KTH ROYAL INSTITUTE
OF TECHNOLOGY

Dangers of CRS misuse in Car Crashes

A biomechanical analysis of head and neck injuries using PIPER child Human Body Model

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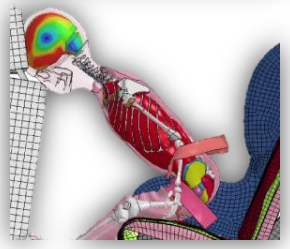
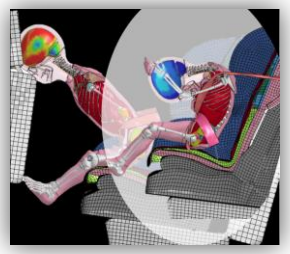
SAFER seminar: Child Occupant Protection | Göteborg | Sep 4th 2019

Outline

- PIPER Model & Validation



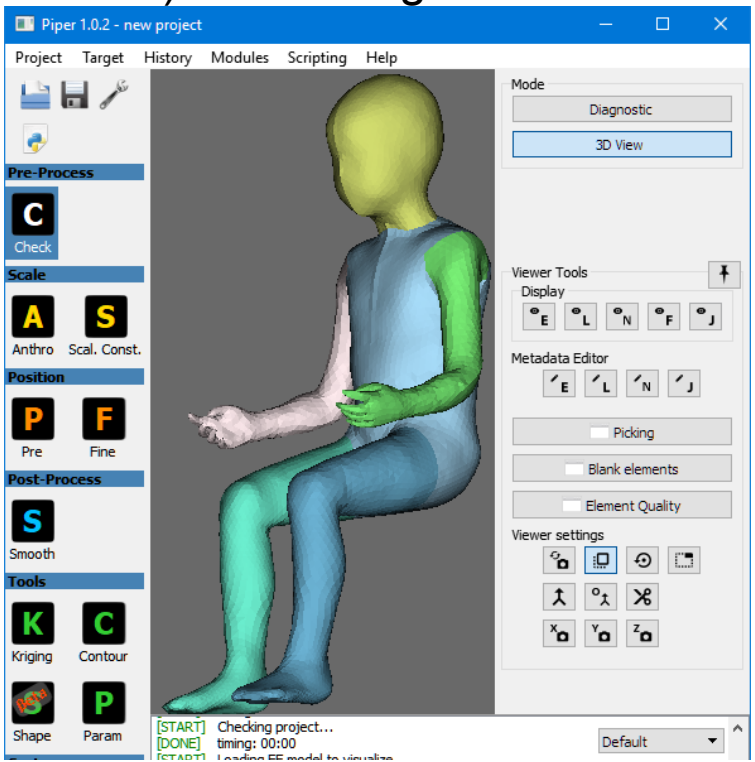
- Performance in Accident Reconstruction
- CRS Misuse Simulation



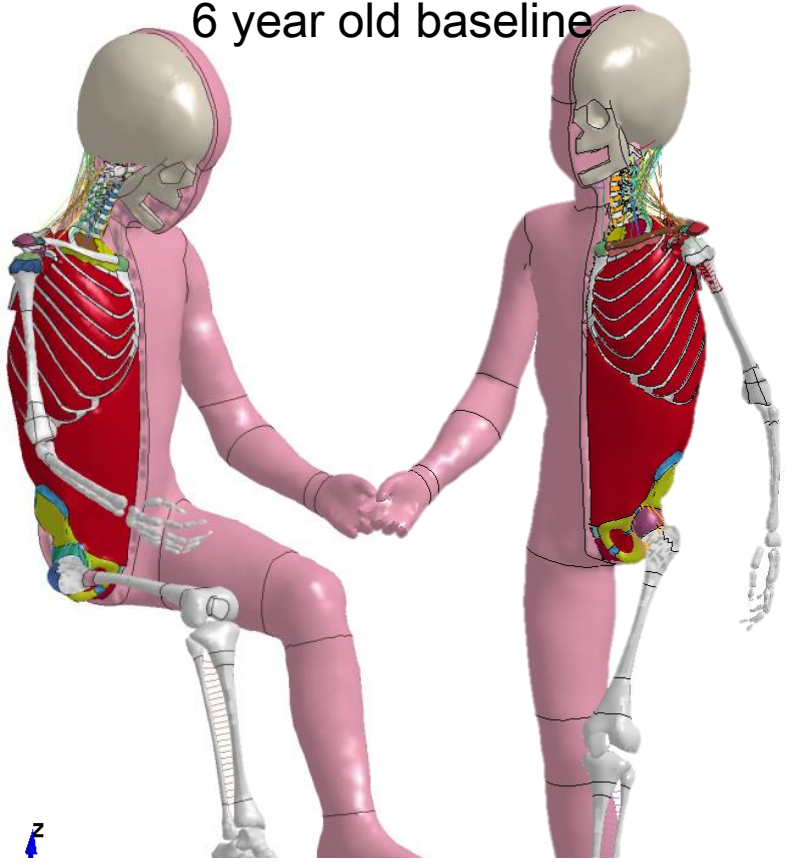
- Biomechanical Visualization for CRS Intervention

PIPER Tool & Child Model

Personalization (child: growth, adult: BMI, local dim....) Positioning

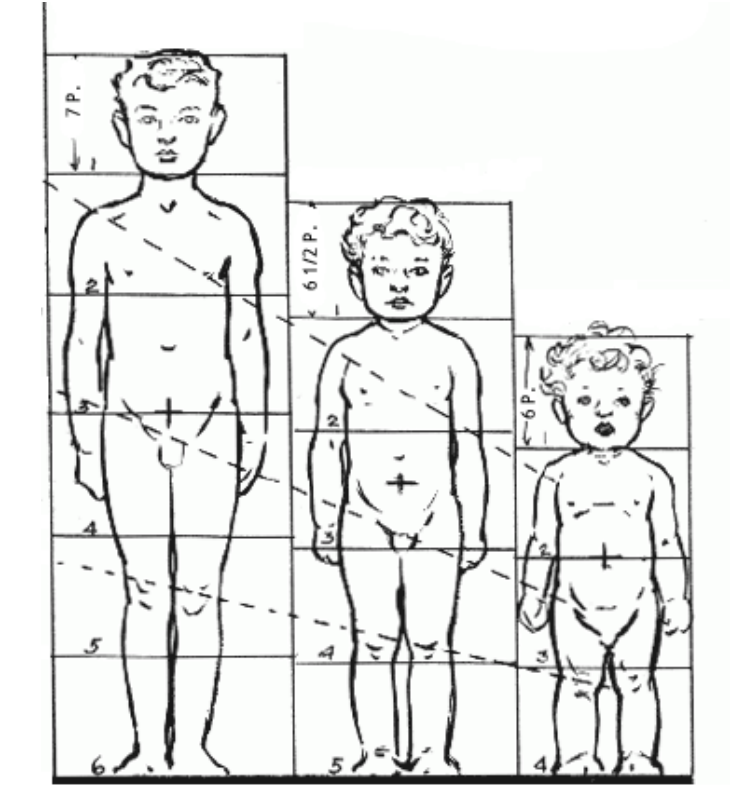


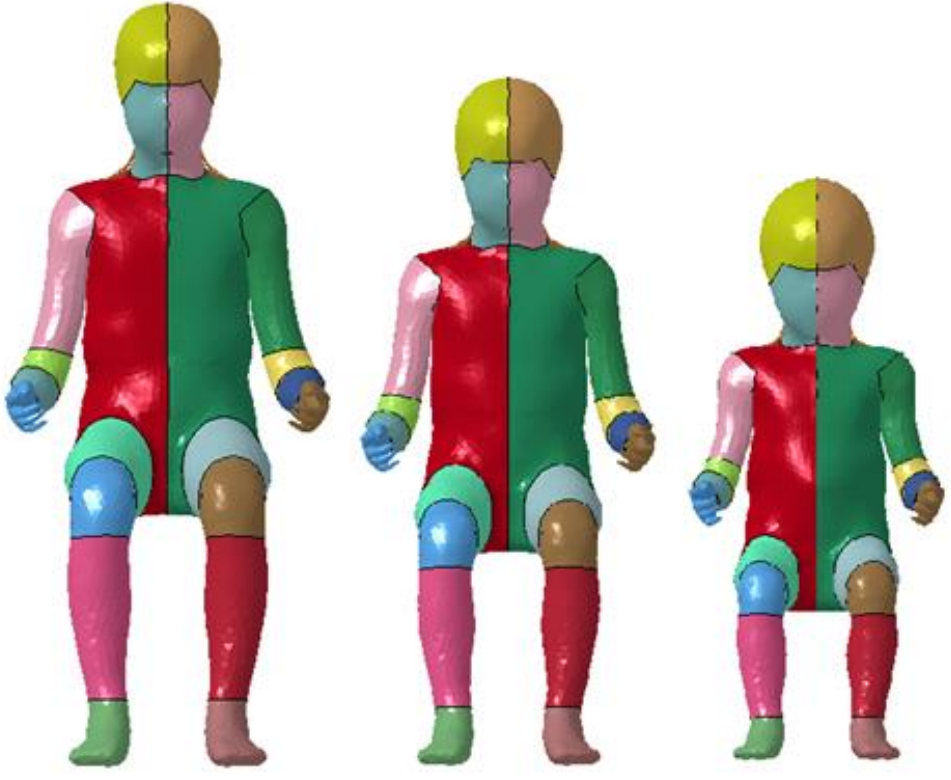
6 year old baseline



Scaling/Age Changes

The PIPER scalable human body model is continuously scalable in the range 1.5 - 6 (12) y.o. using Kriging

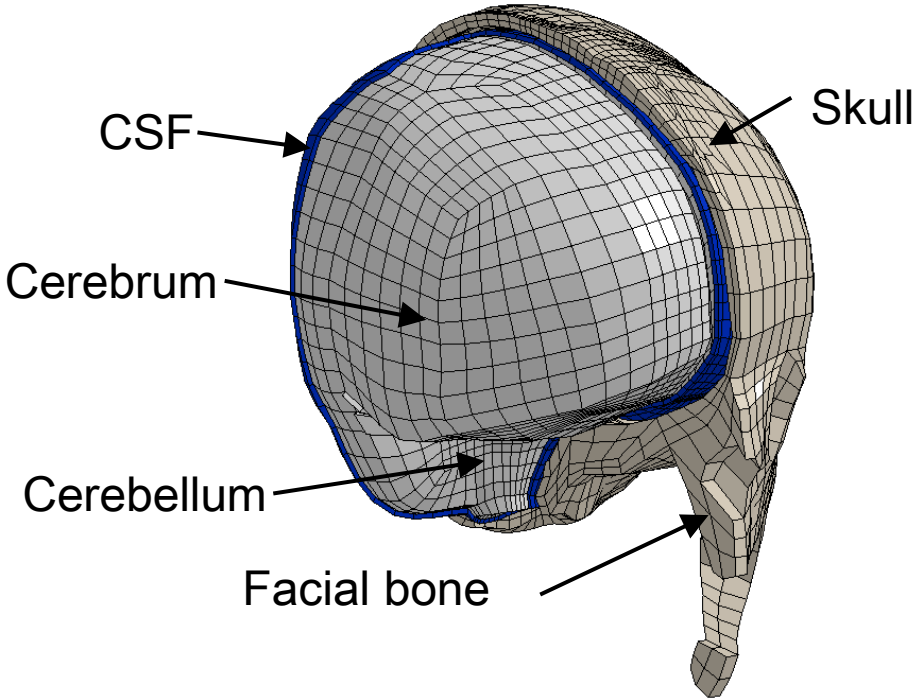


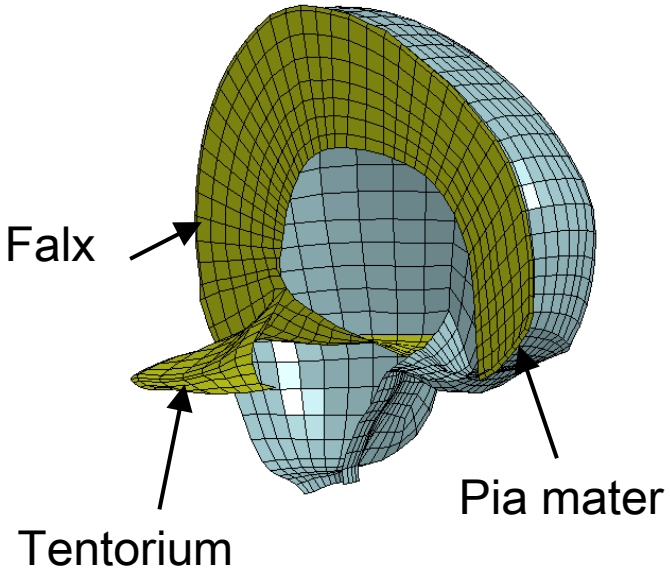


PIPER Head Model

Improvement

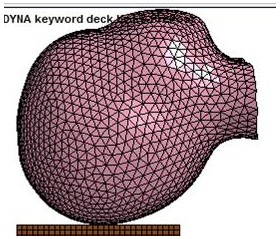
- Mesh: tentorium, porous bone
- Material model: dura, pia, scalp



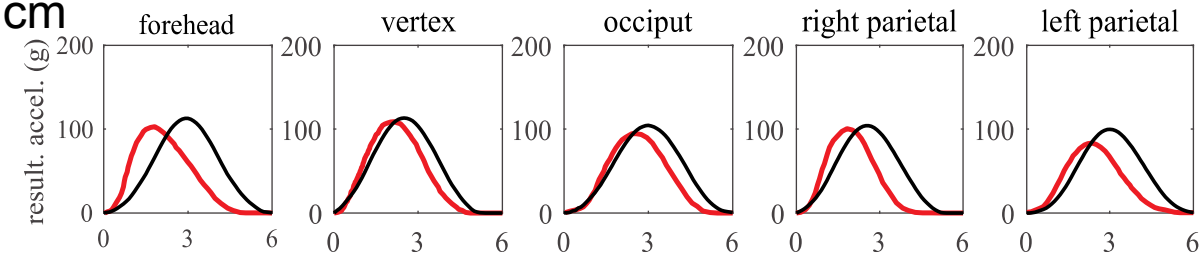


Valiation: Global Response

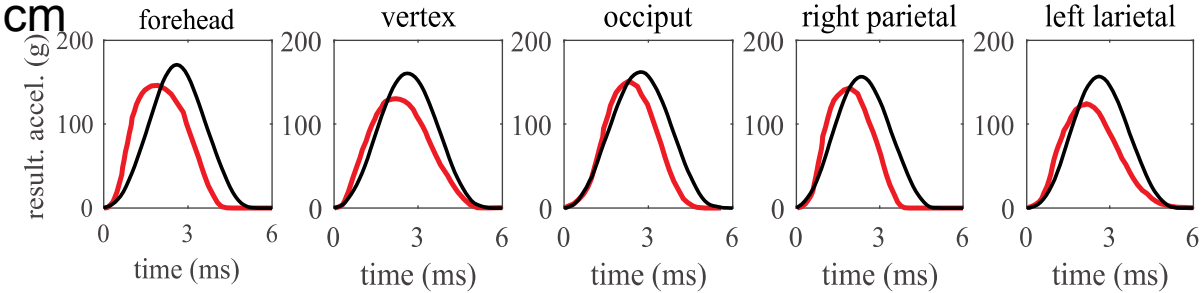
Impact and compression
Loyd (2011)

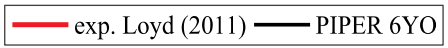


15 cm



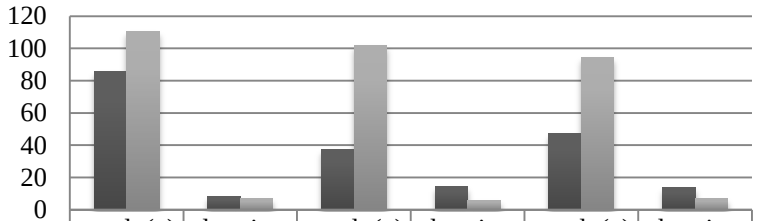
30 cm





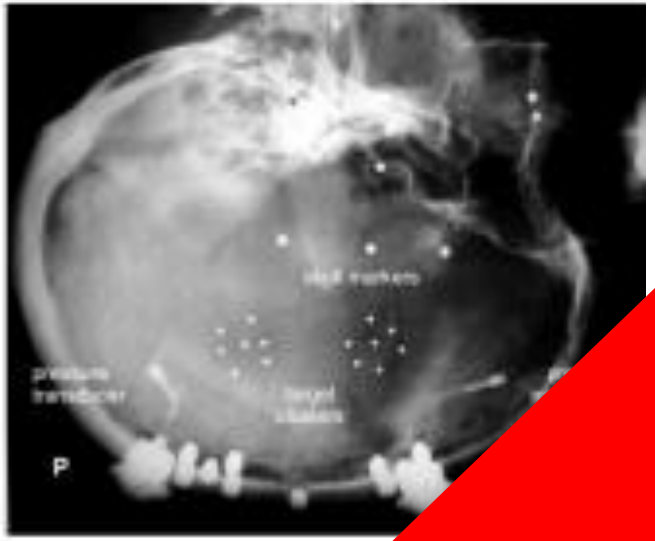
6YO head validation

1.5YO head validation



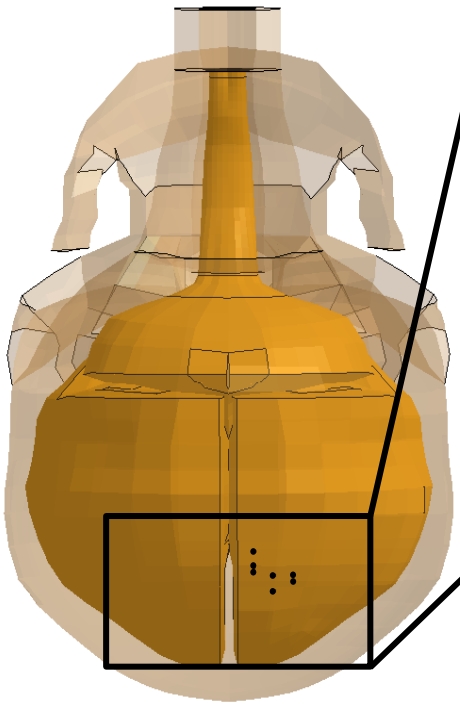
	forehead		occiput		vertex	
	accel. (g)	duration	accel. (g)	duration	accel. (g)	duration
exp. Loyd (2011)	85.6	8.2	37.6	14.2	47.2	13.6
PIPER 18M	110.6	6.8	101.9	6	94.4	6.9

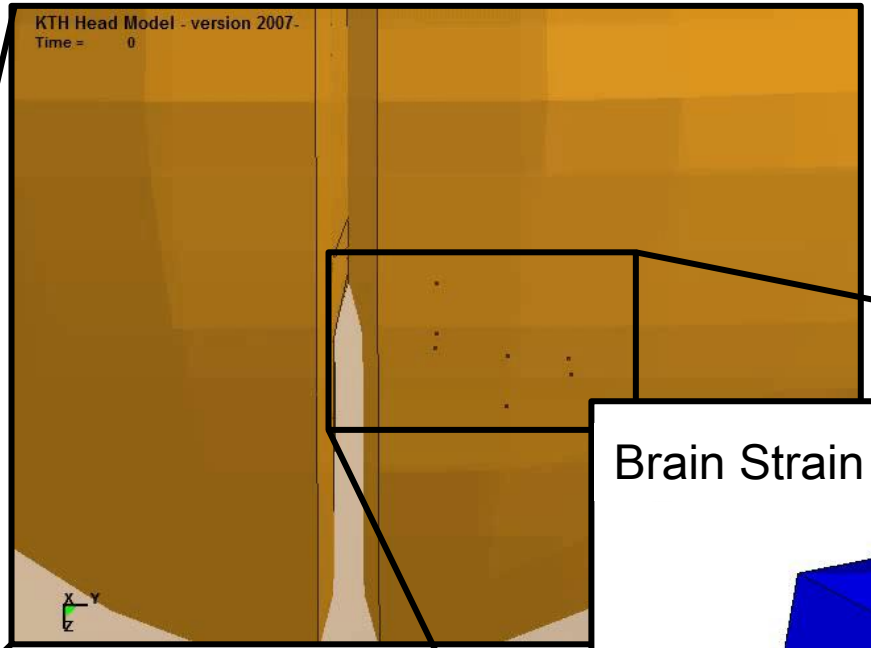
Validation: Brain-Skull Relative Motion

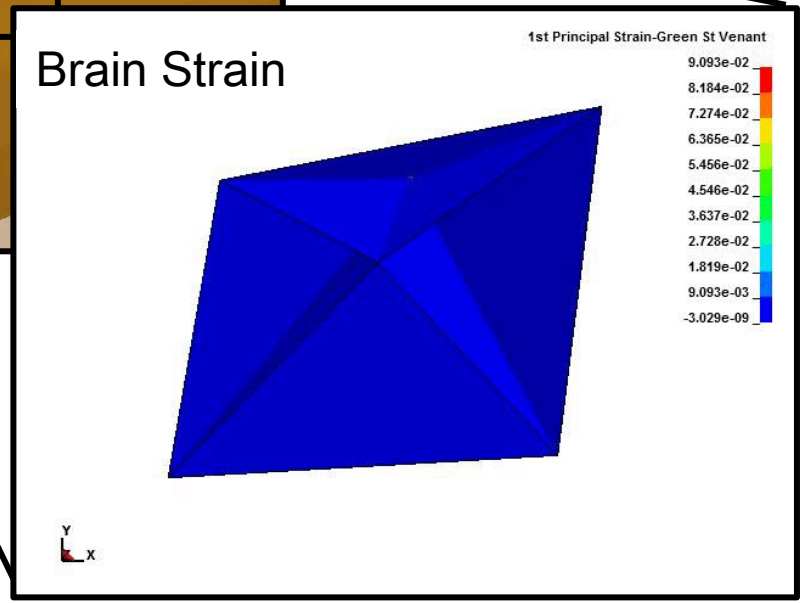


Hardy et al. (2007)

Brain-Skull Relative Motion

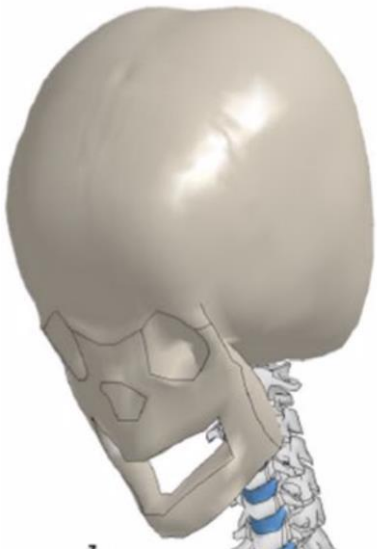




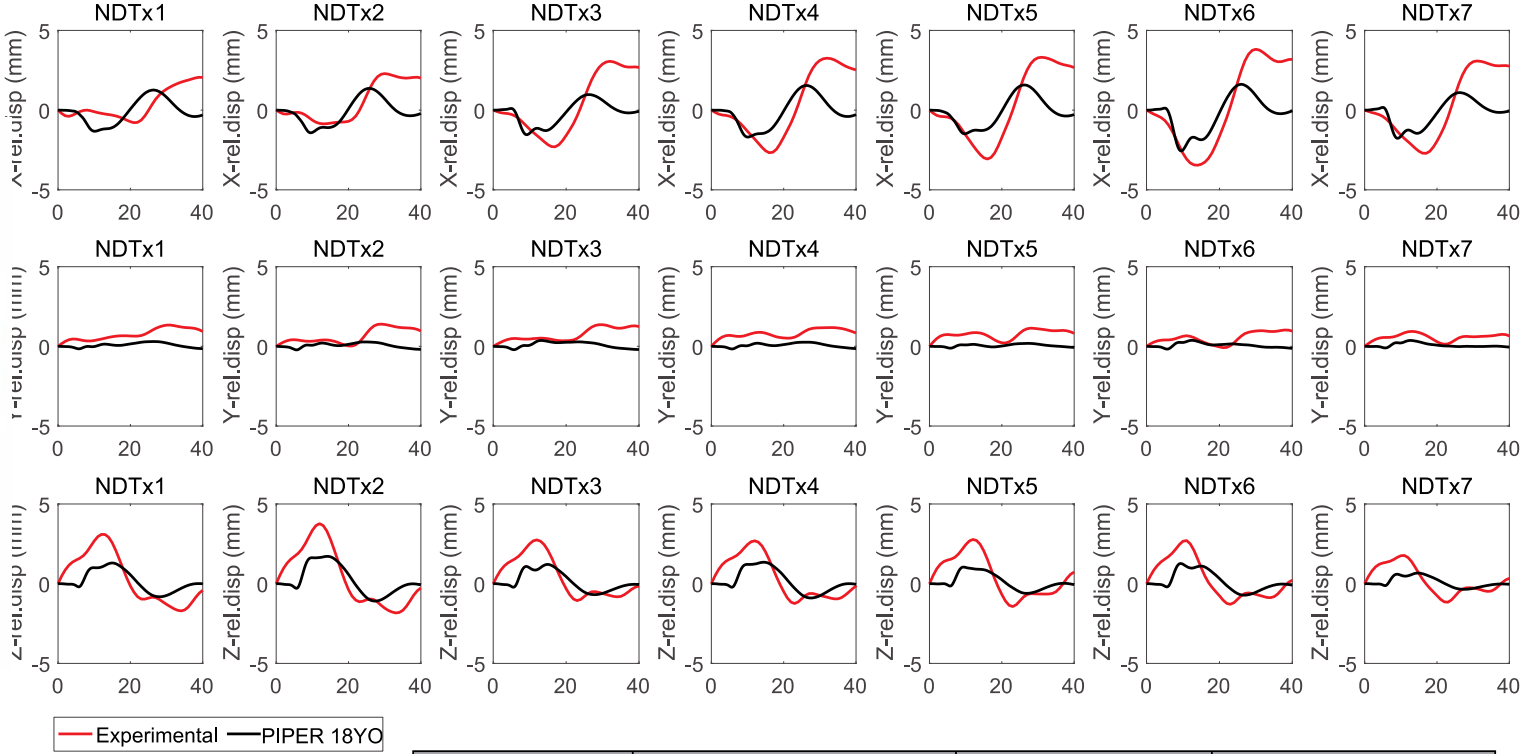


Courtesy of Zhou Zhou

Validation: Brain-Skull Relative Motion



18YO head



C288-T3 C1

Age	Test	R_NISE	R_CORA
18YO	C288-T3	7.82	5.27
	C380-T4	8.62	6.93
	C380-T5	7.95	5.85

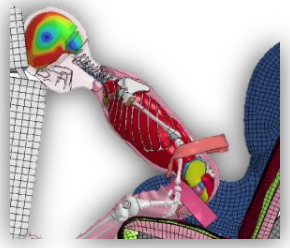
Li X, Kleiven S (2018). Sci Rep 8:15061.

Validation Matrix: Full Body

Published Study	ROI	Dir	Impactor/loading	Subjects and ages		Target model
Loyd (2011)	Head	Regional	Drop test (dyn)	PMHS	9, 1.5	6, 1.5
Loyd (2011)	Head	Regional	Compression (dyn)	PMHS	9	6
Ouyang et al. (2005)	Neck	Regional	Bending + tensile	PMHS	6	6
Luck et al. (2008)	Neck	Regional	Tensile	PMHS	6	6
EEVC Q (2008)	Shoulder	Side	Pendulum, free back (dyn) Scaled	PMHS	Adult	6, 3
Ouyang et al (2006)	Thorax	Frontal	Pendulum, free back (dyn)	PMHS	various	6, 3, 1.5
Kent et al (2011)	Thorax	Frontal	Belt distributed, fixed back (dyn)	PMHS	6 & 7	6
Kent et al (2011)	Thorax	Frontal	Belt diagonal, fixed back (dyn)	PMHS	6 & 7	6
EEVC Q (2008)	Abdo	Frontal	Belt, fixed back Scaled corr.	Porcine	6	6
Kent et al (2011)	Abdo	Frontal	Belt mid abdo, fixed back (dyn)	PMHS	6 & 7	6
Kent et al (2011)	Abdo	Frontal	Belt upper abdo, fixed back	PMHS	6 & 7	6
Part 572	Lumbar	Frontal	Torso flexion (static)	HIII	6	6
Ouyang et al (2003a)	Pelvis	Side	Pendulum, free back (dyn)	PMHS	various	6, 3
Ouyang et al. (2003b)	Femur	Regional	Bending test	PMHS		
Wismans et al (1979)	WB neck	Frontal	Sled test, harness (4 YO anthro)	PMHS	6	6
Kallieris et al (1976)	WB	Frontal	Sled test with shield	PMHS	2.5, 6	
Lopez et al (2011)	WB spine	Frontal	Sled test with belt (dyn)	Volunteer		6
Arbogast et al (2009)	WB neck	Frontal	Sled test, 3pt belt	Volunteer	6+	6

Outline

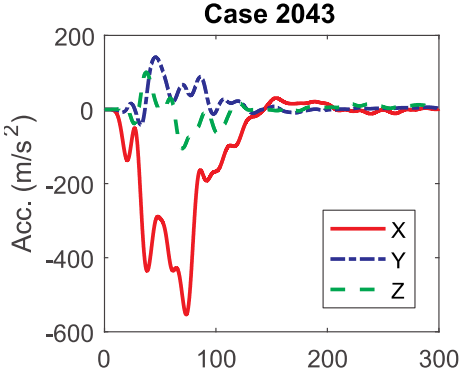
- PIPER Model & Validation



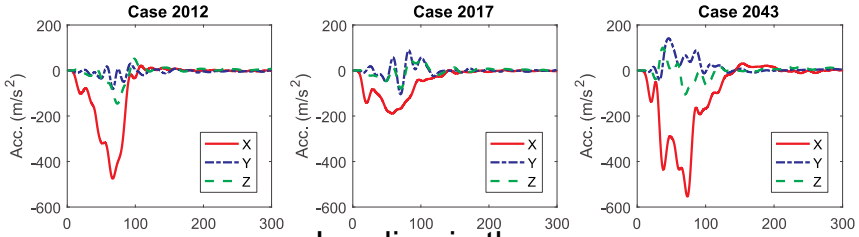
- Performance in Accident Reconstruction
- CRS Misuse Simulation
- Biomechanical Visualization for CRS Intervention

Cases and Physical Reconstruction

Estimated speed: 85 km/h



PIPER Reconstruction



Loading in the rec.

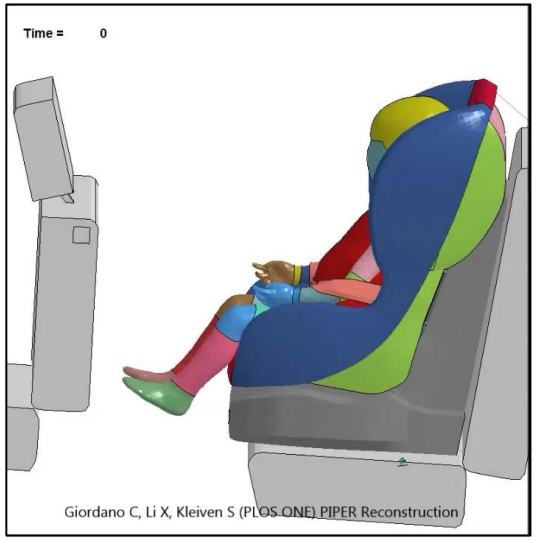
Case 2012
- 26 m.o
- Positioned
- CRS group 1

Case 2017
- 5 y.o.
- Positioned
- CRS group 2 lower booster

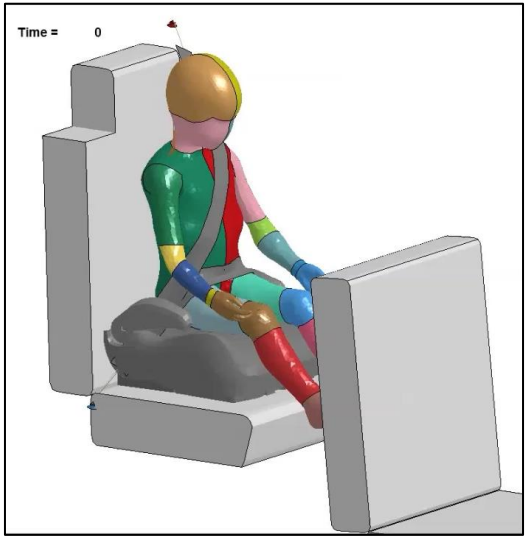
Case 2043
- 5 y.o
- Positioned
- CRS group 2 scaled

Results

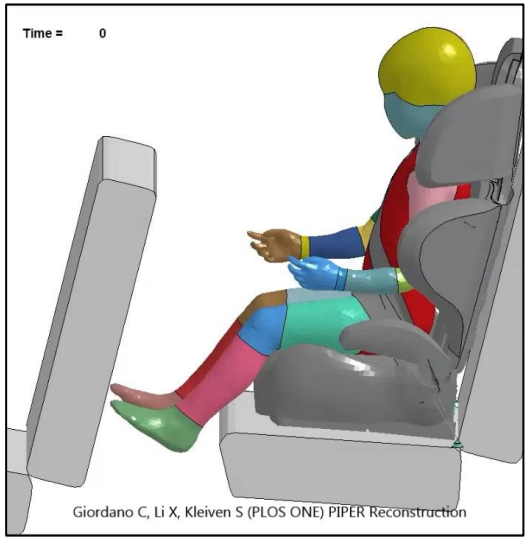
Case 2012

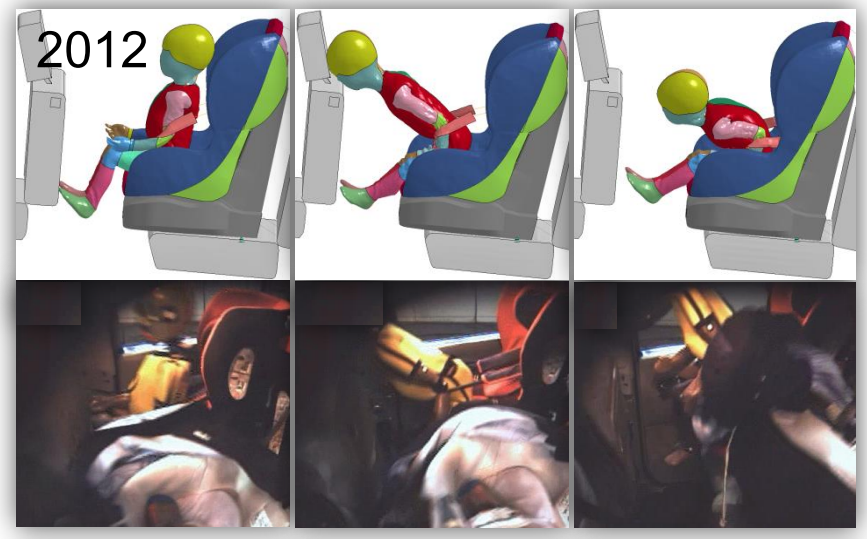


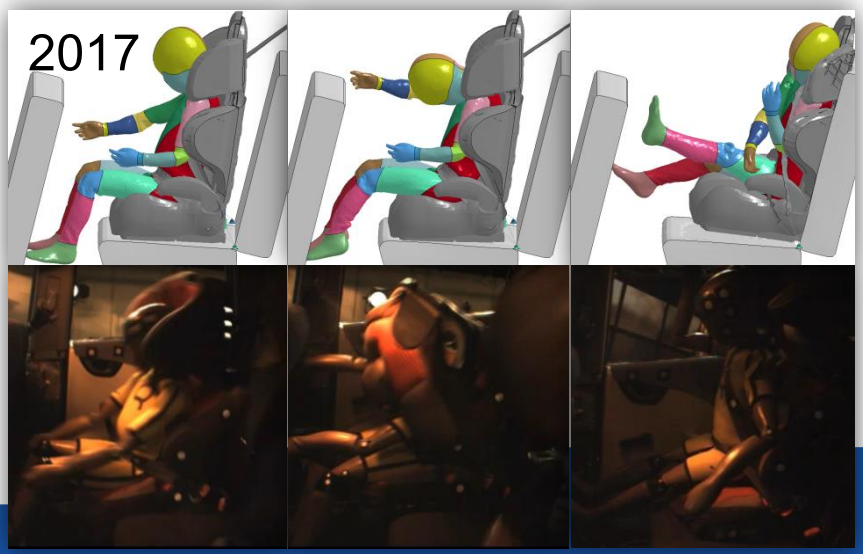
Case 2017



Case 2043

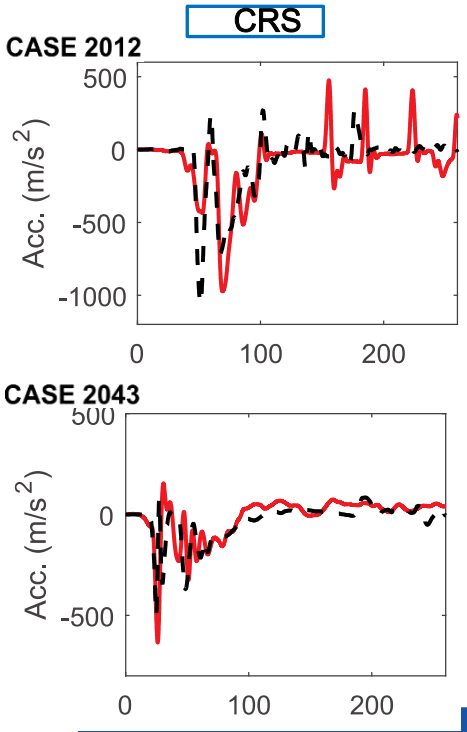


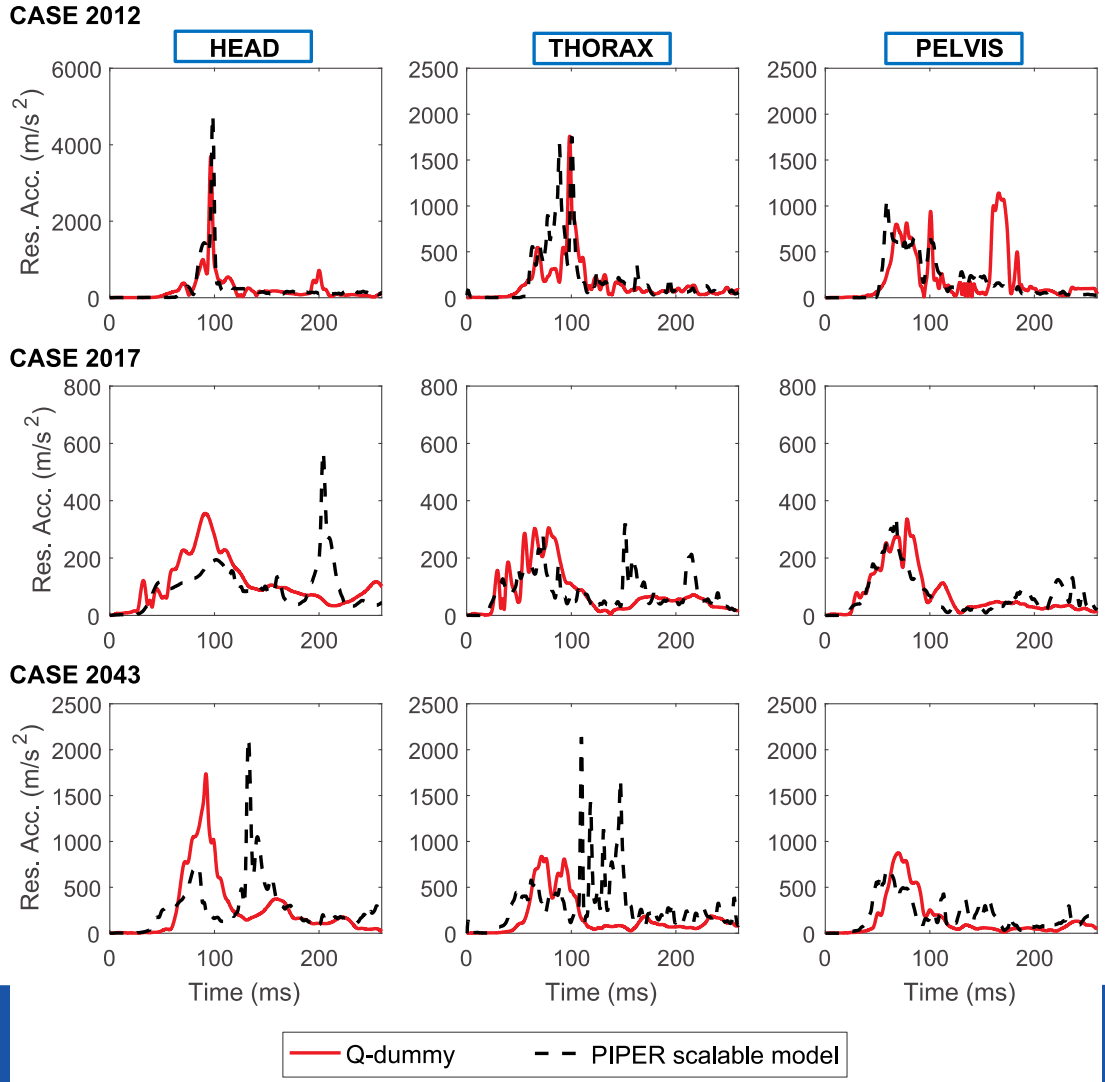

2012


2017

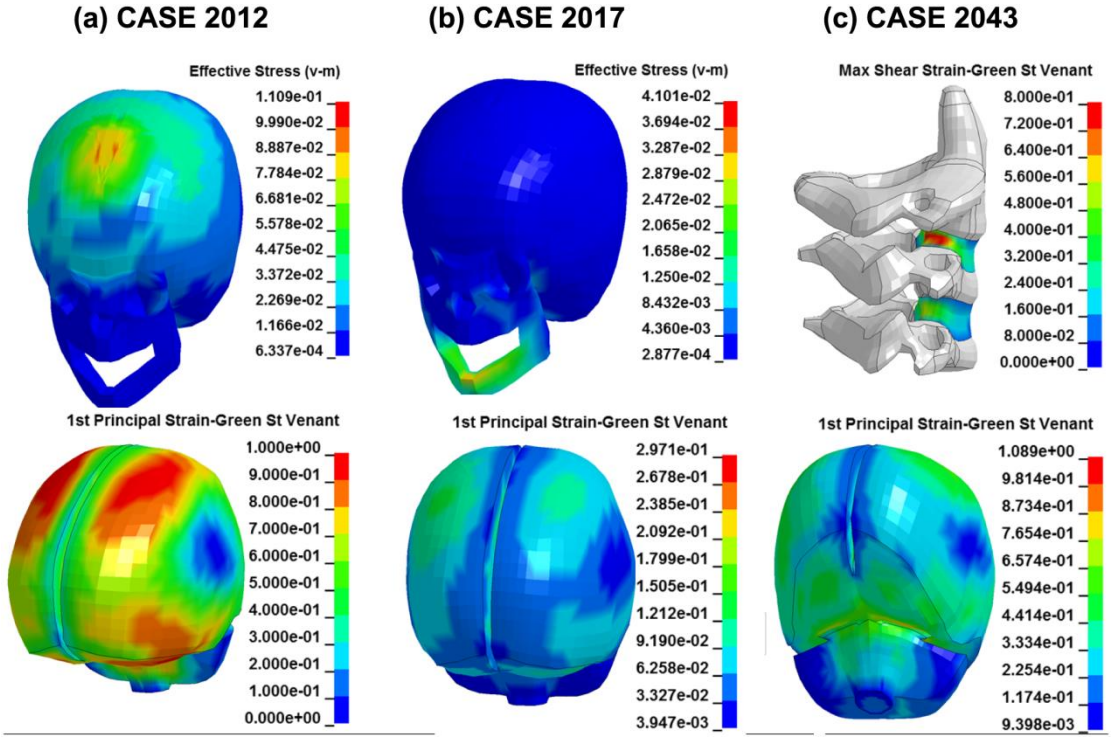

2043

Resultant acce.





Tissue injury evaluation



Skull: von Mises stress
Brain: 1st principal strain
Cervical disk: shear strain

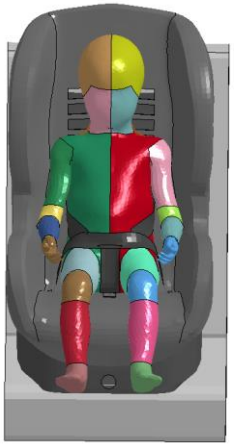
Misuses: Case 2012

No misuse

Harness not at mid-shoulder

Harness attachment too low

Loose harness



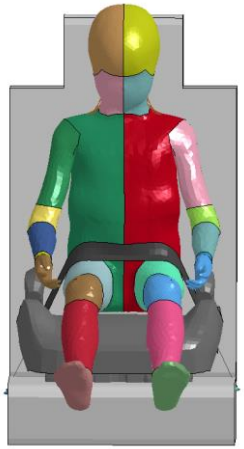
Harness under arms

Harness with chest clip

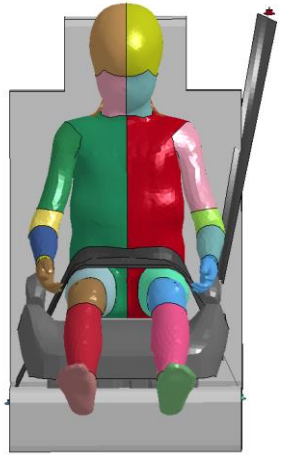
Misuses: Case 2017

No misuse

Shoulder belt not at mid-shoulder

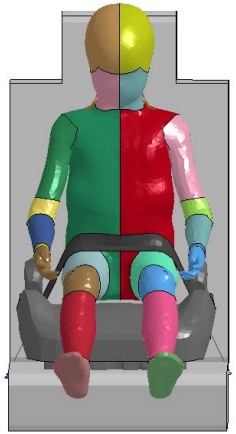


No shoulder belt



Shoulder belt under armrest

Shoulder belt under arm

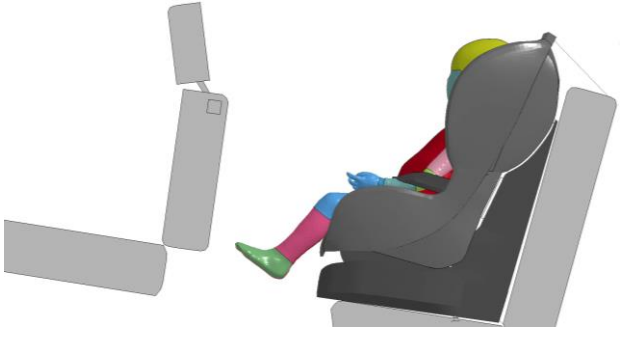


No shoulder belt and no front seat

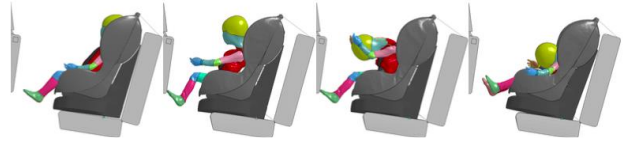
Results Case 2012

Kinematics

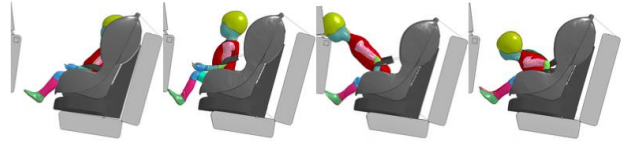
Case 2012 – No misuse



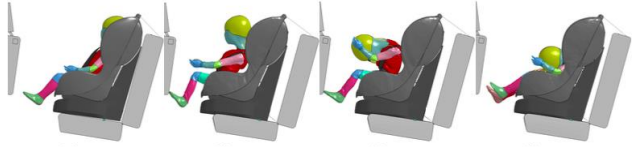
Case 2012 – Harness not at mid-shoulder



No misuse



Harness not at mid-shoulder



Harness attachments too low

Loose harness

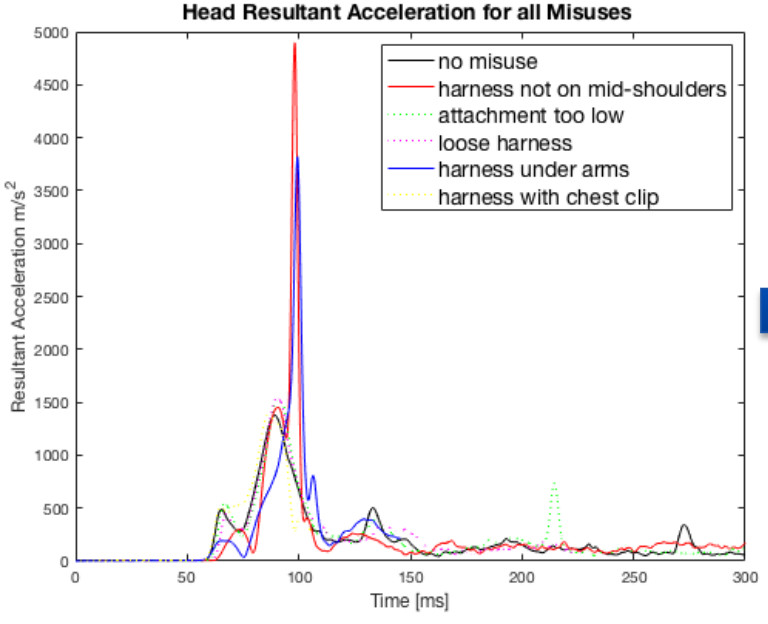
Harness under arms

Harness with chest clip

Beginning Braking Crash Rebound phase

Results Case 2012

Resultant acceleration of the he



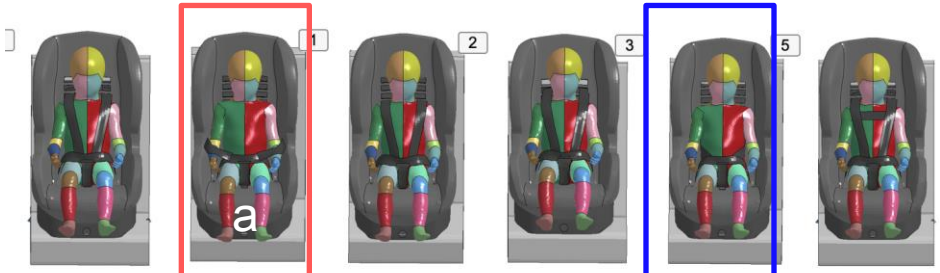
CRS configuration	HIC15
Harness not at mid-shoulder	11270
Harness under arms	7356

Due to:

1. High speed of the car (60km/h)
2. Head impacts with front seat

Results Case 2012

Upper neck z force



No misuse

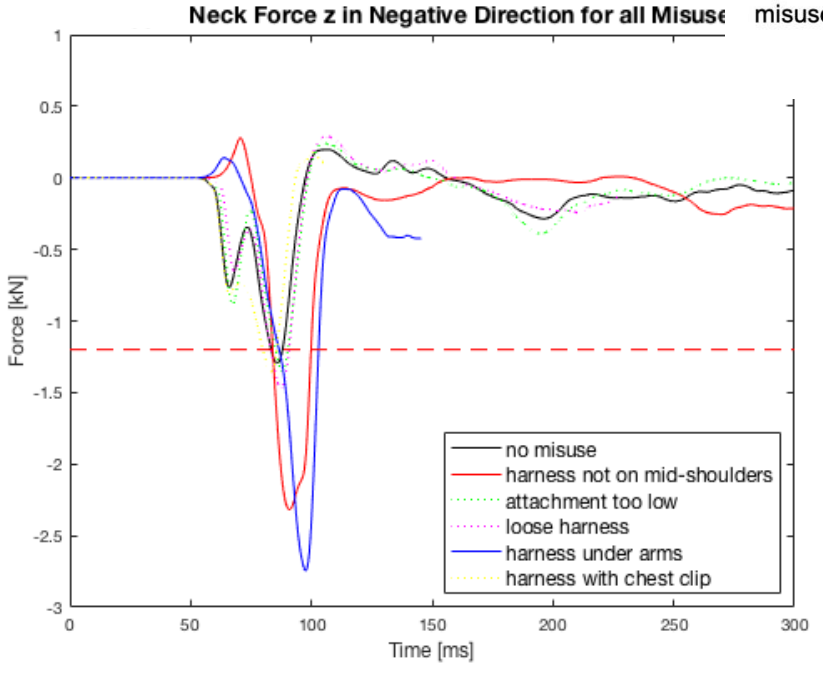
Harness not at mid-shoulder

Harness attachment too low

Loose harness

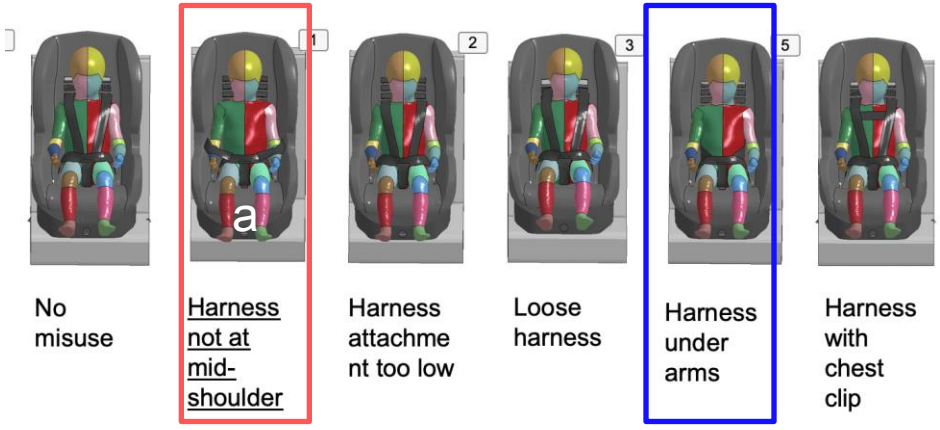
Harness under arms

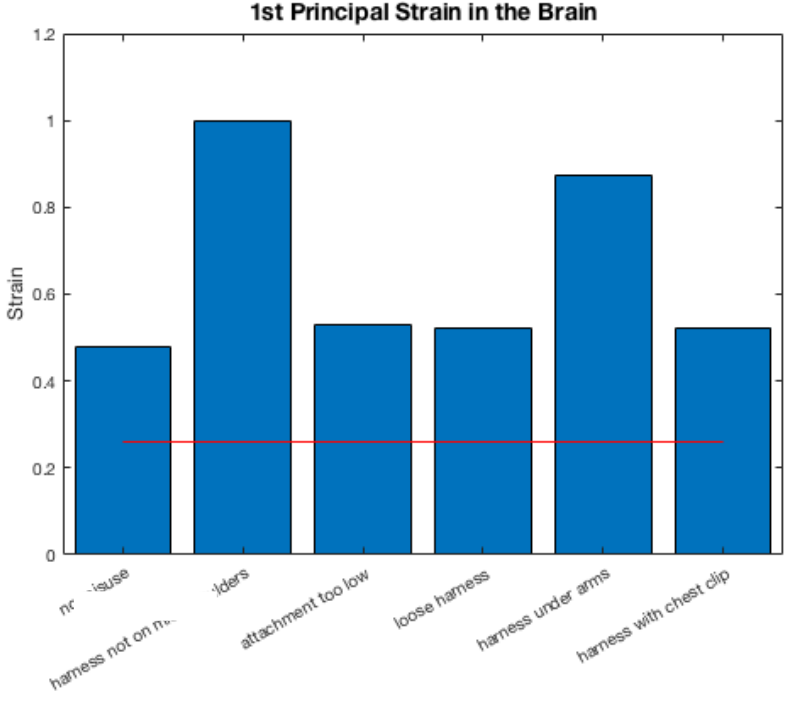
Harness with chest clip

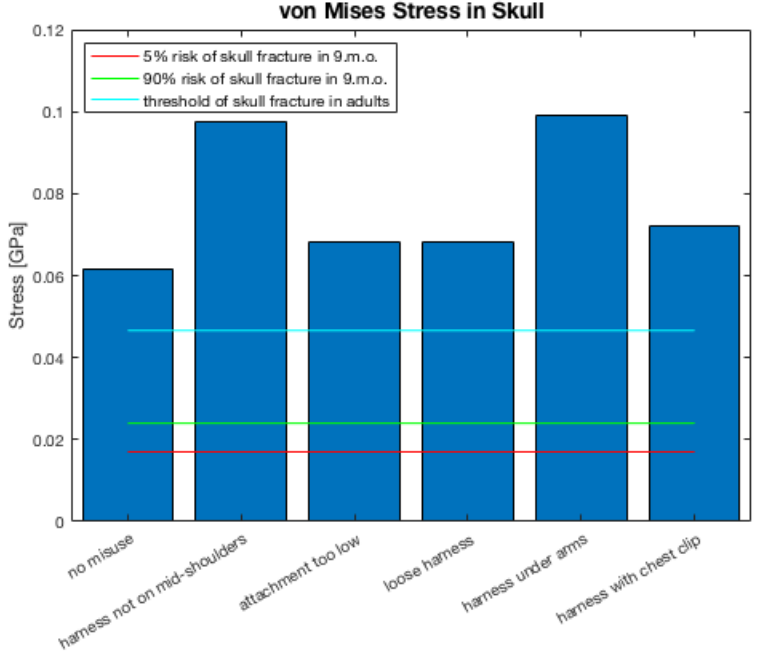


Results Case 2012

Brain strain & skull stress





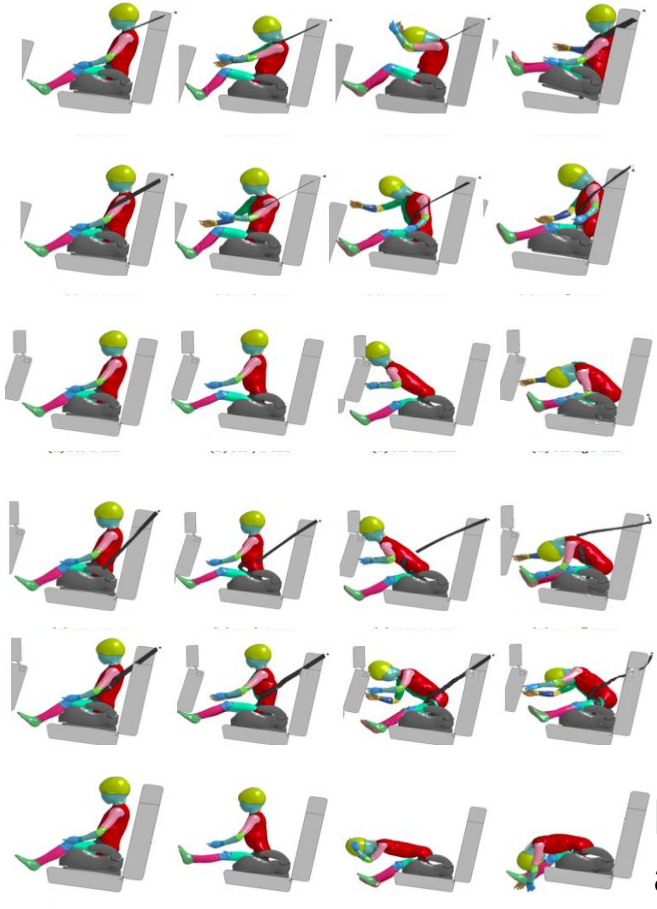


Results Case 2017

Kinetics

Case 2017 – No misuse

Case 2017 – No shoulder belt



No misuse

Shoulder belt not at mid-shoulder

No shoulder belt

Shoulder belt under armrest

Shoulder belt under arm

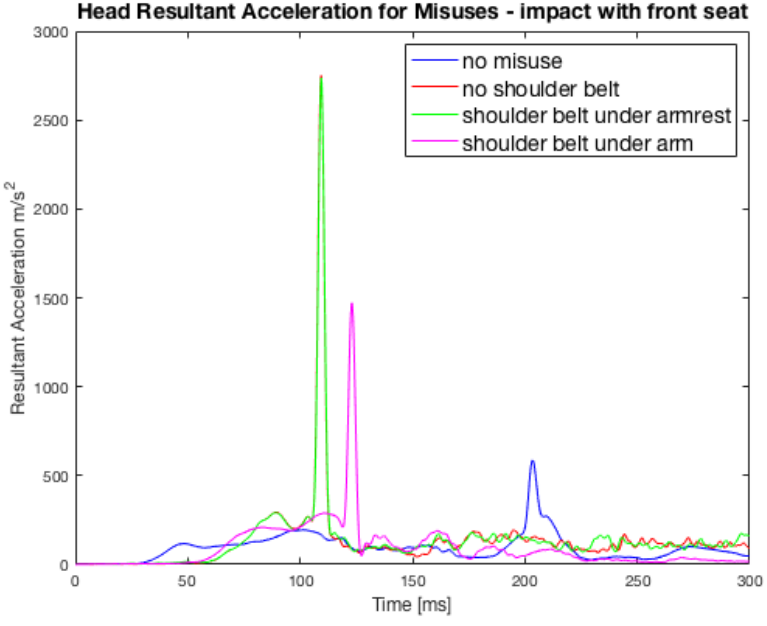
No shoulder belt and no front seat

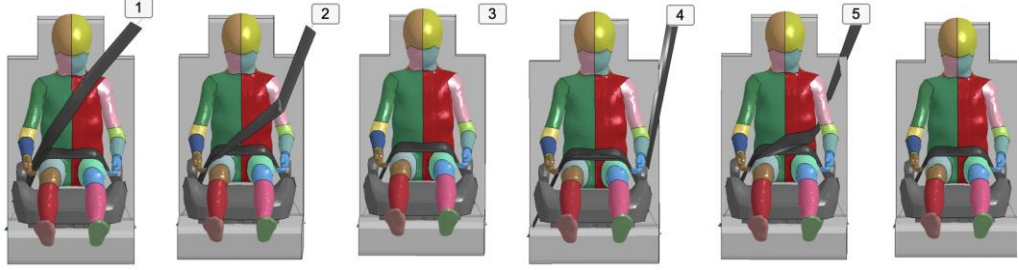
Beginning Braking Crash Rebound phase

Results Case 2017

Resut. Acce. of the head

Resultant acceleration of the head

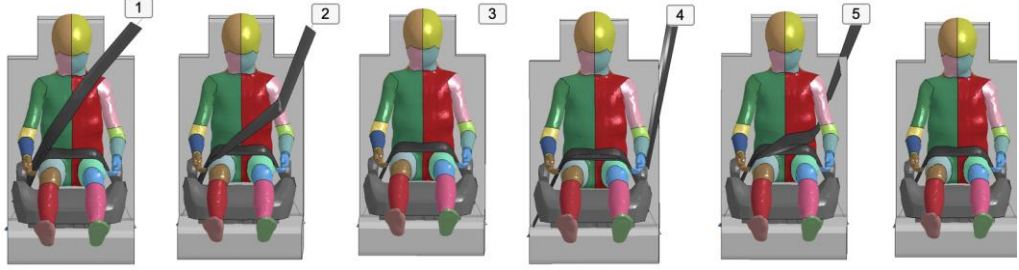




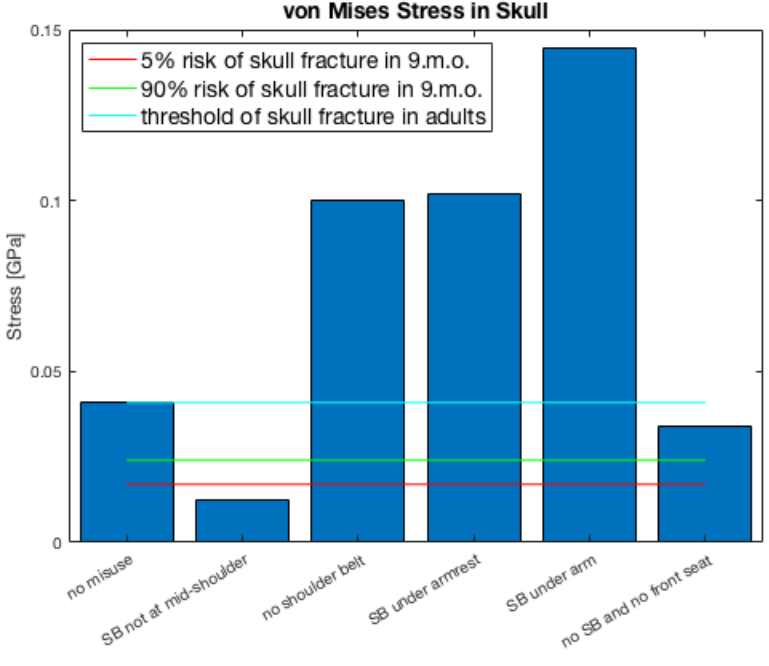
No misuse	Shoulder belt not at mid-shoulder	No shoulder belt	Shoulder belt under armrest	Shoulder belt under arm	No shoulder belt and no front

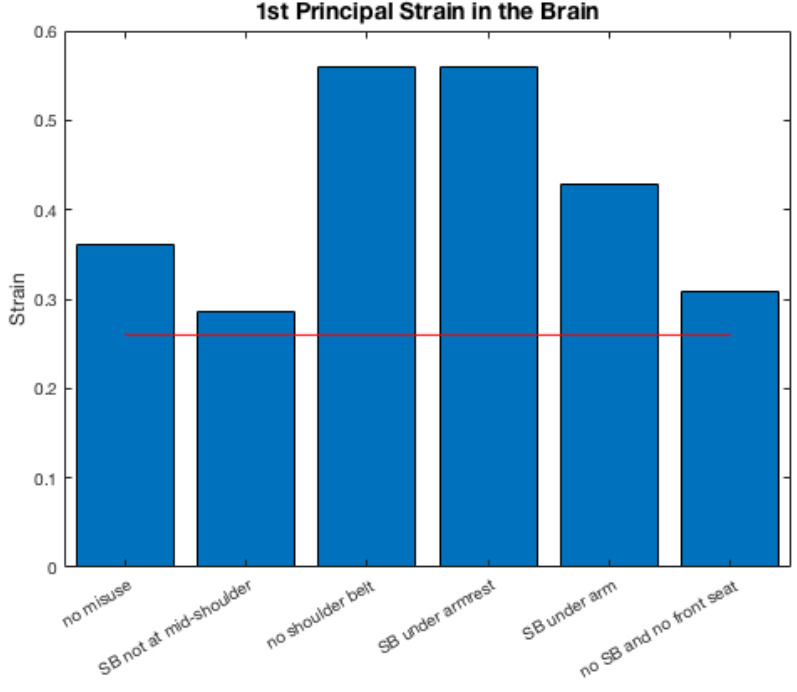
Results Case 2017

Brain strain & skull stress



No misuse	Shoulder belt not at mid-shoulder	No shoulder belt	Shoulder belt under armrest	Shoulder belt under arm	No shoulder belt and no front

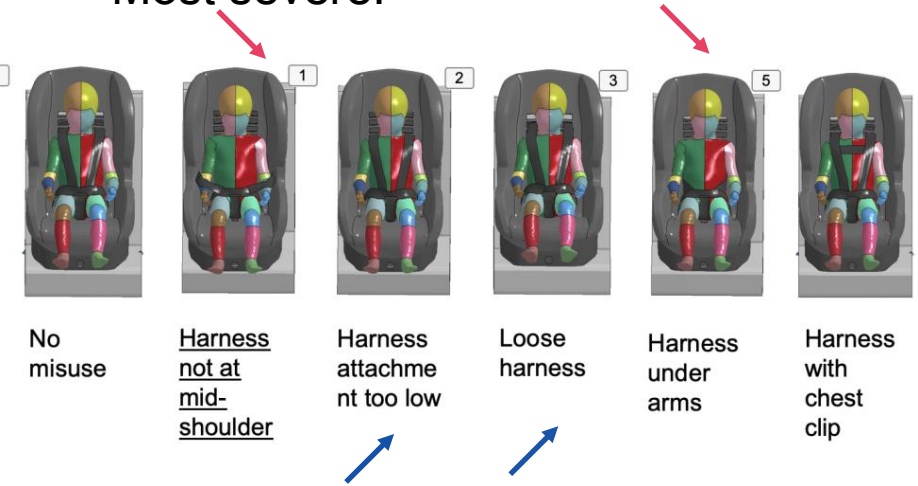




Best and Worst Misuse

Case 2012 – Forward-facing CRS, 2YO

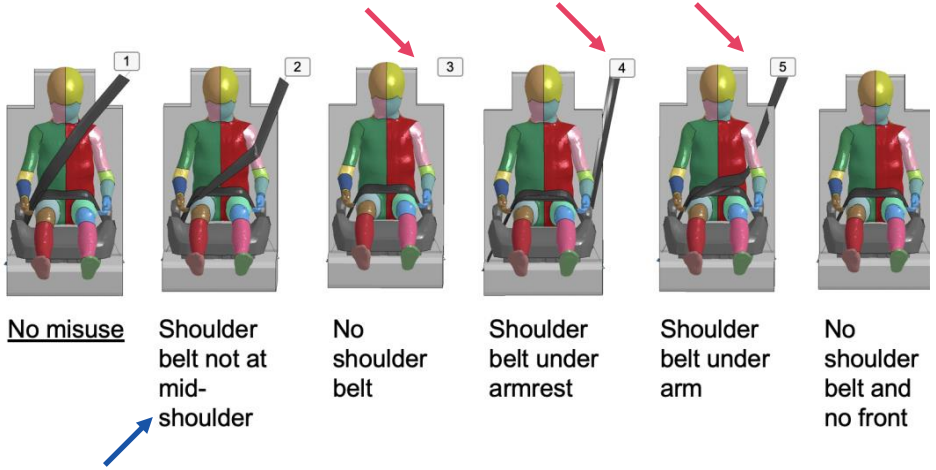
- Most severe:



- Least severe

Case 2017 – Booster seat, 5 YO

- Most severe



- Least severe:

Compare with study using dummies

(Lesire et al. 2007)

Forward-facing CRS:
Loose harness
- Medium risk of head injuries

Harness under arms
- High risk of head injuries
- High risk of abdominal injuries
- Medium risk of neck injuries

	Loose harness	**Harness under arms**
HIC15	23% higher	x3 higher
Abdo. Pres.		x2 higher
Neck z force		26% higher

Comparison btw misuse vs. no misuse

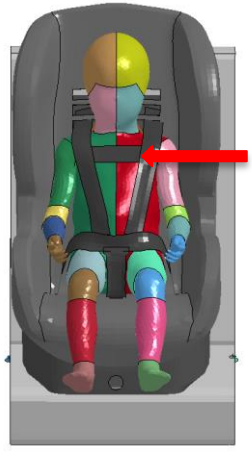
Booster seat:
Shoulder belt behind child's back
Shoulder belt under arm

High risk of head injuries
High risk of abdominal injuries
Low risk of neck injuries

	No shoulder belt	**Shoulder belt under arm**
HIC15	x26 higher	x6 higher
Abdo. Pres.	11% lower	75% higher
Neck z force	x2 higher	x1.5 higher

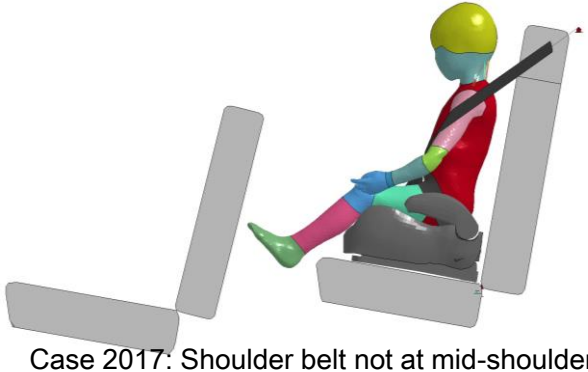
Comparison btw misuse vs. no misuse

Misuse vs No Misuse

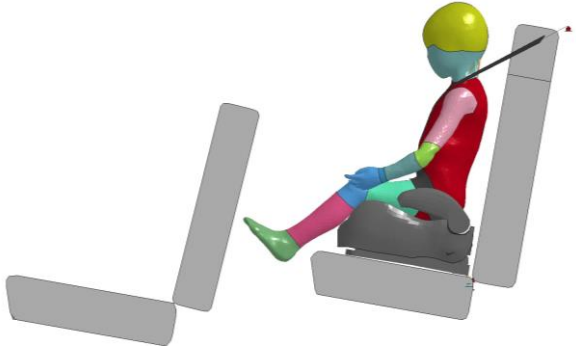


- **Case 2012:** no misuse shows better results than all misuses
- Possible enhancement -> Chest clip

- **Case 2017**: no misuse shows better results than all misuses except one
- Exception: shoulder belt not at mid-shoulder



Case 2017: Shoulder belt not at mid-shoulder



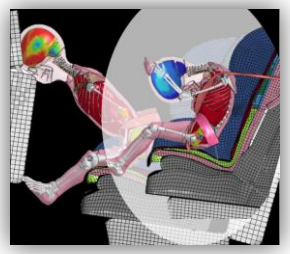
Case 2017: No misuse

Summary of misuse simulations

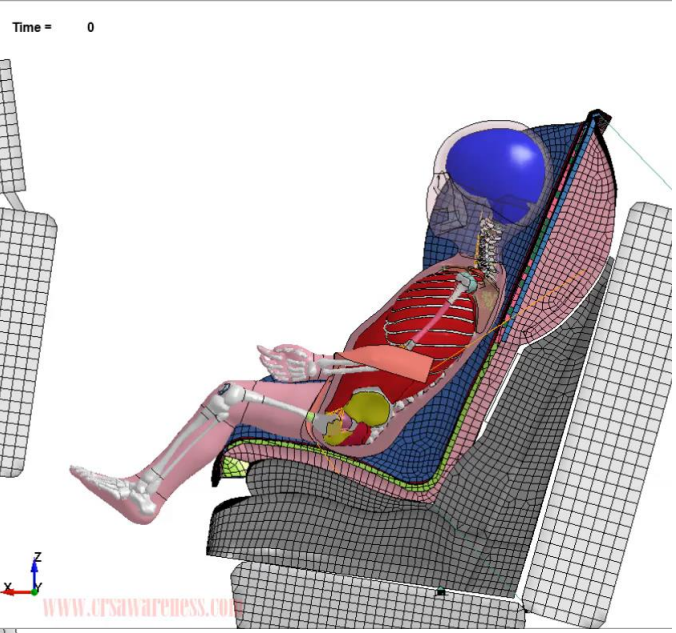
- Correctly routed belt gives better protection (**restraint**)
- PIPER model promising for missuse severity evaluation (as complement to crash dummies)
- Head & neck only, to evlauate injury in other body regions

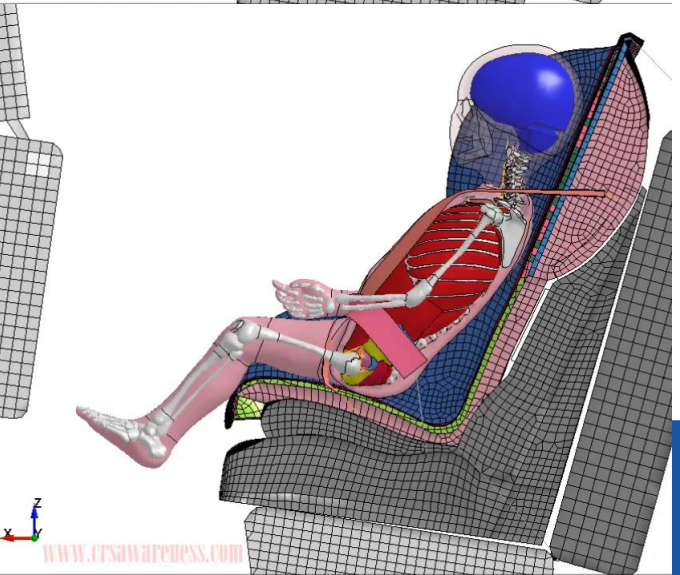
Outline

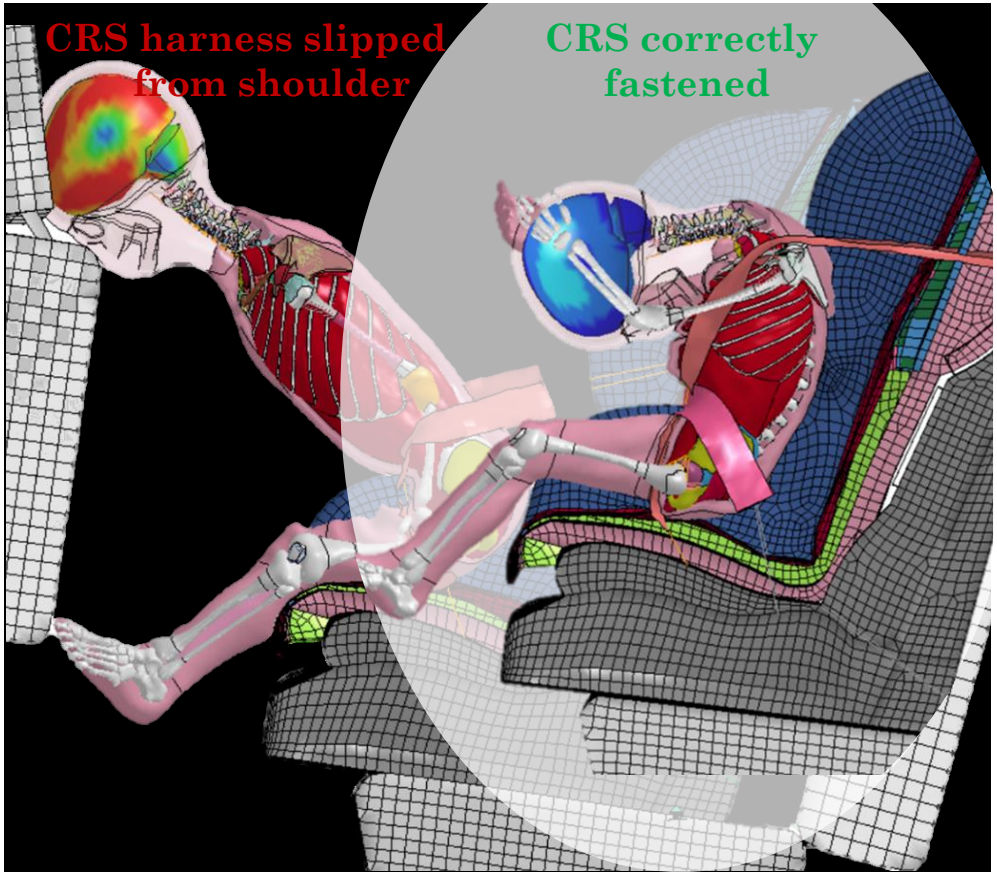
- PIPER Model & Validation
- Performance in Accident Reconstruction
- CRS Misuse Simulation



- Biomechanical Visualization for CRS Intervention







https://www.crsawareness.com/

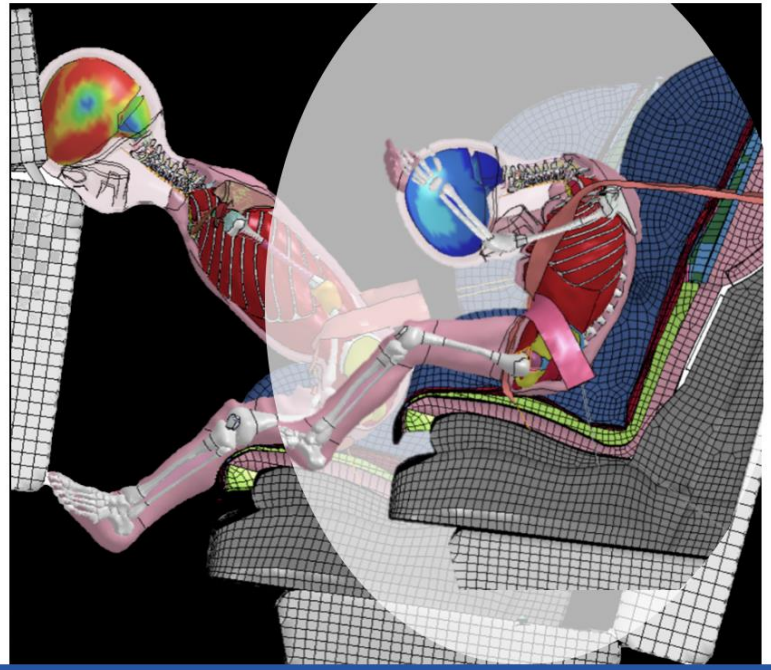
CRS Intervention in China

汕头大学医学院
Shantou University Medical College

KTH ROYAL
INSTITUTE
OF TECHNOLOGY

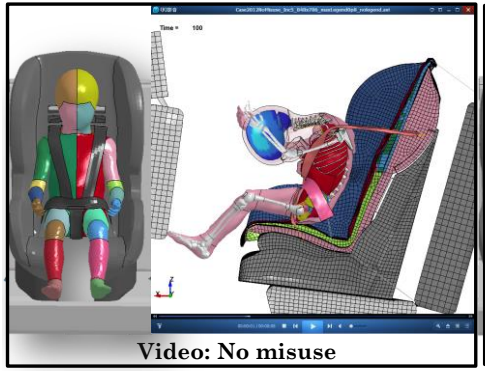
Biomechanical Visualizations as a New Tool for CRS Awareness

A booklet introducing the theoretical background

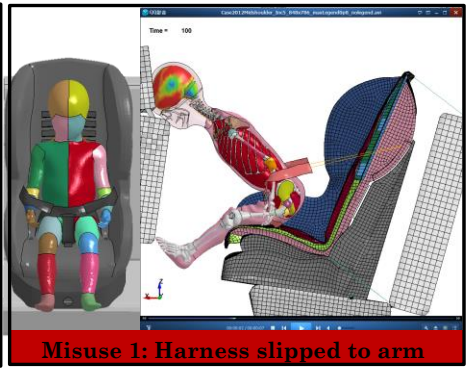


Contact xiaogai@kth.se or sveink@kth.se for any technical questions regarding the booklet

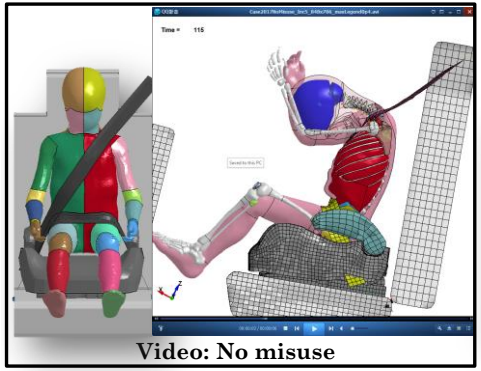
http://crsawareness.com



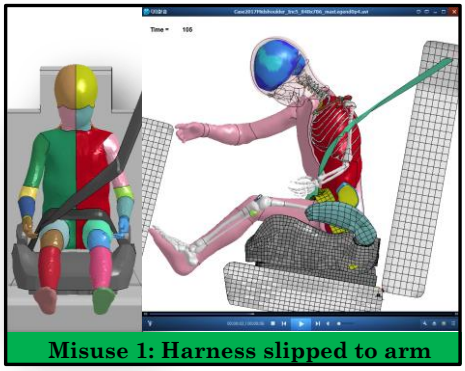
Video: No misuse



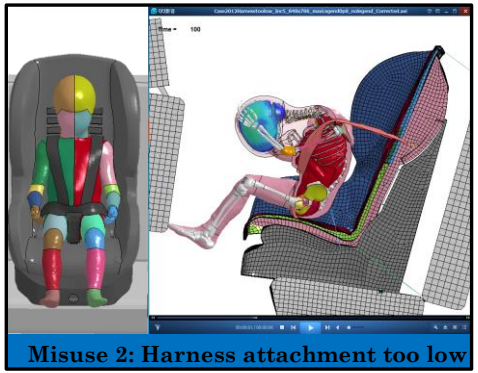
Misuse 1: Harness slipped to arm



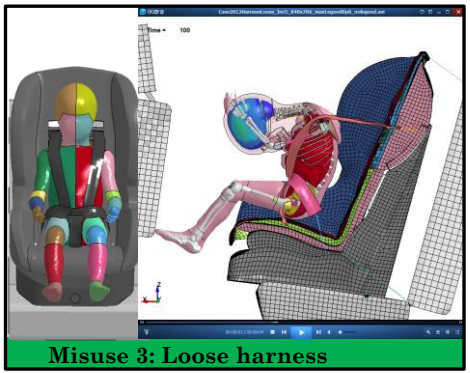
Video: No misuse



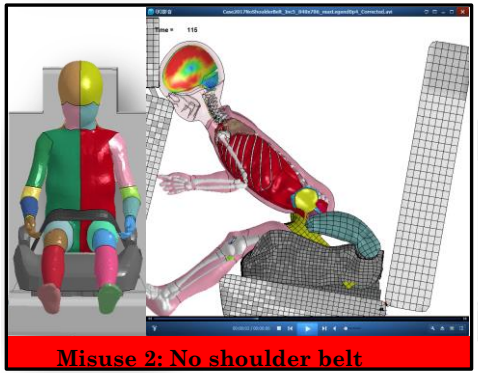
Misuse 1: Harness slipped to arm



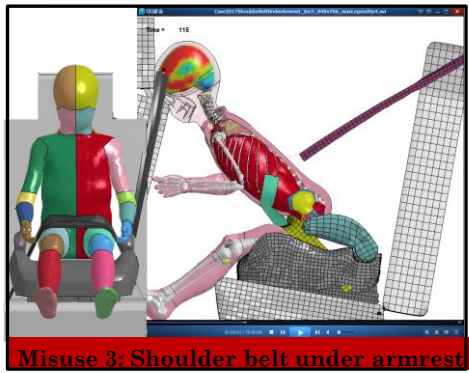
Misuse 2: Harness attachment too low



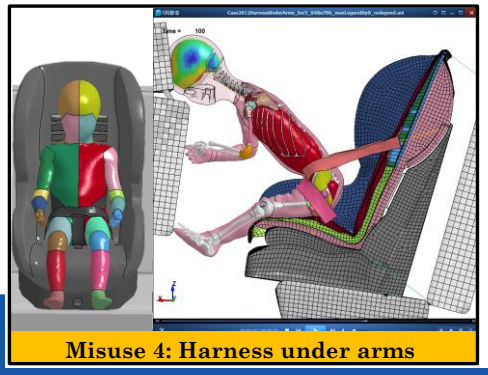
Misuse 3: Loose harness



Misuse 2: No shoulder belt



Misuse 3: Shoulder belt under armrest

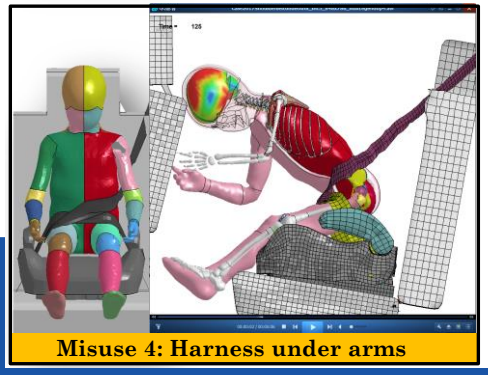


Misuse 4: Harness under arms

Case 2012

Videos produced based on reconstructions of real-world accident Case 2012 presented in *Giordano C, Li X, Kleiven S. (2017) PLOS ONE* and misuse simulations in *Master thesis by Steinunn Jóhannsdóttir.*

Red color represents the most dangerous misuse, and green the least dangerous.



Misuse 4: Harness under arms

Case 2017

Videos produced based on reconstructions of real-world accident Case 2017 presented in *Giordano C, Li X, Kleiven S. (2017) PLOS ONE* and misuse simulations in *Master thesis by Steinunn Jóhannsdóttir.*

Red color represents the most dangerous misuse, and green the least dangerous.

Acknowledgements

PIPER reconstructions

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- Svein Kleiven
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- Heiko Johannsen (MUH)
- Philippe Beillas (IFSTTAR)

CRS Intervention

- Liping Li (SUMC)
- Lotta Jakobsson (VCC)

PIPER

- http://piper-project.org