Version 2020-04-23

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Biomechanical Visualizations as a New Tool for CRS Awareness

A booklet introducing the theoretical background

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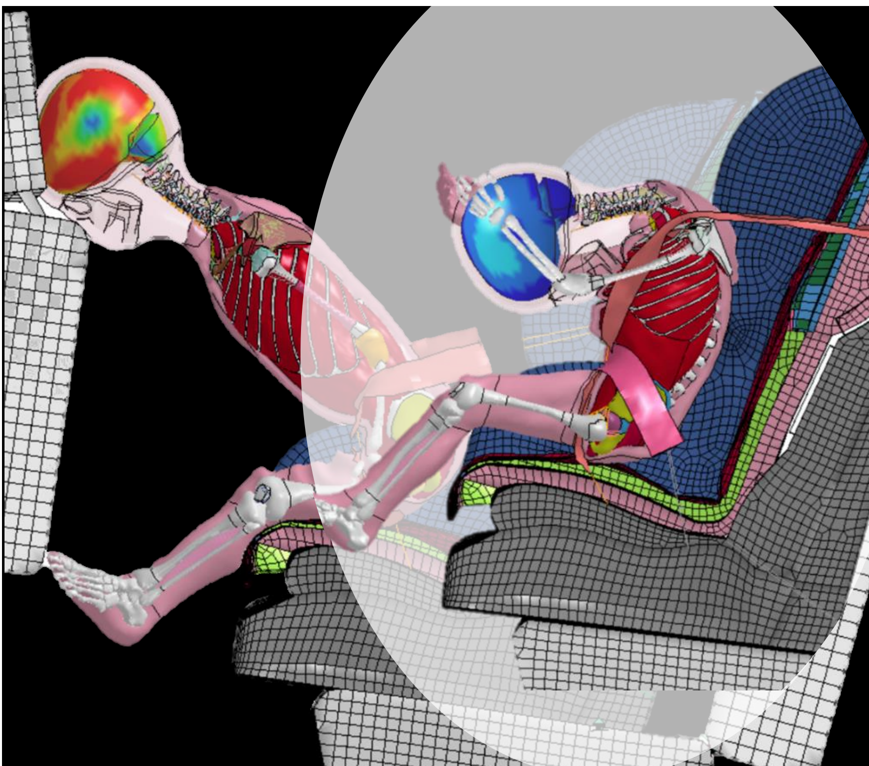


Children need CRS

This booklet introduces Biomechanical Visulizations as a new tool for Child Restraint System (CRS) awareness. With videos generated from scientific studies showing the devasting dangers to the child due to non-CRS usage or misuses, urge parents or caretakers to use CRS use and avoid misuse, thus to better protect children on the road in cars.

The main contents include:

- Biomechanical background of how CRSs on the market are tested and ranked using crash-dummies;
- How advanced human body models of children are emerging as a new tool to complement crash-dummies to evaluate CRS safety
- Biomechanical visualizations generated to reveal the devastating dangers that may pose to the children when nonuse or misuse of CRS occurs.

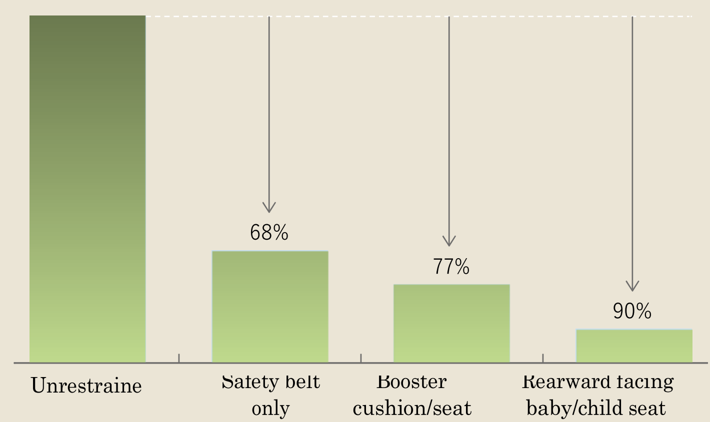
1.

CRS protects children but misuses are common

CRS PROTECTS CHILDREN

Child Restraint Systems (CRSs) can significantly reduce the injury risks in child occupants during vehicle crashes. Studies show appropriate use of CRS can reduce death by 70% than without any restraint[1], and further up to 90% by putting CRSs rear-facing[2, 3]. Despite the indisputable evidence, fatal injuries are still causing tens of thousands of deaths in child occupants every year worldwide, and leaving millions non-fatally injured[1], while most tragedies could have been avoided by appropriate use of CRSs.

Thousands of real-world cases collectd at Volvo database show injury risk decreases by 68% by using safety belt only to and further by 77% with boosters assuming unrestrained with 100% injury risk[4].



INJURY RISKS PER RESTRAINT TYPE

Children aged 0–15 in Volvo cars in Sweden

SOURCE: ADAPTED from VOLVO CARS CHILDREN & CARS SAFETY MANUAL (BASED ON JAKOBSSON ET AL. 2005)

LACK OF AWARENESS

Tremendous research efforts, including field data collection, crash/sled tests using Anthropomorphic Test Devices (ATDs), as well as advanced child human model development, have resulted in safety recommendations of CRS use. Unfortunately, these research results haven't been conveyed sufficiently to the public reflected by a large number of tragedies due to continuous nonuse and misuse of CRSs worldwide[5-7].

The reasons for nonuse or misuse of CRS are multiple, and partially attributed to the **lack of awareness** of the danger and potential injury risks to the children[6-8], or just think of luck due to short travel distance, or simply the child complains not wanting to be restrained. Children being unrestrained are causing the largest sufferings, which could have been avoided by using CRS and further use correctly.

COMMON MISUSE

The effectiveness of CRS protection depends on correct usage. An observational study in Shanghai shows 98% had misuse[9,] and the majority of misuse was severe such as placing the belt behind the arm.

Many on-field studies have identified the most common misuse:
For the age group 0 - 4 years old with five belted CRS:

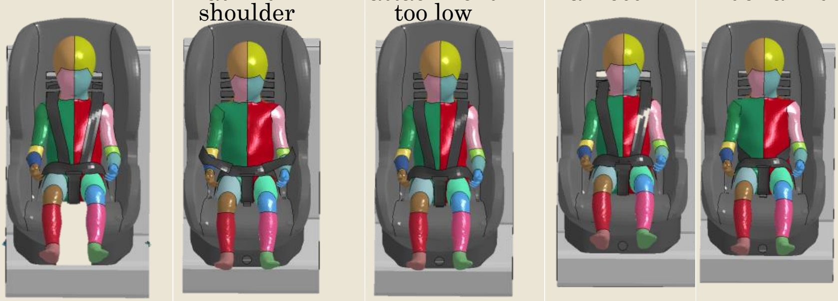
- Harness not at mid-shoulder (i.e., slipped to the arm)
- Harness attachment too low
- Loose harness
- Harness under the arm instead of across the shoulder

For the age group 4 - 10 years old with booster cushion:

- Harness not at mid-shoulder (i.e., slipped to the arm)
- No shoulder belt
- Shoulder belt under the armrest
- Shoulder belt under the arm

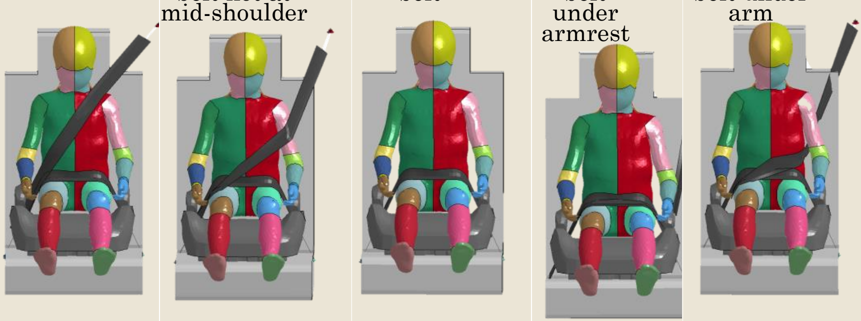
FIVE-POINT CRS: Newborn – 4 YEARS

No misuse	Harness not at mid-shoulder	Harness attachment too low	Loose harness	Harness under arms



BELT-POSITIONING BOOSTERS: 4 – 10 YEARS

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



2.

Crash dummies for CRS testing and ranking

CRS TESTING REGULATIONS

Most CRSs on the market have labels attached indicating what tests have passed. You may also have seen *best car seat in test* with a ranking. The tests and rankings are performed by a variety of organizations, including:

- **ECE R44/04** All car seats that are for sale in Europe have passed this standard.
- **ADAC** Every year the German motoring organization, the ADAC carries out crash tests on many new car seats that are available in Europe.
- **3C** test in China: equivalent to ECE R44/04 in Europe.

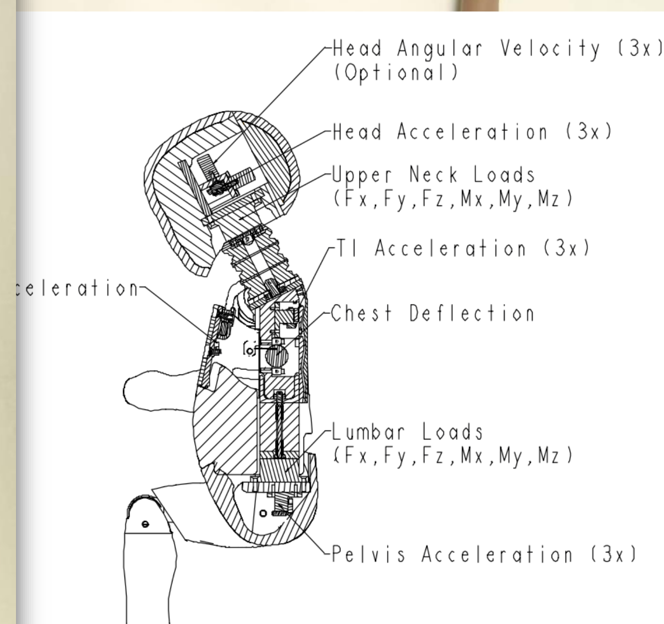
Source: http://www.sohu.com/a/237670336_589138

CRASH-DUMMIES FOR CRS TESTING & RANKING

In all tests, crash dummies, especially the latest dummies called Q-dummies[10-12] are used as a substitute to a child in the crash testing to evaluate the protection of CRSs.

The dummies are embedded with sensors to measure the kinetics during the impact[10, 12]. During the test, dummies are sitting in car seats impacted at frontal/side impact at a certain velocity (e.g., in ECE, the frontal crash test is done at 40mph and the side impact test at 31mph, while higher speed is used in ADAC). Biomechanical parameters indicating injury risks according to injury criteria for different body parts such as head accelerations, Head Injury Criterion (HIC), neck force, chest deflection et al.[13] are extracted from sensors to evaluate the protection offered by different types of CRS. Besides safety evaluation, the final ranking of child car seat also includes ease of use and child comfort.

Source: Wismans J et al. (2008) (used with permission)



Source: de Jager, van Ratingen M, Lesire P et al. (2005) (used with permission)

Source: ADAC test 2017 captured from video
https://www.youtube.com/watch?v=qFqCMMomfeo&t=22s1

Source: ECE R44-04 test captured from video
https://www.youtube.com/watch?v=cs18mg7Ux3c

3.

Biomechanical models replicating crash-dummies

Crash-dummies have played an important role in evaluating CRS and develop CRS with better protections. But biofedelity of dummies are far more from like humans, and can not reproduce tissue injury response.

Human Body Models (HBMs) have emerged as a powerful tool to evaluate safety products as a complement to crash-dummies. Recently, Euro NCAP (New Car Assessment Program) has introduced HMBs in the assessment of deployable systems (i.e., active bonnets) for pedestrian protection in combination with crash-dummies, which is the first application of HBMs in a consumer information rating[14]. The models have unique advances compared with dummies with higher biofedelity allowing for evaluations of various human shapes and scenarios[14].

In a European PIPER project (http://piper-project.org/) involving partners from different fields have developed a full-body PIPER child model validated against major components[15] showing promising in several applications[16-18], in particular traffic accidents[13]. The PIPER model replicated well crash-dummy responses measured from sensors such as head, thorax & pelvis accelerations, also neck force and chest deflection etc. (details of the real accidents and simulation results are found in an early study[13].

PIPER is a project funded by the European Union Seventh Framework Programme
(2013-2017)

http://piper-project.org/

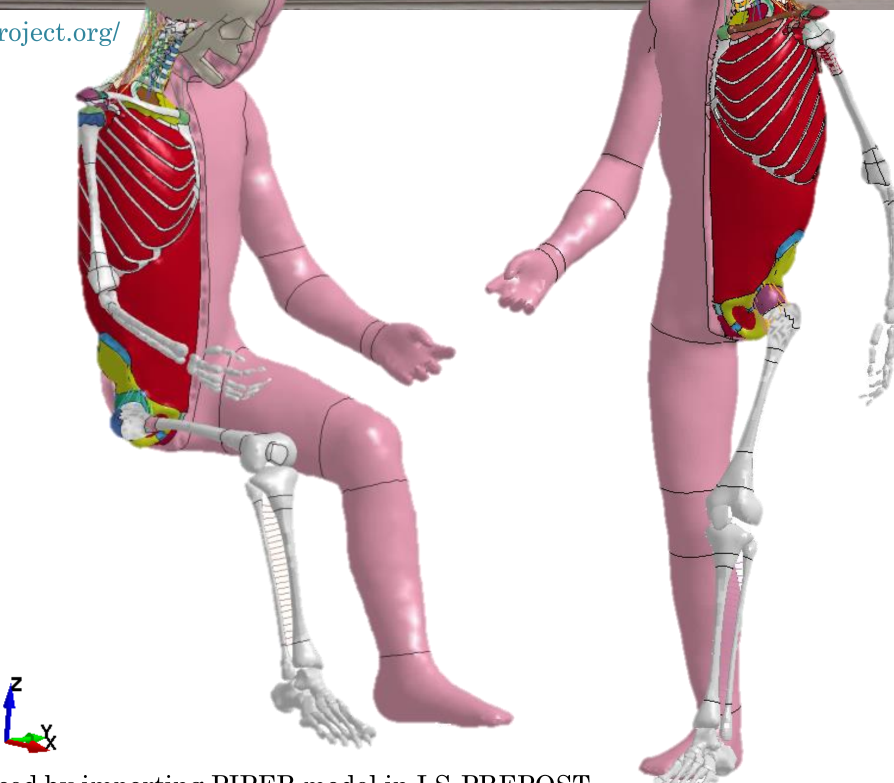
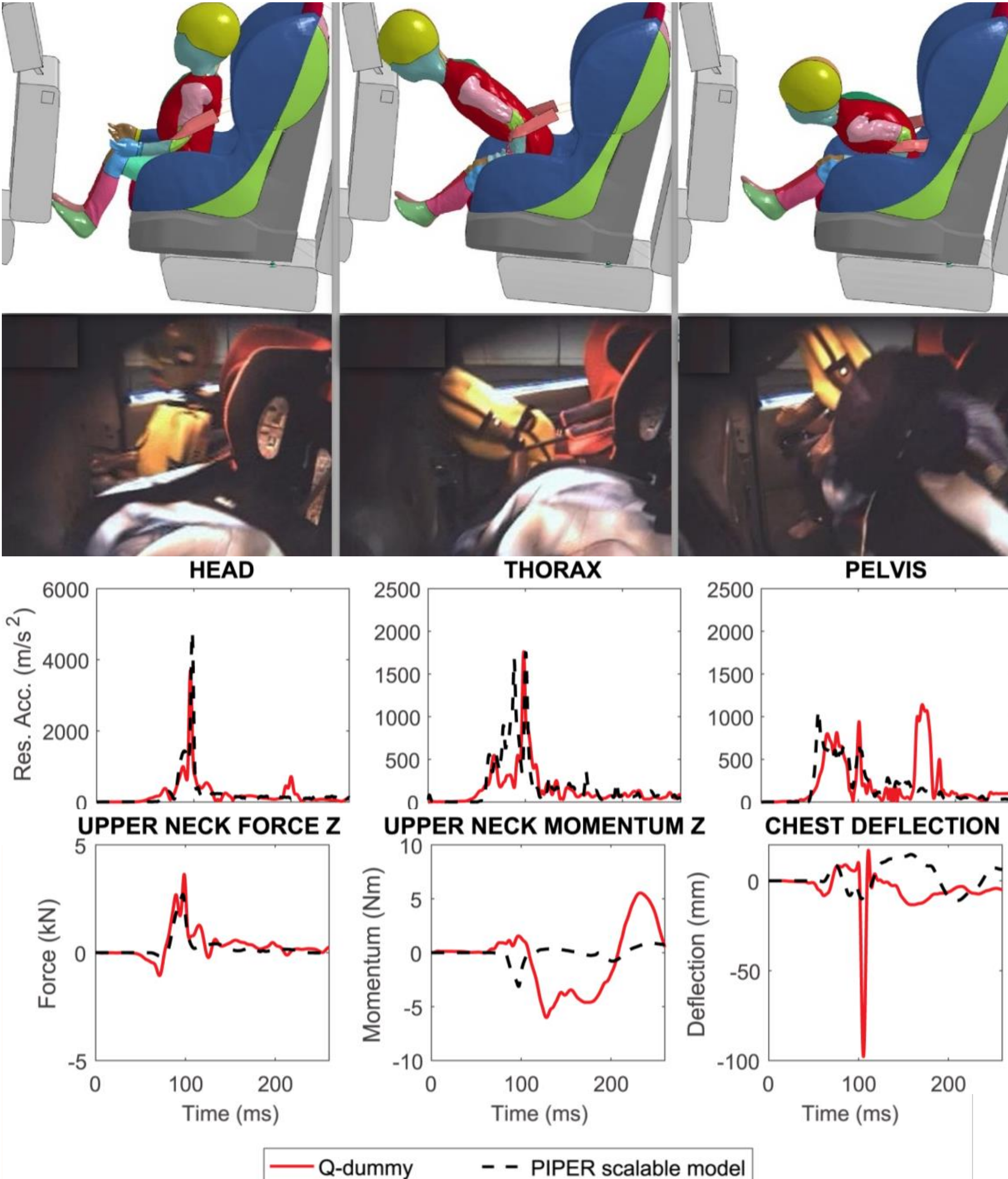


Image produced by importing PIPER model in LS-PREPOST



Source: Giordano C, Li X, Kleiven S. (2017) PLOS ONE.

4.

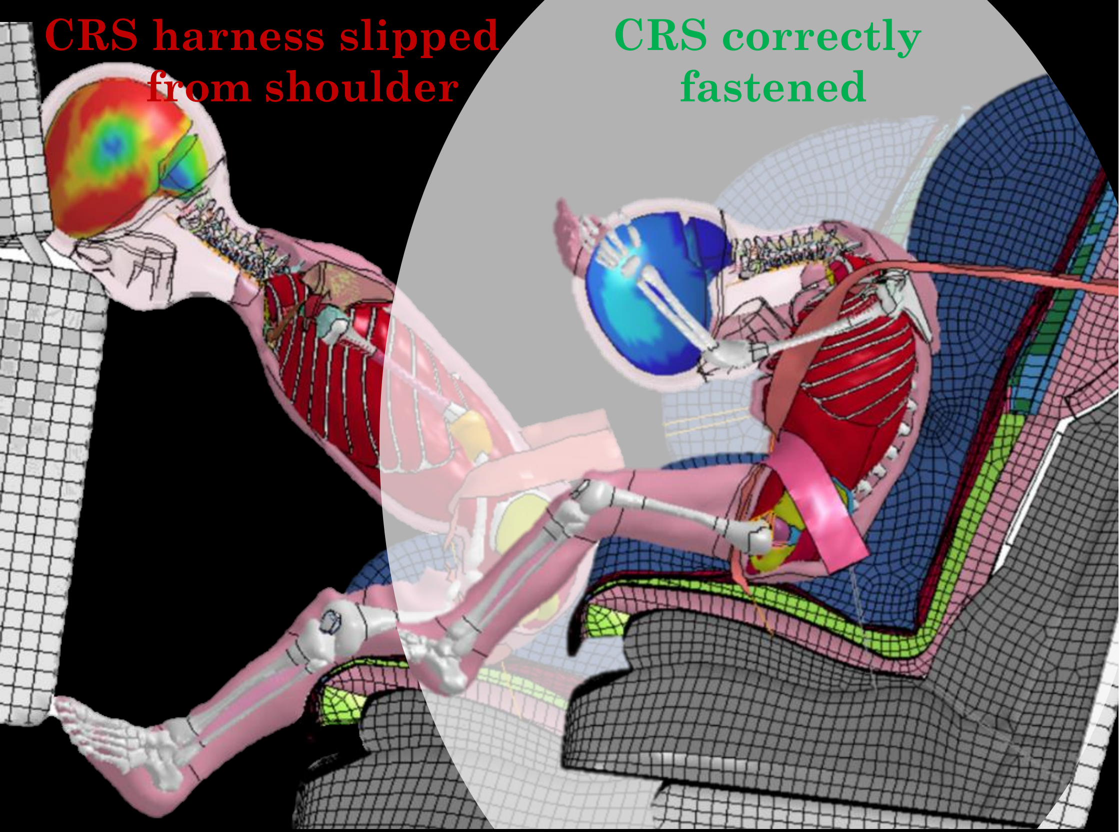
Biomechanical visualization

Validated models allow injury evaluation, such as brain injuries relating to brain tissue stretch (e.g. 30% stretch results into result into concussion[19]. Biomechanical visualizations[1] can be generated in the form of videos from these simulations.

Following is an example showing in a real accident a 26 month-old girl had impacted the frontal seat due to wearing a slippery winter jacket and slipped from the harness during the impact, causing a hard impact on the brain, resulting in MAIS 4 severe injury.

A paired simulation with the harness properly fastened[20,] showing a decreased level of injury indicating the child could have been saved from a severe head injury to minor injuries. Facing these evidences, it is hard not to imagine *what-if* the child was not wearing a slippery jacket…

[1] DEFINITION Biomechanical visualizations: are defined as visualizations generated from biomechanical simulations using advanced HBMs presented in a variety of forms including videos/animations, 3D interactions.



Red - blue: High to low risk of brain injuries

The real accident: In 2008, a 26-month-old girl sitting on the rear right seat of a Renault Megan Scenic II that, because of wet road, impacted frontally a BMW 525TDS. The child sustained a hard impact of the head with the front seatback due to the girl wearing a slippery winter coat and the shoulder escaped from harness straps during the crash resulting a MAIS 4 level severe injury (MAIS 4 has 5-50% prob. of death).

(what if ...)

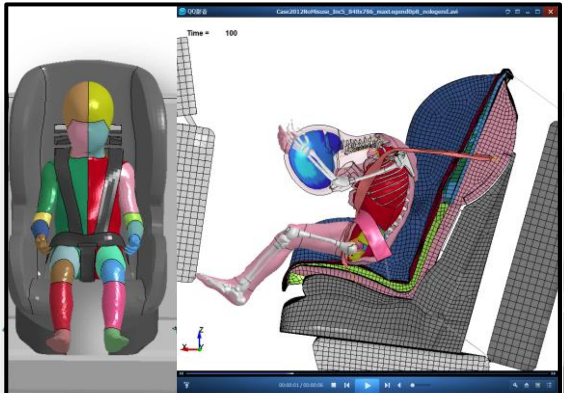
The child could have been saved from severe to minor injuries…

5.

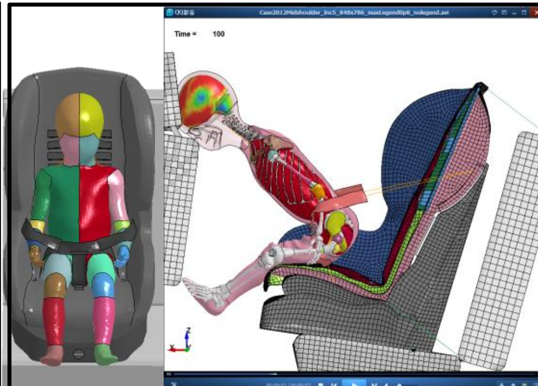
Biomechanical visualizations showing dangers of misuse

Based on real accident loading measured from physical reconstructions using crash-dummies with the same car model[13], the consequences of common misuse are simulated for Case 2012 & Case 2017[20,] revealing the devastating dangers may pose to the child with CRS misuses as shown in the following images.

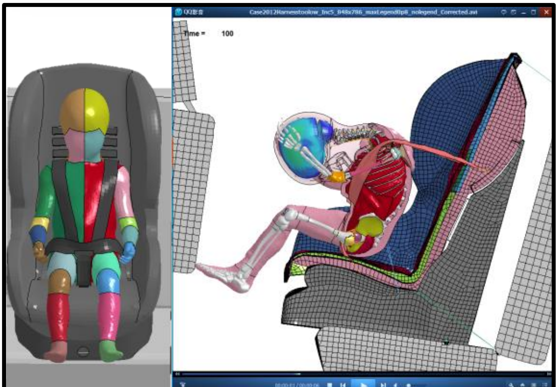
With this indisputable evidence, will we adult choose and insist on seating the children the best way we could to give the best protection to the little ones who cannot yet decide for themselves being restraint nor knowing what is the best...



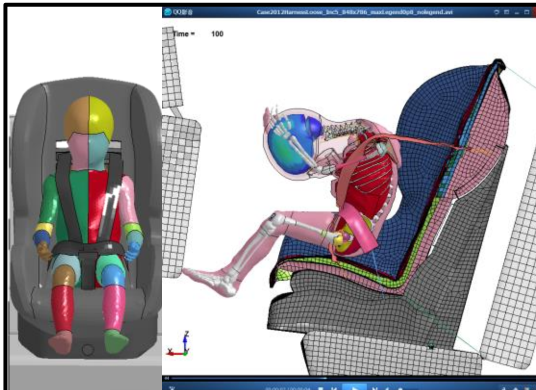
Video: No misuse



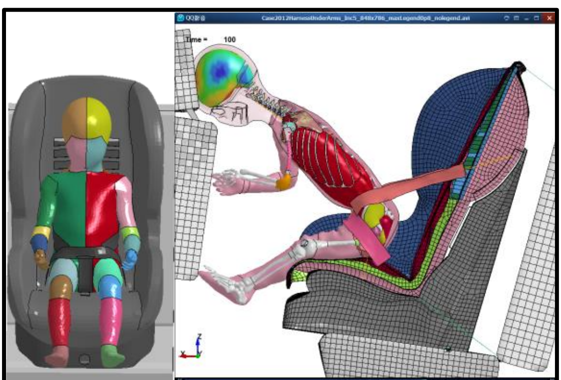
Misuse 1: Harness slipped to arm



Misuse 2: Harness attachment too low



Misuse 3: Loose harness

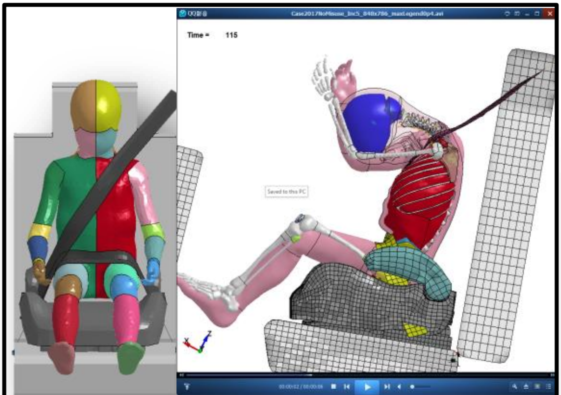


Misuse 4: Harness under arms

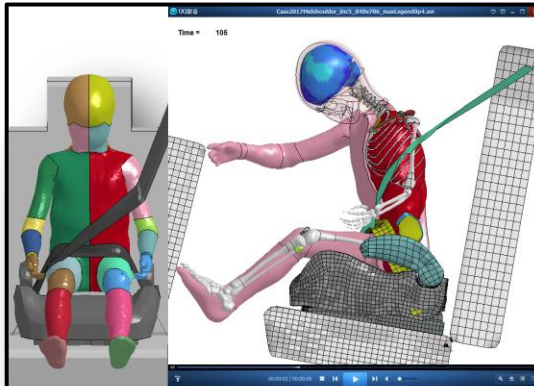
Case 2012

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*.

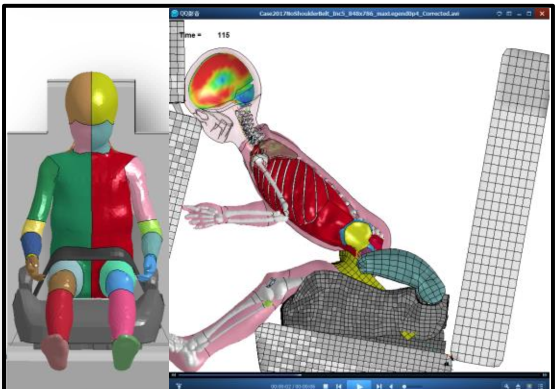
Red color represents the most dangerous misuse, and green the least dangerous.



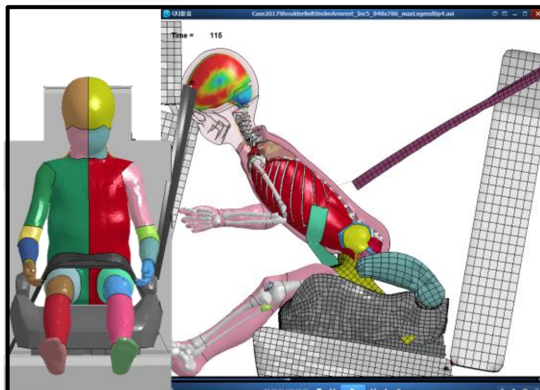
Video: No misuse



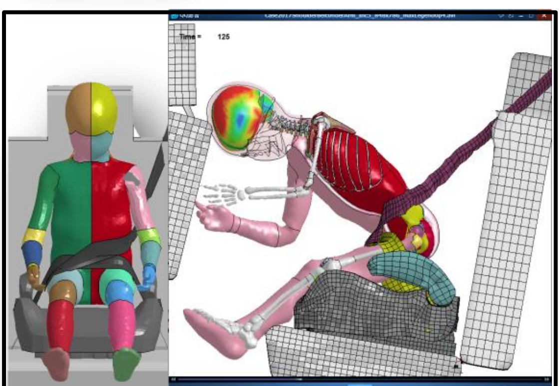
Misuse 1: Harness slipped to arm



Misuse 2: No shoulder belt



Misuse 3: Shoulder belt under armrest



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.

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