.5	108.6	123.1
60–69 years	889	76.6	0.90	49.0	55.6	58.8	63.7	74.6	86.7	93.8	102.0	111.4
70–79 years	527	75.2	0.94	49.1	54.5	58.1	62.9	71.9	85.5	93.3	98.2	108.0
80 years and over	339	64.4	0.74	44.0	47.1	50.2	55.2	64.0	72.8	78.2	81.8	86.5



- Legends:
- Colored bars = 20 years and over for each %-ile.
  - Black line = Mean for each %-ile.

**Autoliv**

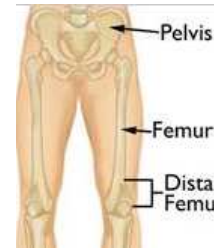
# Evaluation-tools.

## Anthropomorphic Data (example). Female Upper Leg Length.

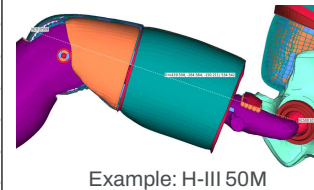
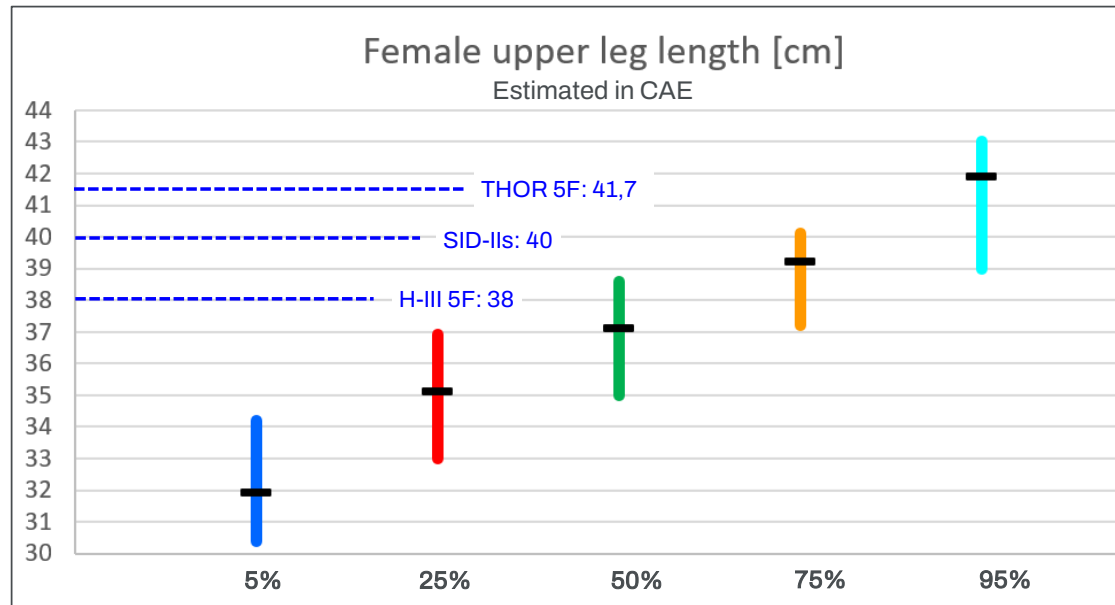
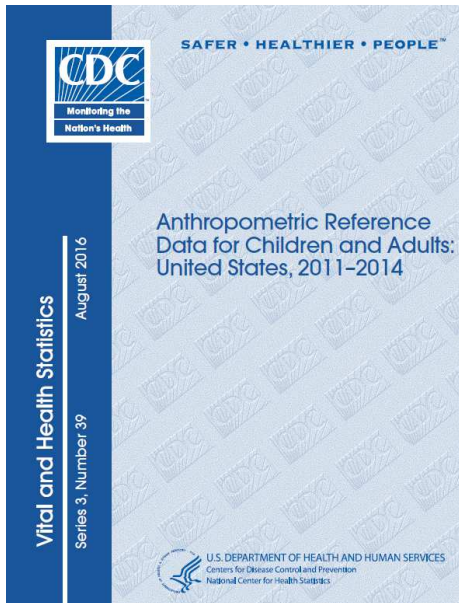
**Table 31. Upper leg length in centimeters for females aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and Hispanic origin and age: United States, 2011–2014**

Race and Hispanic origin and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and Hispanic-origin groups <sup>1</sup>												
Centimeters												
20 years and over	5,225	37.1	0.07	31.9	33.1	33.9	35.1	37.1	39.2	40.1	40.9	41.9
20–29 years	886	38.6	0.12	34.2	35.3	36.0	36.9	38.6	40.1	41.0	41.6	43.0
30–39 years	917	38.1	0.10	33.3	34.3	35.0	36.1	38.0	39.9	41.0	41.5	42.8
40–49 years	953	37.4	0.11	32.0	33.2	34.2	35.4	37.2	39.5	40.4	41.1	42.1
50–59 years	884	36.8	0.14	31.8	33.0	33.6	34.9	36.9	38.8	39.5	40.1	41.3
60–69 years	844	35.9	0.15	30.9	32.2	33.1	34.0	35.9	37.9	38.8	39.4	40.4
70–79 years	473	35.4	0.17	30.4	31.2	32.2	33.5	35.4	37.4	38.2	39.0	40.0
80 years and over	268	35.0	0.20	30.5	31.4	32.0	33.0	35.0	37.2	37.9	38.4	39.0

Upper leg measurements were taken on seated participants; the distance from the inguinal crease to the distal end of the femur was measured.



The upper leg length has been defined by measuring (by CAE and/or on a physical ATD) the distance from the hip-joint to the front of the knee.



- Legends:
- Colored bars = 20 years and over for each %-ile.
  - Black line = Mean for each %-ile.



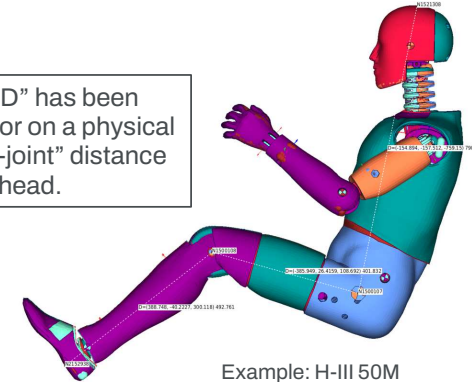
# Evaluation-tools.

## Anthropomorphic Data (example). Male Standing Height.

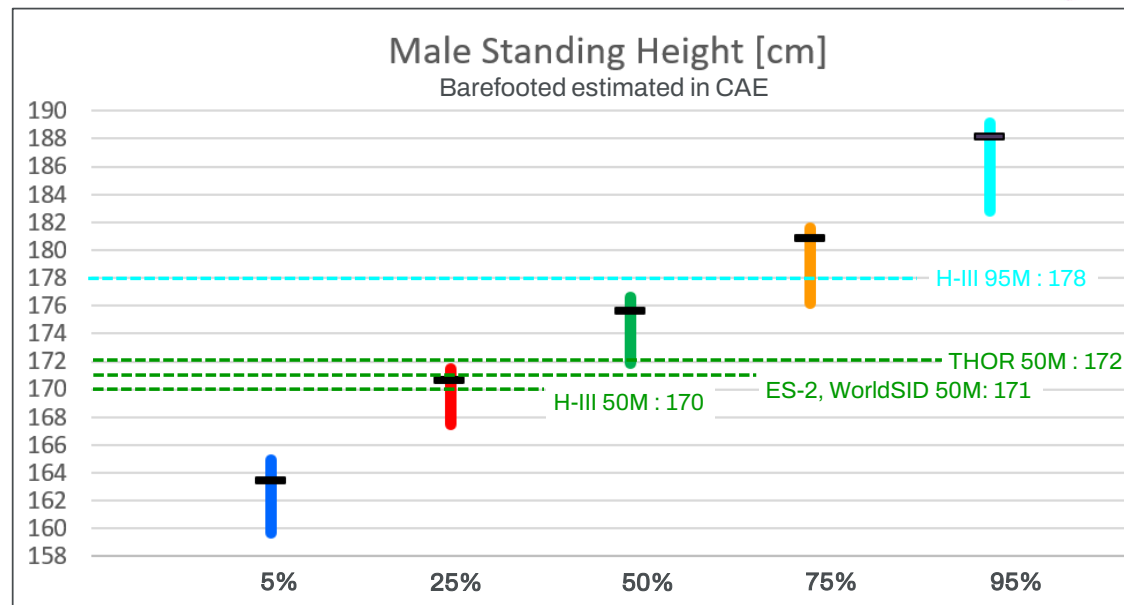
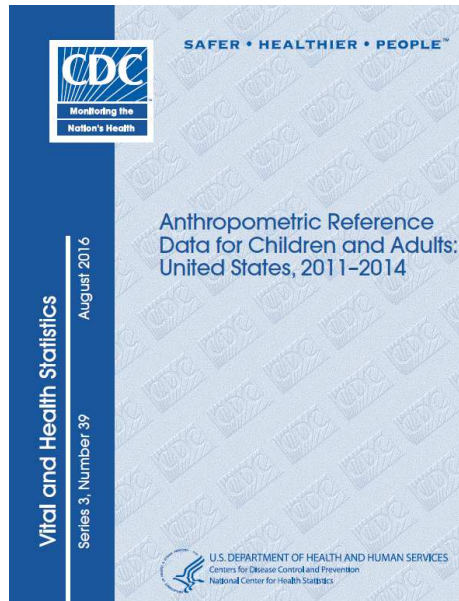
Table 11. Height in centimeters for males aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and Hispanic origin and age: United States, 2011–2014

Race and Hispanic origin and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and Hispanic-origin groups <sup>1</sup>												
Centimeters												
20 years and over	5,232	175.7	0.21	163.4	166.2	168.0	170.6	175.6	180.8	183.7	185.4	188.1
20–29 years	937	176.4	0.26	164.9	166.9	168.5	171.1	176.2	181.3	184.5	186.4	188.8
30–39 years	914	176.6	0.30	163.8	167.1	168.8	171.5	176.6	181.6	184.4	186.6	189.1
40–49 years	872	176.2	0.42	163.8	166.8	168.5	171.0	176.1	180.9	184.3	185.7	187.7
50–59 years	852	176.0	0.50	164.5	166.9	168.5	170.7	175.6	181.3	183.7	185.4	188.5
60–69 years	877	175.3	0.46	162.1	165.5	167.4	170.3	175.6	180.8	183.1	184.2	187.4
70–79 years	486	173.0	0.32	162.2	164.3	165.4	168.3	172.6	177.4	180.0	182.2	185.2
80 years and over	294	171.6	0.59	159.7	163.0	164.2	167.5	171.9	176.2	179.0	180.3	182.8

The standing height for a “sitting ATD” has been defined by measuring (by CAE and/or on a physical ATD) and summarizing the “joint-to-joint” distance from under the foot to the top of the head.



Example: H-III 50M



Legends:

- Colored bars = 20 years and over for each %-ile.
- Black line = Mean for each %-ile.



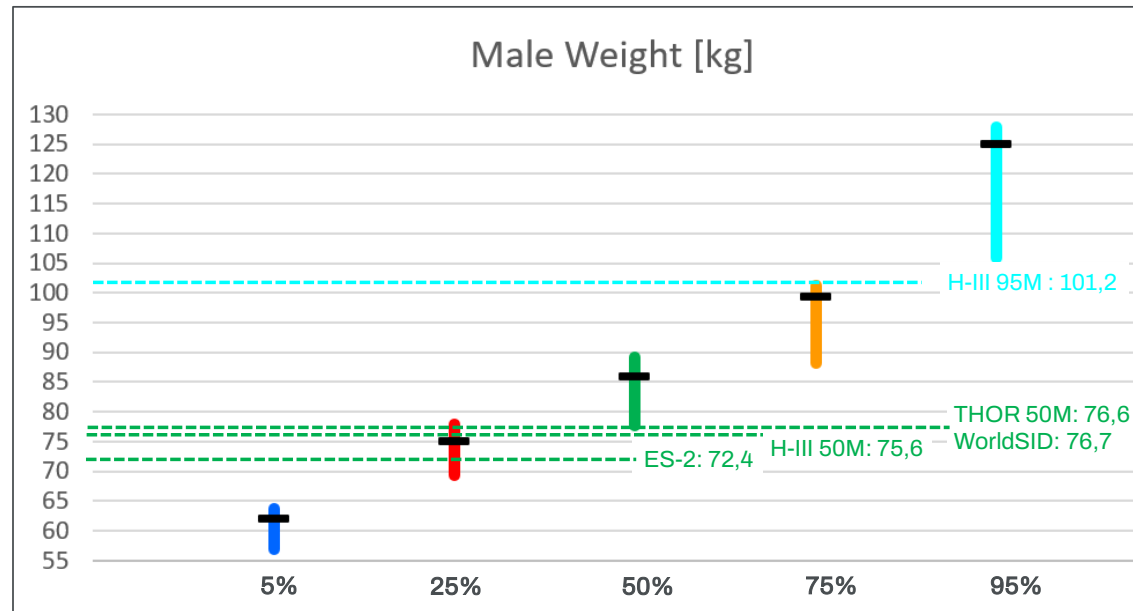
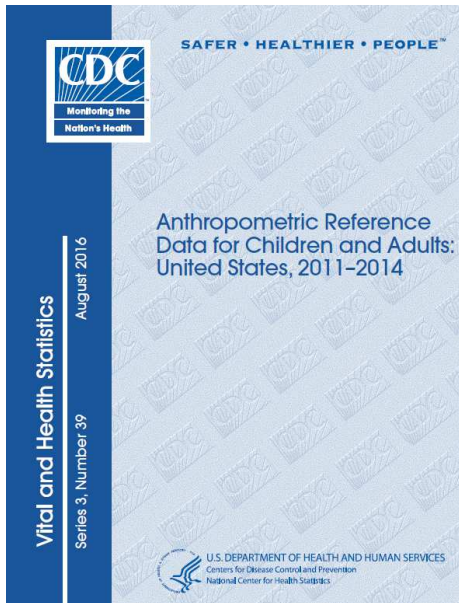


# Evaluation-tools.

## Anthropomorphic Data (example). Male Weight.

Table 5. Weight in kilograms for males aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and Hispanic origin and age: United States, 2011–2014

Race and Hispanic origin and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
Kilograms												
All racial and Hispanic-origin groups <sup>1</sup>												
20 years and over	5,236	88.8	0.43	62.0	66.3	69.9	74.9	85.9	99.2	107.4	113.3	124.9
20–29 years	936	84.7	1.18	57.3	62.4	65.3	69.4	80.7	94.6	105.3	112.1	127.4
30–39 years	914	90.2	0.78	63.6	68.1	71.7	76.2	86.6	100.3	110.2	117.7	127.9
40–49 years	872	91.5	0.73	66.3	70.9	73.9	77.9	89.1	100.9	107.6	113.0	126.6
50–59 years	854	90.5	0.92	63.5	69.0	72.6	77.2	88.8	100.8	107.4	113.6	126.7
60–69 years	874	90.6	1.37	62.5	66.7	70.0	76.2	88.6	101.2	110.8	115.8	126.6
70–79 years	486	85.8	0.92	61.9	66.3	69.2	75.6	83.3	96.1	103.0	107.2	114.1
80 years and over	300	79.2	0.86	56.8	60.1	64.1	69.9	77.6	88.2	94.0	98.0	105.9



Legends:

- Colored bars = 20 years and over for each %-ile.
- Black line = Mean for each %-ile.



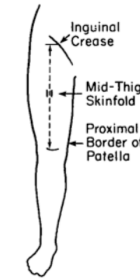
# Evaluation-tools.

## Anthropomorphic Data (example). Male Upper Leg Length.

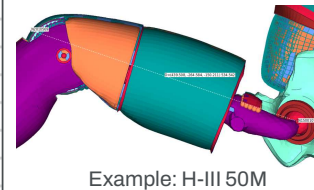
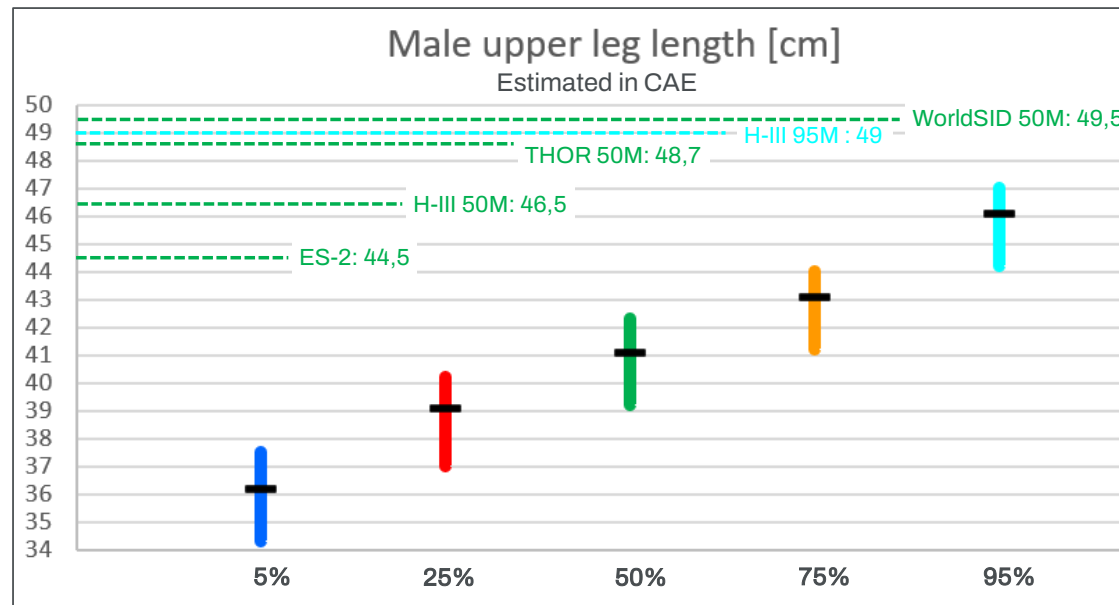
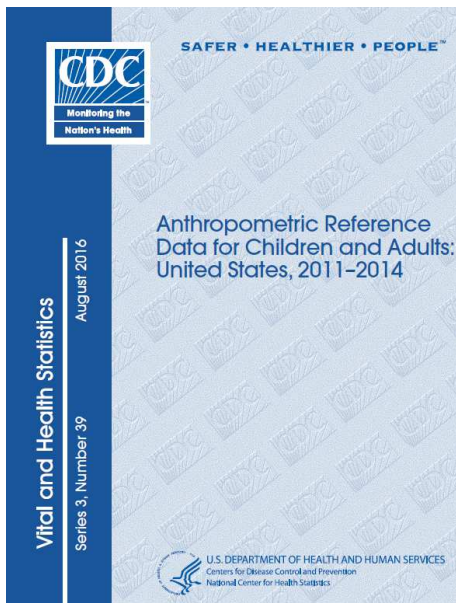
Table 32. Upper leg length in centimeters for males aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and Hispanic origin and age: United States, 2011–2014

Race and Hispanic origin and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and Hispanic-origin groups <sup>1</sup>				Centimeters								
20 years and over	5,013	41.2	0.09	36.2	37.2	38.0	39.1	41.1	43.1	44.2	45.0	46.1
20–29 years	912	42.3	0.09	37.5	38.6	39.3	40.2	42.3	44.0	45.1	46.1	47.0
30–39 years	887	41.8	0.10	37.3	38.3	39.2	40.0	41.7	43.6	44.6	45.2	46.3
40–49 years	837	41.3	0.15	36.7	37.6	38.2	39.3	41.1	43.1	44.2	45.0	46.0
50–59 years	832	40.9	0.17	35.8	37.0	37.9	39.0	41.0	42.9	44.1	44.8	45.5
60–69 years	841	40.2	0.26	34.9	36.3	37.0	38.1	40.1	42.4	43.5	44.2	45.4
70–79 years	454	39.2	0.14	34.3	35.5	36.2	37.0	39.2	41.2	42.2	42.9	44.2
80 years and over	250	39.4	0.22	34.5	35.6	36.5	37.3	39.2	41.2	42.4	43.2	44.3

Upper leg measurements were taken on seated participants; the distance from the inguinal crease to the distal end of the femur was measured.



The upper leg length has been defined by measuring (by CAE and/or on a physical ATD) the distance from the hip-joint to the front of the knee.

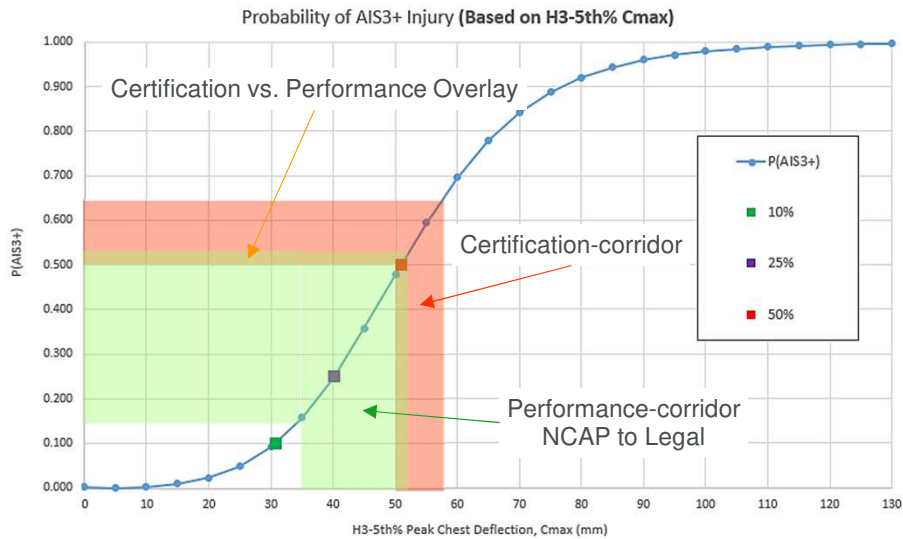
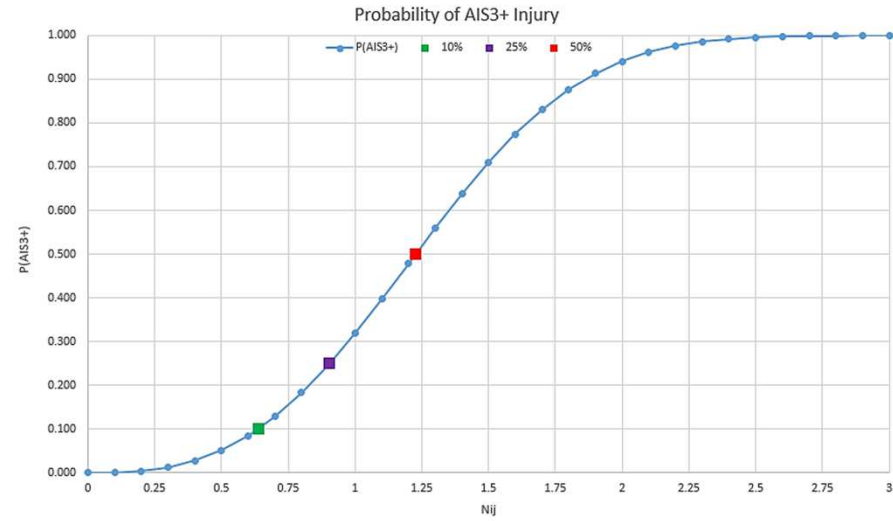
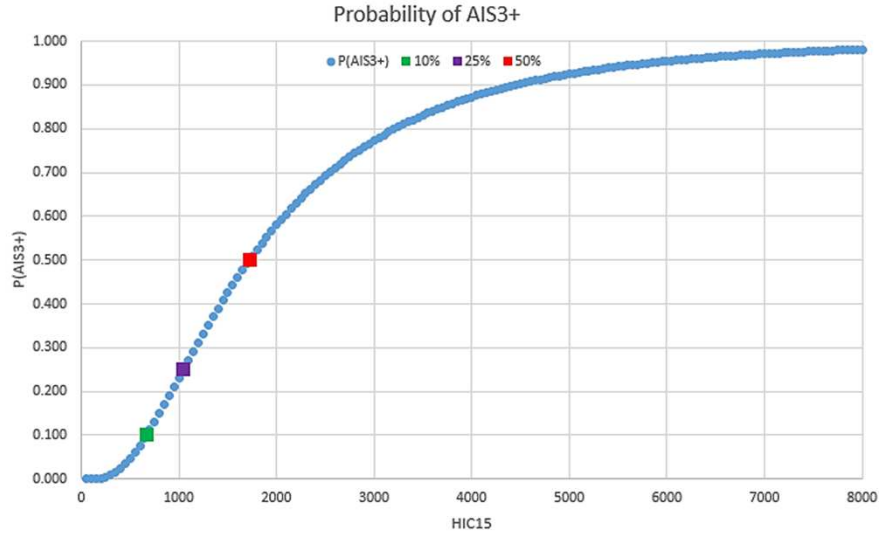


- Legends:
- Colored bars = 20 years and over for each %-ile.
  - Black line = Mean for each %-ile.

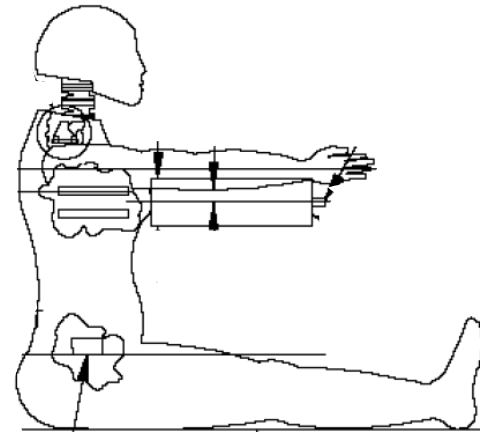


# Evaluation-tools.

## H-III 5F. Sample of Injury Risk Curves.



### H-III 5F Thorax Certification

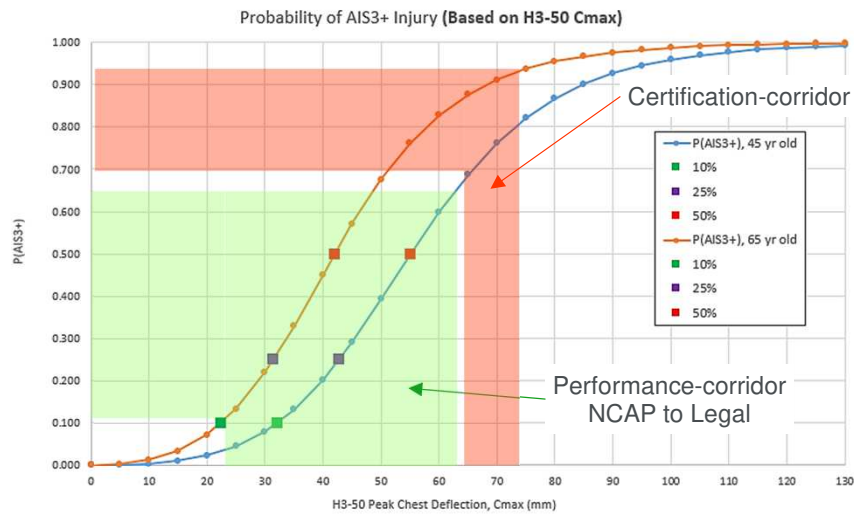
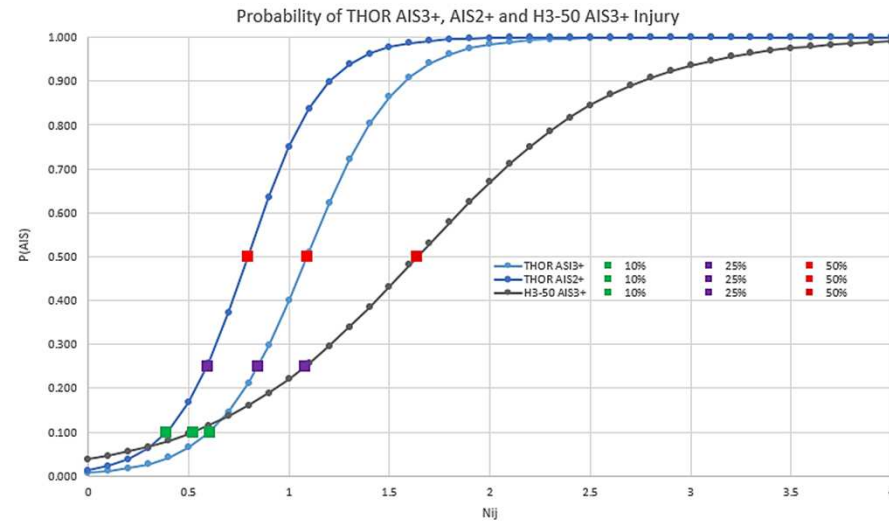
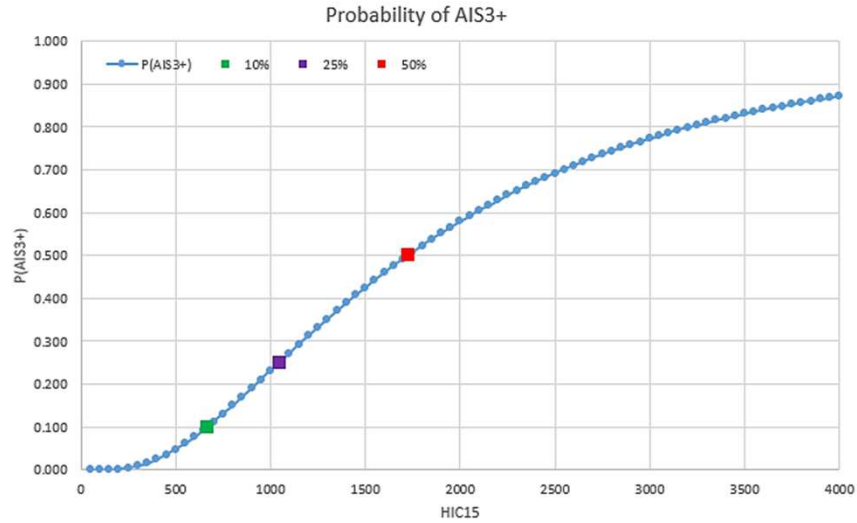


#### Test Specifications:

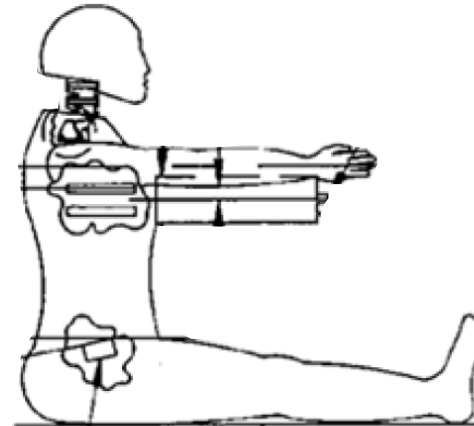
- Pendulum mass = 13,97kg
- Pendulum velocity = 6,71m/s
- Chest displacement = 50 to 58mm
- Pendulum peak force = 3,9 to 4,4kN

# Evaluation-tools.

## H-III 50M. Sample of Injury Risk Curves.



### H-III 50M Thorax Certification



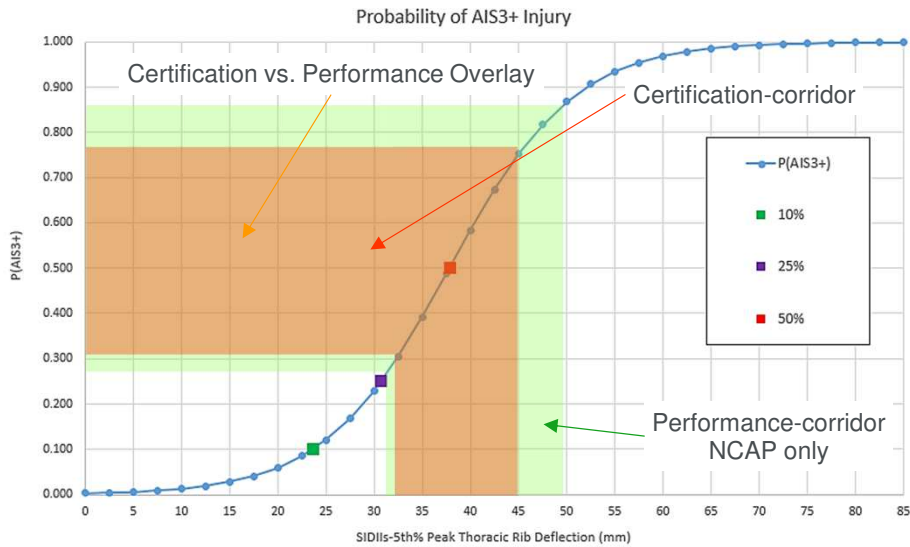
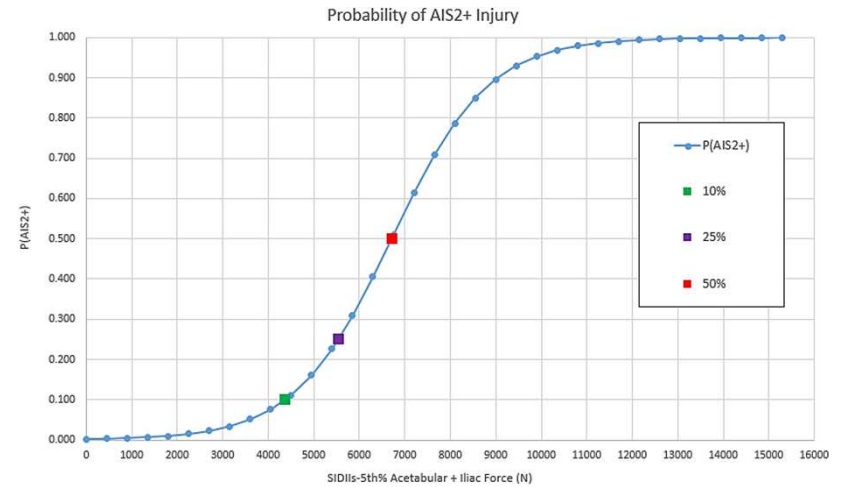
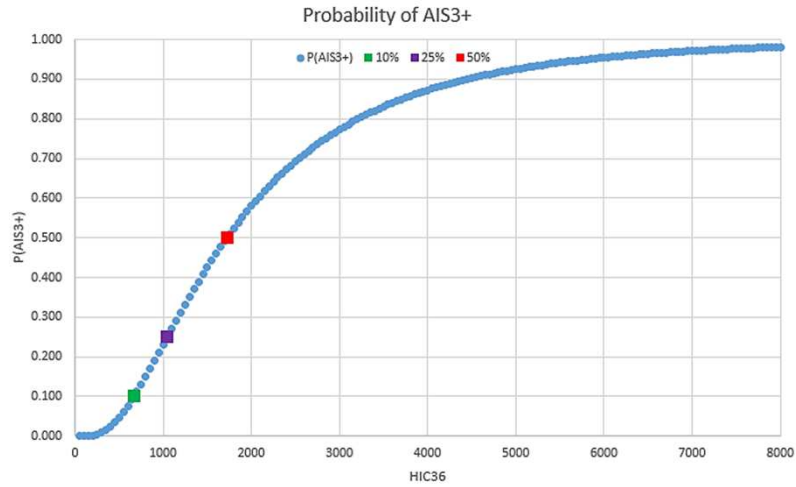
#### Test Specifications:

- Pendulum mass = 23,36kg
- Pendulum velocity = 6,59 to 6,83m/s
- Chest displacement = 64 to 73mm
- Pendulum peak force = 5,16 to 5,894kN



# Evaluation-tools.

## SID-IIIs. Sample of Injury Risk Curves.



### SID-IIIs Thorax Certification (without arm)



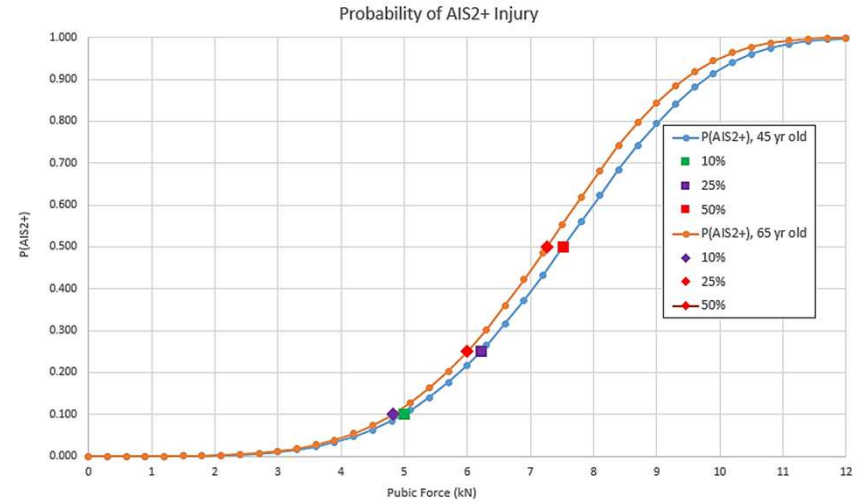
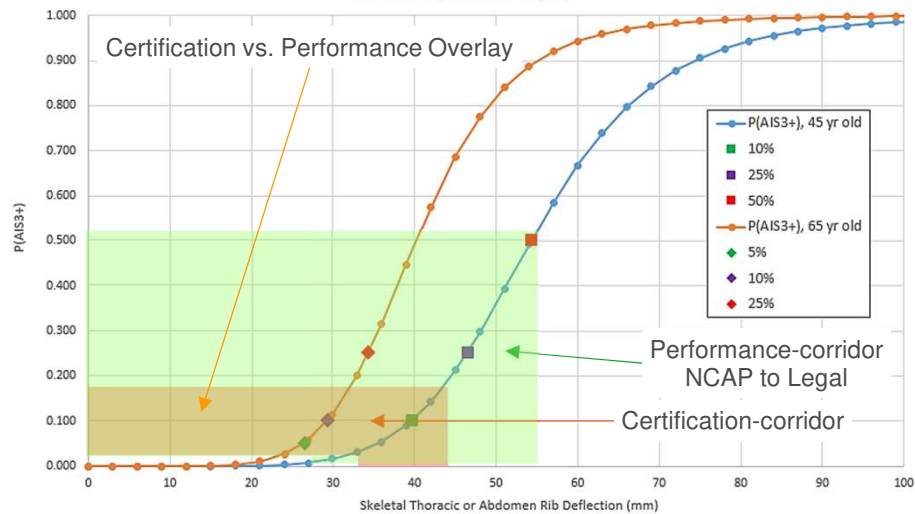
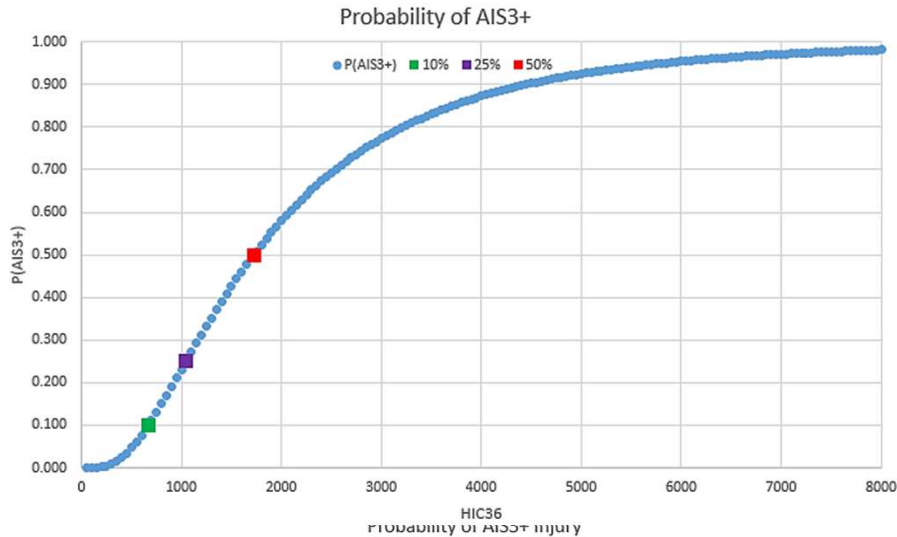
#### Test Specifications:

- Pendulum mass = 13,97kg
- Pendulum velocity = 4,2 to 4,4m/s
- Thorax displacement\* = 32 to 45mm
- Pendulum peak acc = 14 to 18g

\*Including all Thorax ribs

# Evaluation-tools.

## WorldSID 50M. Sample of Injury Risk Curves.



### WorldSID 50M Thorax Certification (without arm)

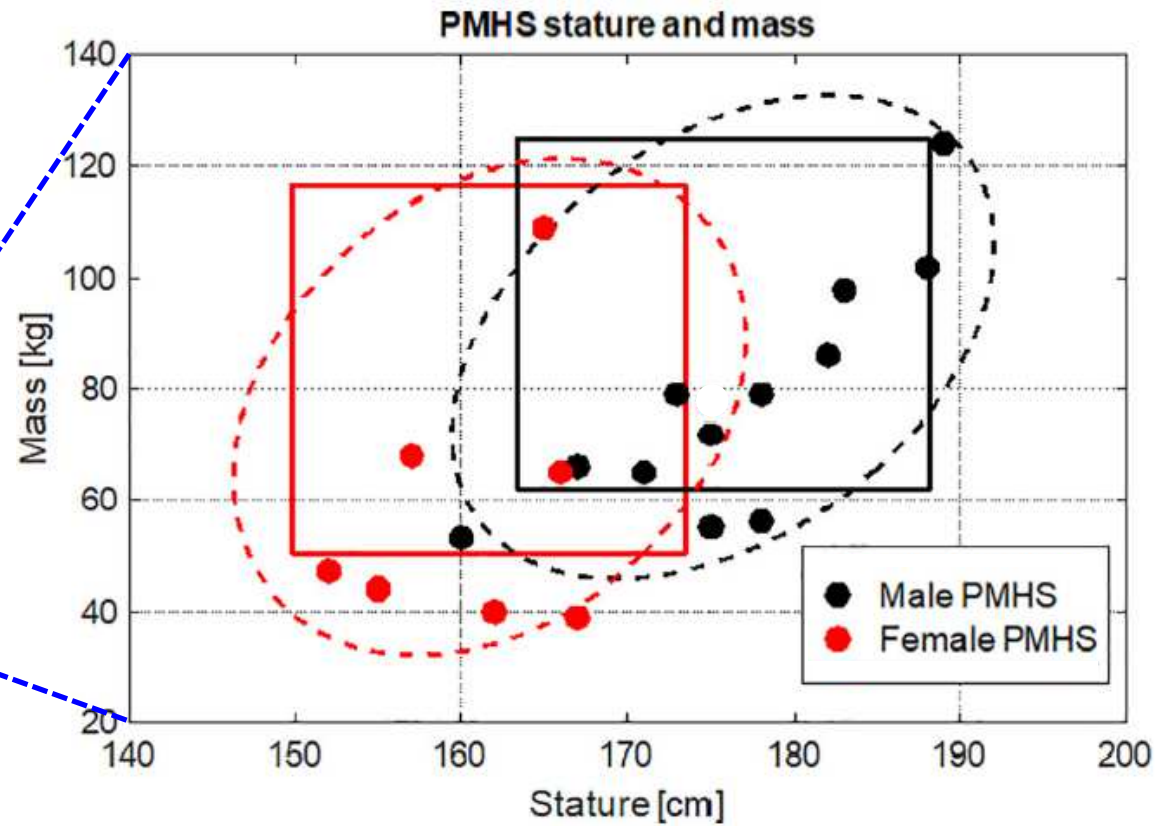
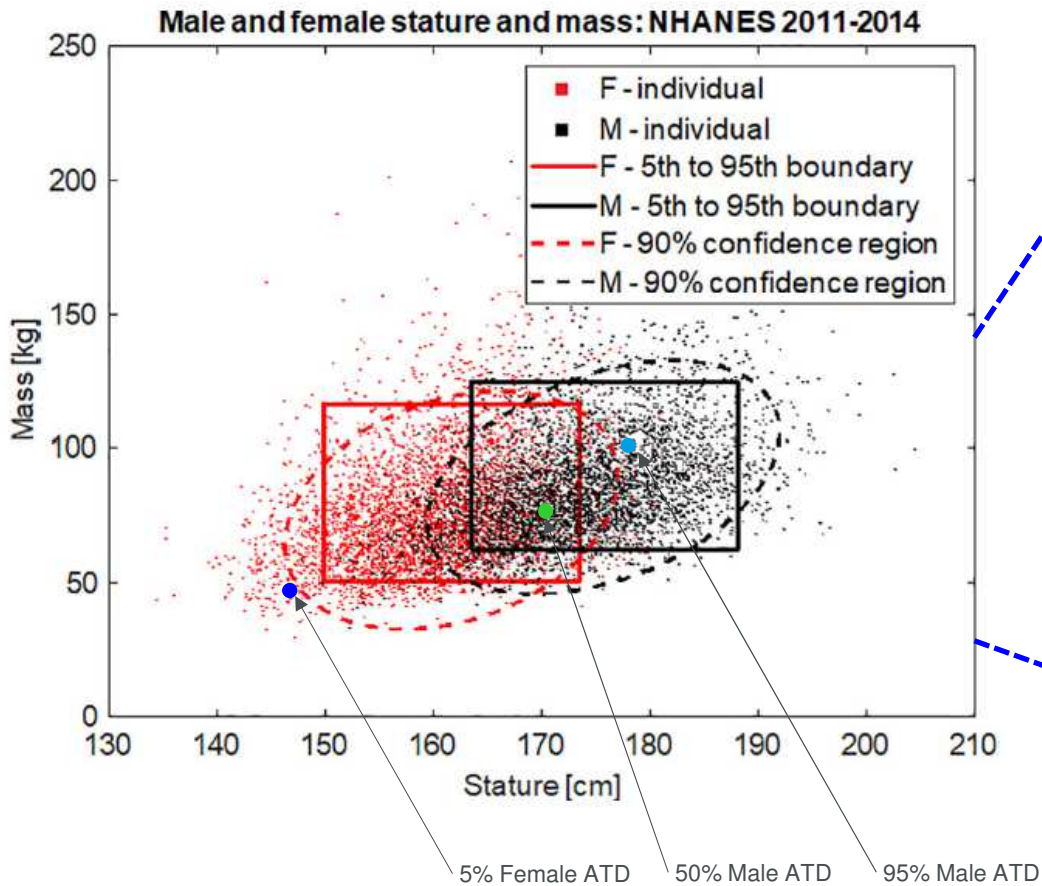


#### Test Specifications:

- Pendulum mass = 23,36kg
- Pendulum velocity = 4,2 to 4,4m/s
- Thorax displacement\* = 32 to 43mm
- Pendulum peak force = 3,2 to 3,8kN

\*Including all Thorax ribs

# Mixed Population. Male and Female Mass vs. Stature Distribution.



Possible "validation-points" for a HBM.

Source: Larsson et al. - 2021

Date

Presentation Name

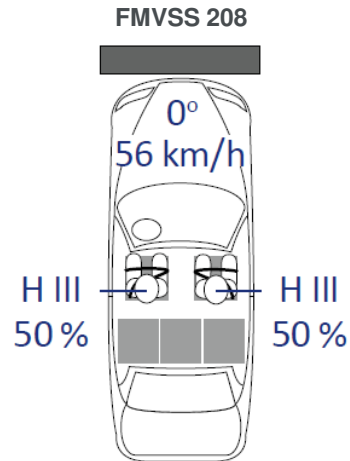
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Internal

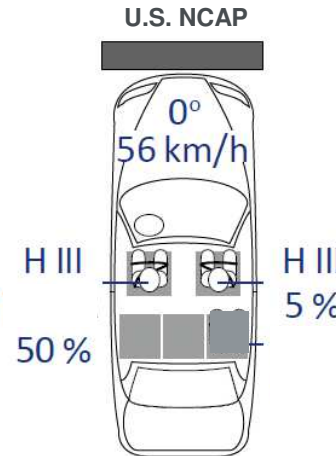


# Targets & Rewards.

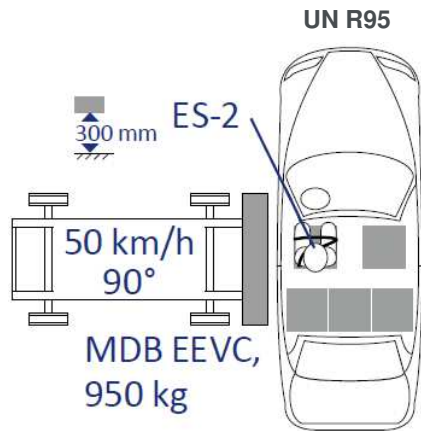
## Samples of Regulatory Requirements vs. Rating Requirements.



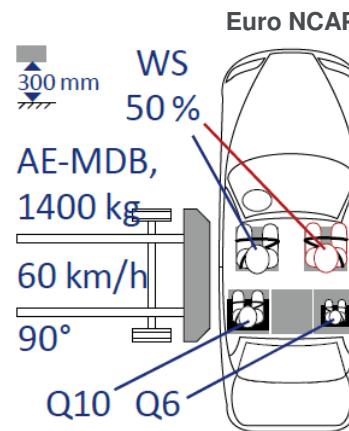
Dummy		Hybrid III	Hybrid III
Size		50 % male	5 % female
Head	HIC <sub>36</sub> / HPC <sub>36</sub> [-]		
	HIC <sub>15</sub> [-]	700	700
	a <sub>3ms</sub> [g]		
Neck	N <sub>ij</sub> [-] (4 Values)	1.0	1.0
	F <sub>x, shear</sub> [kN]		
	F <sub>z, tension</sub> [kN]	4.17	2.62
	F <sub>z, compr.</sub> [kN]	4.0	2.52
	M <sub>y</sub> [Nm]		
Chest	a <sub>3ms</sub> [g]	60	60
	Deflection [mm]	63	52
	VC [m/s]		
Femur	Axial Force [kN]	10	6.805



Dummy	Hybrid III 50 % (Driver)	Hybrid III 5 % (Passenger)
Head (HIC <sub>15</sub> )	$P_{\text{head}}(\text{AIS } 3+) = \Phi\left(\frac{\ln(\text{HIC}_{15}) - 7.45231}{0.73998}\right)$ where $\Phi$ = cumulative normal distribution	$P_{\text{head}}(\text{AIS } 3+) = \Phi\left(\frac{\ln(\text{HIC}_{15}) - 7.45231}{0.73998}\right)$ where $\Phi$ = cumulative normal distribution
Chest (Deflection in mm)	$P_{\text{chest\_defl}}(\text{AIS } 3+) = \frac{1}{1 + e^{10.5456 - 1.568 * (\text{ChestDefl})^{0.4612}}}$	$P_{\text{chest\_defl}}(\text{AIS } 3+) = \frac{1}{1 + e^{10.5456 - 1.7212 * (\text{ChestDefl})^{0.4612}}}$
Femur (Force in kN)	$P(\text{AIS } 2+) = \frac{1}{1 + e^{5.795 - 0.5186 * \text{Femur\_Force}}}$	$P(\text{AIS } 2+) = \frac{1}{1 + e^{5.794 - 0.519 * \text{Femur\_Force}}}$
Neck (N <sub>ij</sub> and Tension/Compression in kN)	$P_{\text{neck\_Nij}}(\text{AIS } 3+) = \frac{1}{1 + e^{3.2269 - 1.9683 * N_{ij}}}$	$P_{\text{neck\_Nij}}(\text{AIS } 3+) = \frac{1}{1 + e^{3.2269 - 1.9683 * N_{ij}}}$
	$P_{\text{neck\_Tens}}(\text{AIS } 3+) = \frac{1}{1 + e^{10.9745 - 2.375 * \text{Neck\_Tension}}}$	$P_{\text{neck\_Tens}}(\text{AIS } 3+) = \frac{1}{1 + e^{10.9745 - 2.375 * \text{Neck\_Tension}}}$
	$P_{\text{neck\_Comp}}(\text{AIS } 3+) = \frac{1}{1 + e^{10.9745 - 2.375 * \text{Neck\_Compression}}}$	$P_{\text{neck\_Comp}}(\text{AIS } 3+) = \frac{1}{1 + e^{10.9745 - 2.375 * \text{Neck\_Compression}}}$
	$P_{\text{neck}} = \max(\text{imum}(P_{\text{neck\_Nij}}, P_{\text{neck\_Tens}}, P_{\text{neck\_Comp}}))$	$P_{\text{neck}} = \max(\text{imum}(P_{\text{neck\_Nij}}, P_{\text{neck\_Tens}}, P_{\text{neck\_Comp}}))$
Overall	$P_{\text{total}} = 1 - (1 - P_{\text{head}}) \times (1 - P_{\text{chest}}) \times (1 - P_{\text{femur}}) \times (1 - P_{\text{neck}})$	



Head HPC < 1000  
 Chest VC < 1.0 m/s  
 Rib deflection D < 42 mm  
 Abdomen Σ APF < 2.5 kN  
 Pelvis PSPF < 6.0 kN



World SID 50 %	Head <sup>1</sup>	HIC <sub>15</sub>	< 500	> 700
		a <sub>3ms</sub> [g]	< 72	> 80
Chest	Deflection (mm)	< 28	> 50	
	Abdomen	Deflection (mm)	< 47	> 65
Pelvis	Pubic Symphysis Peak Force (kN)	< 1.7	> 2.8	

Performance Balancing:  
 “Meet Regulatory Requirements – Peak Rating Requirements”





# Saving More Lives

*Date*

*Presentation Name*

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