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An Improvement to the THOR-50M Upper Leg Qualification Test Methodology

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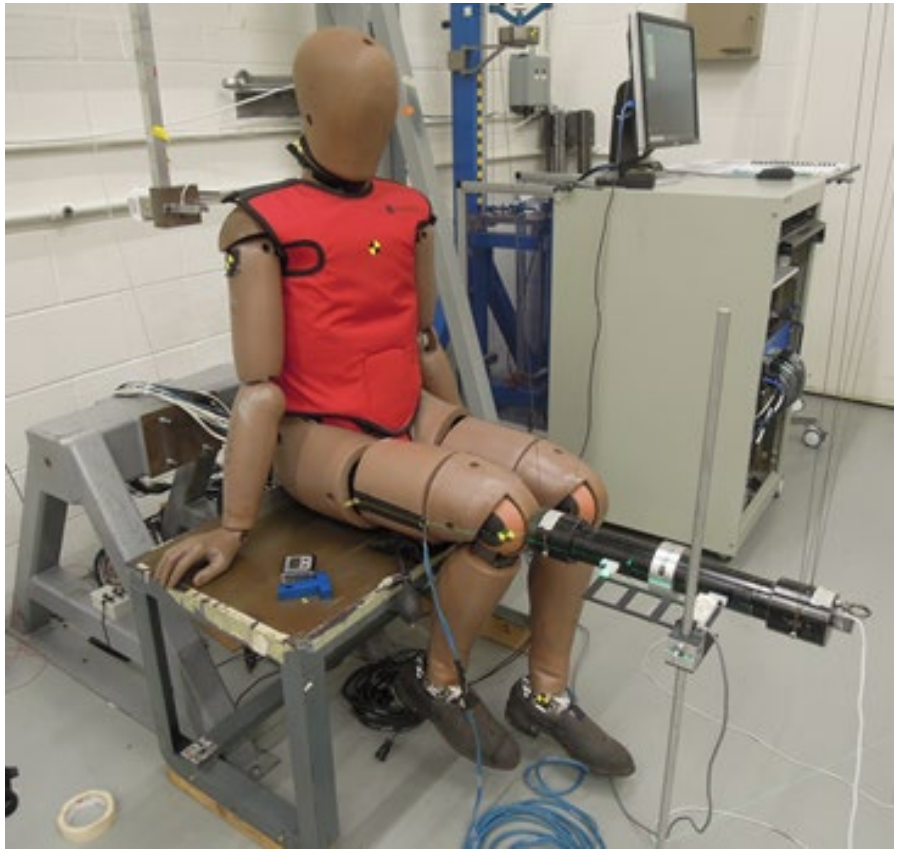
Overview

- THOR-50M upper leg qualification test overview
- Previous test procedures and R&R analysis (2016)
- Focus areas for test improvement
- Improved test procedures and R&R analysis (2020)
- Differences between the 2016 and 2020 test procedures and results



About the THOR-50M Upper Leg Test

- Test examines the response of the femur to axial impacts

- Data collected
  - Peak probe force
  - Peak femur force
  - Peak resultant acetabulum force

What is R&R?

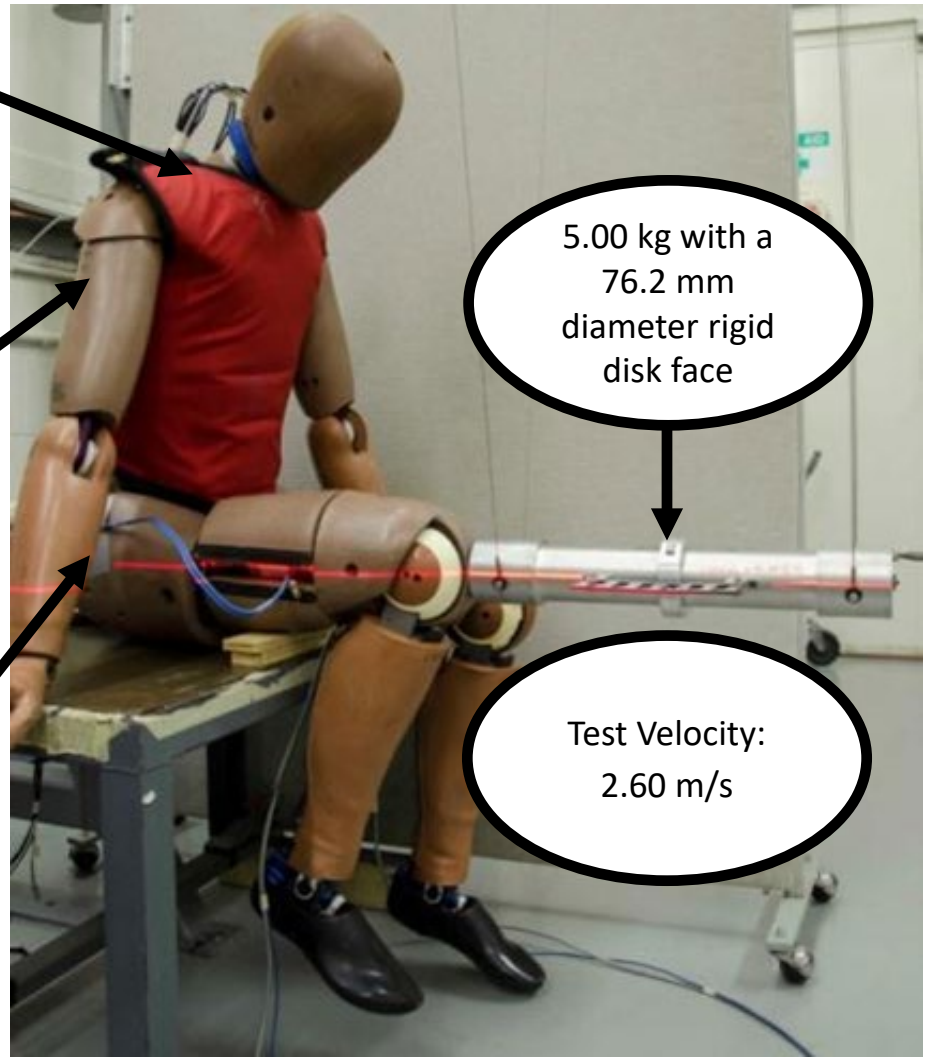
- **Repeatability** is the measure of how well a single dummy produces the same response with successive tests
  - Five repeat tests on a single dummy
- **Reproducibility** is the measure of how well a dummy type/model produces the same response with successive tests
  - Three different dummies at same lab (dummy reproducibility)
  - A single dummy at three labs (test reproducibility)
- R&R results are evaluated by calculating the coefficient of variation $\left(CV = \frac{std.dev.}{mean}\right)$
- CV is evaluated as follows:
  - Below 5%: No further investigation
  - Between 5% - 10%: Sources of variation investigated
  - Greater than 10%: Test procedure thoroughly reviewed and dummies inspected

2016 Upper Leg Test Requirements

Neck Pitch Change Setting: Neutral

Lower Thoracic Spine Pitch Change Setting: Slouched

Pelvis Tilt Sensor Reading: X = 0 ± 0.5º; Y = 15 ± 1º

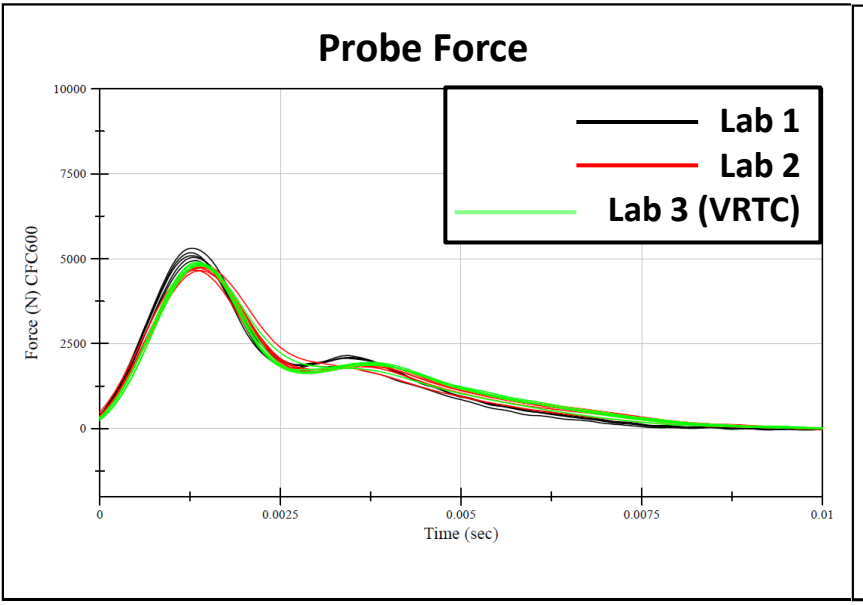


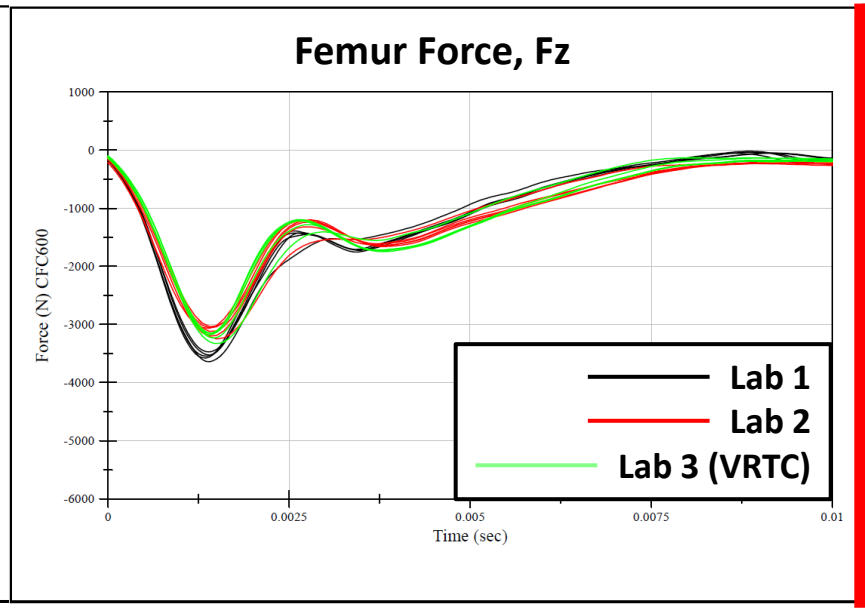
2016 Requirements			
Parameter	**Units**	**Specification**	
		Min.	**Max.**
Impact Velocity	**m/s**	**2.55**	**2.65**
Peak Impactor Force	**N**	**4221**	**5158**
Peak Femur Force, Fz	**N**	**-3314**	**-2712**
Peak Resultant Acetabulum Force	**N**	**1478**	**1806**

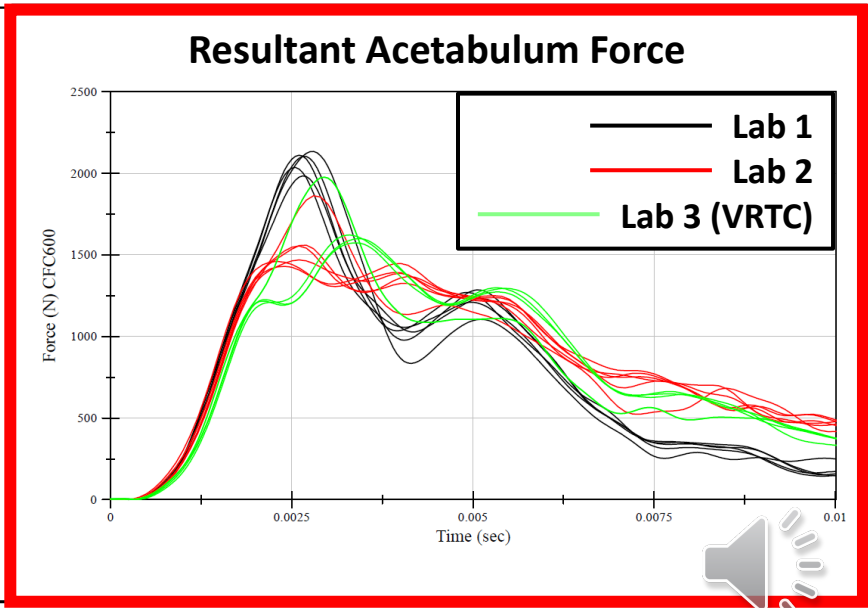
Note: Upper leg test procedure and requirements, originally published in 2016, remained unchanged in 2018 THOR-50M Qualification Procedures Manual

2016 Upper Leg Test Reproducibility

Test Reproducibility			
Response Requirement	Peak Probe Force (N)	Peak Femur Force, F_z (N)	Peak Resultant Acetabulum Force (N)
Mean	4887	-3282	1760
Standard Deviation	184	204	259
CV	3.8%	6.2%	14.7%



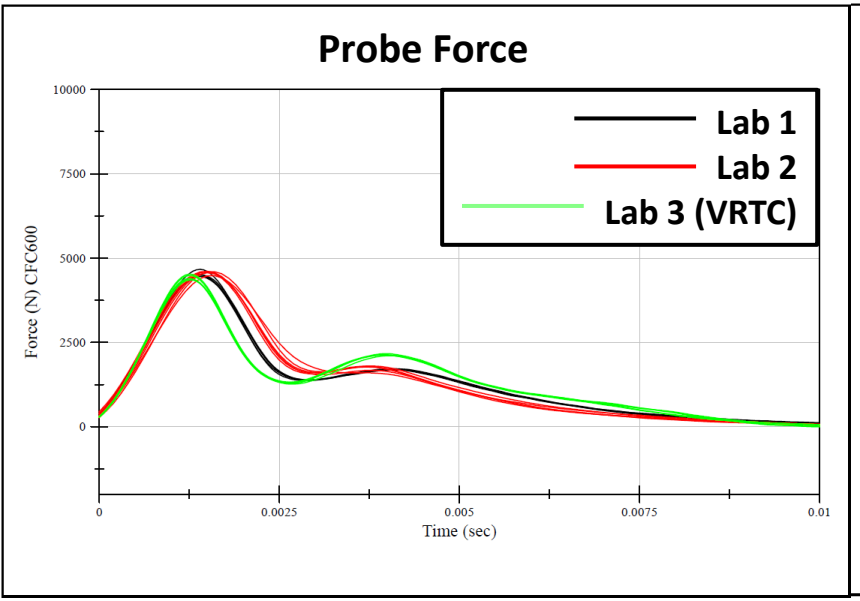


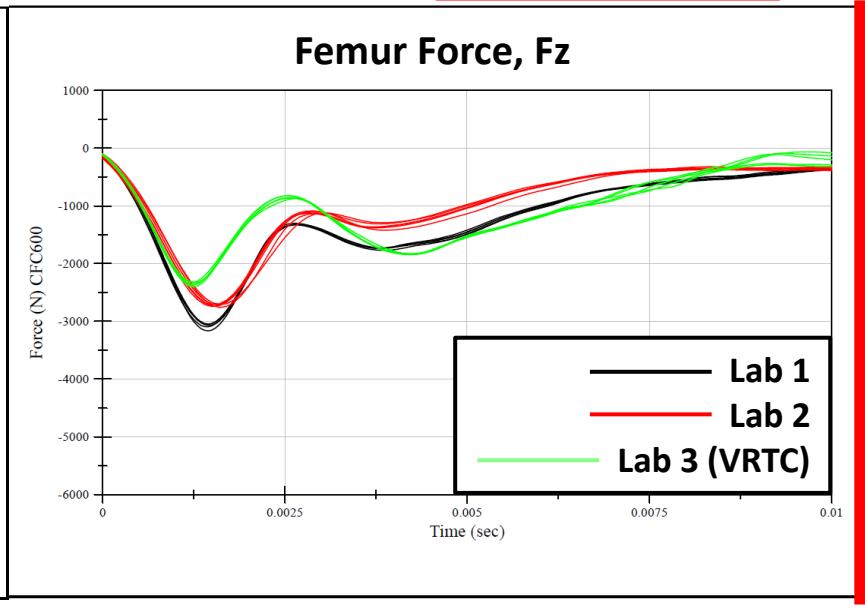


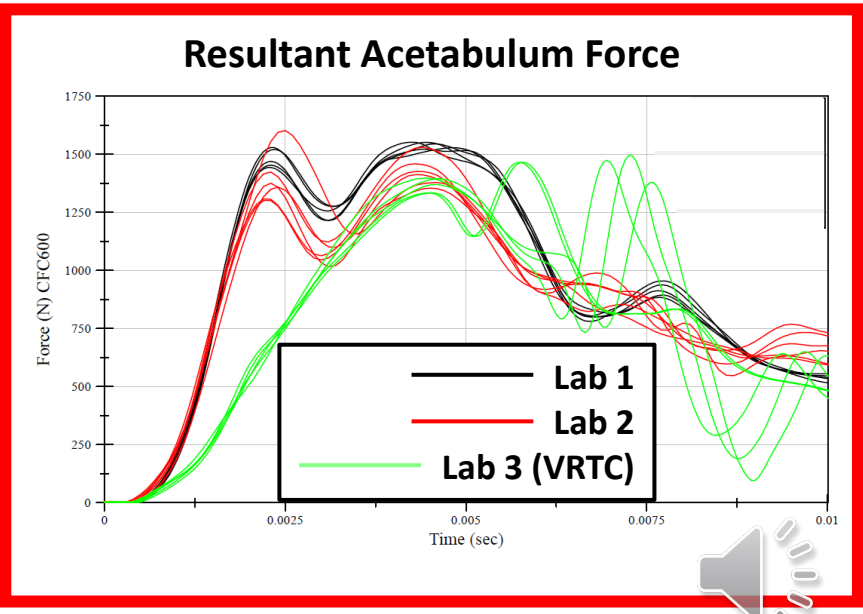
- Test data derived from DO9799 upper left leg

2016 Upper Leg Test Reproducibility

Test Reproducibility			
Response Requirement	Peak Probe Force (N)	Peak Femur Force, F_z (N)	Peak Resultant Acetabulum Force (N)
Mean	4514	-2723	1487
Standard Deviation	91	300	64
CV	2.0%	11.0%	4.3%



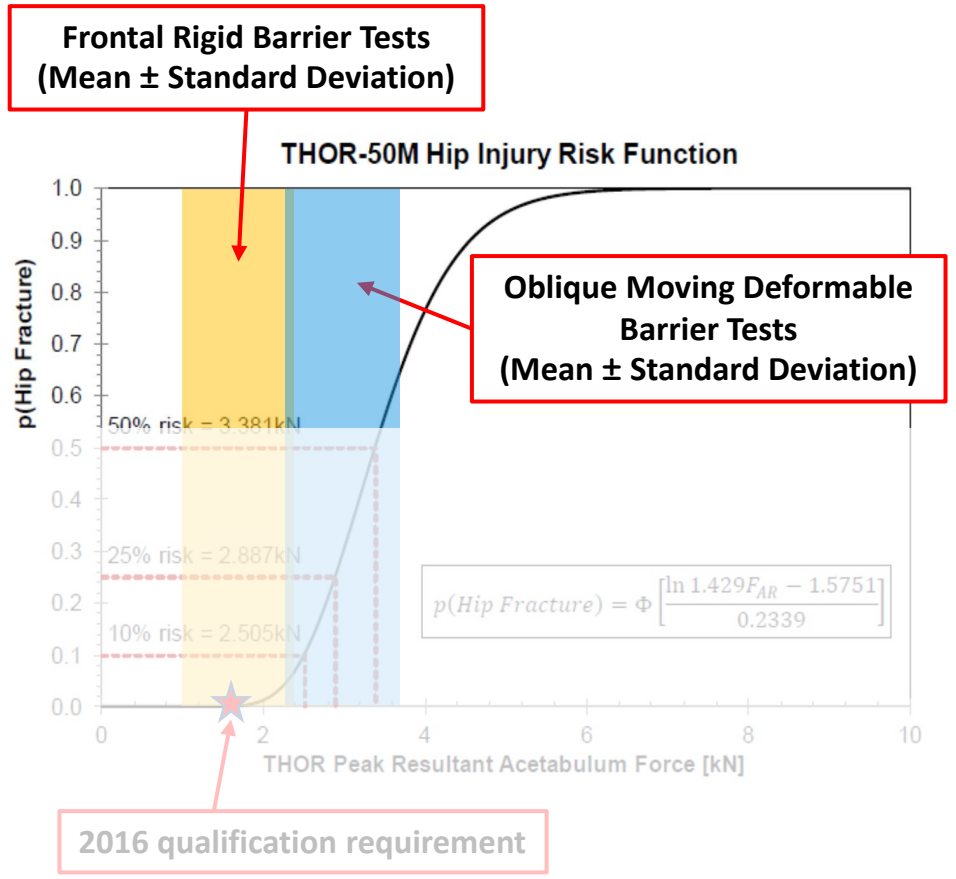




- Test data derived from DO9799 upper right leg

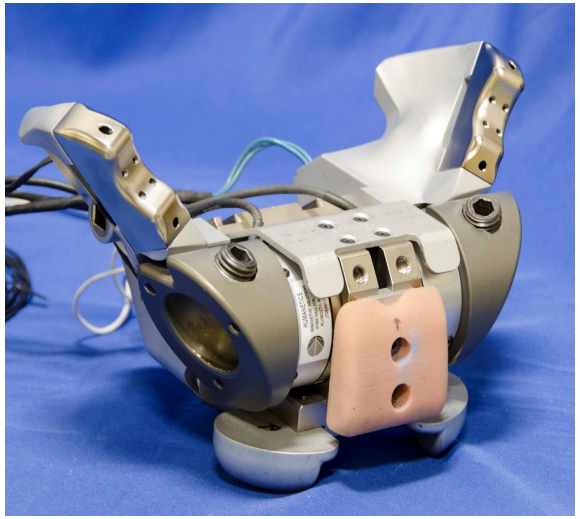
Findings

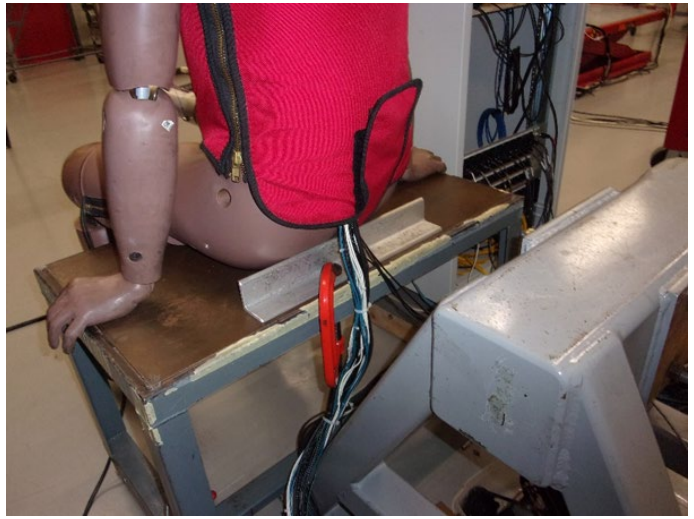
- Test Reproducibility CV > 10% in the peak Z-axis femur forces and peak resultant acetabulum forces
- Inconsistent shape of peak resultant acetabulum forces
- Resultant acetabulum force: qualification test vs. crash tests
  - ~1,700 N average in frontal rigid barrier tests (Summers et al, 2020)
  - ~3,000 N average in oblique moving deformable barrier tests (Saunders et al, 2015)
  - p(hip fracture) ~ 0.003 (Craig et al, 2020)



Methods for Test Improvement

- Increase response to real-world targets
- Implement use of backer plate brace
- Critical attention to positioning
- Monitor loosening of pelvic fasteners



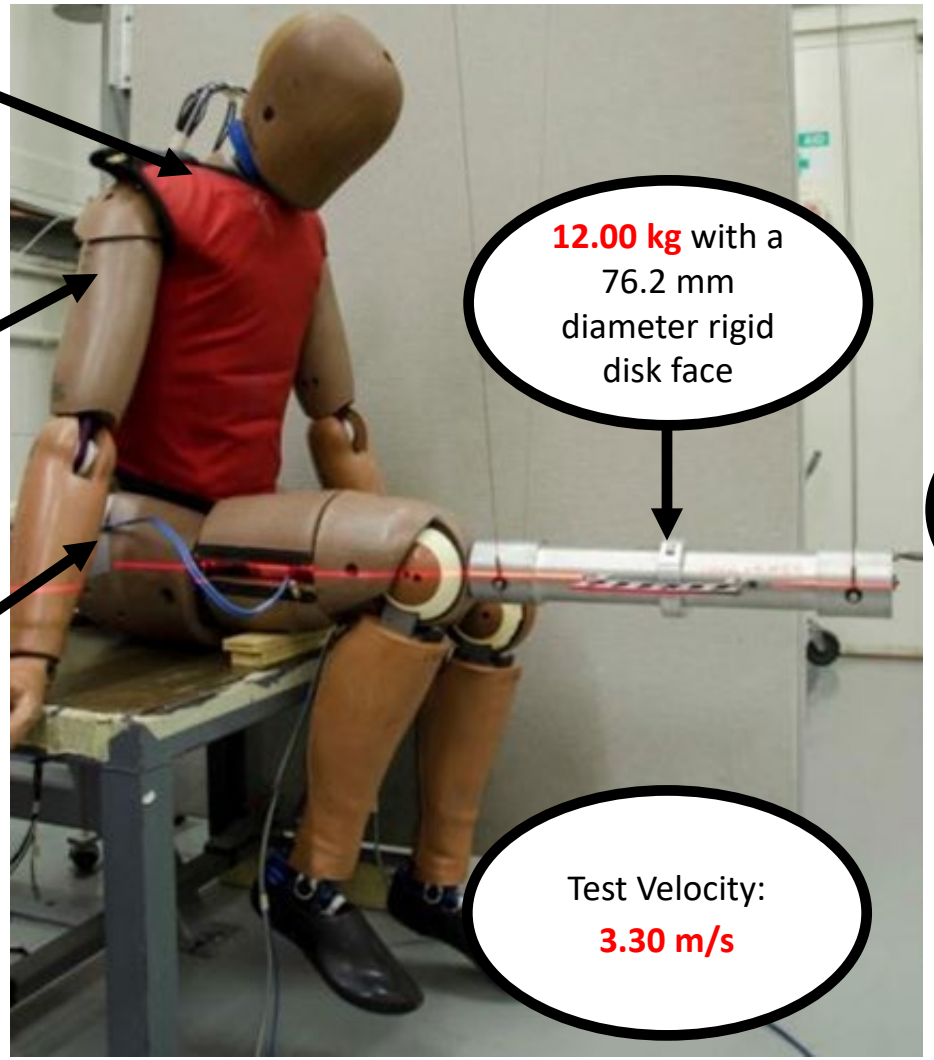


2020 Upper Leg Test Requirements

Neck Pitch Change Setting: Neutral

Lower Thoracic Spine Pitch Change Setting: Slouched

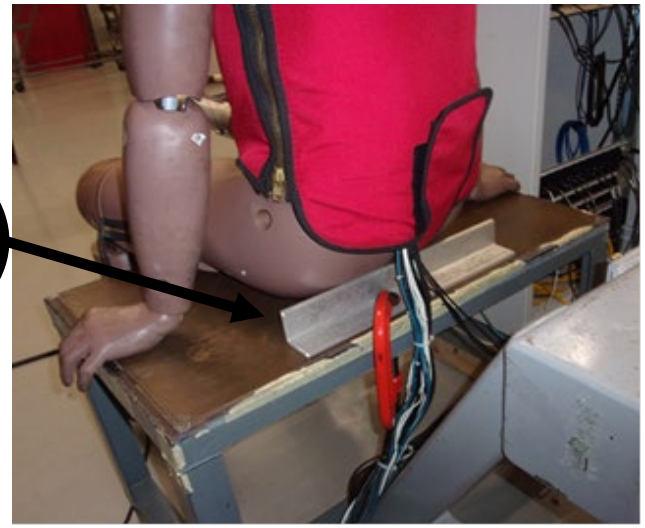
Pelvis Tilt Sensor Reading: X = 0 ± 0.5º; Y = 15 ± 1º



12.00 kg with a 76.2 mm diameter rigid disk face

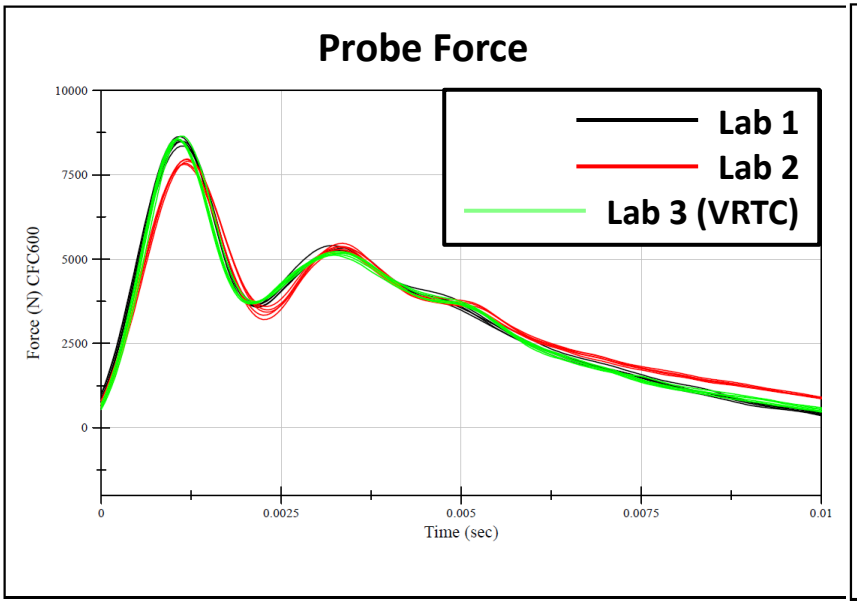
Test Velocity: **3.30 m/s**

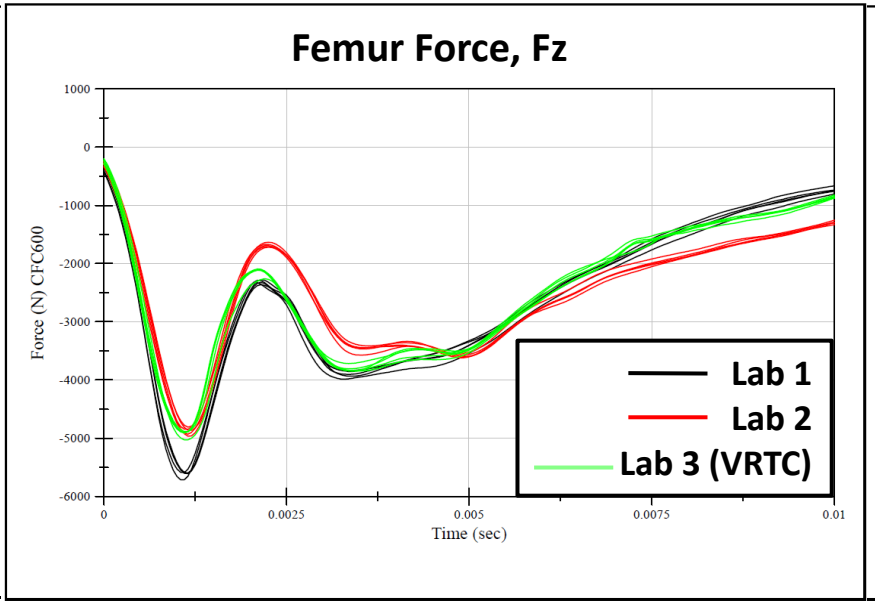
Backer Plate Brace

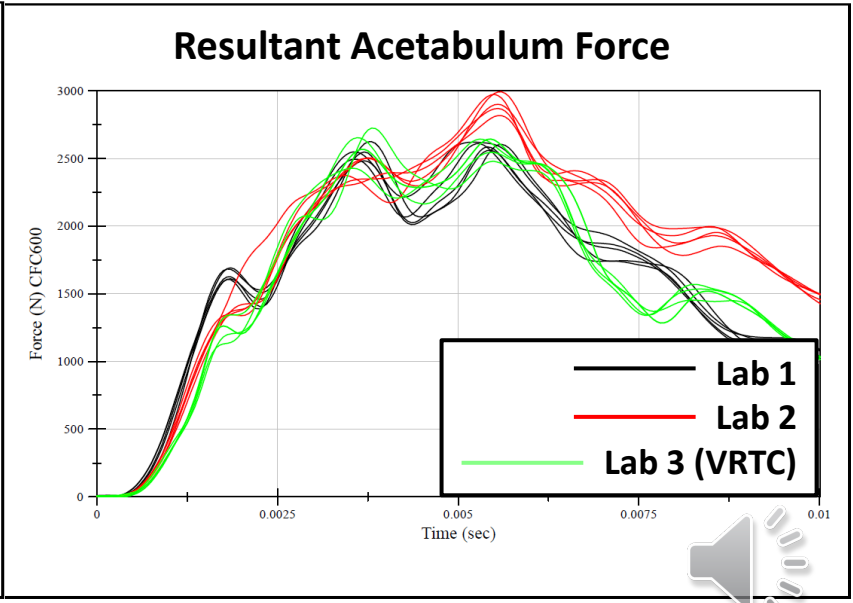


2020 Upper Leg Test Reproducibility

Test Reproducibility			
Response Requirement	Peak Probe Force (N)	Peak Femur Force, F_z (N)	Peak Resultant Acetabulum Force (N)
Mean	8323	-5144	2723
Standard Deviation	322	355	146
CV	3.9%	6.9%	5.4%



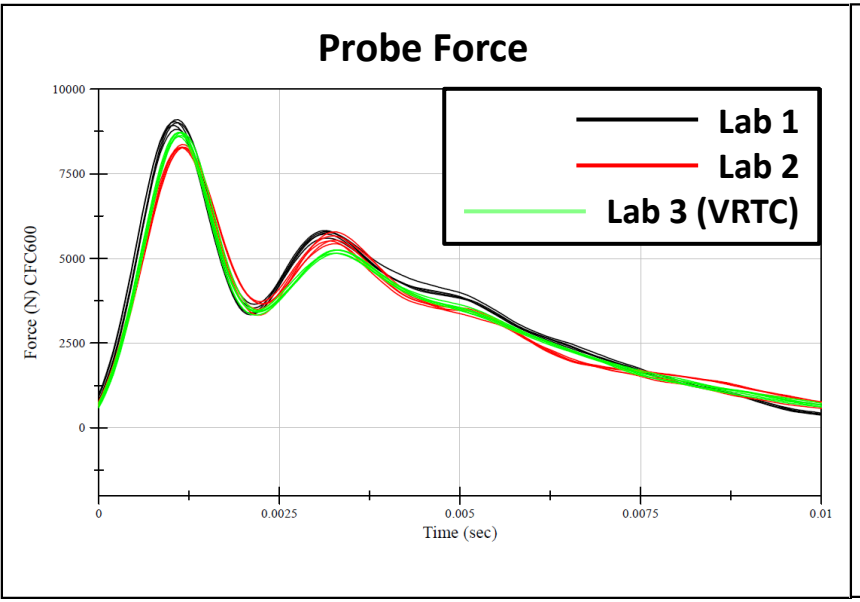


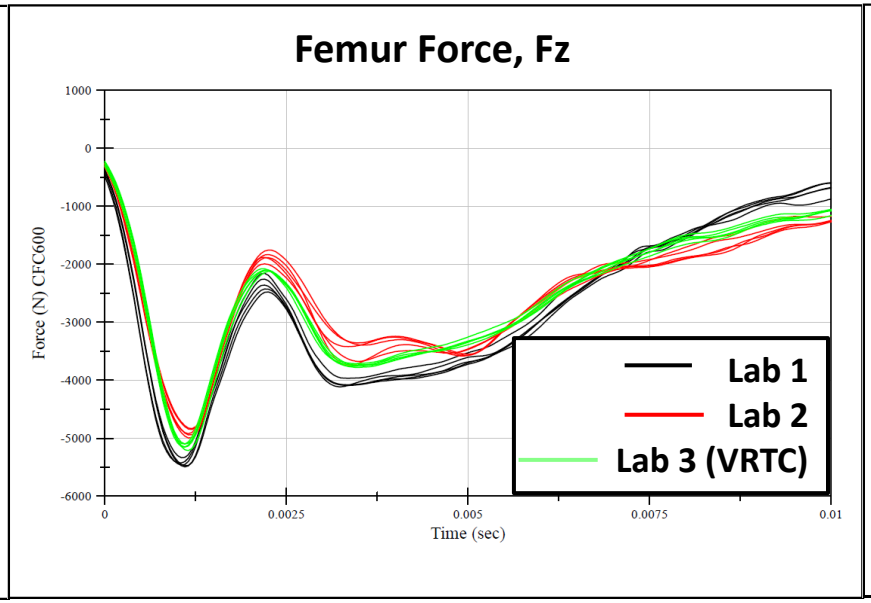


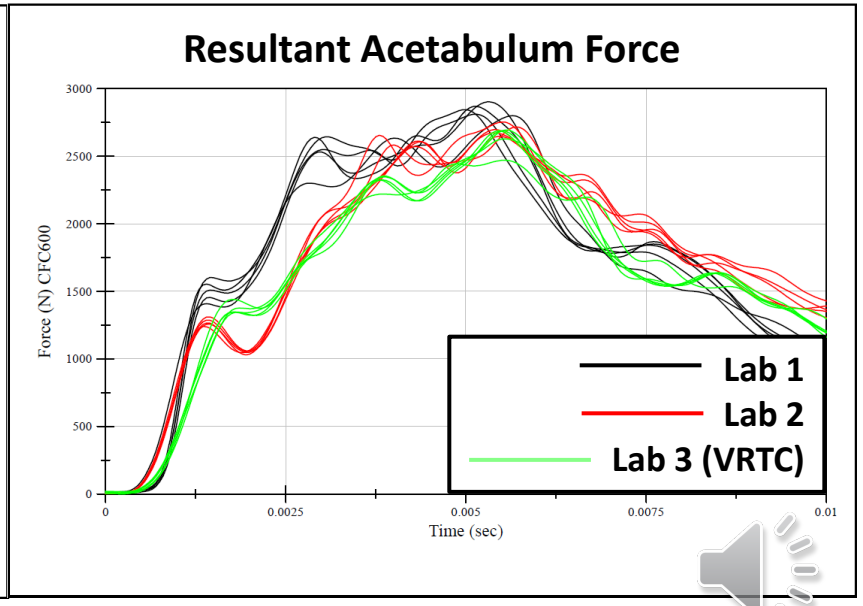
- Test data derived from DO9799 upper left leg

2020 Upper Leg Test Reproducibility

Test Reproducibility			
Response Requirement	Peak Probe Force (N)	Peak Femur Force, F_z (N)	Peak Resultant Acetabulum Force (N)
Mean	8653	-5162	2710
Standard Deviation	297	231	131
CV	3.4%	4.5%	4.8%

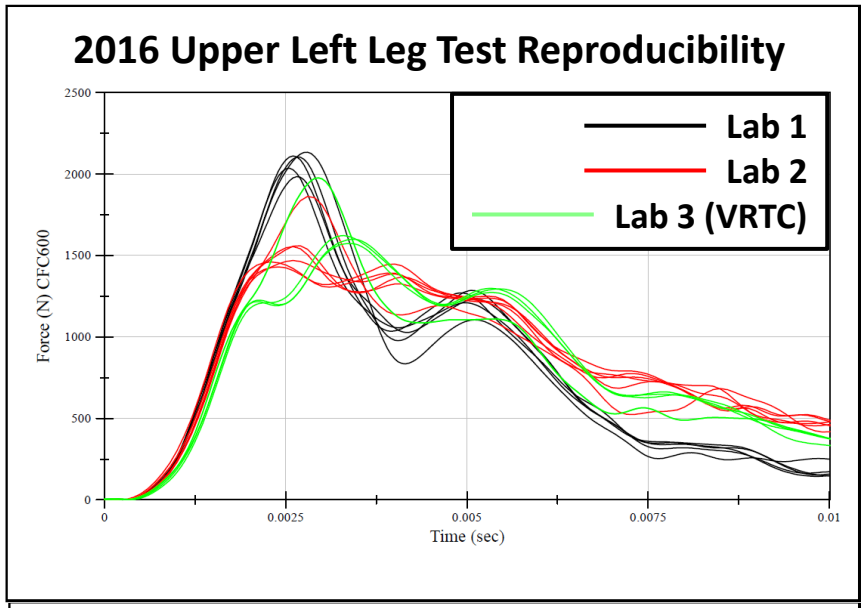


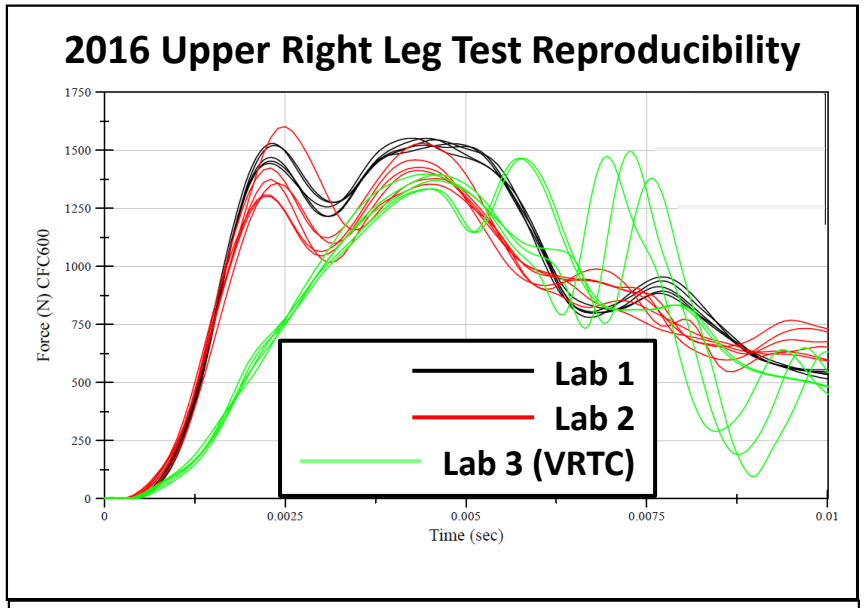


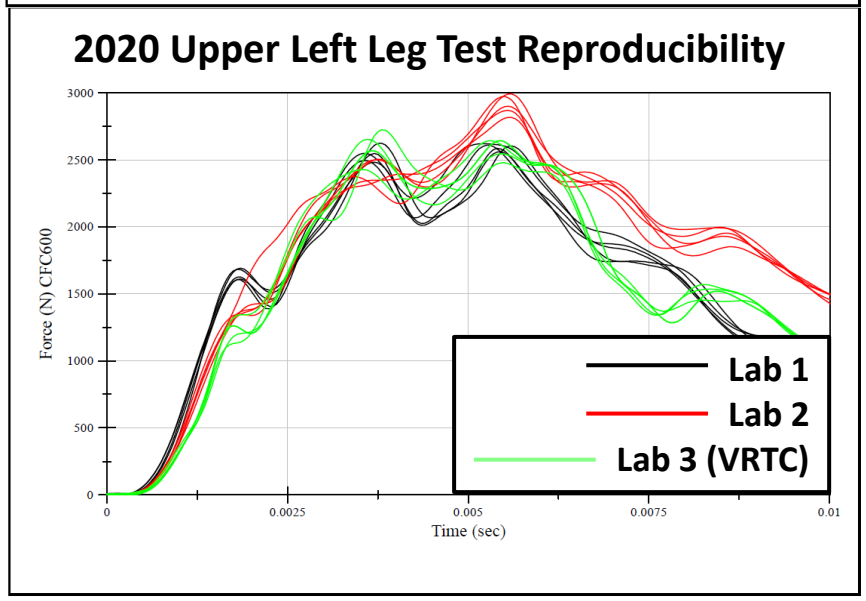


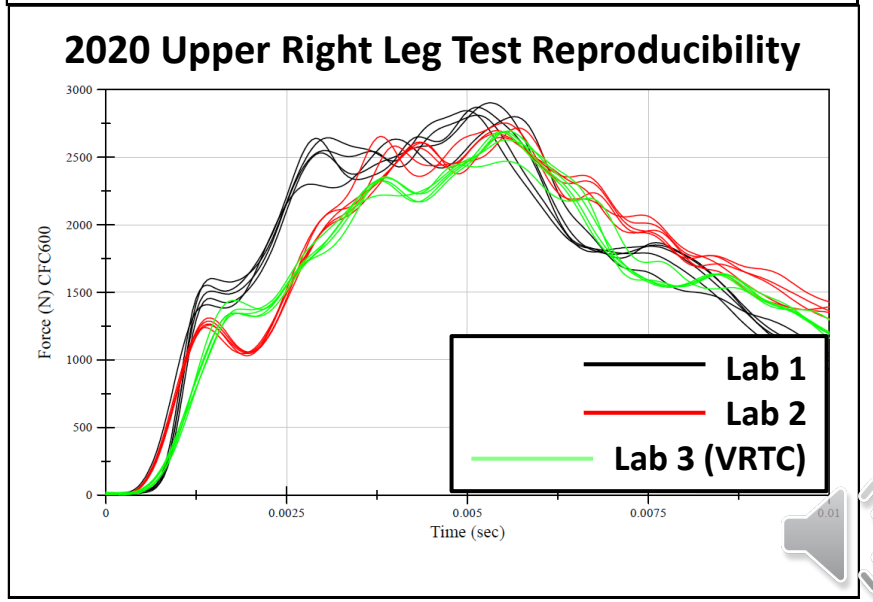
- Test data derived from DO9799 upper right leg

Resultant Acetabulum Force Comparison



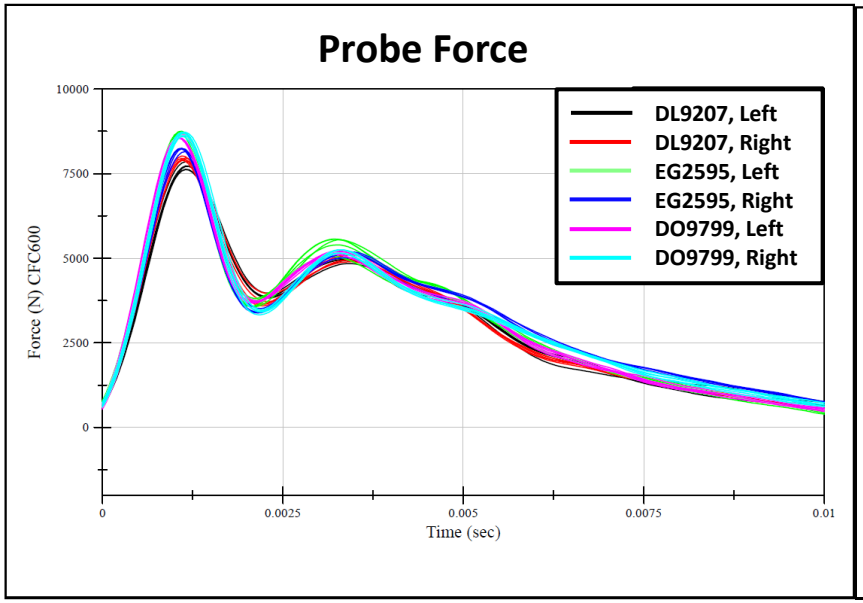


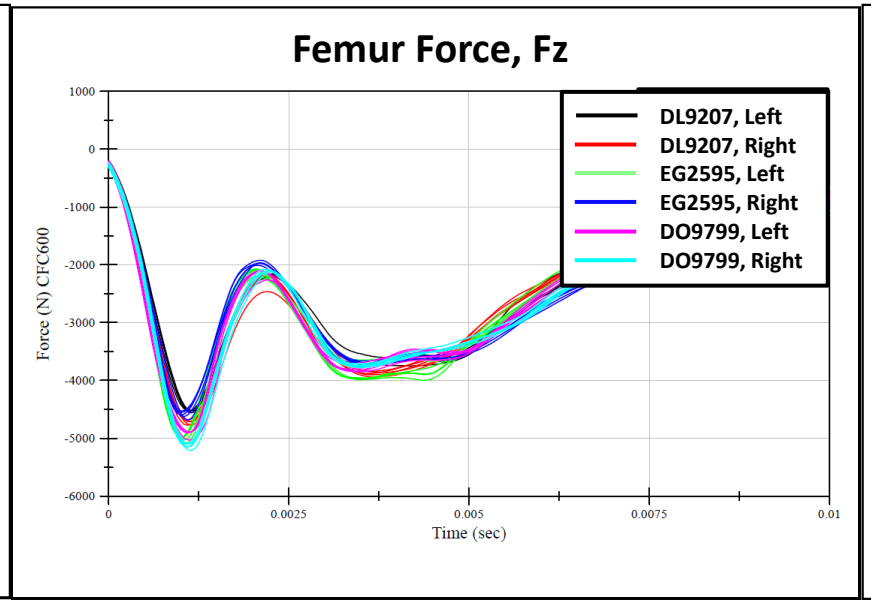


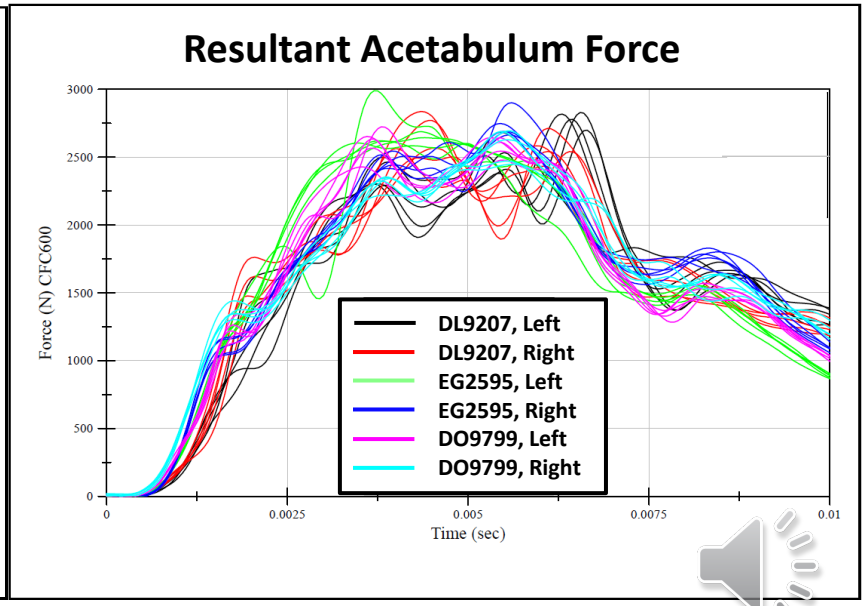


2020 Upper Leg Dummy Reproducibility

Dummy Reproducibility			
Response Requirement	Peak Probe Force (N)	Peak Femur Force, F_z (N)	Peak Resultant Acetabulum Force (N)
Mean	8310	-4824	2690
Standard Deviation	391	229	115
CV	4.7%	4.7%	4.3%







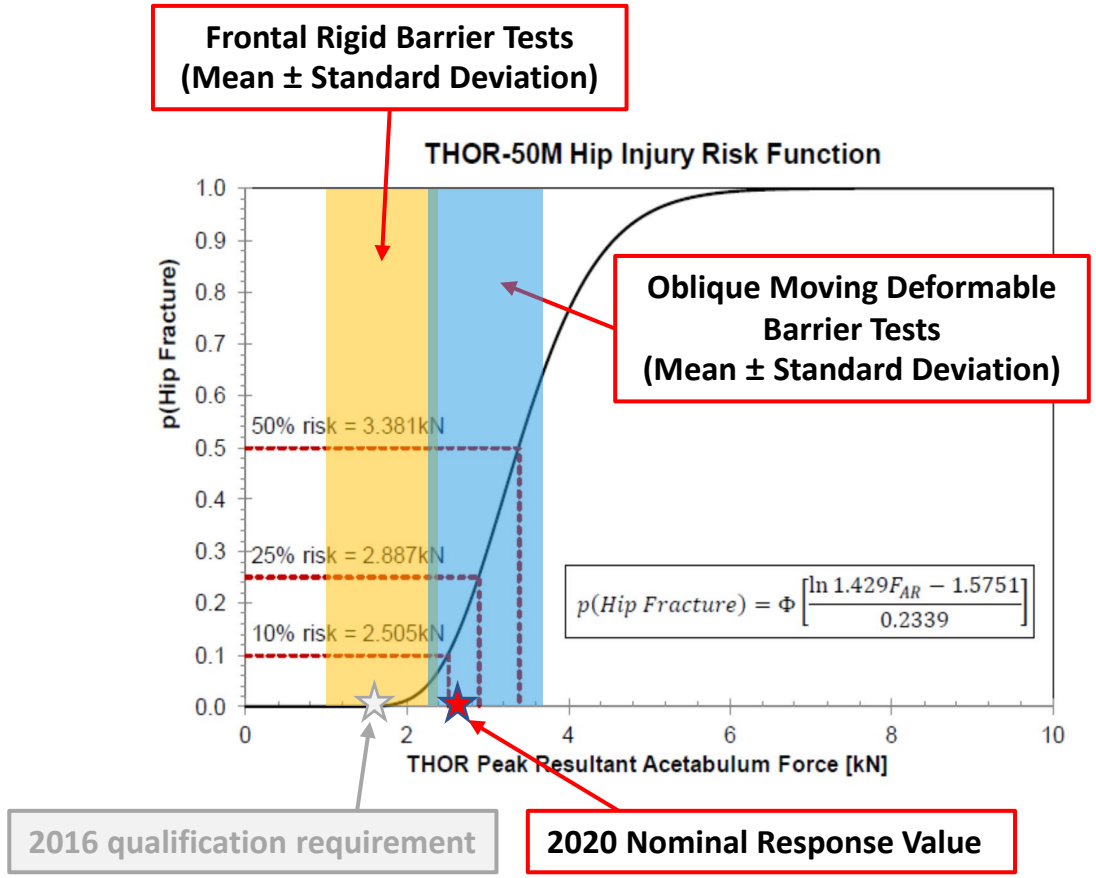
Summary of Upper Leg Test Improvements

Test Setup Parameter	2016	2020
Velocity (m/s)	2.55 - 2.65	3.25 - 3.35
Probe Mass	5.00 kg	12.00 kg
Backer Plate Brace	No	Yes
Lower Thoracic Spine (LTS) Pitch Change Setting	Slouched	Slouched
Neck Pitch Change Setting	Neutral	Neutral
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 15 ± 1º	X = 0 ± 0.5º; Y = 15 ± 1º
Wait Time Between Tests	At Least 30 Minutes	At Least 30 Minutes

Response Requirement	Units	2016 Nominal Response Value	2020 Nominal Response Value
Peak Impactor Force	N	4689.5	8352.5
Peak Femur Force, Fz	N	-3013	-4980
Peak Resultant Acetabulum Force	N	1642	2719

Review

- 2016 R&R analysis identified areas for test improvement
- Improvements implemented
- 2020 R&R analysis demonstrates that test improvements address previous findings
- Minimal test changes
  - Increased velocity
  - Increased mass (same probe used during knee impact test)
  - Addition of backer plate



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Thank you

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