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Development of a Biofidelic Flexible Pedestrian Legform Impactor (Flex-PLI 2003)

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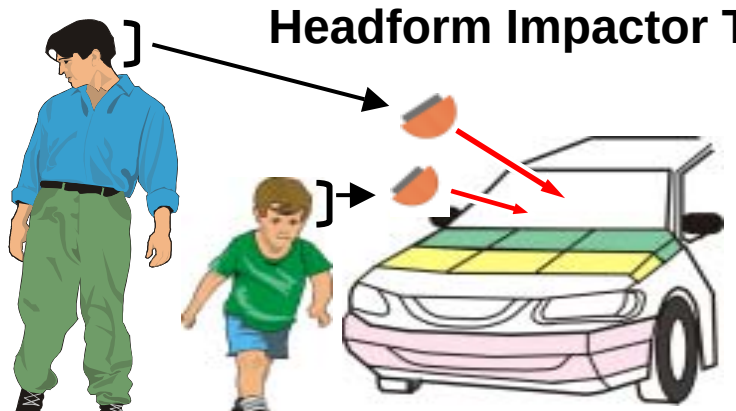
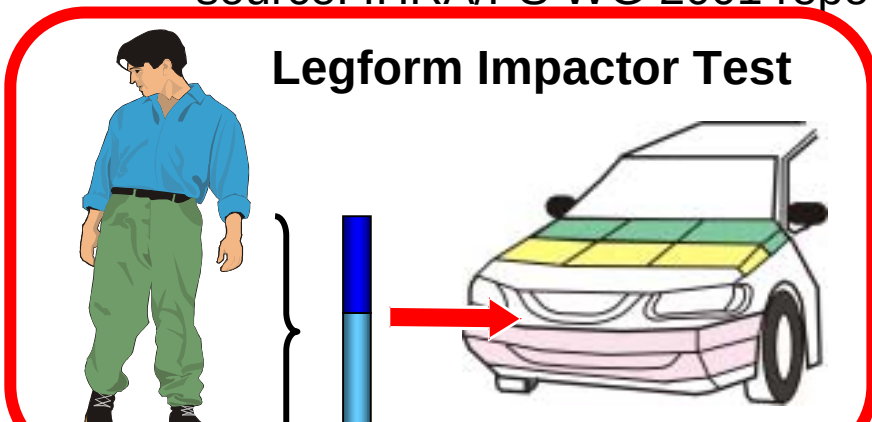
Back Ground

Distributions of Pedestrian Injuries by Body Region and Country (All Age Groups, AIS 2-6)

Body Region	USA (1994-1999)	Germany (1985-1998)	Japan (1987-1998)	Australia (1999-2000)	All Contries
Head	**32.7%**	**29.9%**	**28.9%**	**39.3%**	**31.4%**
Face	3.7%	5.2%	2.2%	3.7%	4.2%
Neck	0.0%	1.7%	4.7%	3.1%	1.4%
Chest	9.4%	11.7%	8.6%	10.4%	10.3%
Abdomen	7.7%	3.4%	4.7%	4.9%	5.4%
Pelvis	5.3%	7.9%	4.4%	4.9%	6.3%
Arms	7.9%	8.2%	9.2%	8.0%	8.2%
Lower Limbs	**33.3%**	**31.6%**	**37.2%**	**25.8%**	**32.6%**
Unknown	0.0%	0.4%	0.0%	0.0%	0.2%
TOTAL	100%	100%	100%	100%	100%

source: IHRA/PS WG 2001 repo





Relationship between Pedestrian Lower Limb Injuries and Contact Locations

AIS 2-6 USA, Japan, Europe, and Australia	Ages > 15 (Adult)				
Contact Location	Overall	Thigh	**Knee**	**Leg**	Foot
Front Bumper	1.6%	2.9%	**7.0%**	**43.5%**	2.9%
Top surface of bonnet/wing	2.1%	0.3%	0.1%	0.1%	0.2%
Leading edge of bonnet/ wing	4.7%	3.3%	0.5%	2.4%	0.1%
Windscreen glass	0.1%			0.1%	0.1%
Windscreen frame/ A pillars	0.5%	0.1%			
Front Panel	0.9%	0.9%	1.0%	3.2%	0.3%
Others	0.6%	0.4%	0.5%	2.6%	1.3%
Sub-Total	10.5%	8.0%	9.1%	52.0%	5.0%

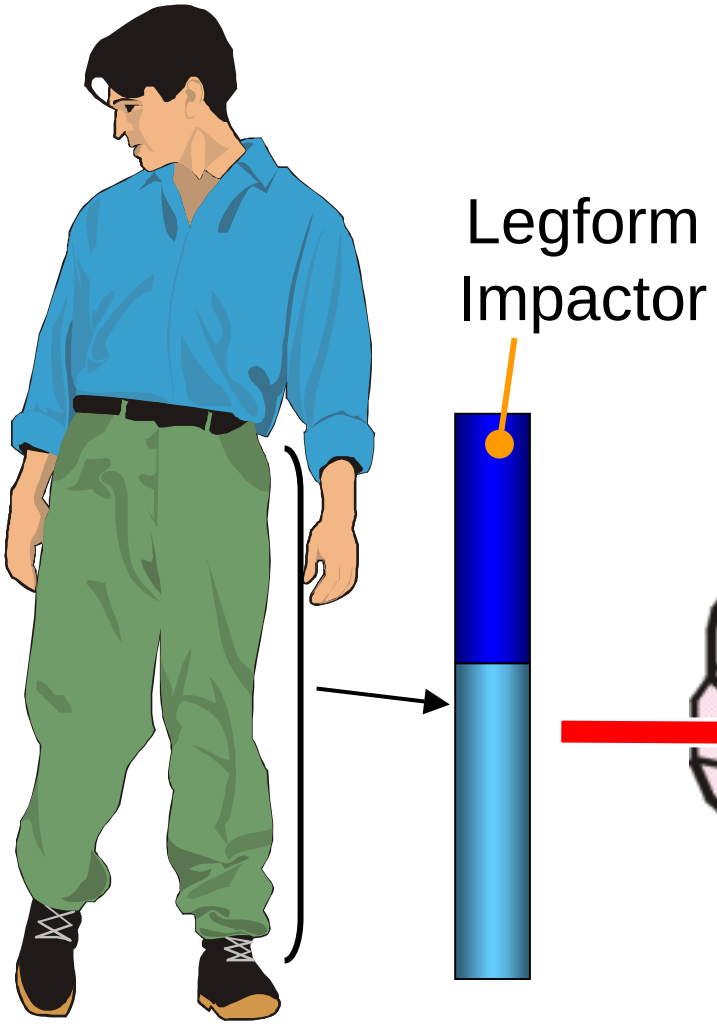
AIS 2-6 USA, Japan, Europe, and Australia	Ages < 16 (Child)				
Contact Location	Overall	Thigh	Knee	Leg	Foot
Front Bumper	0.3%	3.0%	0.7%	4.8%	0.2%
Top surface of bonnet/wing	0.2%				
Leading edge of bonnet/ wing	0.4%	0.7%	0.1%	0.6%	
Windscreen glass	0.1%				
Windscreen frame/ A pillars					
Front Panel		0.5%	0.1%	0.3%	
Others	0.9%	0.5%		1.3%	0.5%
Sub-Total	1.9%	4.8%	0.9%	7.0%	0.7%

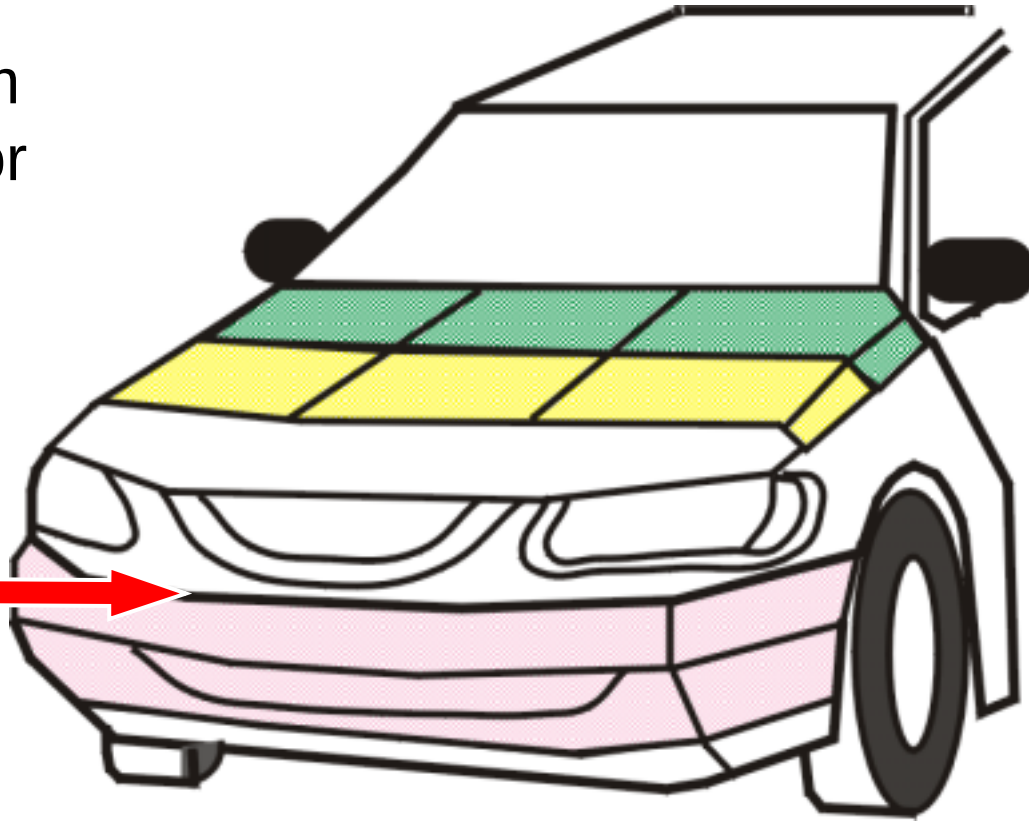
source: IHRA/PS WG 2001 report

Pedestrian Legform Impactor Test Proposals

- EEVC/WG10(1994), and EEVC/WG17 (1998)
- ISO/TC22/SC10/WG2 (2002)

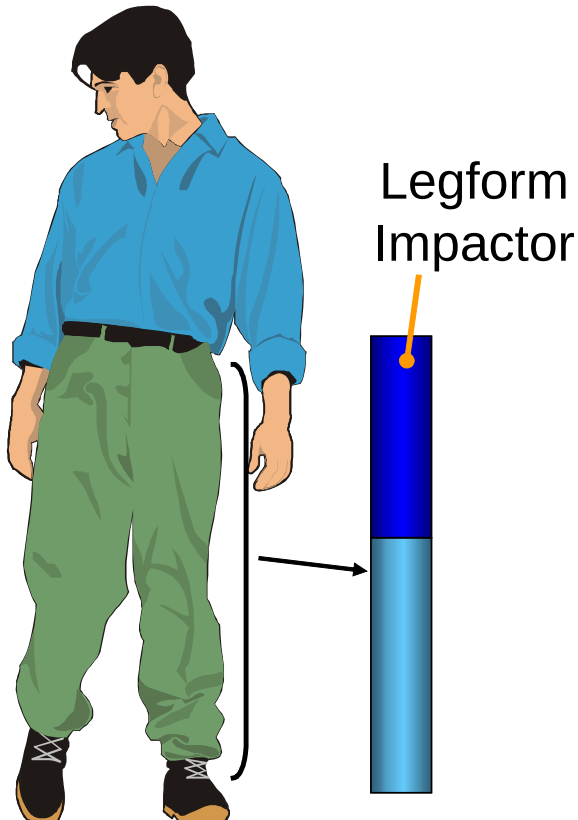
Legform to Bumper Test



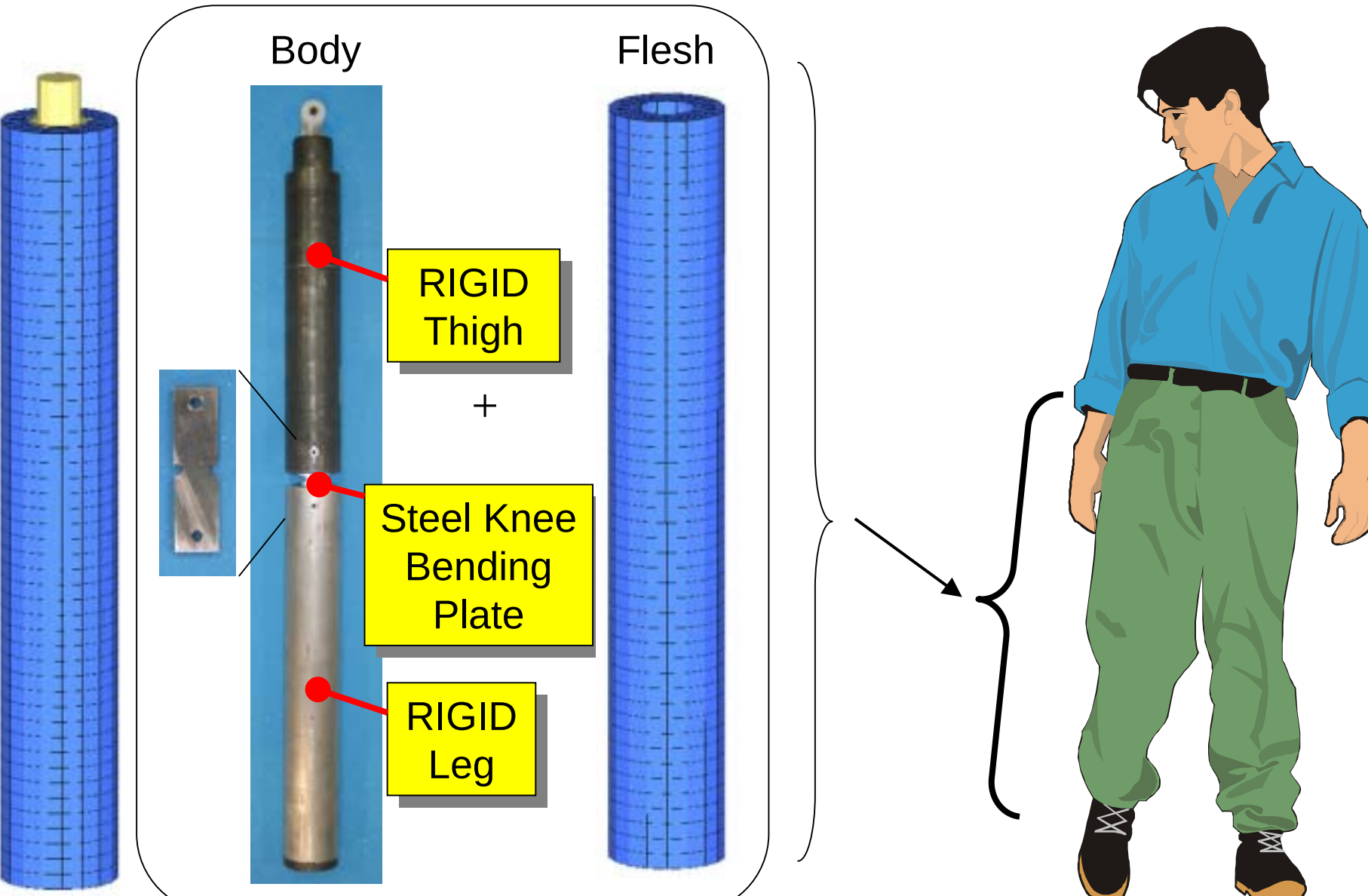


Proposed Pedestrian Legform Impactor

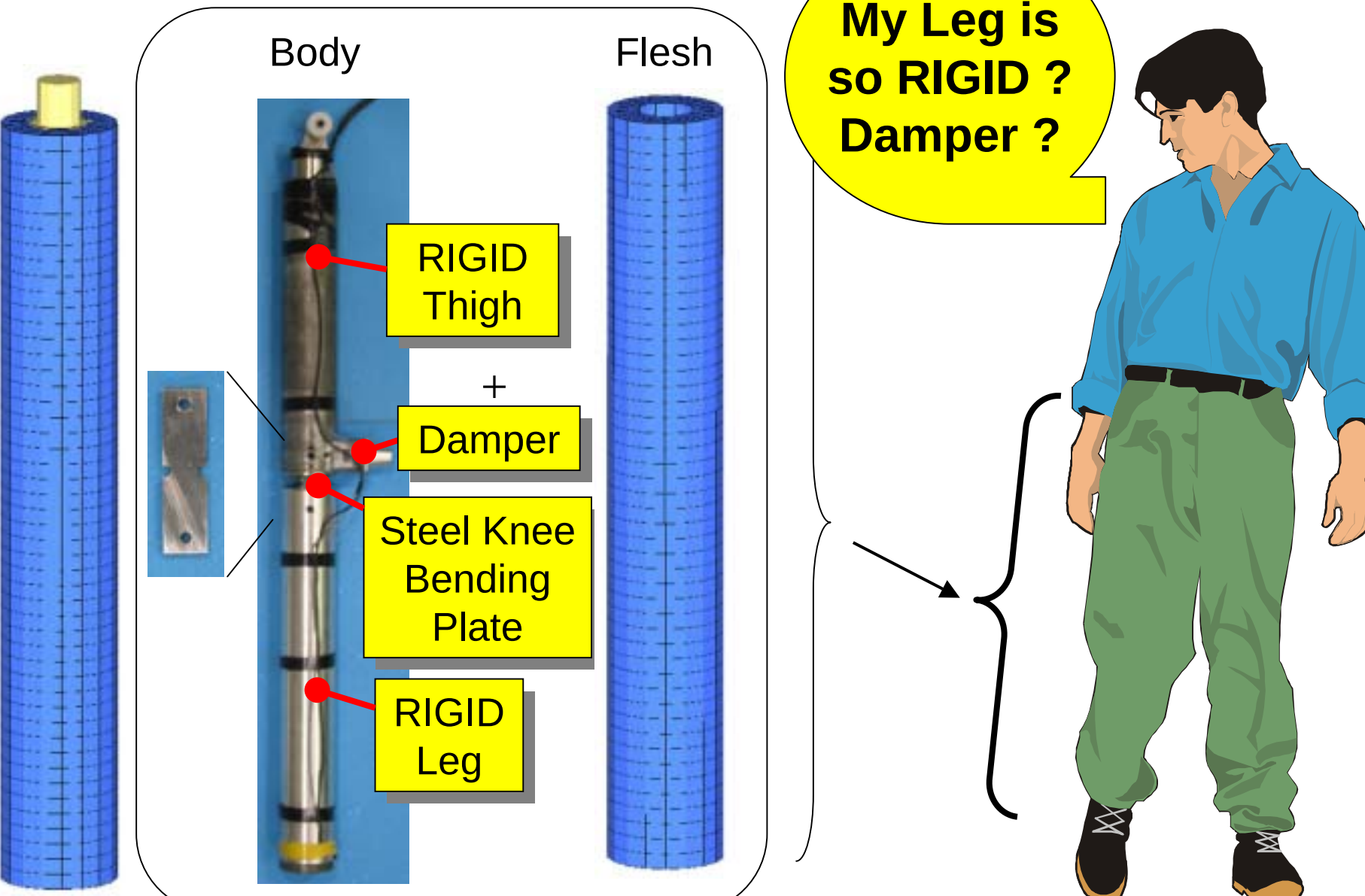
- EEVC/WG10(1994), and EEVC/WG17 (1998)
  -> TRL Pedestrian Legform Impactor (TRL-PLI)
- ISO/TC22/SC10/WG2 (2002)
  -> Only Requirements



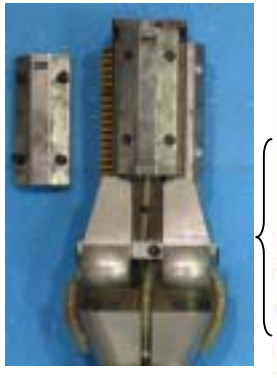
Design for TRL-PLI (1994-1996)



Design for TRL-PLI (1998-2000)



Development of a Biofidelic Pedestrian Legform Impactor



Knee Joint *
(ligament restraint system)

* utilized Polar pedestrian dummy knee joint

Thigh
(RIGID)

Leg
(RIGID)

a) JAMA-JARI PLI 2000

Knee Joint*
(ligament restraint system)

* compact design

Thigh
(FLEXIBLE)

Leg
(FLEXIBLE)

b) JAMA-JARI PLI 2002 (Flex-PLI 2002)

Knee Joint*
(ligament restraint system)

Thigh*
(FLEXIBLE)

Leg
(FLEXIBLE)

* Improved its dynamic respons

c) JAMA-JARI PLI 2003 (Flex-PLI 2003)

Flexible Pedestrian Legform Impactor (Flex-PLI 2003)

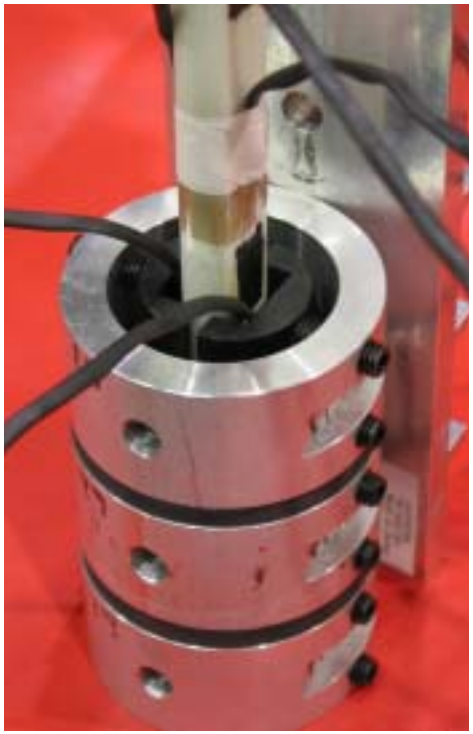
Knee Joint*
(ligament restraint system)

Thigh*
(Flexible)

Leg
(Flexible)

* Improved its dynamic response

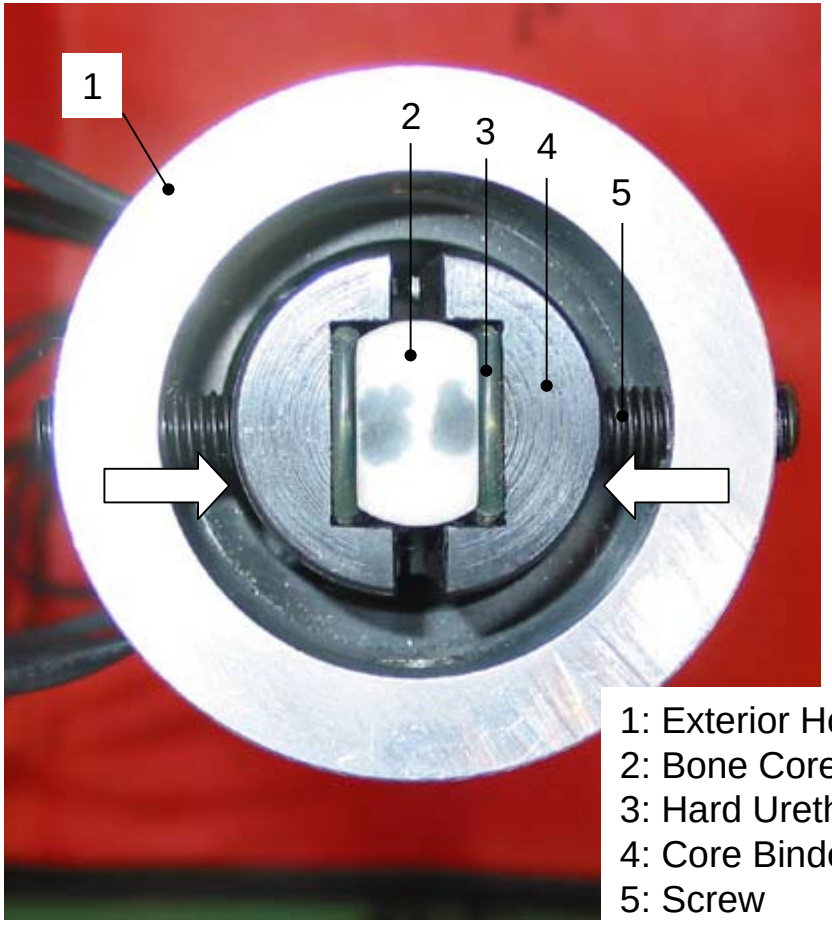
Thigh/Leg

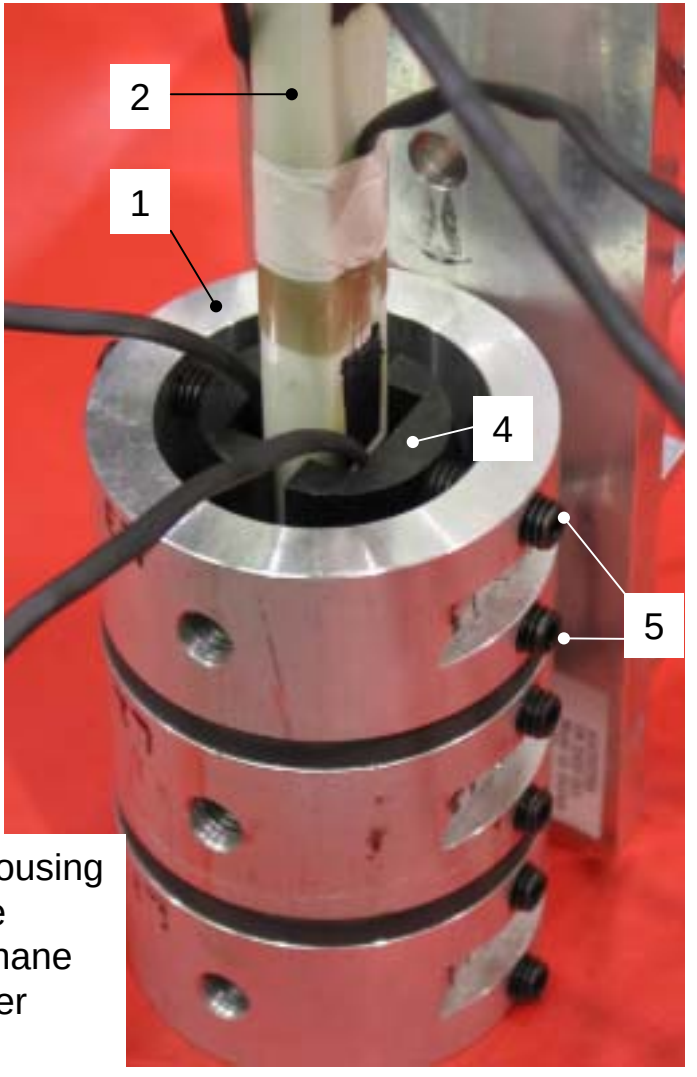


Knee Joint

Thigh/Leg Construction

Compressive force

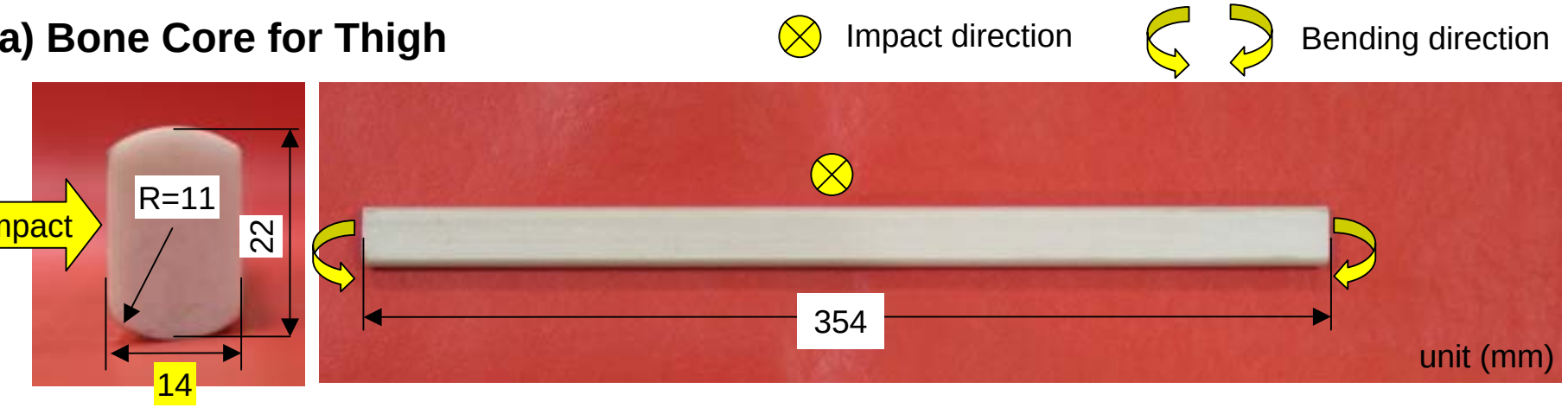




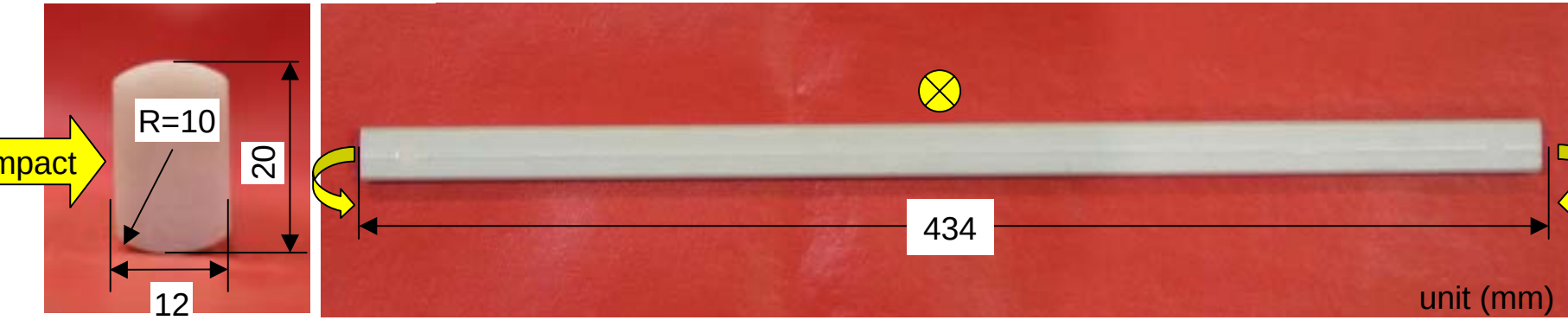
1: Exterior Housing
2: Bone Core
3: Hard Urethane
4: Core Binder
5: Screw

Bone Core Specification

(a) Bone Core for Thigh

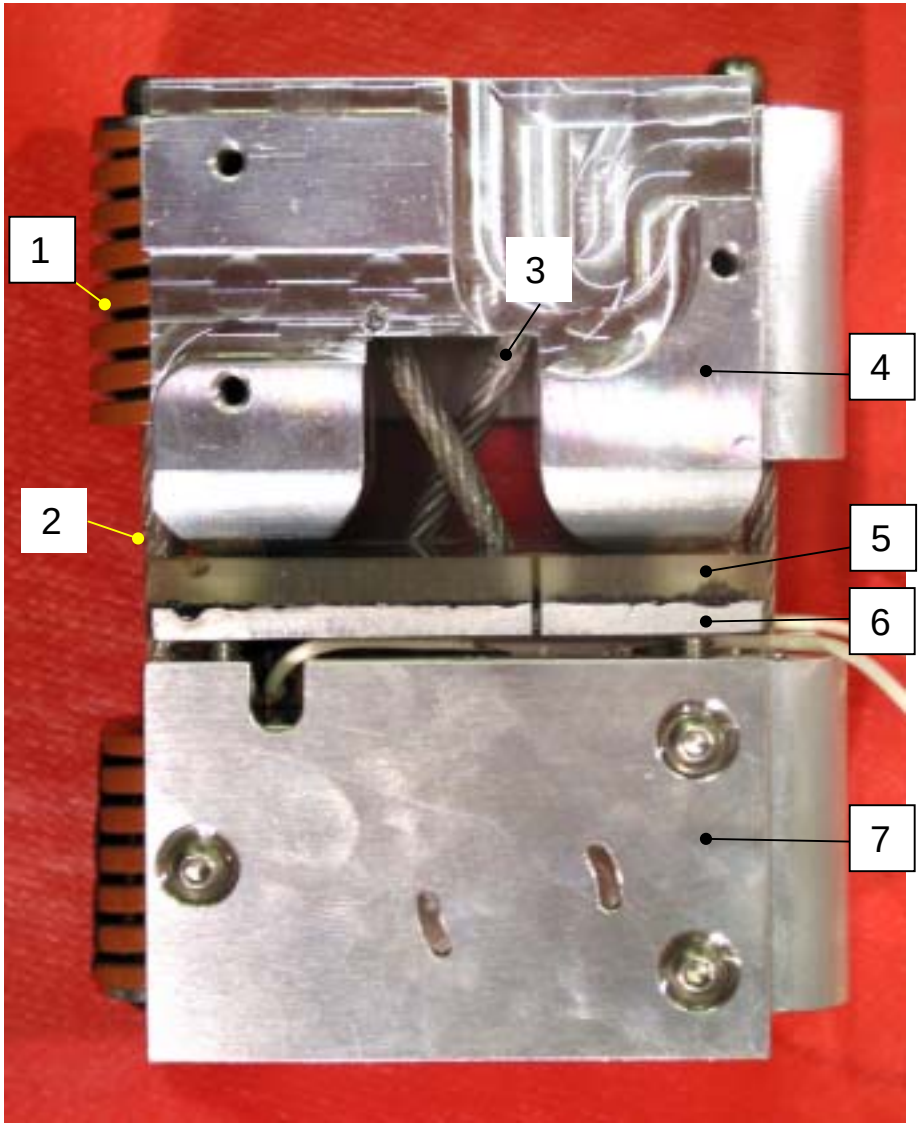


(b) Bone Core for Leg



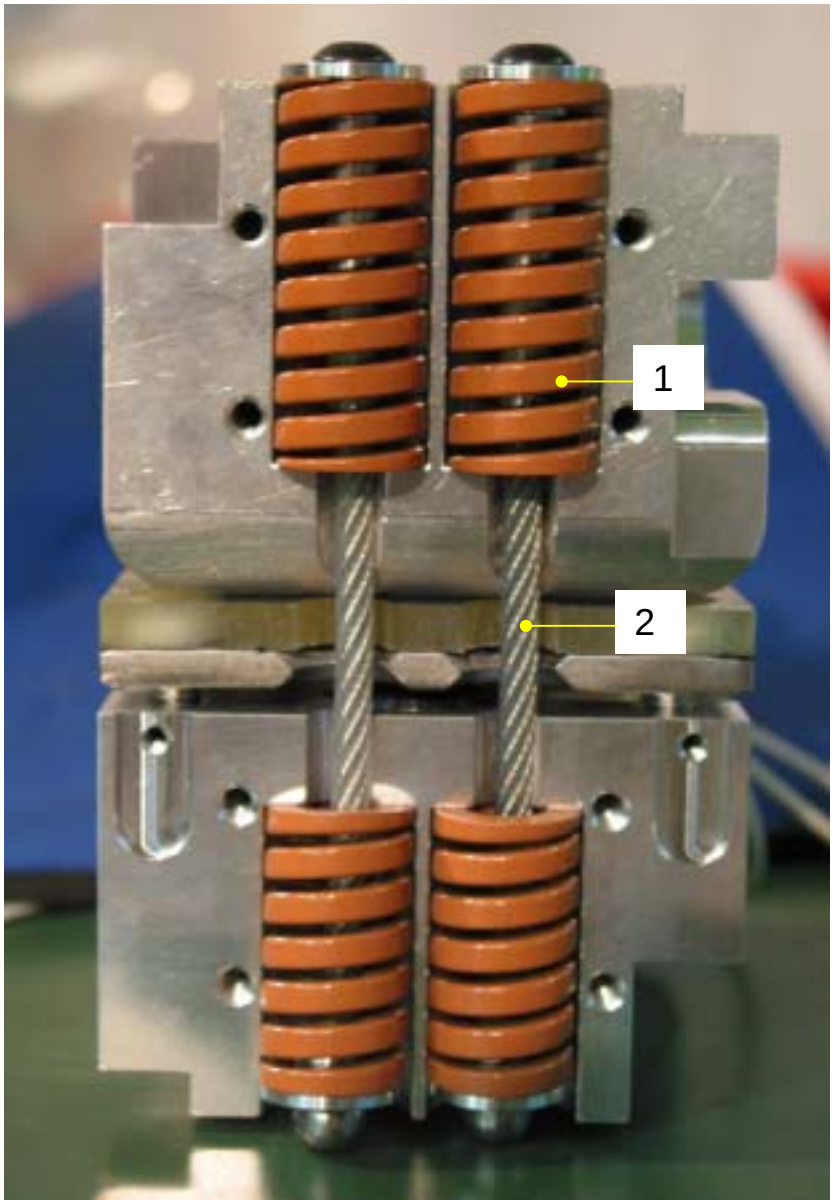
Material: Glass-Reinforced Plastic (GRP)

Knee Joint Construction



1: Knee spring
2: Knee cable (lateral ligament)
3: Knee cable (cruciate ligament)
4: Femoral condyle
5: Hard Urethane
6: Tibial plateau
7: Tibial condyle

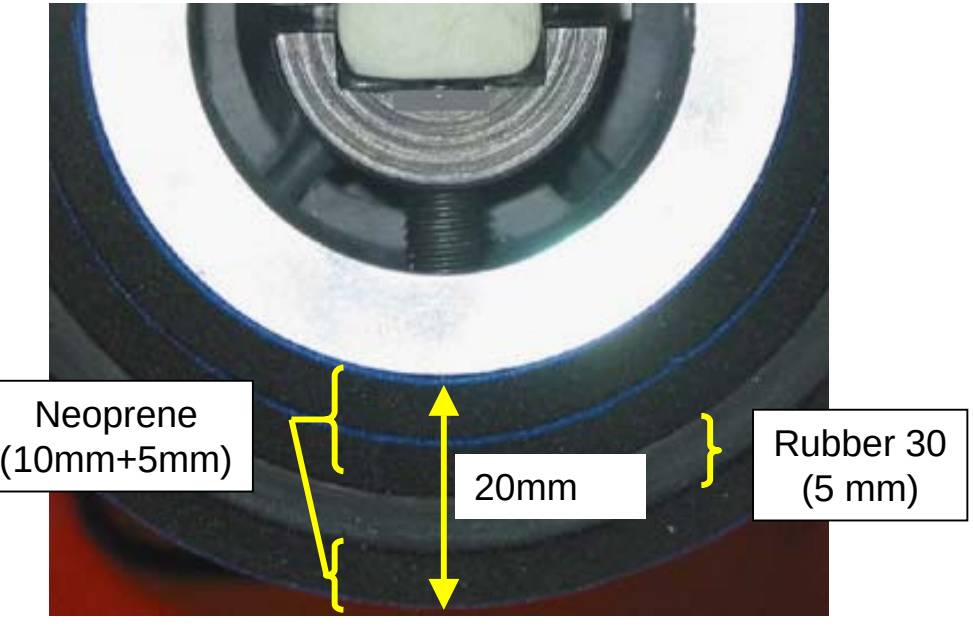
Knee Joint Construction (lateral view)



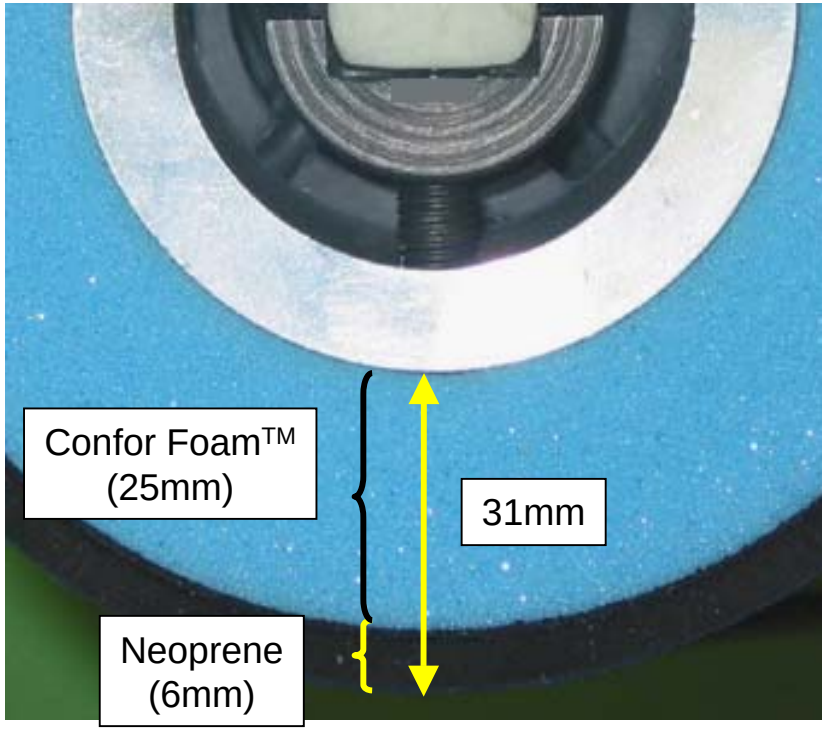
1: Knee Spring
2: Knee Cable

Flesh Construction

Flesh for Flex-PLI 2003

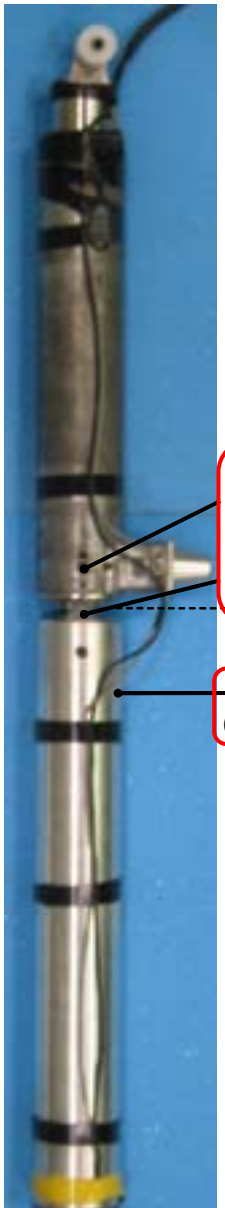


Flesh for Flex-PLI 2002 (TRL-PLI)

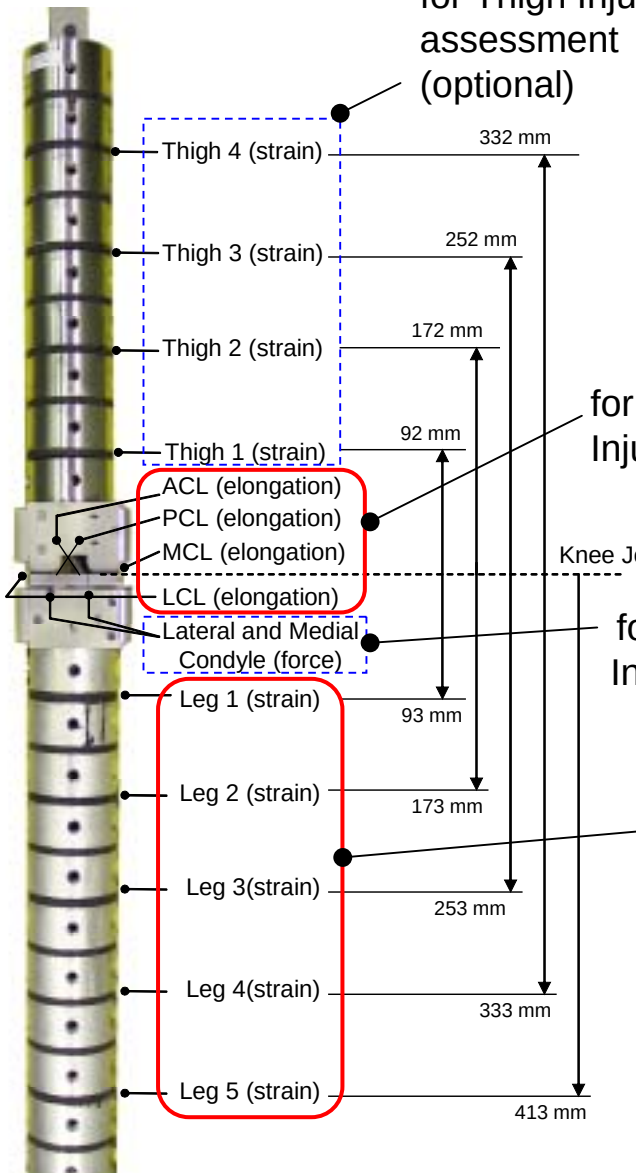


Measurement Instrumentation

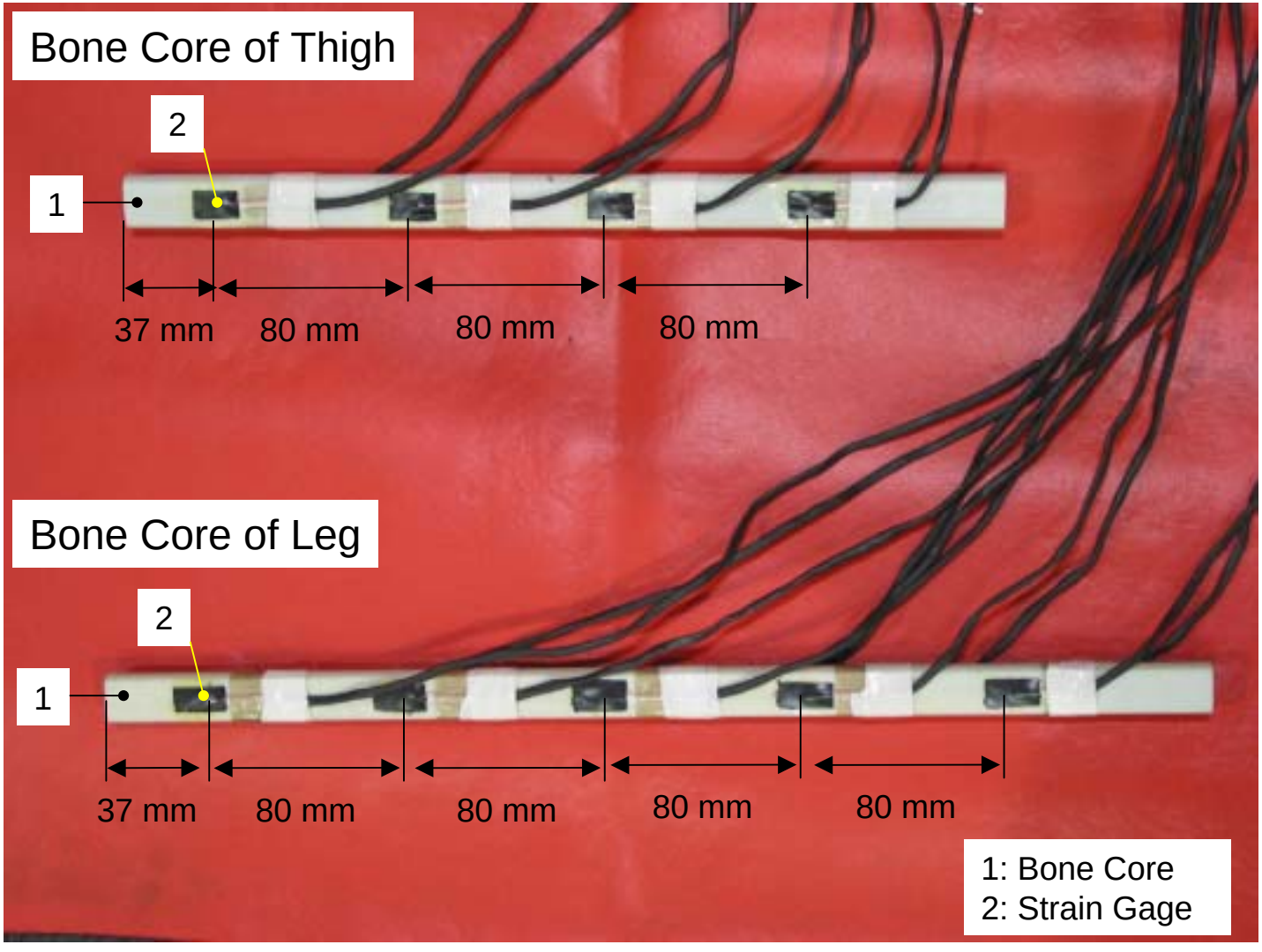
TRL-PLI



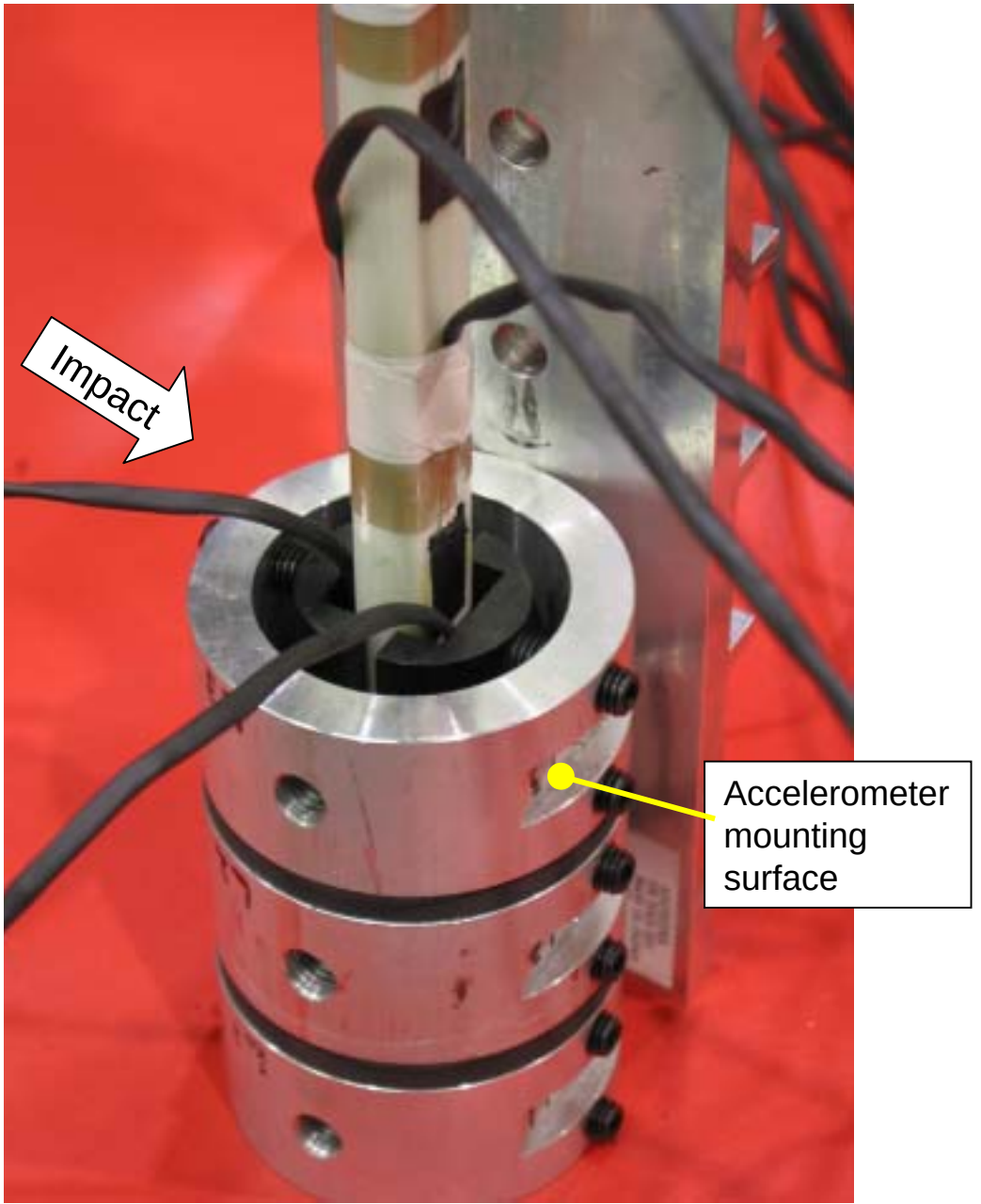
Flex-PLI 2003



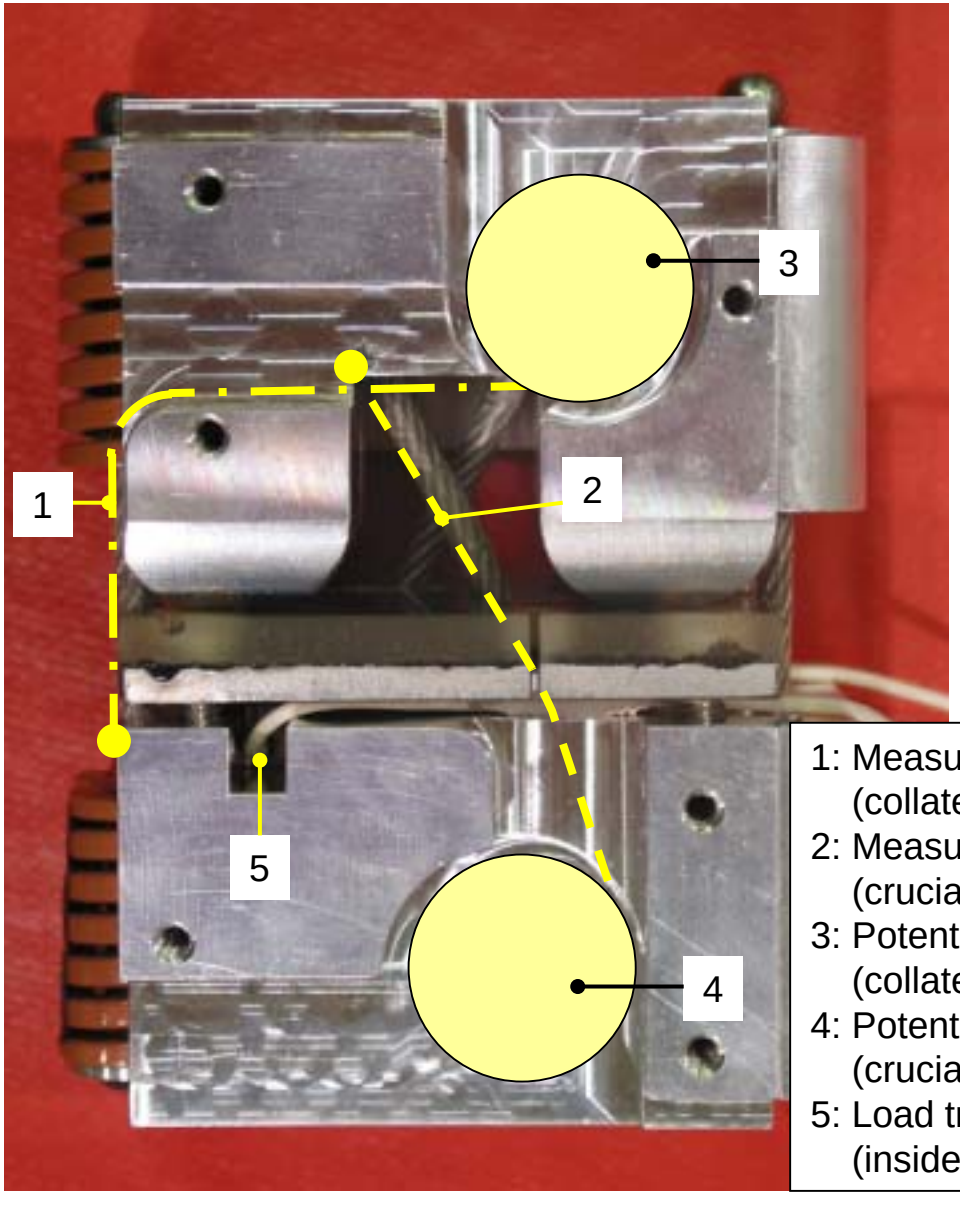
Thigh/Leg Measurement (Strain)



Thigh/Leg Measurement (Acceleration)

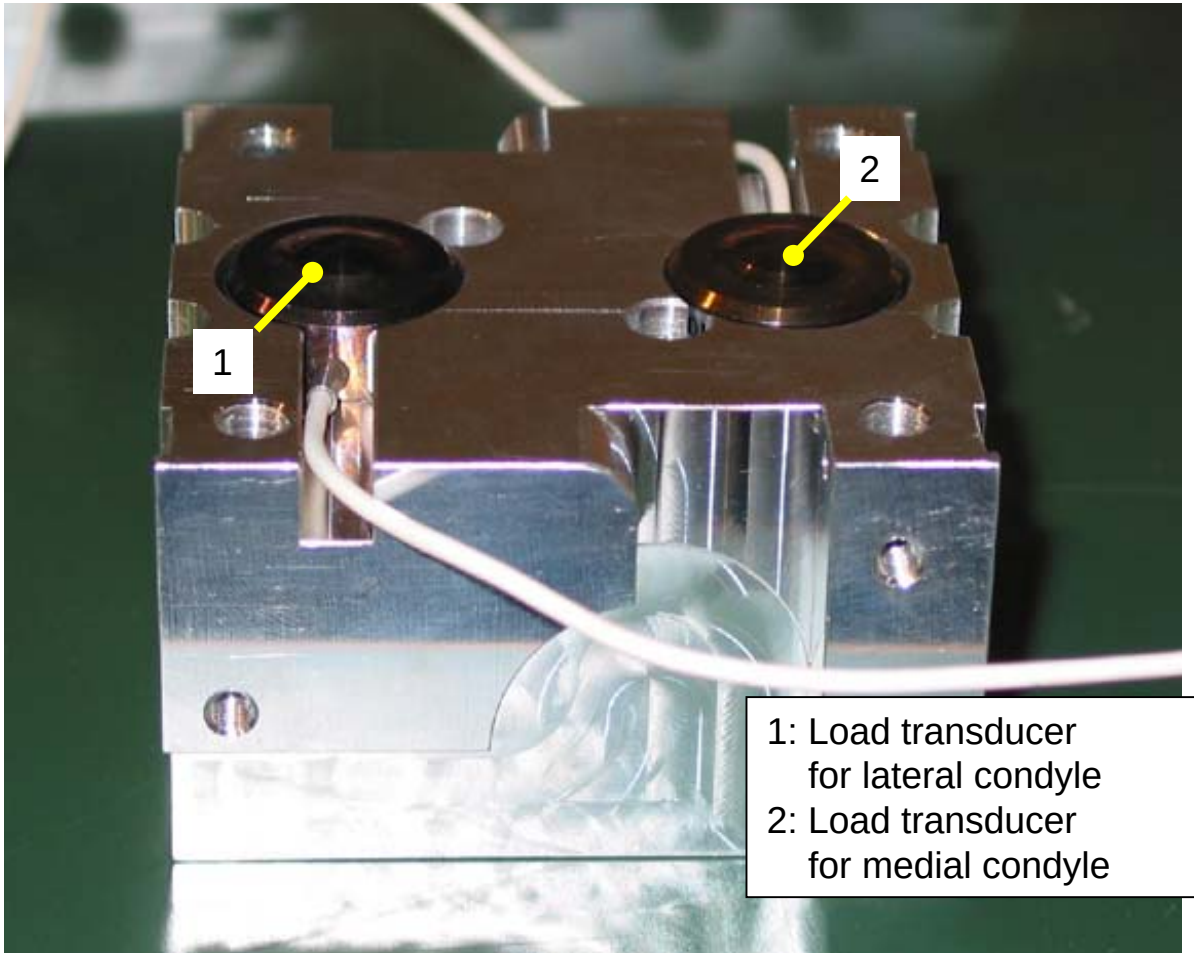


Knee Joint Measurement
(Elongation and Compressive Force)



1: Measurement cable (collateral)
2: Measurement cable (cruciate)
3: Potentiometer (collateral)
4: Potentiometer (cruciate)
5: Load transducer (inside of the condyle)

Knee Joint Measurement (Compressive Force)



Biofidelity Evaluation for Flex-PLI 2003

Knee Joint*
(ligament restraint system)

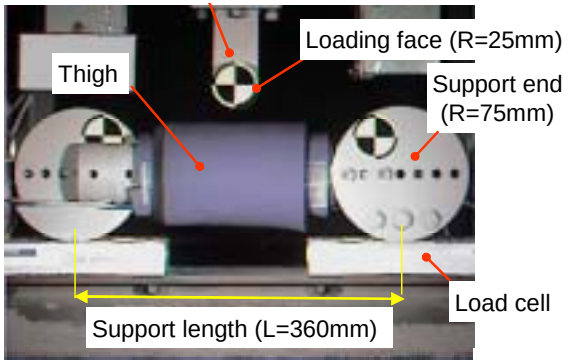
Thigh*
(Flexible)

Leg
(Flexible)

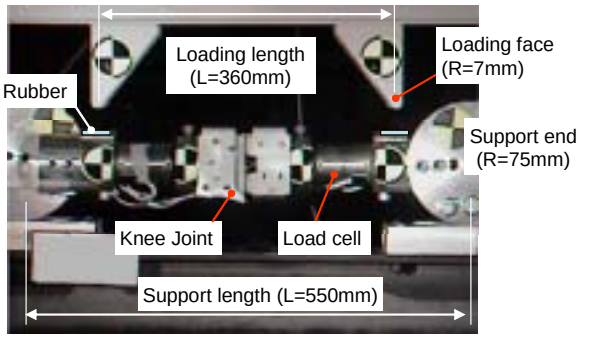
* Improved its dynamic response

Dynamic Bending Test

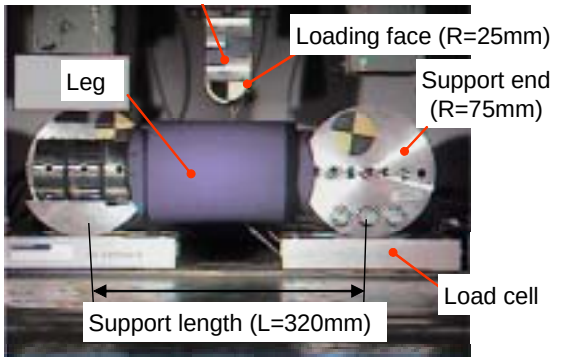
Ram (Mass: 67.8kg, Initial impact speed: 1.0 m/s)



Ram (Mass: 74.5kg, Initial impact speed: 1.4m/s)

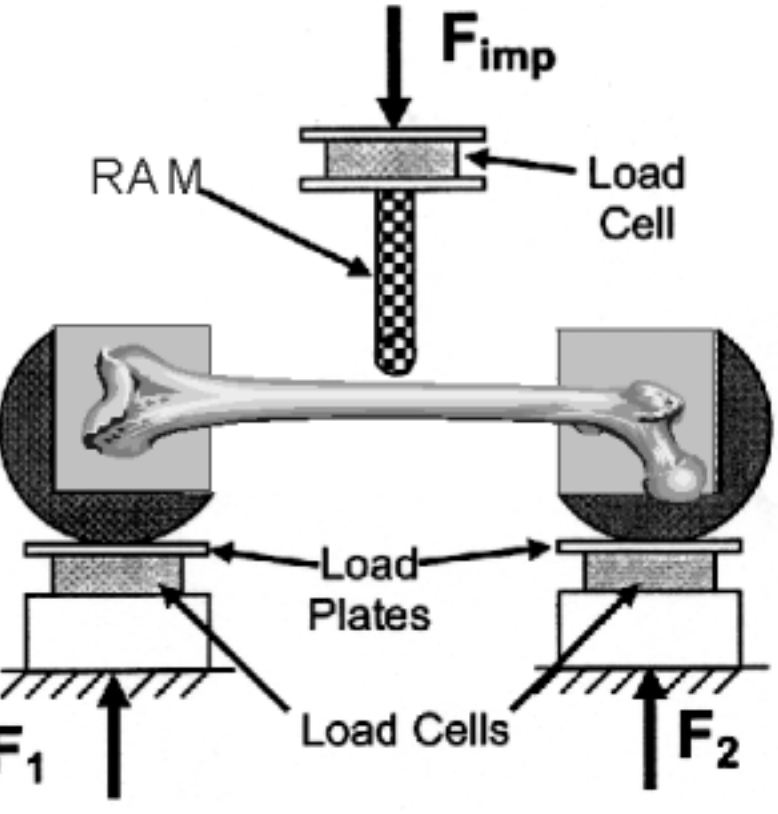


Ram (Mass: 67.8kg, Initial impact speed: 1.0m/s)



Biofidelity Evaluation for Thigh of Flex-PLI 2003

PMHS (Femur)



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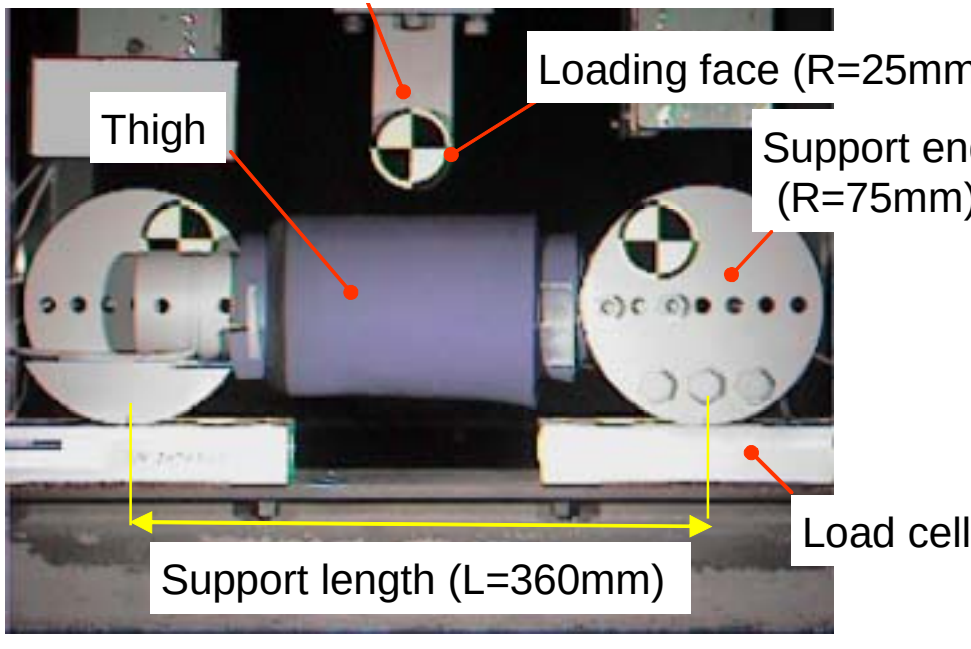
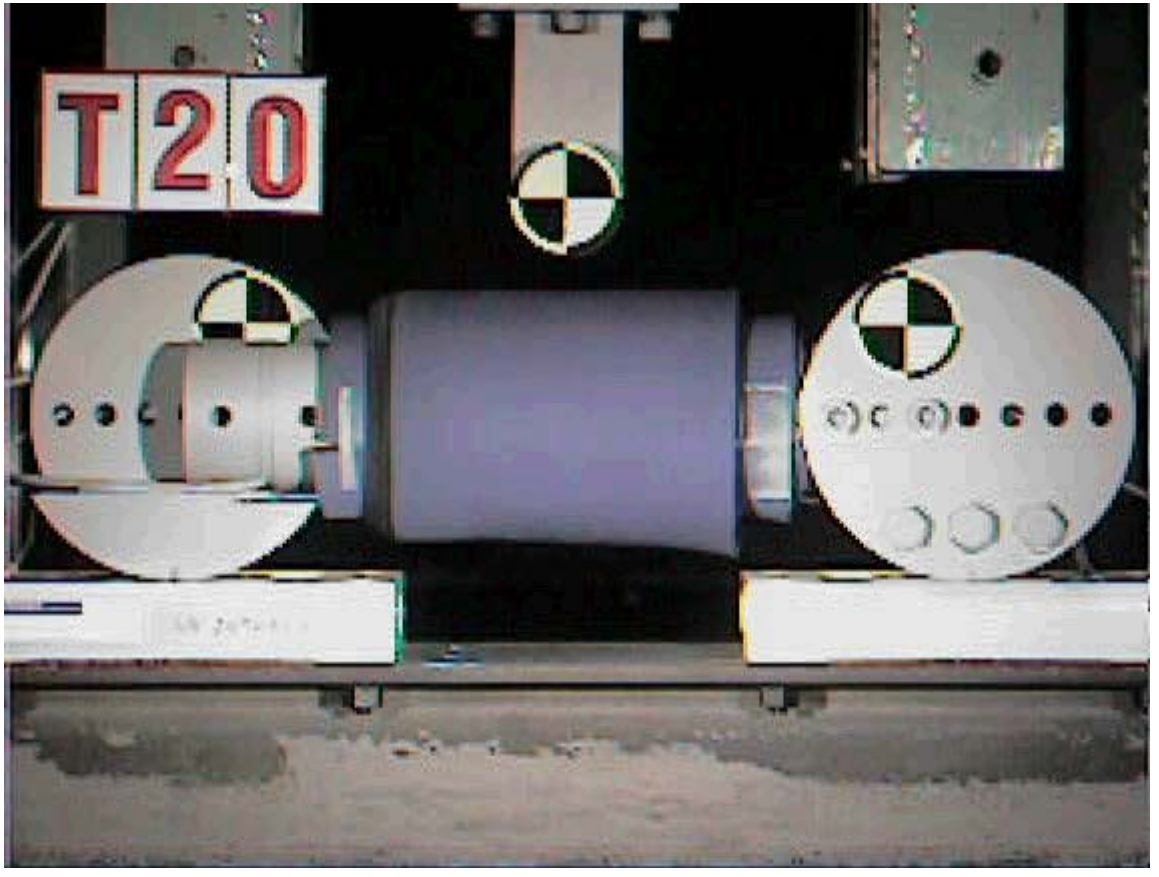
Flex-PLI 2003 (Thigh)

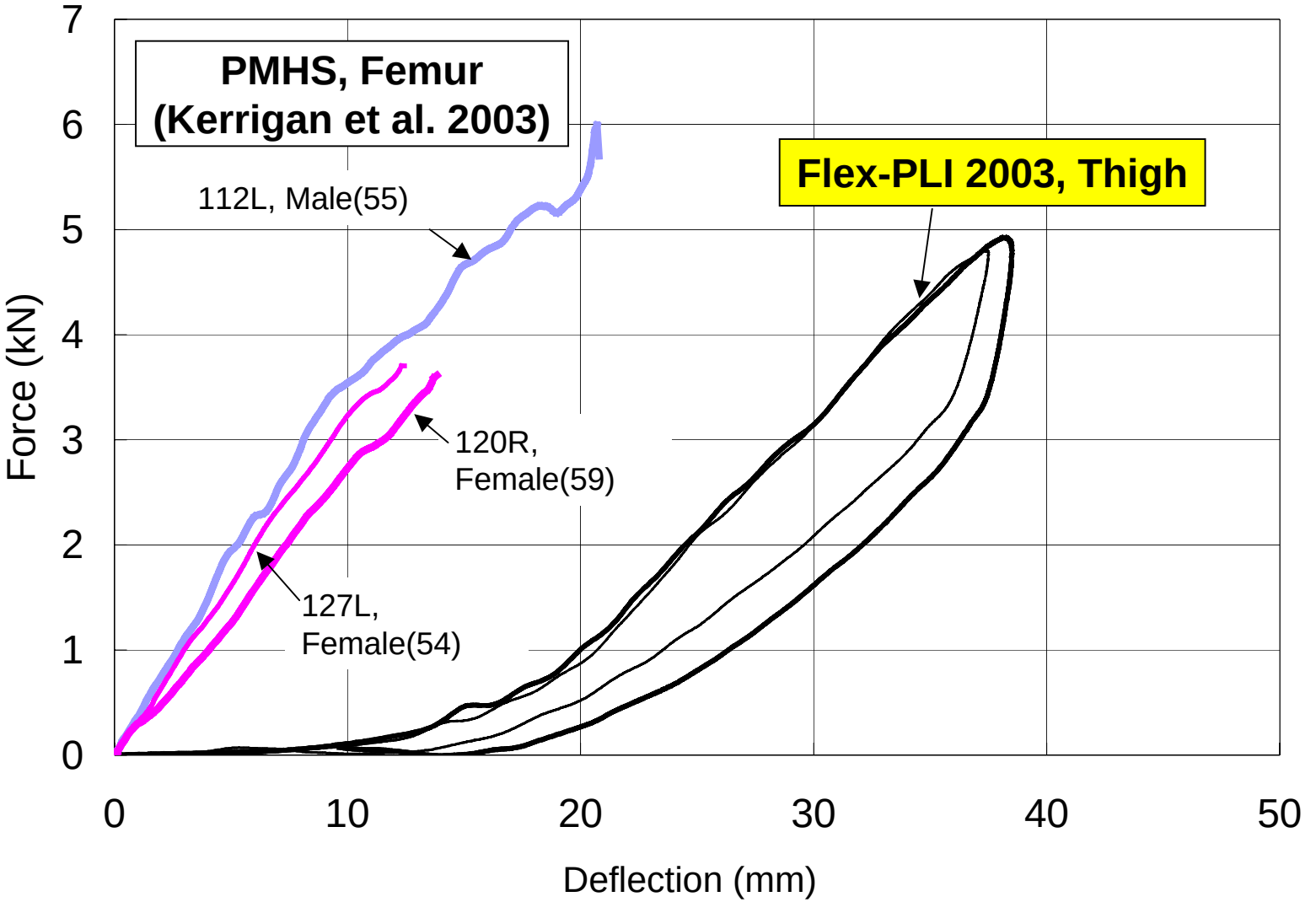
Ram (Mass: 67.8kg, Initial impact speed: 1.0 m/s)



Dynamic Response
for Thigh of Flex-PLI 2003

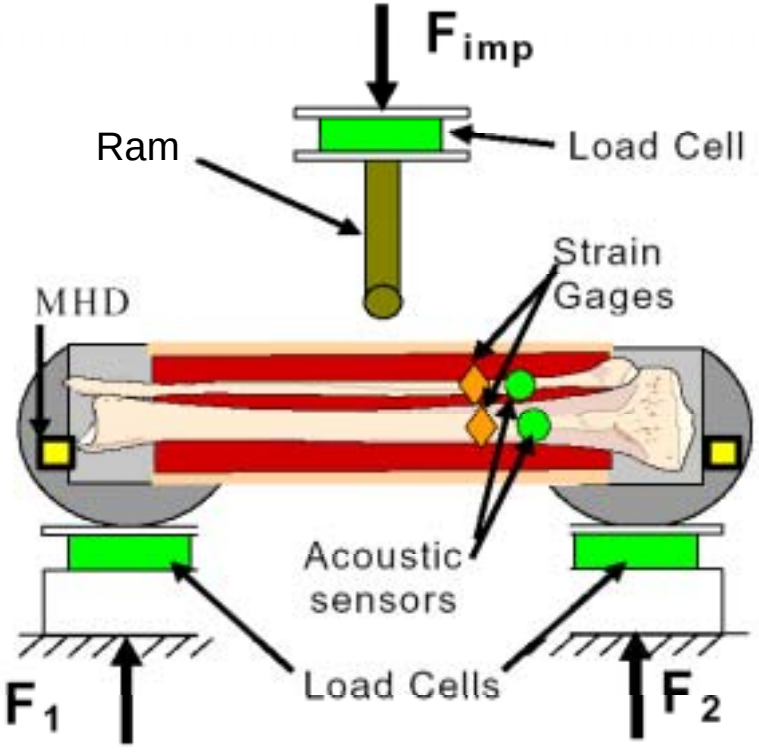


Result of Biofidelity Evaluation for Thigh of Flex-PLI 2003



Biofidelity Evaluation for Leg of Flex-PLI 2003

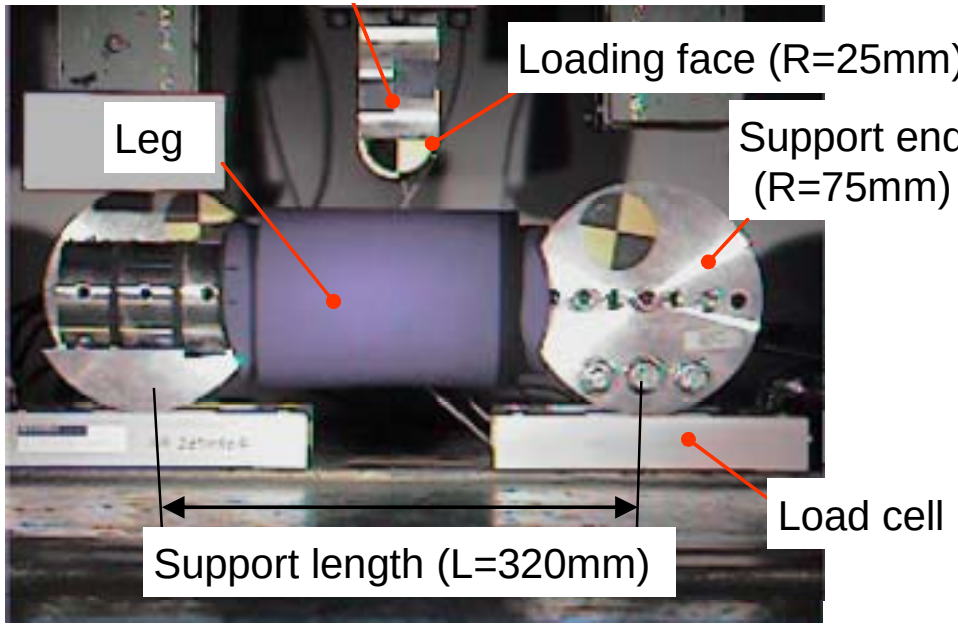
PMHS (Leg)



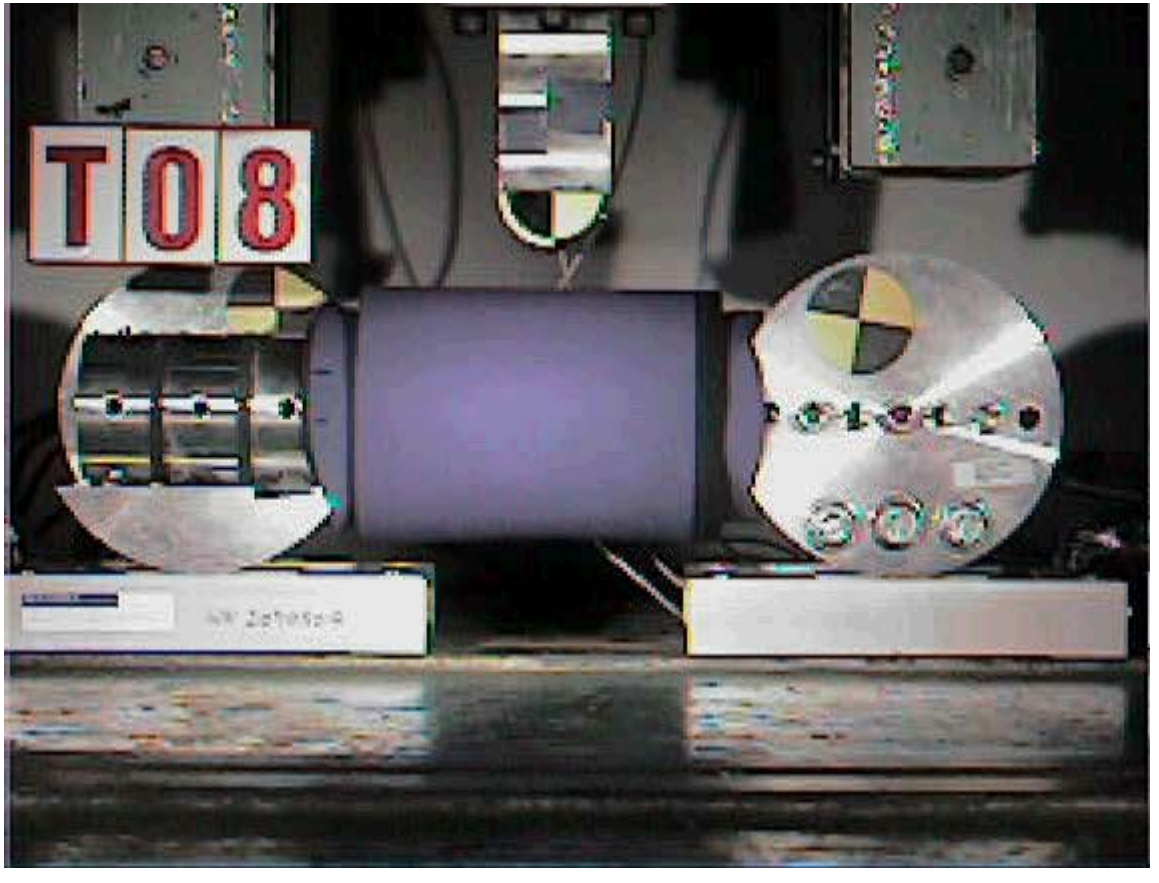
Kerrigan et al. 2003

Flex-PLI 2003 (Leg)

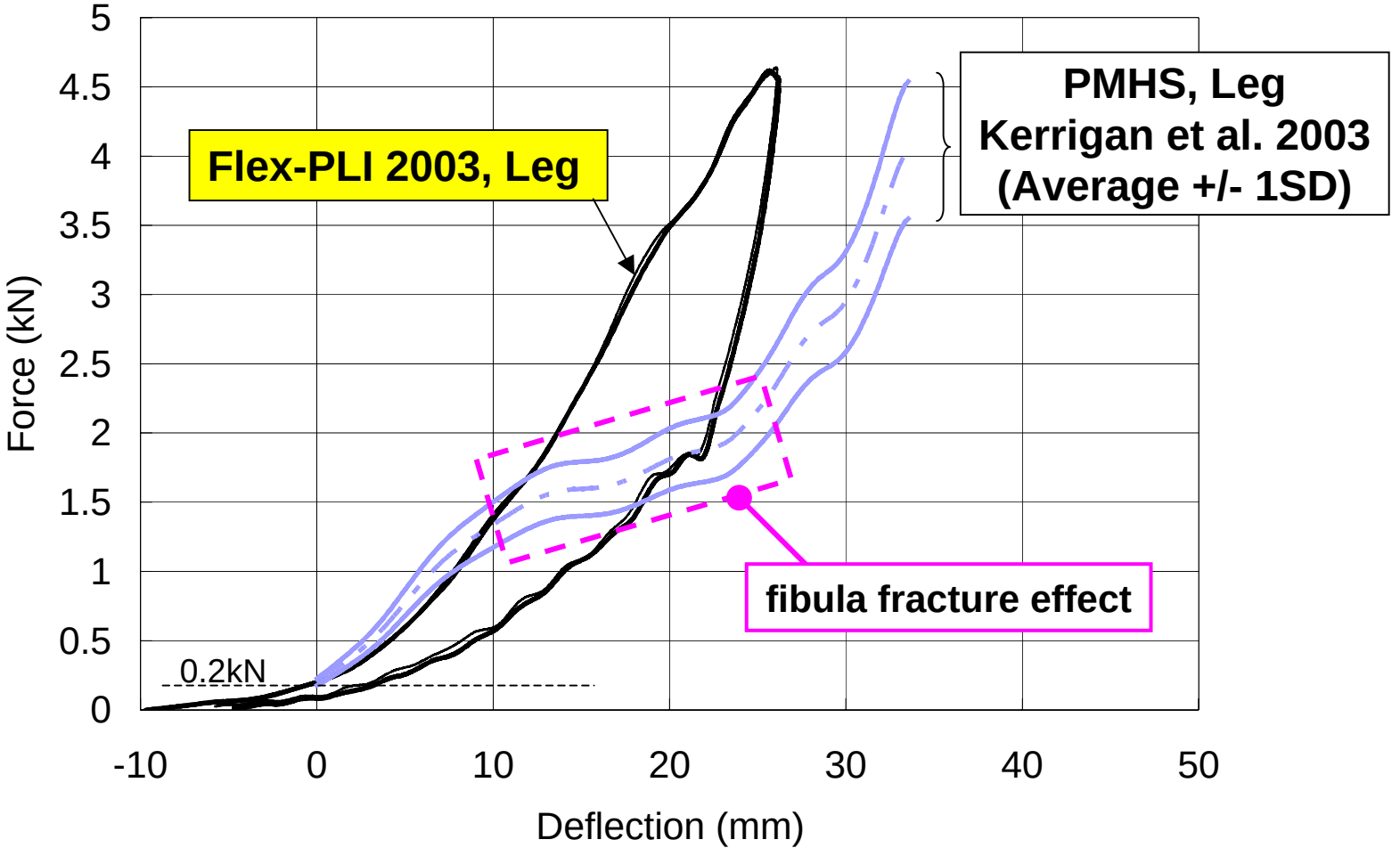
Ram (Mass: 67.8kg, Initial impact speed: 1.0m/s)



Dynamic Response
for Leg of Flex-PLI 2003

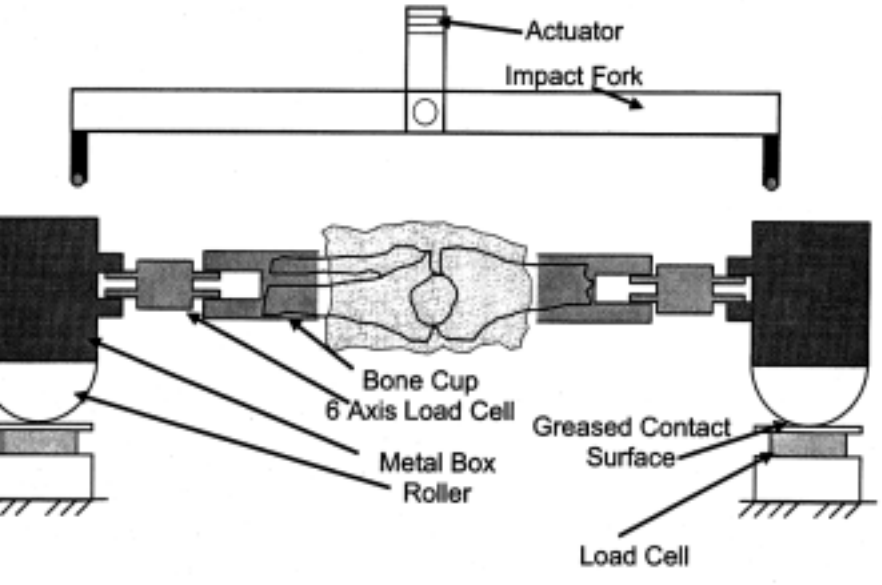


Results of Biofidelity Evaluation for Leg of Flex-PLI 2003



Biofidelity Evaluation for Knee Joint of Flex-PLI 2003

PMHS (Knee Joint)



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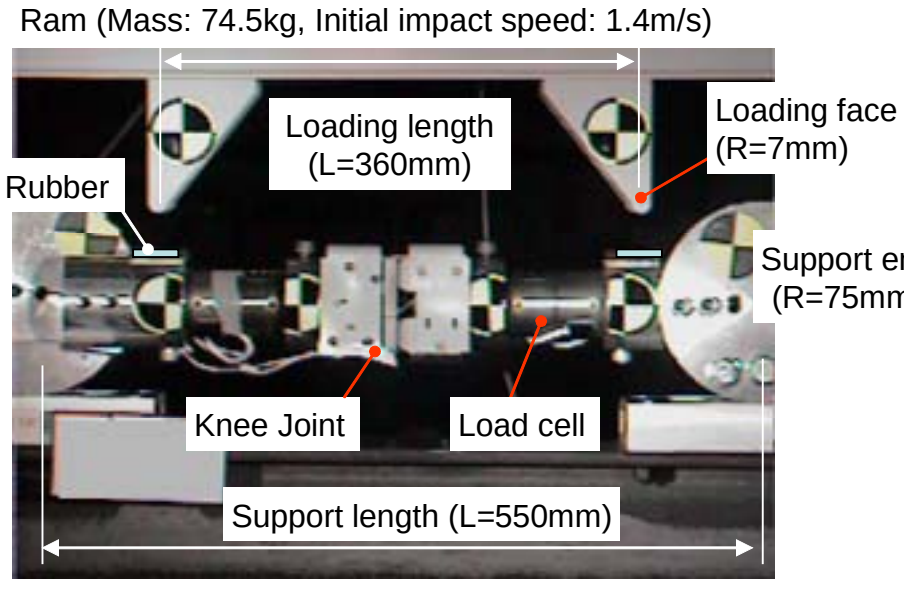
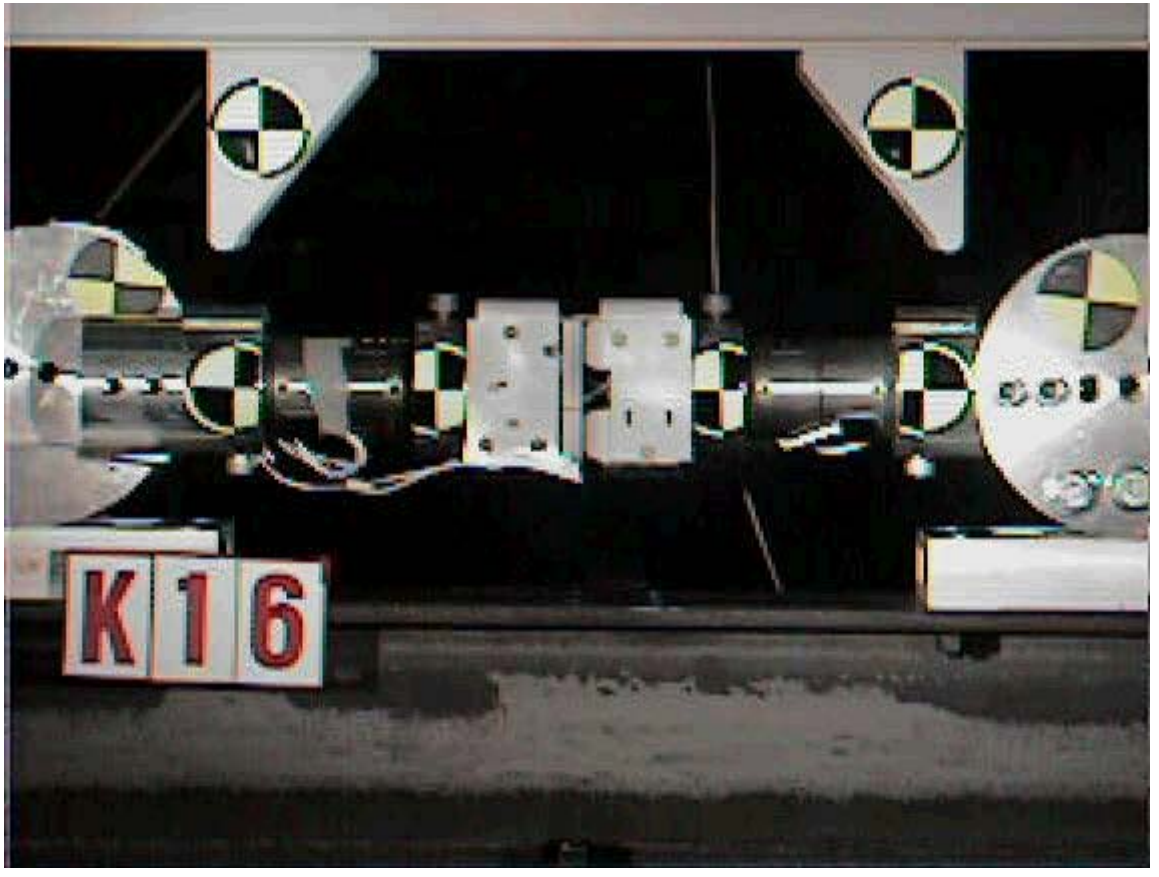
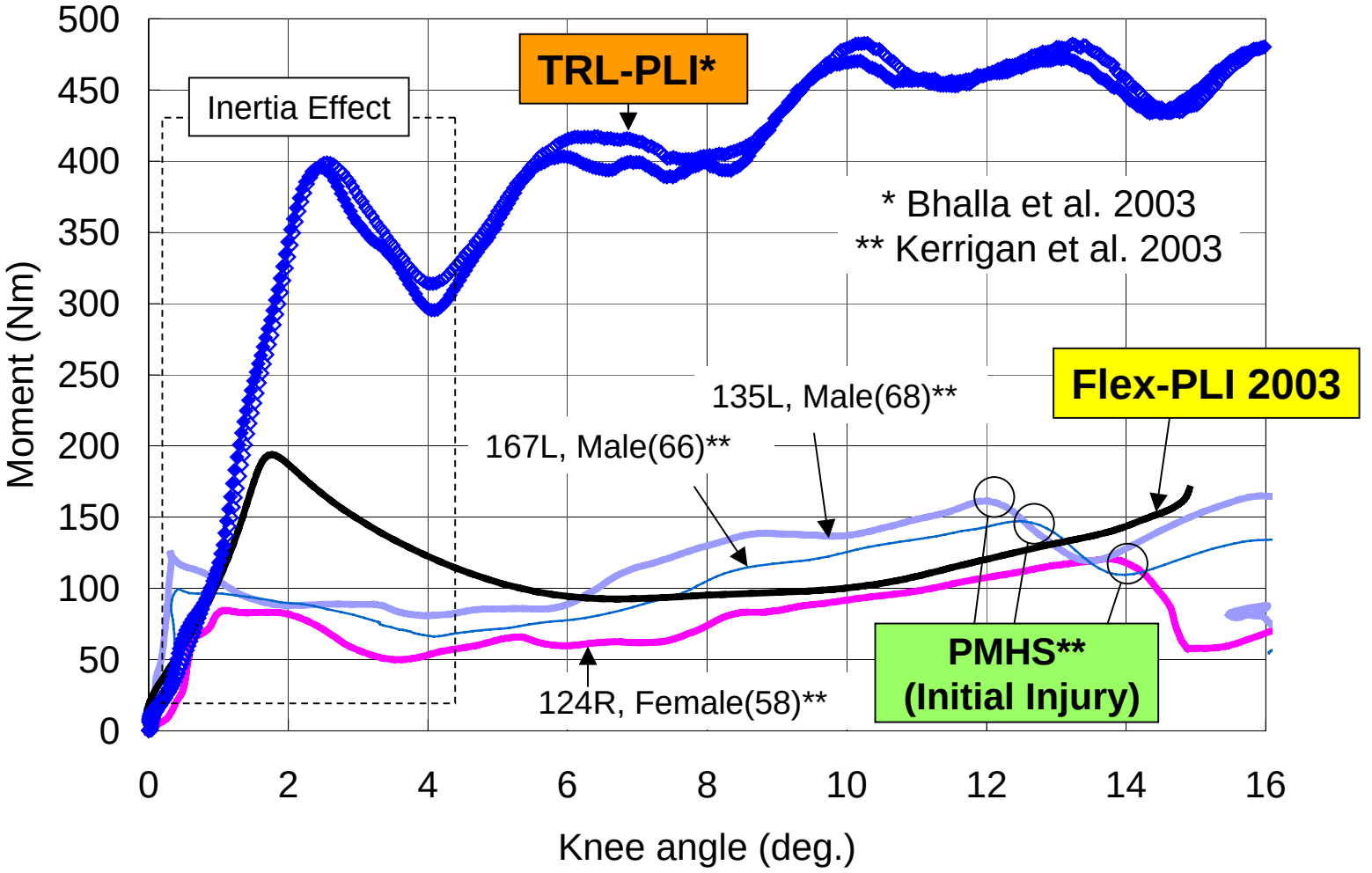
Flex-PLI 2003 (Knee Joint)



Dynamic Response for Knee Joint of Flex-PLI 2003



Results of Biofidelity Evaluation for Knee Joint of Flex-PLI 2003



Conclusions

JAMA-JARI developed a biofidelic PLI (Flex-PLI 2003)
Flex-PLI 2003 response is compared with PMHS component tests (Thigh, Leg, Knee Joint). Therefore, the Flex-PLI 2003 has a high possibility to reproduce more proper response in a car-pedestrian impact than that of other PLI.
Flex-PLI 2003 installs sensors in wide range.
Therefore, the Flex-PLI 2003 has a high possibility to conduct more detailed and proper lower limb injury assessment than that of other PLI.

Future work

- PMHS component test data for Thigh, Leg, Knee Join is limited. Therefore, additional PMHS test results are needed for more certain validation.
- The Flex-PLI 2003 is validated in component test, however, assembly level (Thigh-Knee Joint-Leg) validation is also needed.
- Flex-PLI 2003 does not have fibula construction. Therefore, the effect should be considered for the leg injury assessment.

Thank you for your attention!