History of Development of the Flexible Pedestrian Legform Impactor (Flex-PLI)

November 3rd, 2011
Japan

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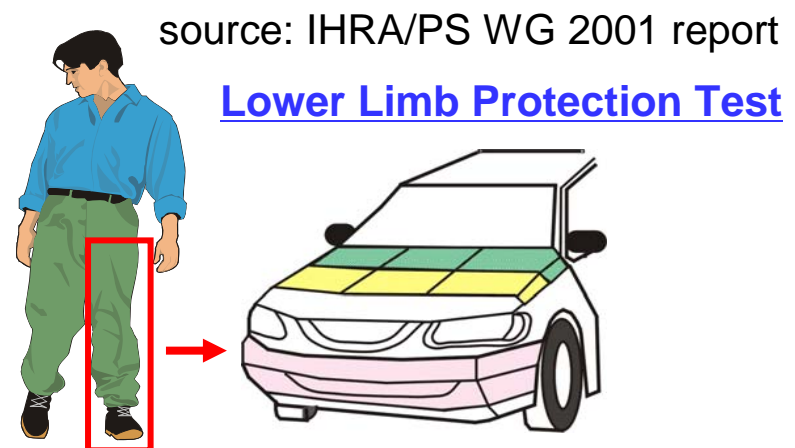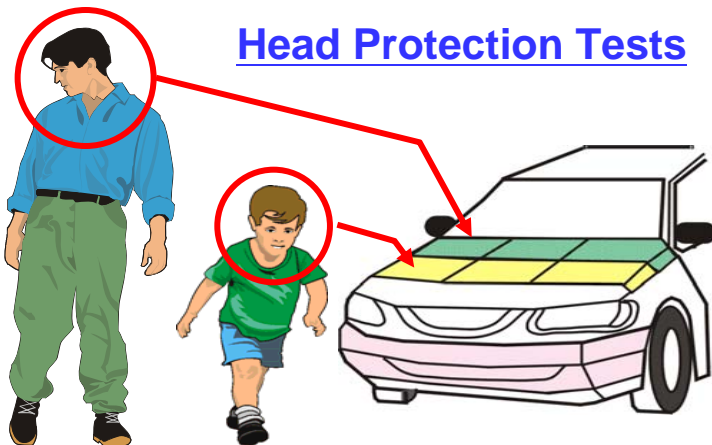
1. Back ground

1. Back ground

- Pedestrian Injured Body Regions -
### (USA, Germany, Japan, and Australia : 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 report

Head Protection Tests

Lower Limb Protection Test

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1. Back ground, contd.

- Lower Limb Injured Parts and Contact Locations -
(USA, Germany, Japan, and Australia : Pedestrian Lower Limb : AIS 2-6)

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%
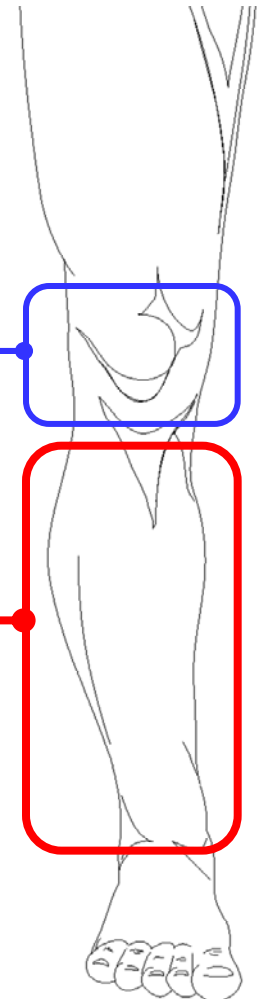
source: IHRA/PS WG 2001 report

1. Back ground, contd.

- EEVC Pedestrian Lower Legform Impactor -

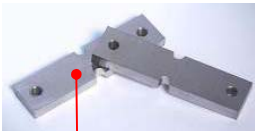### Main Concerns: (1) Low biofidelity and (2) Insufficient Measurement Items

Structure

Instrumentation

Main unit

Exterior

Femur (Rigid)
- Low Biofidelity

Flesh
- Disposable Flesh Foam
- Sensitive to Temperature and Humidity

Confor Foam™

Knee (Hard)
- Low Biofidelity

Knee Ligaments (Steel plate)

Tibia (Rigid)
- Low Biofidelity

Real-world Accident Analysis
Otte et al, 2007

5,1
6,8
6,8
22,0
6,8
8,5
15,2
6,8
18,6
3,4
6,8

0   5   10   15   20
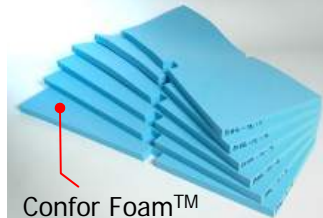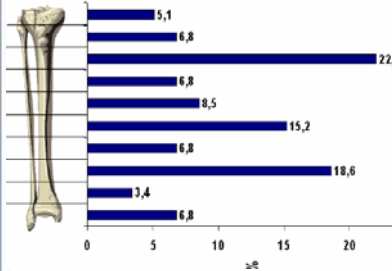
Injury Assessment Items
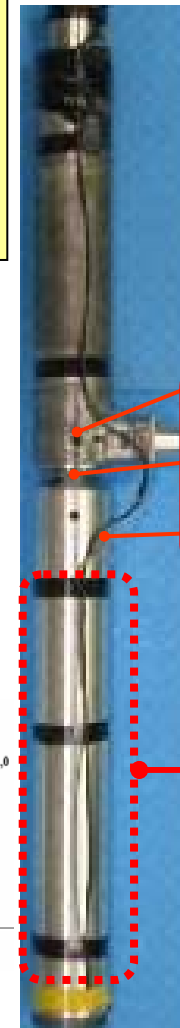
Knee Shearing Displacement
Knee Bending Angle
Upper Tibia Acceleration

Knee center

64 mm

Tibia Middle/Lower
- No measurement Items

2. History of Flex-PLI Development (Overview)

2. History of Flex-PLI Development (Overview), contd.

- The Japan Automobile Research Institute (JARI) and the Japan Automobile Manufacturers Association, Inc. (JAMA) initiated the development regarding a biofidelic flexible pedestrian legform impactor (Flex-PLI) from 2001.
- In 2002, its first version, Flex-PLI 2002, was made.
- The impactor has Flexible Long bones (Femur/Tibia) and knee ligament restraint system like human ones.
- Besides, the impactor has an capability to measure bending moment at multiple locations at Tibia and Femur.

Flex-PLI 2002

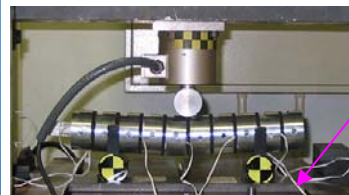**Knee**
Ligament Restraint System

Knee spring

Knee ligaments
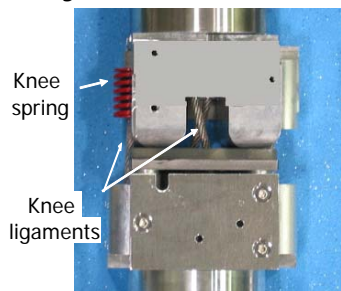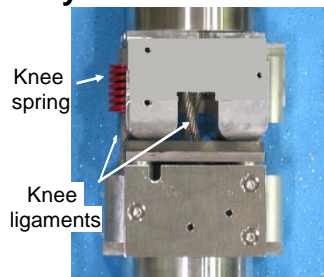
Femur
Flexible

Tibia
Flexible

Measurement cables:
To measure bending moment at multiple locations at tibia and femur

2. History of Flex-PLI Development (Overview), contd.

- After the Flex-PLI 2002 development, several improvements were applied.
- GRSP/Pedestrian Safety Informal Working Group (IG-PS WG) interested in the capability of Flex-PLI, then, Flex-PLI technical Evaluation Group (Flex-TEG) were settled in 2005 under the GRSP/IG-PS WG to evaluate the Flex-PLI capabilities as a regulatory tool from Flex-G.
- Finally, the prototype of final version of Flex-PLI (Flex-GTR) were developed in 2009.
- Flex-TEG members were evaluated Flex-GTR capabilities, then they approved the Flex-GTR capabilities in 2010.
- After that, Flex-TEG chair country, Japan, submitted amendments regarding gtr and ECE to the GRSP using the Flex-GTR specifications, etc..

Flex-PLI 2002

Knee
Ligament Restraint System

Knee spring

Knee ligaments

Femur
Flexible

Tibia
Flexible

Flex-PLI 2003

Flex-G

Flex-PLI 2004

Flex-GT

Flex-GTR

Impact direction

LCL   MCL

PCL   ACL

MCL: Medial Collateral Ligament
ACL: Anterior Cruciate Ligament
PCL: Posterior Cruciate Ligament
LCL: Lateral Collateral Ligament

Femur
flexible long bone

Knee
ligament constraint system

Tibia
flexible long bone

Flesh
neoprene and synthetic rubber sheets
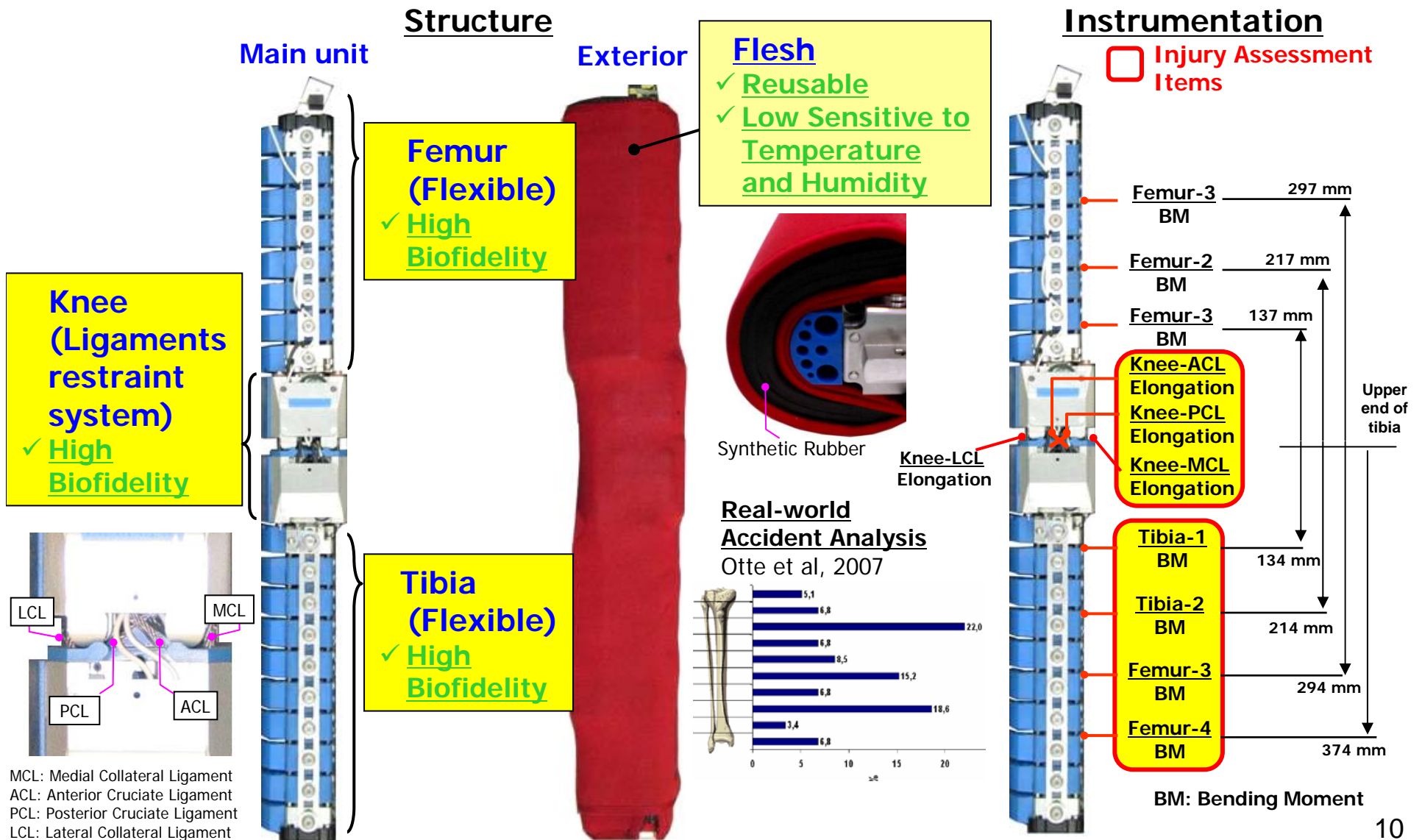
9
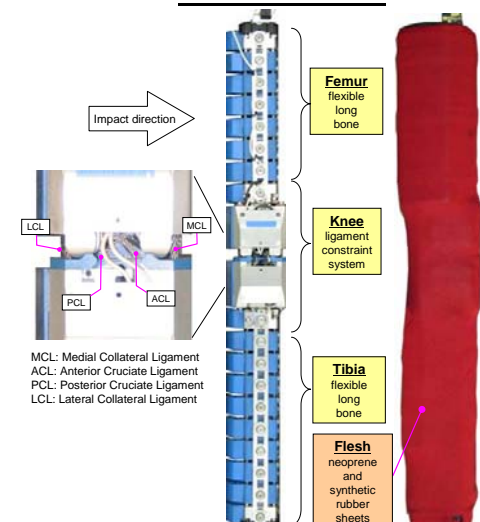
Specifications of Flex-GTR-prototype

Main Achievements: (1) High biofidelity and (2) Multiple Measurement Items

Structure

Main unit

Exterior

Flesh
- ✓ Reusable
- ✓ Low Sensitive to Temperature and Humidity

Femur (Flexible)
- ✓ High Biofidelity

Knee (Ligaments restraint system)
- ✓ High Biofidelity

Synthetic Rubber

Tibia (Flexible)
- ✓ High Biofidelity

Real-world Accident Analysis
Otte et al, 2007

5,1
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3,4
6,8

MCL: Medial Collateral Ligament
ACL: Anterior Cruciate Ligament
PCL: Posterior Cruciate Ligament
LCL: Lateral Collateral Ligament

LCL
MCL
PCL
ACL

Instrumentation

☐ Injury Assessment Items

Femur-3 BM — 297 mm
Femur-2 BM — 217 mm
Femur-3 BM — 137 mm

Knee-ACL Elongation
Knee-PCL Elongation
Knee-LCL Elongation
Knee-MCL Elongation

Upper end of tibia

Tibia-1 BM — 134 mm
Tibia-2 BM — 214 mm
Femur-3 BM — 294 mm
Femur-4 BM — 374 mm

BM: Bending Moment

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2. History of Flex-PLI Development (Overview), contd.

- The Flex-GTR had been developed based on the discussions with the Flex-TEG members.
- Detailed information on discussions and achievements of the Flex-TEG regarding
  - **Biofidelity**
  - **Performance/Injury Criteria**
  - **Benefit**
  - **Durability**
  - **Reproducibility and Repeatability**
  - **Vehicle Countermeasures**

  of Flex-PLI are provided by another document.

Thank you for your attention!