

# ***Biofidelity Analysis of WorldSID and ES-2re***

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# Background

- **Industry petitioned the Agency to include the WorldSID 50th in Part 572 and FMVSS 214**
  - **the ISO biofidelity ranking system (ISO 9790) indicates that the WorldSID biofidelity is superior to ES-2re**
  - **global harmonization**



# Background (cont.)

- **A collaborative project evaluating an improved WorldSID has been completed**
  - **NHTSA worked closely with the WorldSID Task Group using 2 dummies provided by OSRP**
  - **several improvements were made to the dummy during the evaluation**

# Objectives

- **Present the results of the WorldSID and ES-2re biofidelity rankings using an updated version of the NHTSA Biofidelity Ranking System (H. Rhule, 2002 Stapp)**
- **Share our observations relating to dummy design and performance**

# Preview

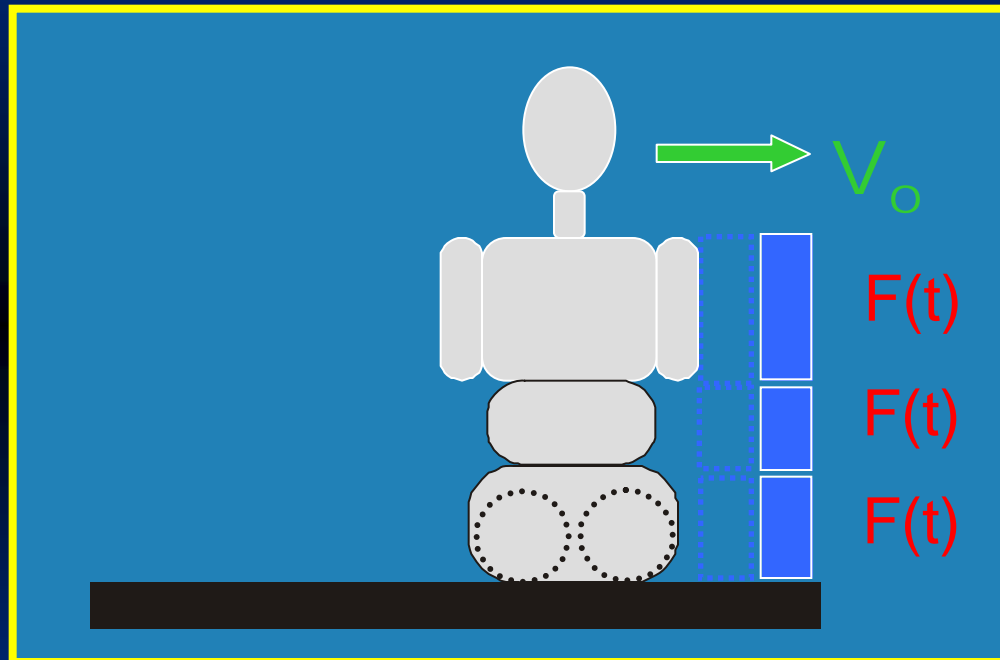
- **Review of Biofidelity Ranking System**
- **Summary of results**
- **Results of specific body regions**
- **Conclusions**

# Biofidelity Ranking System



# External Biofidelity (EB)

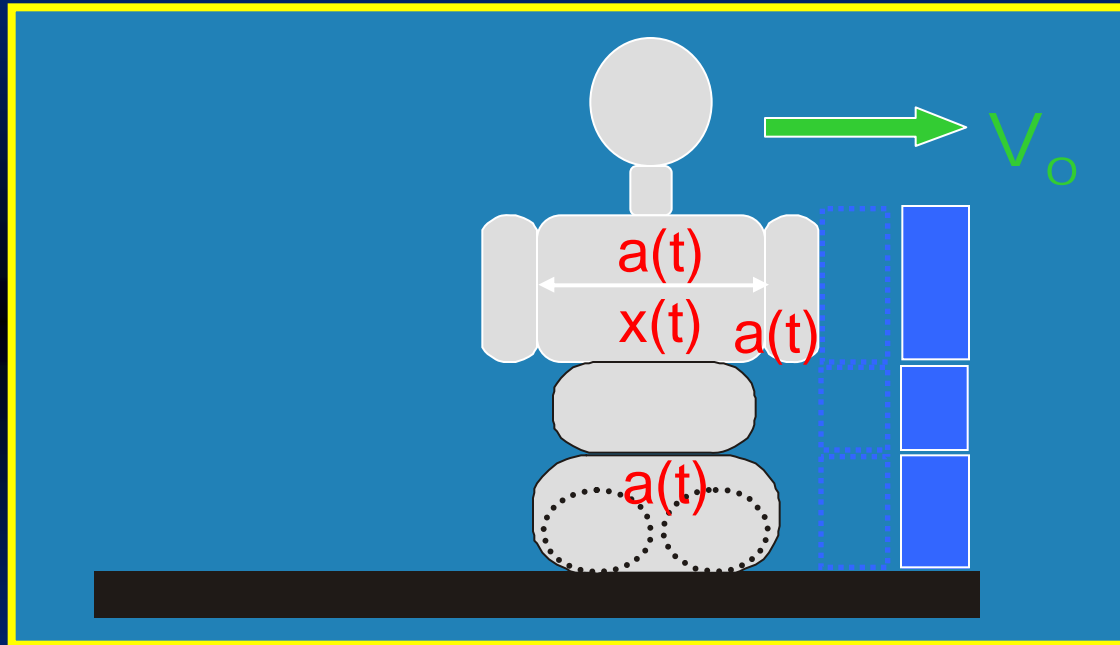
- Ability to replicate human loading of its environment in a crash



- Measurements made externally to human and dummy

# Internal Biofidelity (IB)

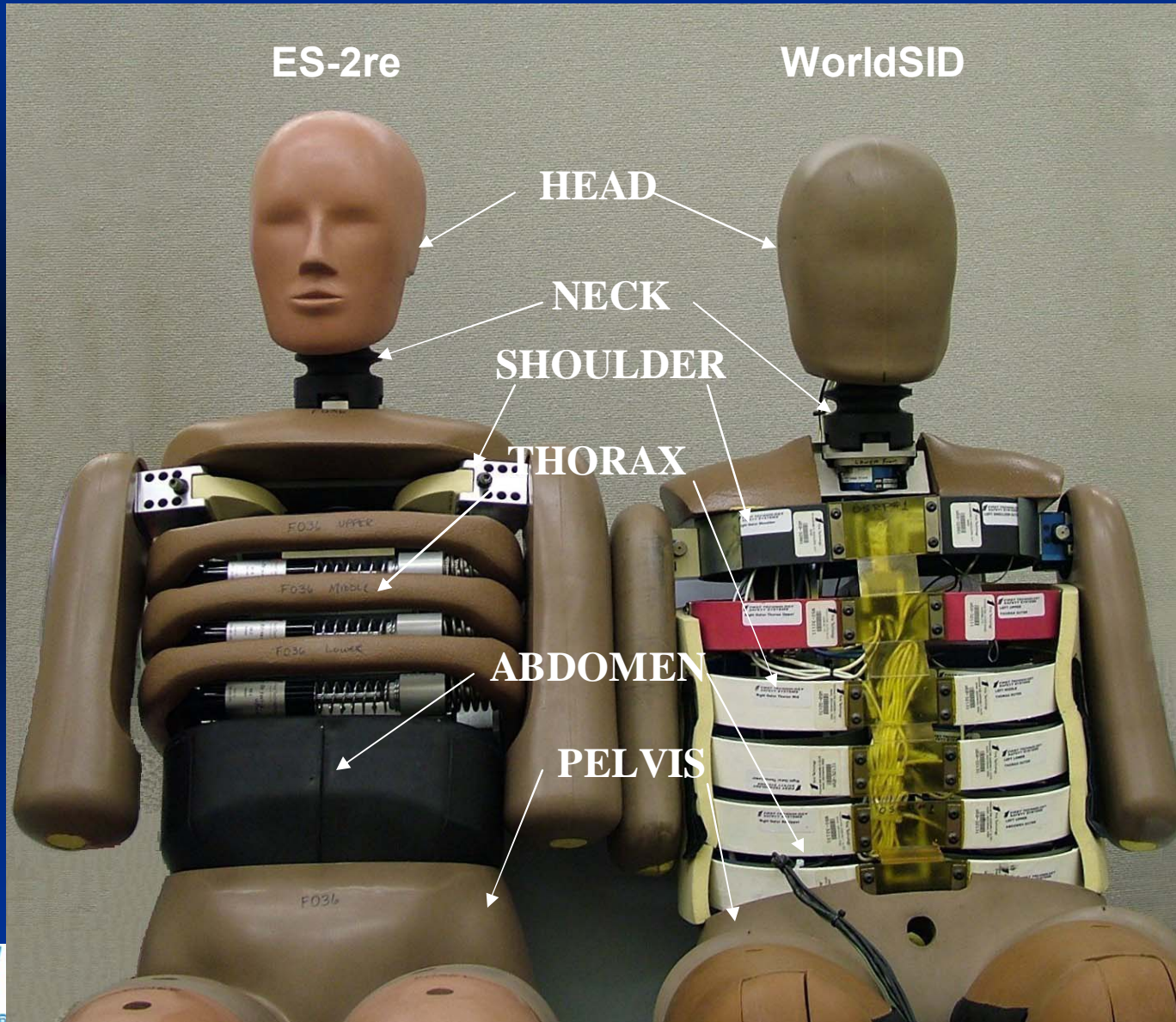
- Ability to replicate human internal response in a crash



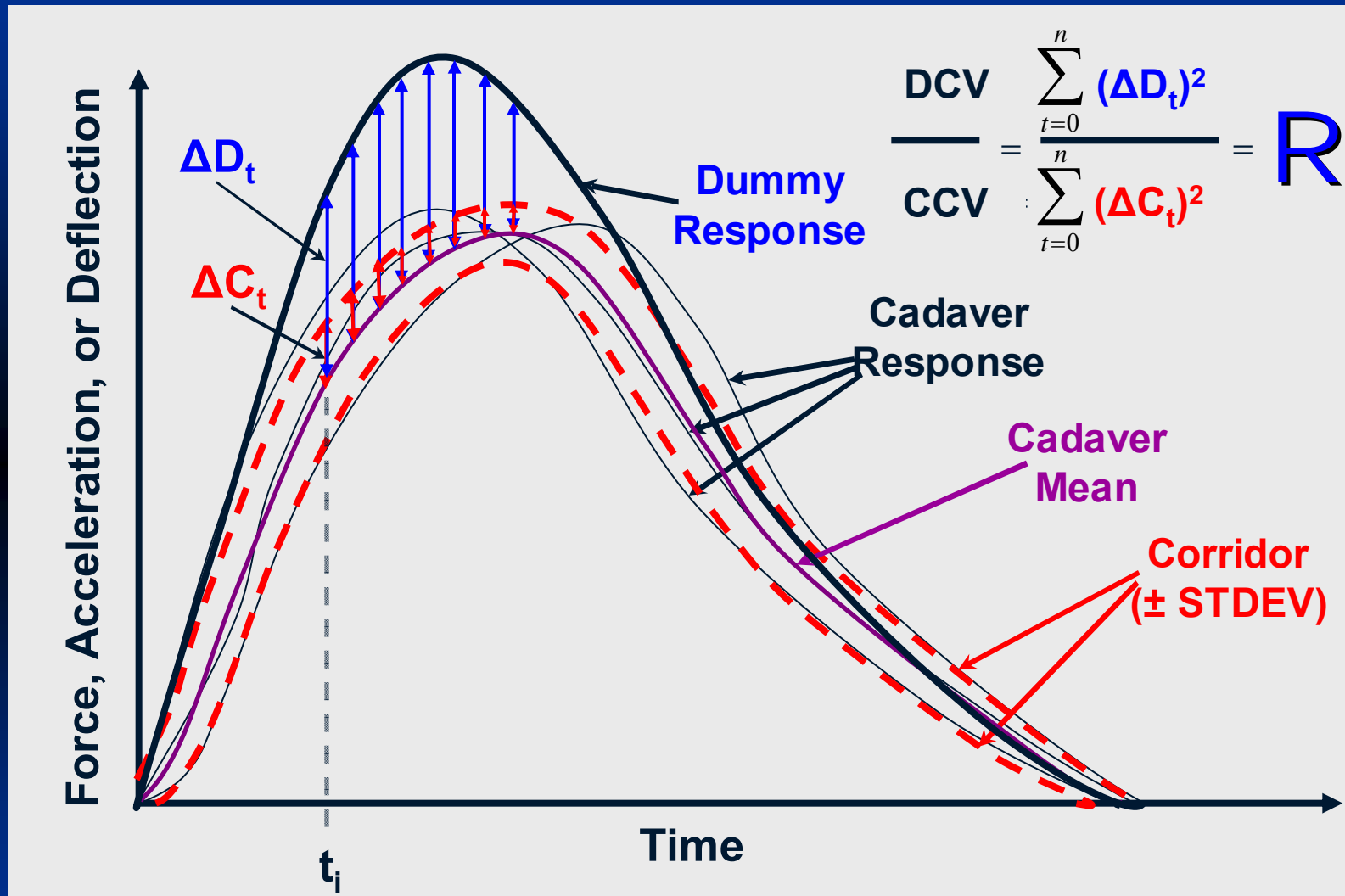
- Internal measurements used for injury criteria



# Ranked Body Regions



# DCV / CCV\* (R)



\* Morgan et al. 1986



# Bioranking (B) Calculation

Thorax Internal Biofidelity

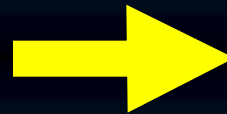
**Test Condition 1**  
Avg.  $\sqrt{R}$  for all internal  
thorax response  
measurements



**Test Condition 2**  
Avg.  $\sqrt{R}$  for all internal  
thorax response  
measurements



**Test Condition n**  
Avg.  $\sqrt{R}$  for all internal  
thorax response  
measurements



**Average results from  
Test Conditions  
1 to n**

= **IB<sub>Thorax</sub>**

Avg. of

**IB<sub>Head</sub>**  
**IB<sub>Shoulder</sub>**  
**IB<sub>Thorax</sub>**  
**IB<sub>Abdomen</sub>**  
**IB<sub>Pelvis</sub>**

=

**Internal  
Biofidelity**



# Bio Rank Test Matrix & References

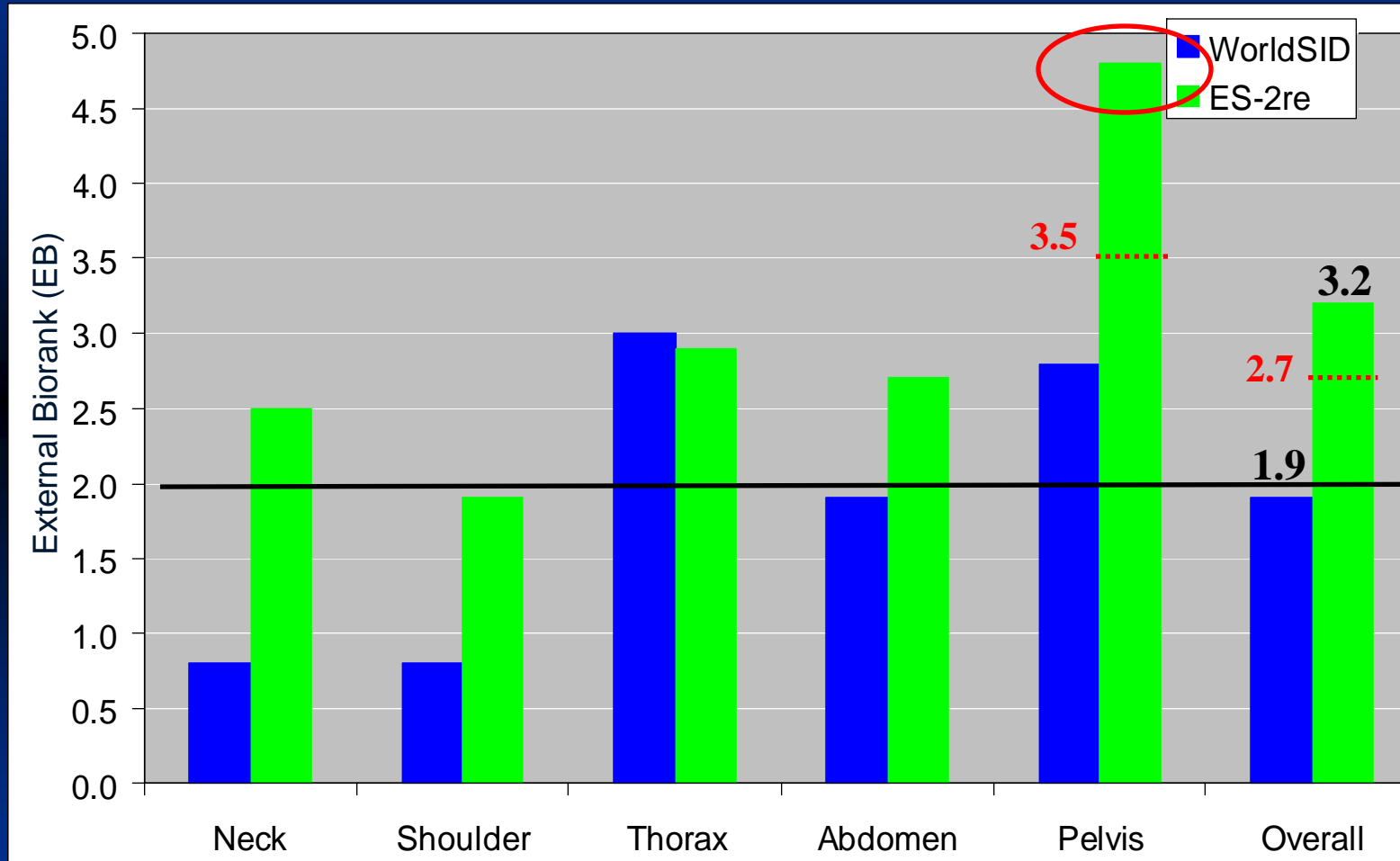
Test Condition	Test Name	Reference
200 mm Rigid Lateral Head Drop	Head Test 1	ISO 9790 - Head Test 1
7.2 g Restrained Occupant Sled	Neck Test 1	ISO 9790 - Neck Test 1 & Shoulder Test 2
12.2 g Restrained Occupant Sled	Neck Test 3	ISO 9790 - Neck Test 3 & Shoulder Test 3
4.3 m/s Rigid Pendulum Lateral Thorax Impact	Thorax Test 1	ISO 9790 - Thorax Test 1
6.8 m/s Rigid Wall Sled	Heidelberg Sled Test	ISO 9790 - Thorax Test 5 & Pelvis Test 7
6.8 m/s Rigid Wall Sled	Wayne State Sled Test	ISO 9790 - Abdomen Test 3 & Pelvis Test 10
6 m/s Rigid Pendulum Pelvis Impact	Pelvis Test 1	ISO 9790 - Pelvis Test 1
10 m/s Rigid Pendulum Pelvis Impact	Pelvis Test 2	ISO 9790 - Pelvis Test 2



# Bio Rank Test Matrix & References (cont.)

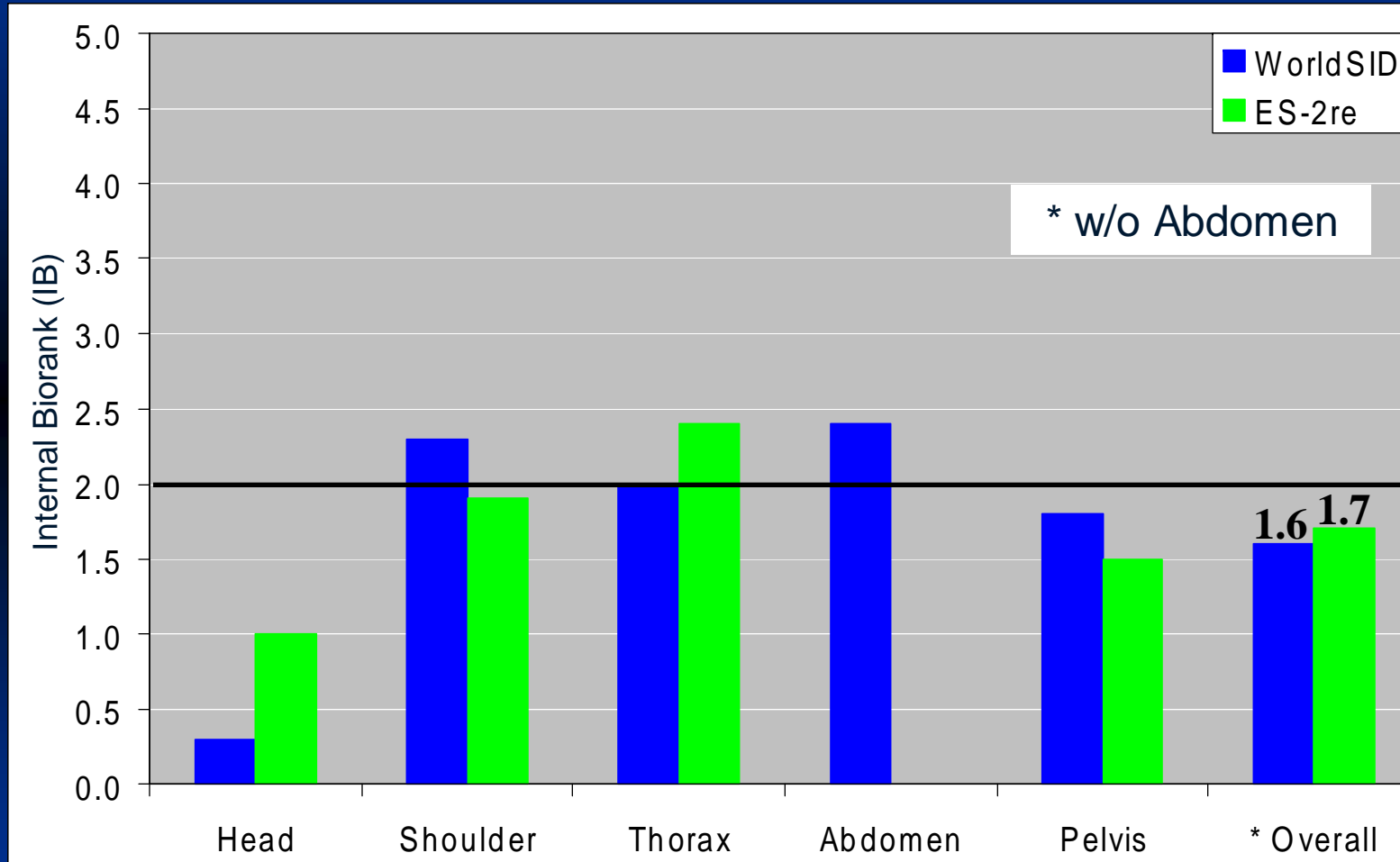
Test Condition	Test Name	Reference
<b>≈ 90 Impactor Tests</b>		
Oblique Thorax Impact	Thorax Test	Shaw et al. 2006
6.7 m/s Flat Rigid Wall Sled	NHTSA LS FR	Maltese et al. 2002
6.7 m/s Flat Padded Wall Sled	<b>≈ 40 Sled Tests w/ 2 occupant sled buck</b>	
6.7 m/s Rigid Abdomen Offset Sled		
6.7 m/s Rigid Pelvis Offset Sled		
8.9 m/s Flat Padded Wall Sled		

# External Biofidelity



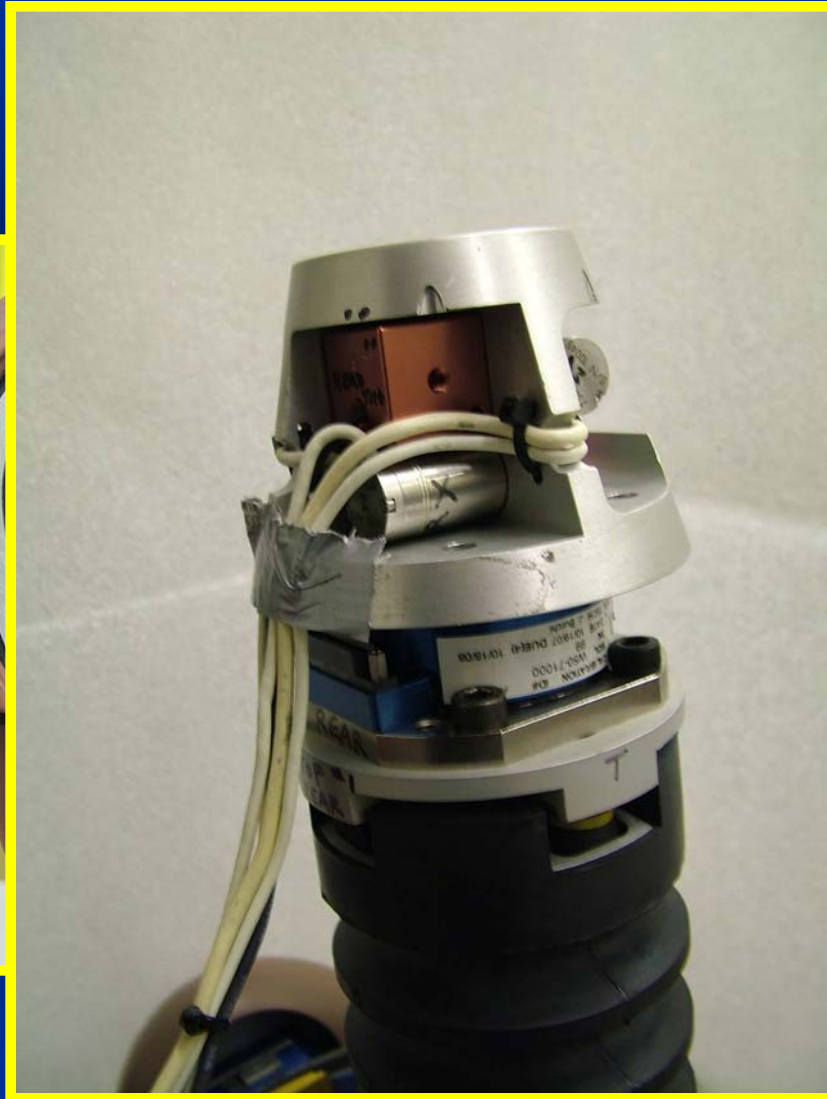
**Better  
Biofidelity**

# Internal Biofidelity



**Better  
Biofidelity**

# Head

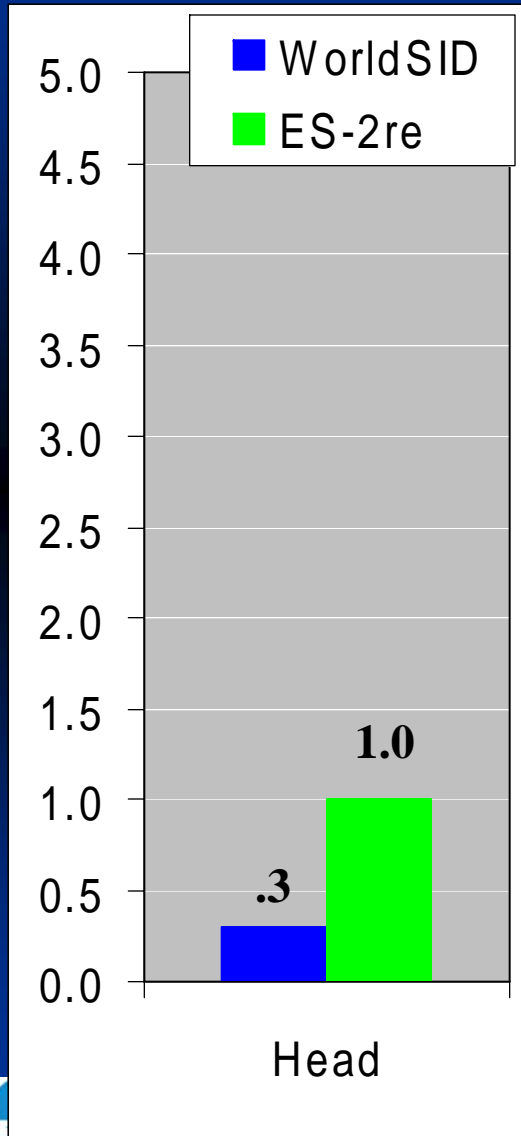


WorldSID





# Head Response Summary



Head Internal Response Summary			
	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
100 mm	Peak Resultant Head Acceleration	0.33	1.02

# Neck

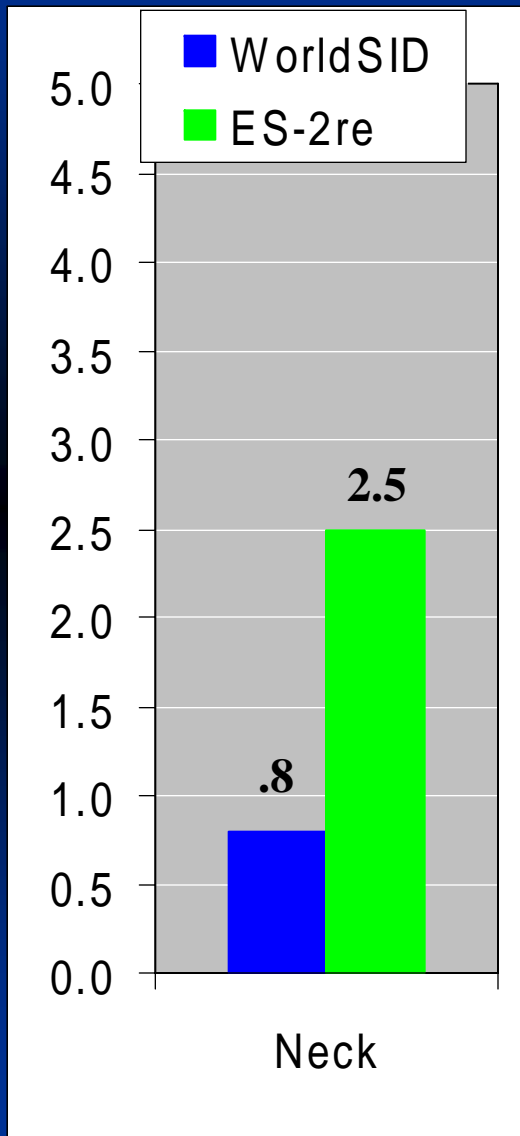
ES-2re



WorldSID



# Neck Response Summary



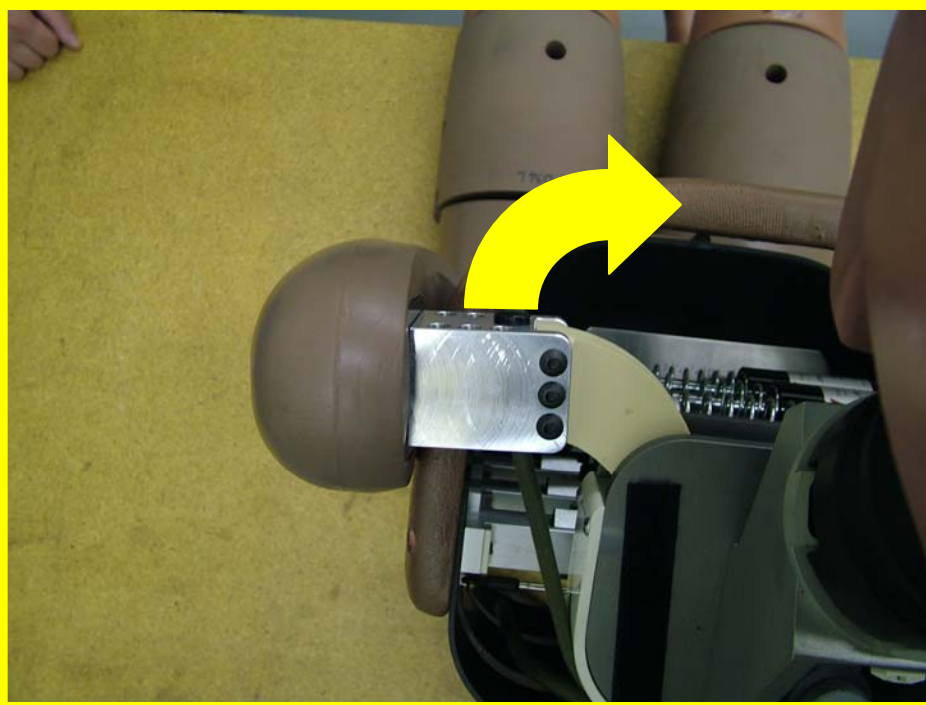
## Neck External Response Summary

Measurement	Response Comparison ( $\sqrt{R}$ )	
	WorldSID	ES-2
Peak Horizontal Displacement of Head cg Relative to T1 (mm)	1.22	3.25
Peak Vertical Displacement of Head cg Relative to T1 (mm)	1.22	2.49*
Peak Flexion Angle (°)	0.40	1.00
Peak Horizontal Displacement of Head cg Relative to Sled (mm)	0.25	1.59
Peak Flexion Angle (°)	1.15	2.85

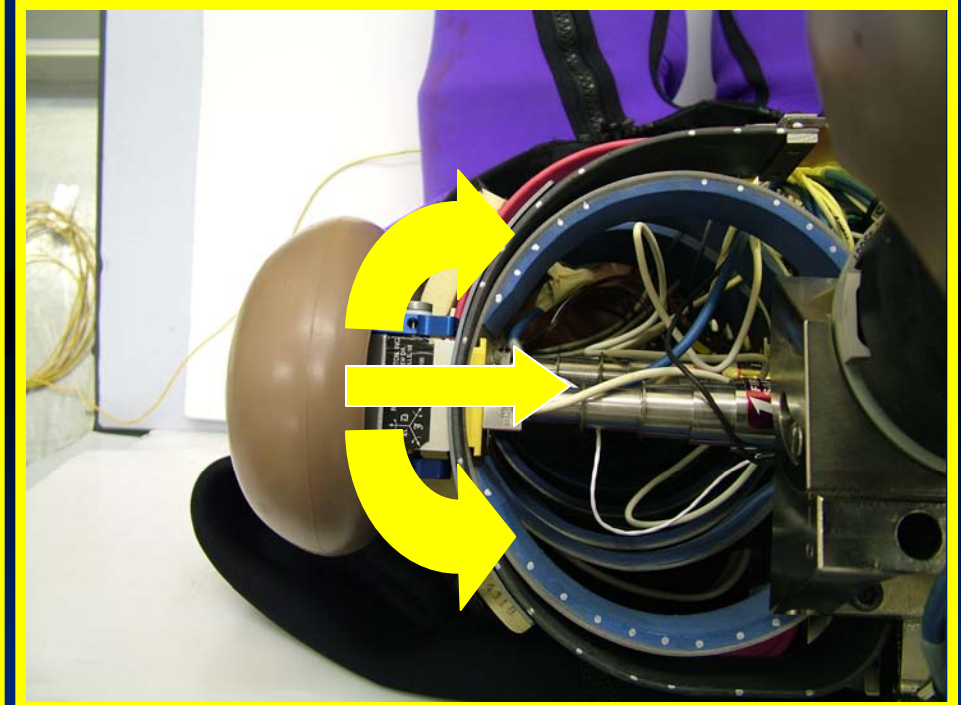
this test is from Byrnes et al., 2002 Stapp Conference

# Shoulder

ES-2re



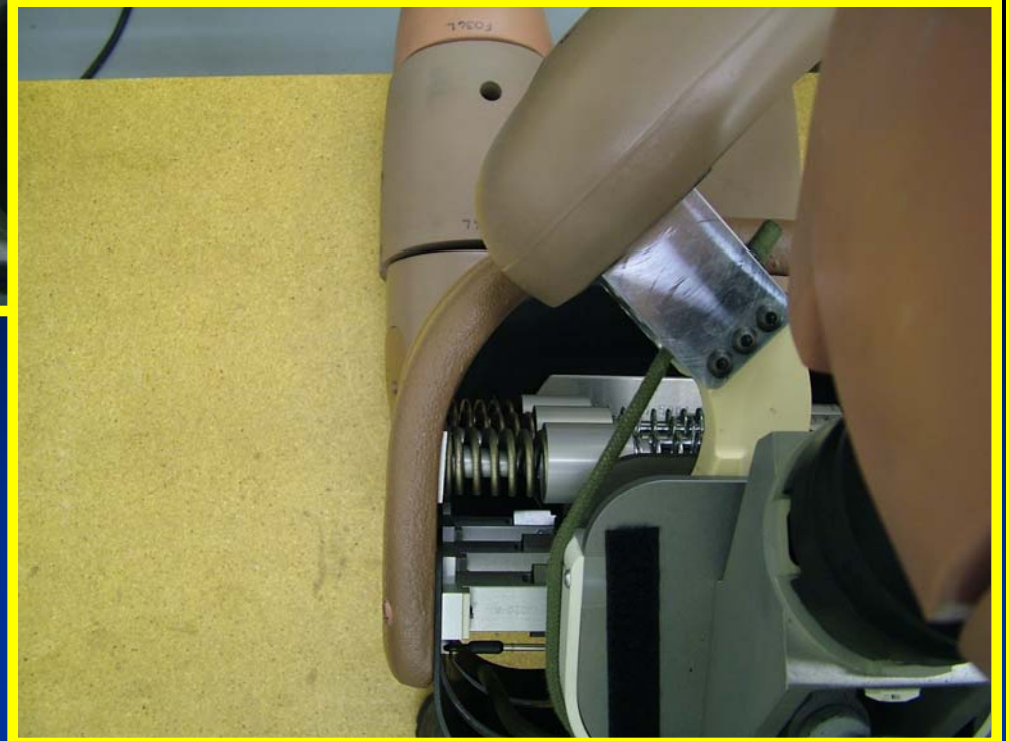
WorldSID



# Shoulder

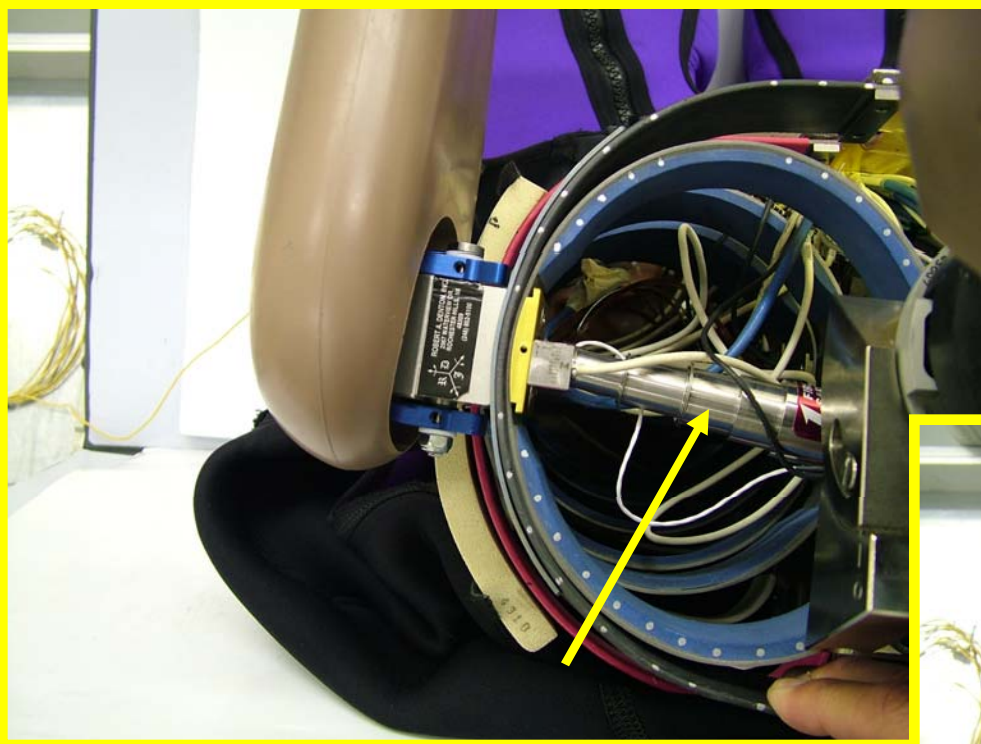


ES-2re

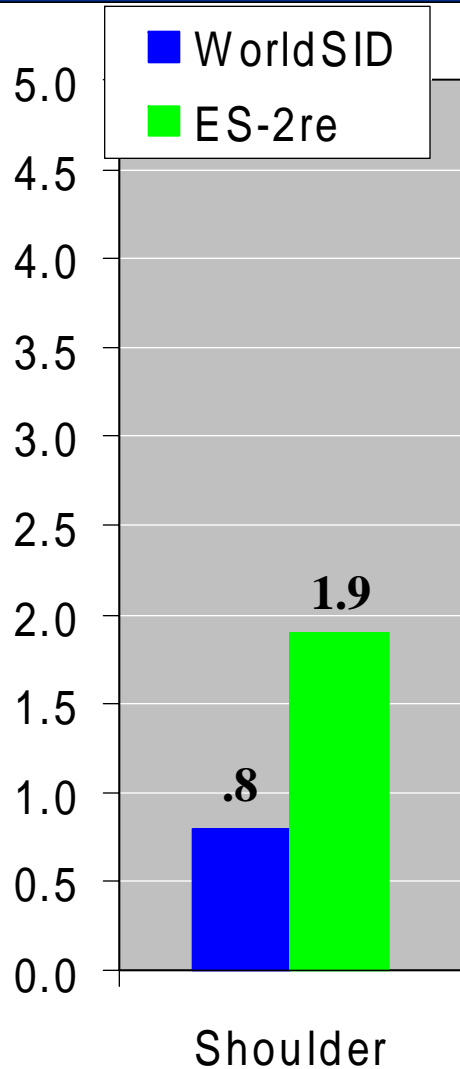


# Shoulder

WorldSID



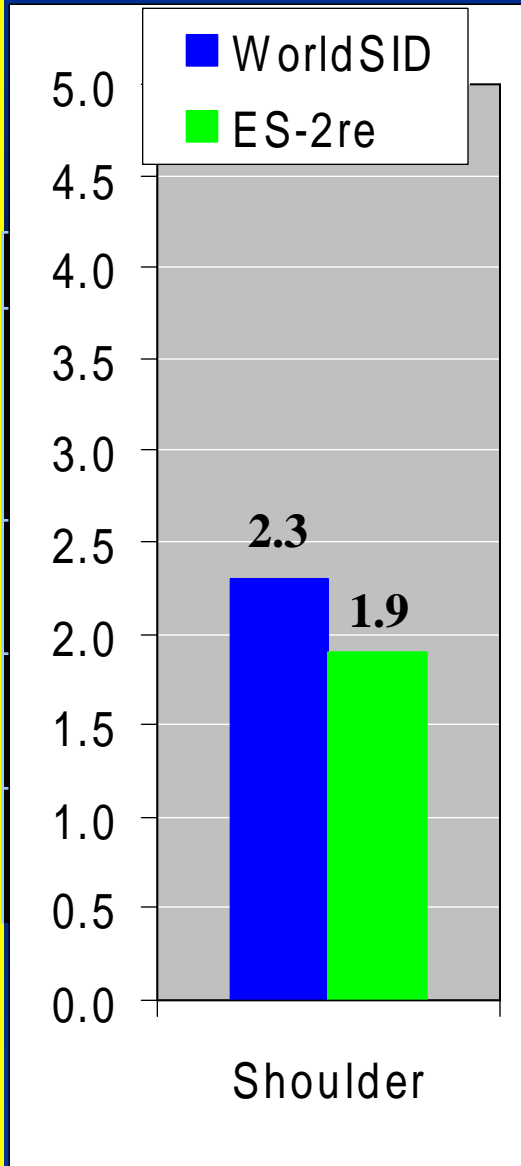
# Shoulder Response Summary



## Shoulder External Response Summary

Measurement	Response Comparison ( $\sqrt{R}$ )	
	WorldSID	ES-2re
Peak Horizontal Displacement of T1 Relative to Sled (mm)	0.24	1.47
Pendulum Force (kN)	0.87	1.10
Pendulum Y-axis Force (kN)	1.26	2.96
Pendulum X-axis Force (kN)	0.84	1.96
Pendulum Y-axis Force (kN)	0.54	3.44
Pendulum X-axis Force (kN)	1.59	1.83

# Shoulder Response Summary

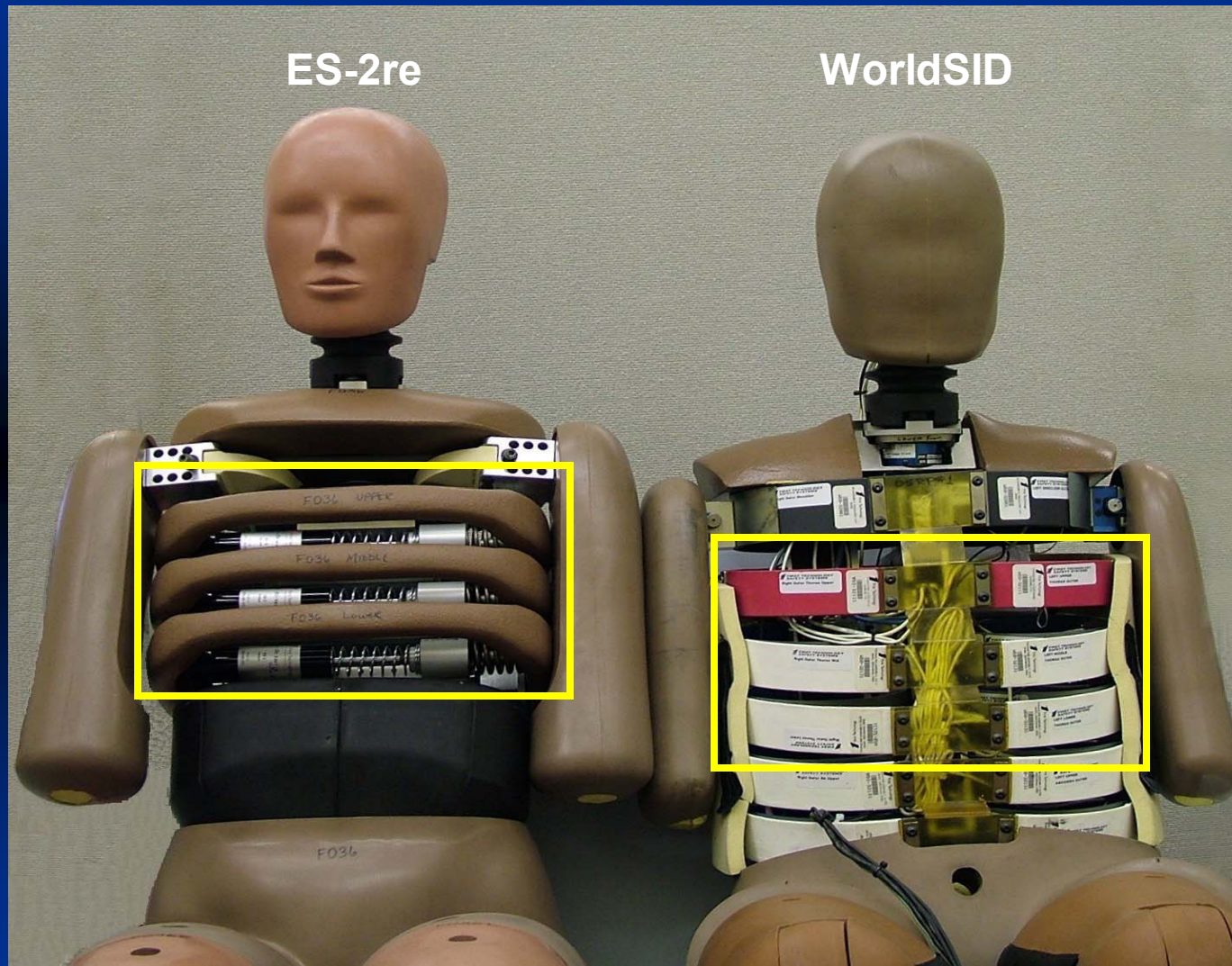


## Shoulder Internal Response Summary

	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
	Shoulder Y-axis Displacement (mm)	1.55	1.11
	Shoulder Y-axis Displacement (mm)	1.70	1.72
	Shoulder Y-axis Displacement (mm)	3.61	2.84

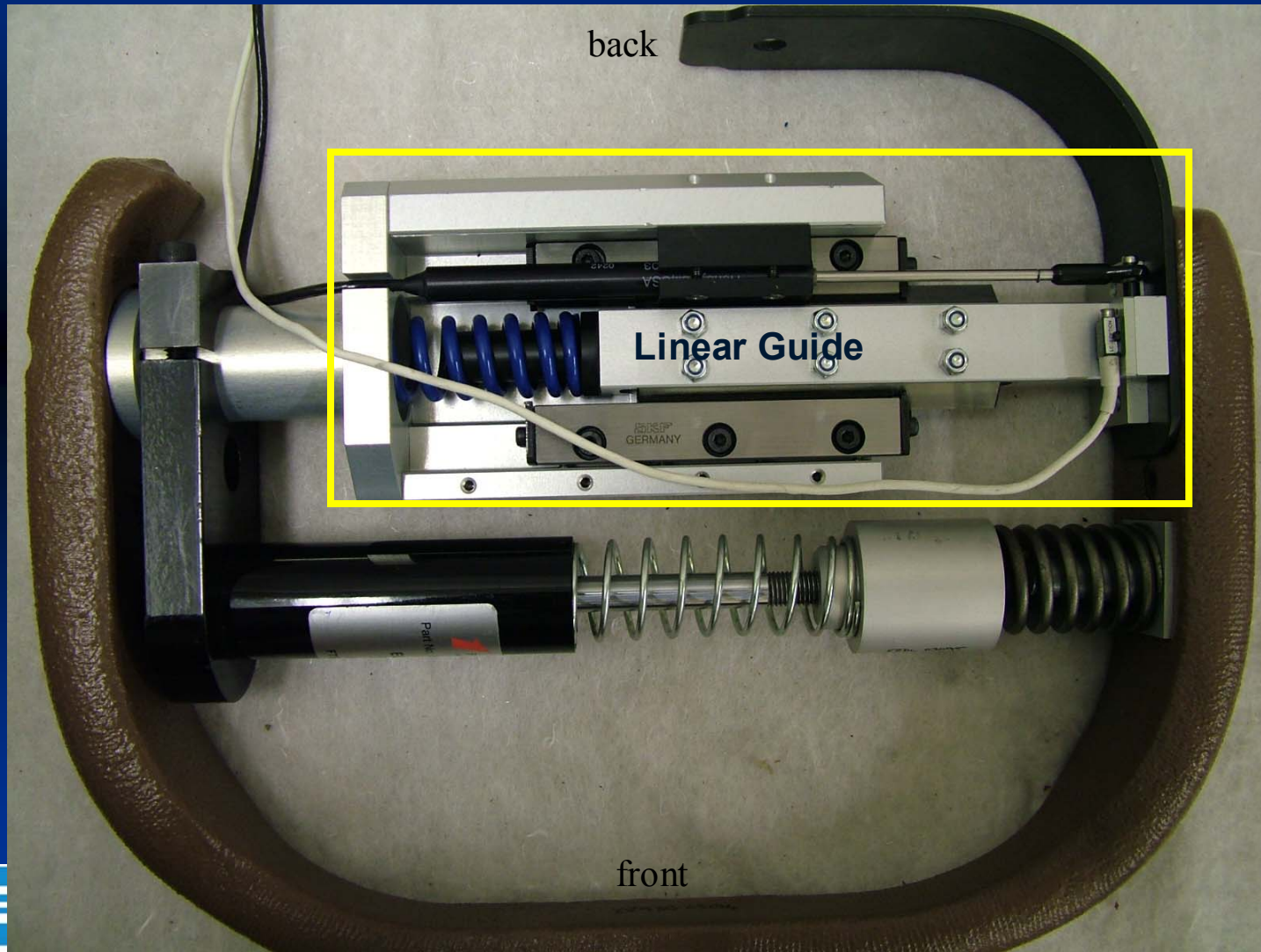


# Thorax



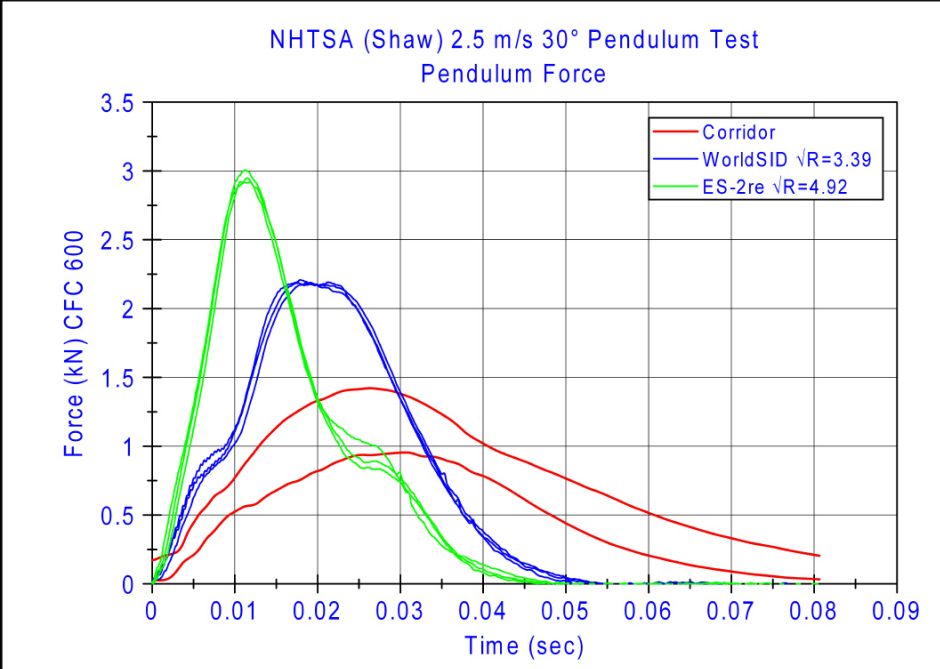
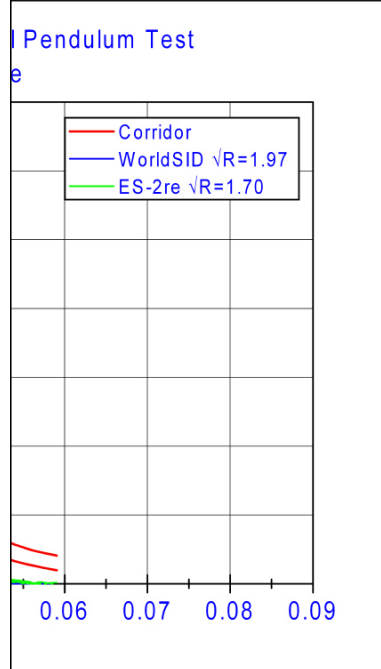
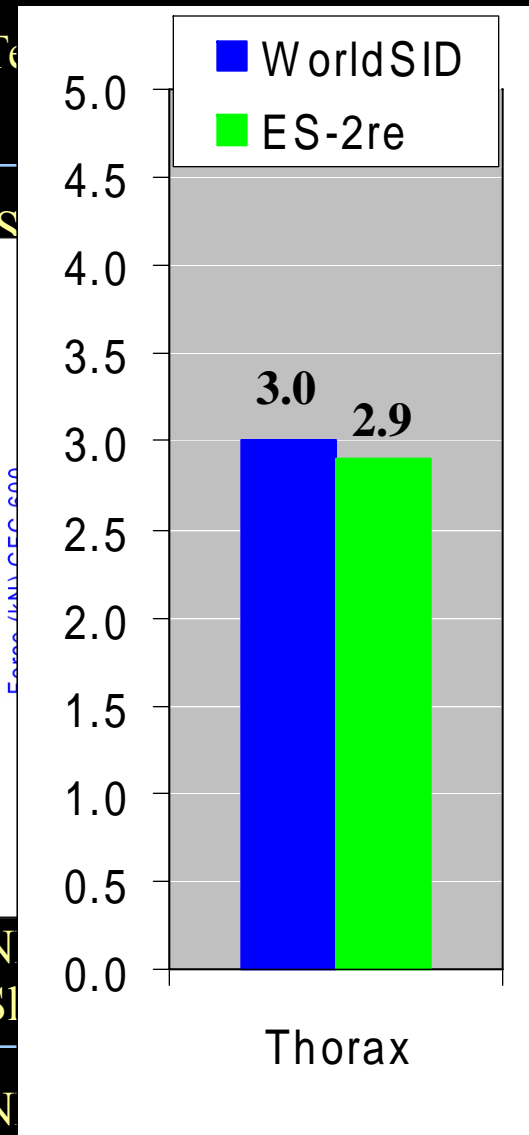
# Thorax

## ES-2re Rib Module

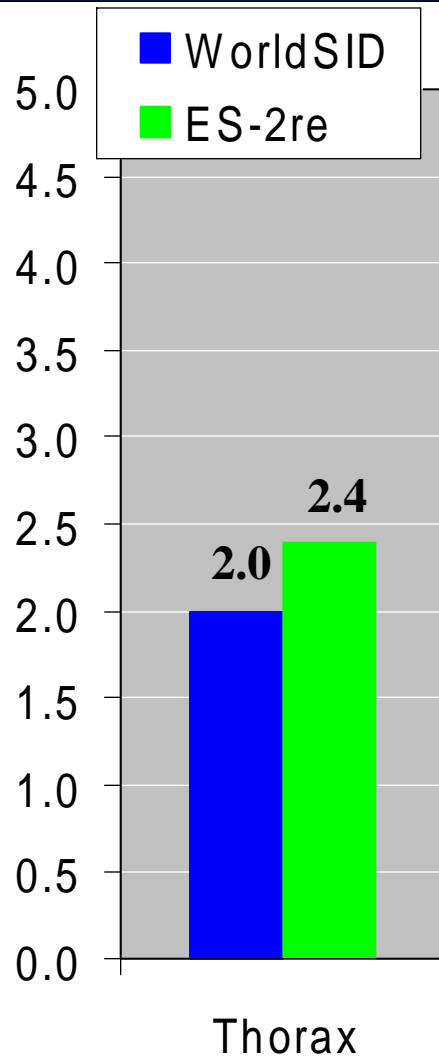


# Thorax External Response Summary

Test	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
IS	2.5 m/s Pendulum Impact	1.27	2.29
NHTSA (Shaw)	2.5 m/s 30° Pendulum Test		
	Pendulum Force		
NHTSA (Maltese)	8.9 m/s Padded Flat Wall Sled		
	Thorax Plate Force	2.57	2.83
NHTSA (Shaw)	2.5 m/s 30° Pendulum Test		
	Thorax Plate Force	3.81	4.22
NHTSA (Shaw)	2.5 m/s 30° Pendulum Test		
	Thorax Plate Force	5.59	2.93



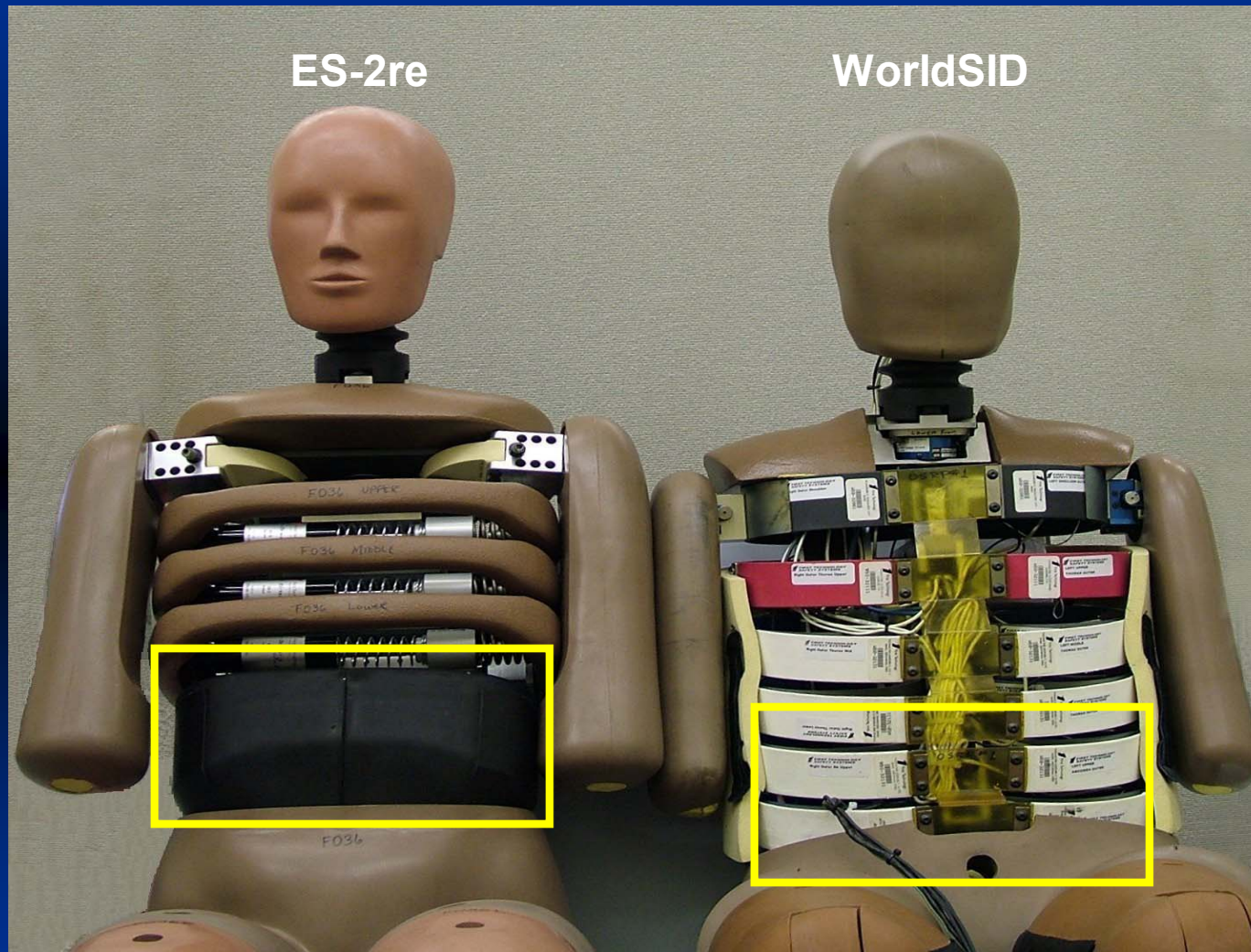
# Thorax Response Summary



## Thorax Internal Response Summary

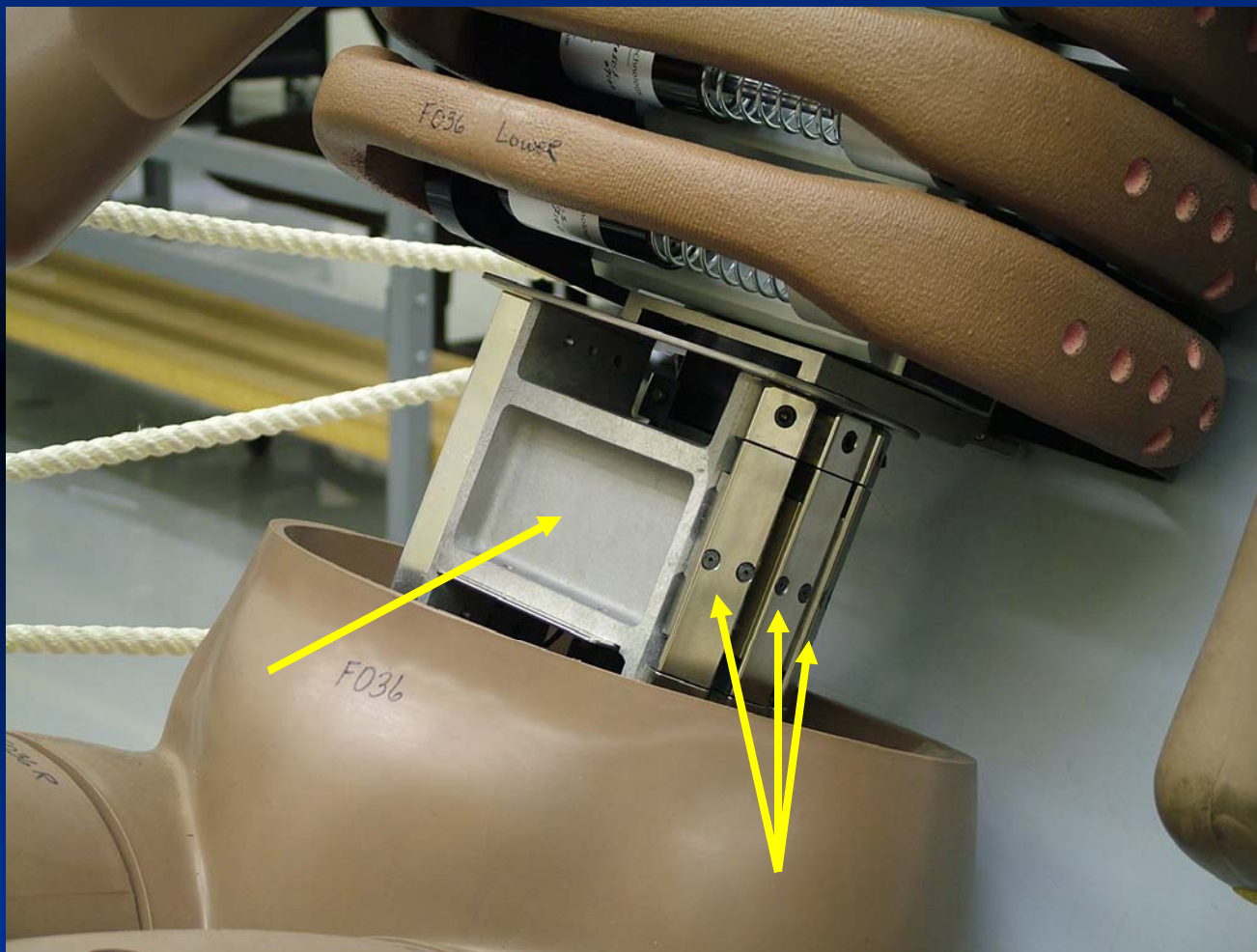
	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
	Upper Spine Lateral Acceleration	1.66	2.64
	Thorax Displacement	1.43	1.13
0°	Thorax Displacement	2.80	2.95
berg	Peak Lateral Acceleration of Upper Spine	6.03	6.86
	Peak Lateral Acceleration of Lower Spine	4.01	4.22
	Peak lateral acceleration of the impacted rib	0.70	2.95

# Abdomen

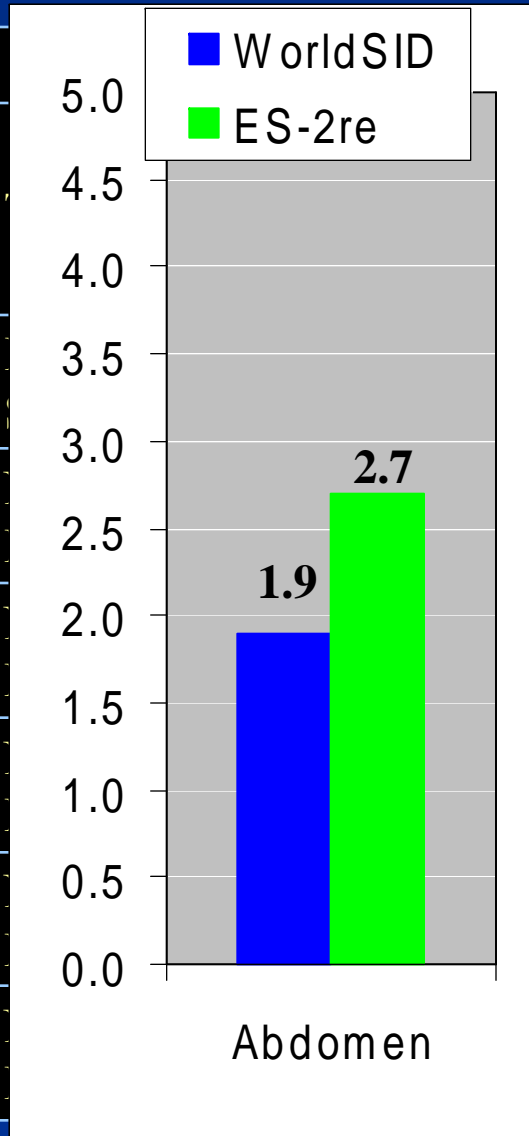


# Abdomen

## ES-2re Rib Abdomen



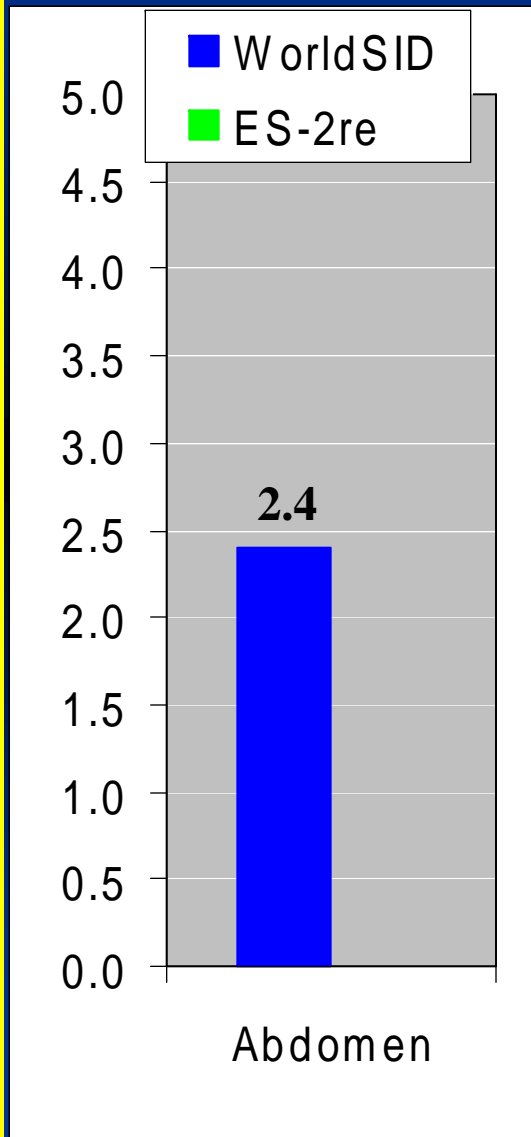
# Abdomen Response Summary



## Abdomen External Response Summary

	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
ate	Abdomen Plate Force	1.72	2.08
	Abdomen Plate Force	0.60	0.58
	Abdomen Plate Force	1.61	1.05
l	Abdomen Plate Force	0.94	5.28
	Abdomen Plate Force	3.71	3.95
	Abdomen Plate Force	2.83	3.24

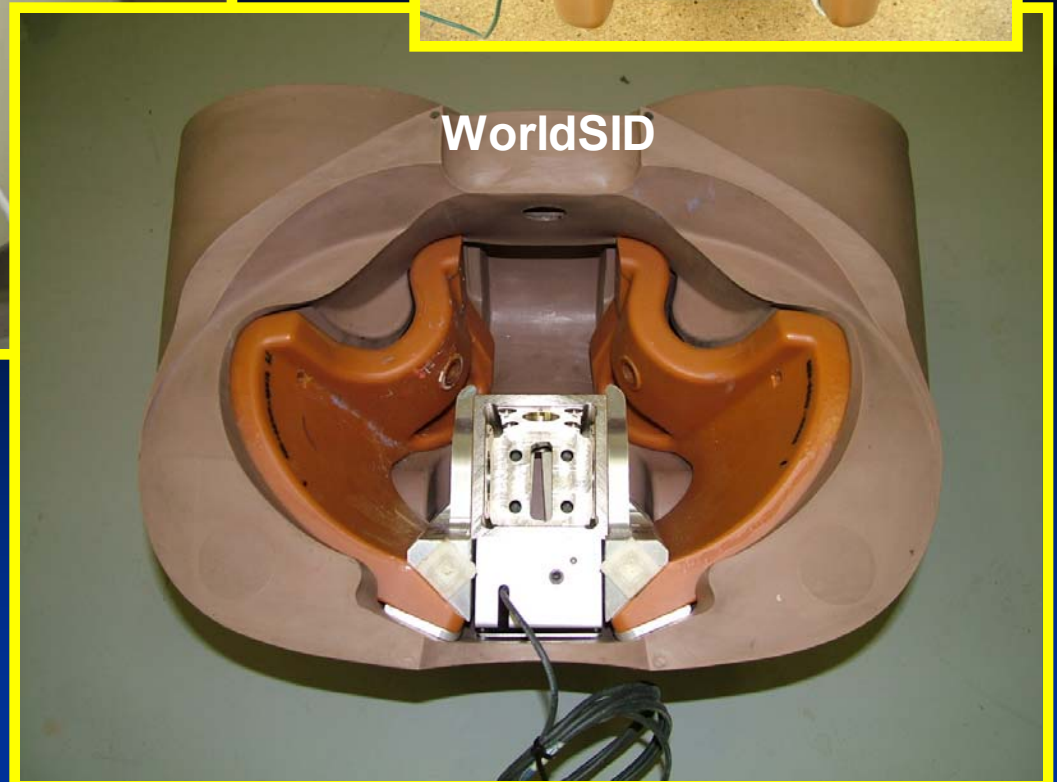
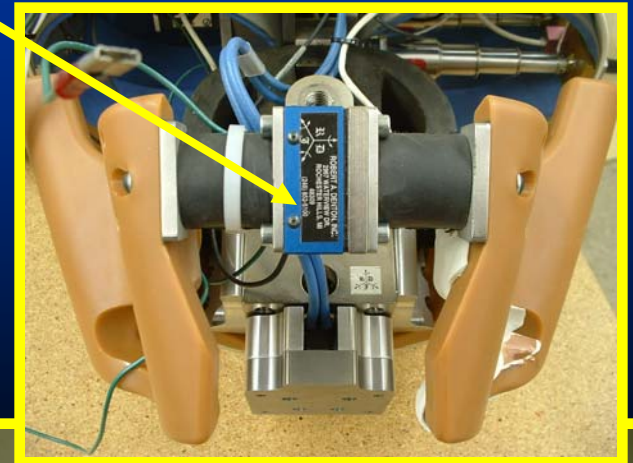
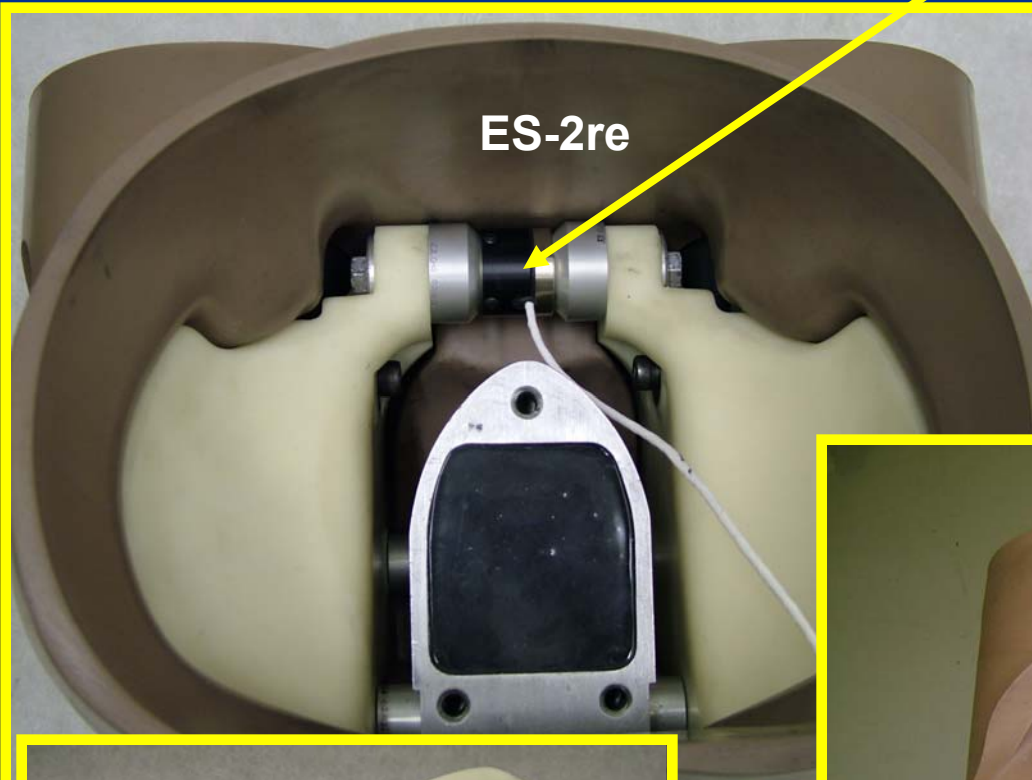
# Abdomen Response Summary



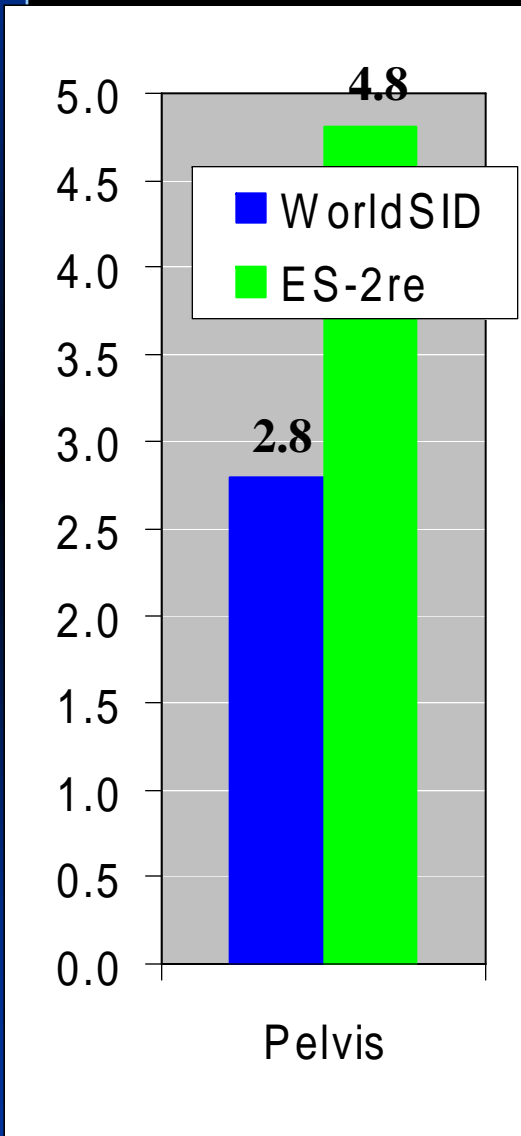
Abdomen Internal Response Summary			
	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
	Mid-Abdominal Deflection	2.75	NA
	Mid-Abdominal Deflection	1.64	NA
	Mid-Abdominal Deflection	1.78	NA
	Mid-Abdominal Deflection	2.79	NA
	Mid-Abdominal Deflection	2.89	NA



# Pelvis



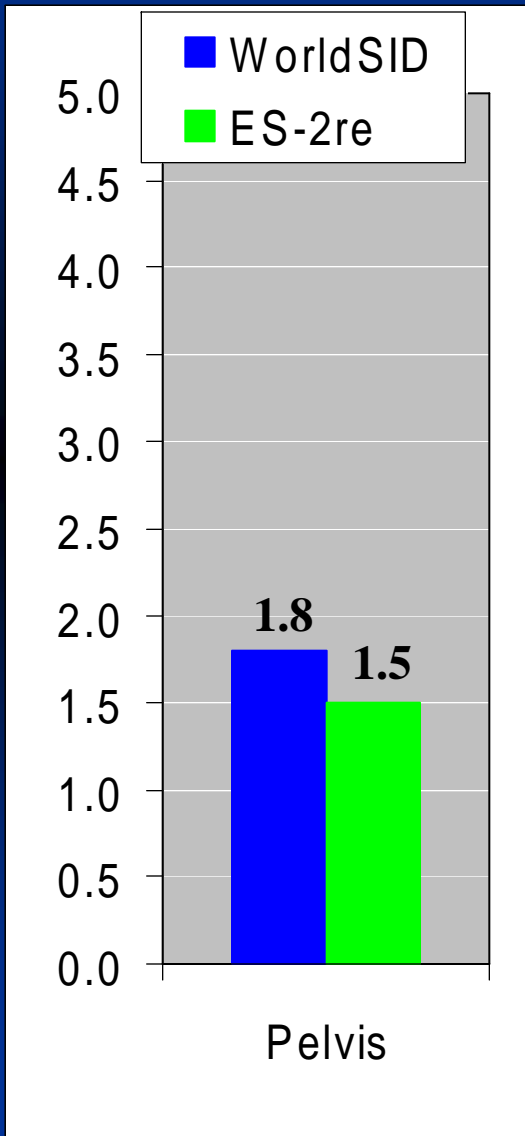
# Pelvis Response Summary



Pelvis External Response Summary

	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
Lateral	Peak Pendulum Force	0.23	5.39
s Lateral	Peak Pendulum Force	3.50	15.29
s	Peak Pelvis Plate Force	6.76	7.89
/s Wayne	Pelvis Plate Force	1.61	1.63
l Flat	Pelvis Plate Force	1.77	2.44
ed Flat	Pelvis Plate Force	2.13	2.13
l	Pelvis Plate Force	4.06	2.14
l Pelvis	Pelvis Plate Force	1.60	1.49
ed Flat	Pelvis Plate Force	3.77	4.82

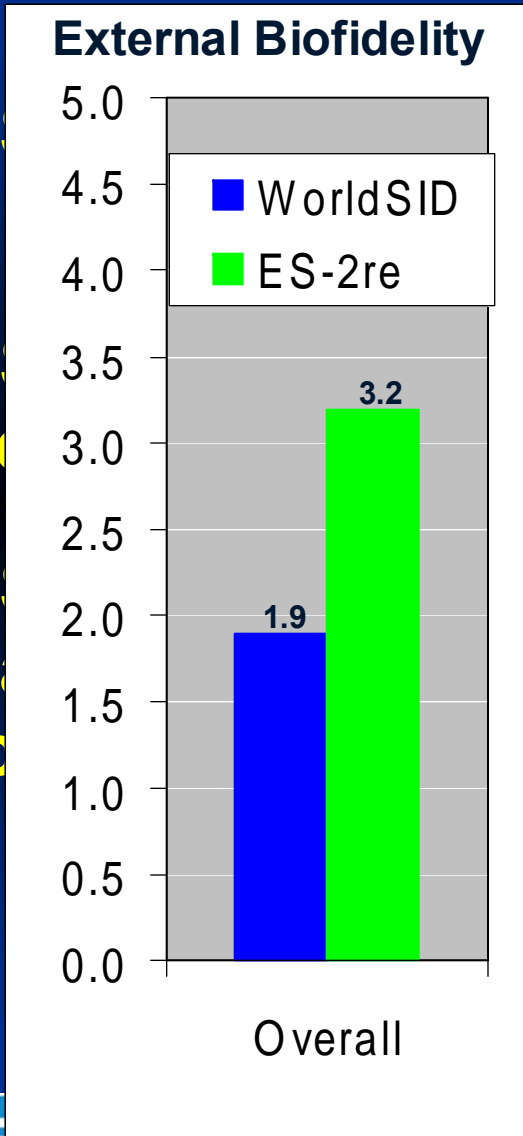
# Pelvis Response Summary



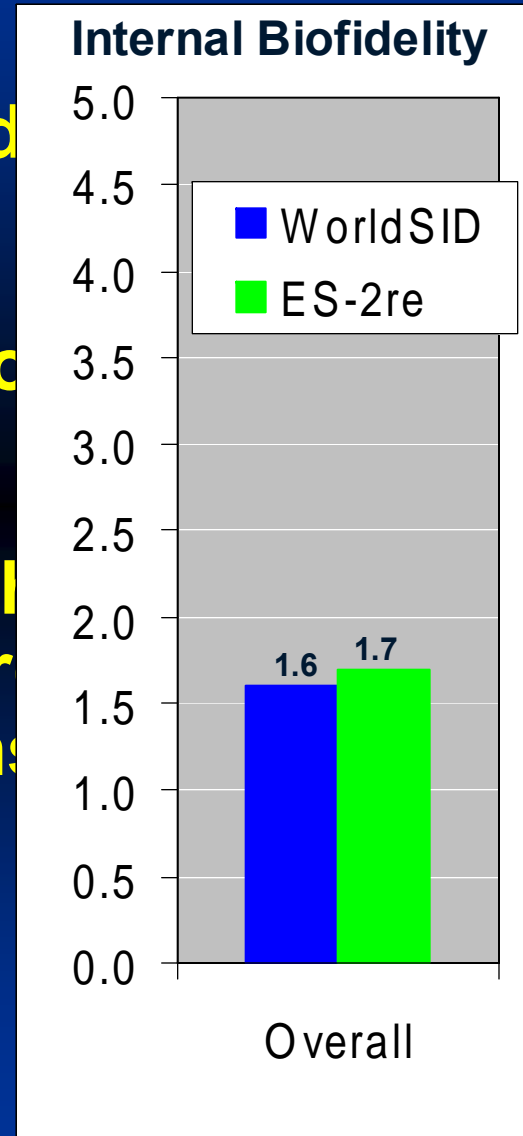
Pelvis Internal Response Summary			
	Measurement	Response Comparison ( $\sqrt{R}$ )	
		WorldSID	ES-2re
m/s	Peak Pelvis Lateral Acceleration	0.35	1.50
m/s	Peak Pelvis Lateral Acceleration	3.98	1.00
igid Flat	Pelvis Lateral Acceleration	1.53	1.72
added	Pelvis Lateral Acceleration	2.09	1.69
igid	Pelvis Lateral Acceleration	1.16	1.09
igid	Pelvis Lateral Acceleration	1.94	2.62
added	Pelvis Lateral Acceleration	1.26	1.09

# Conclusions

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# Conclusions (cont.)

- **WSID abdomen measures displacement**
- **WSID Durability, R&R and Usability are acceptable**

**The WorldSID 50<sup>th</sup> male dummy is an improved side impact test dummy**

# Thank You

