

The balance of vehicle and booster protection. Why ban the booster cushion?

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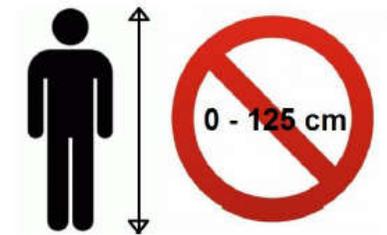
Background

- Children of age 4-12 require a CRS to adapt to the vehicle protection systems.
- Today, CRSs are developed based on a standardized stand-alone test set-up using crash test dummies in one sitting posture.
- Children are active.
- Crashes in future vehicles are likely preceded by an evasive event.
- Increasing use of car sharing and taxis.



European booster certification situation

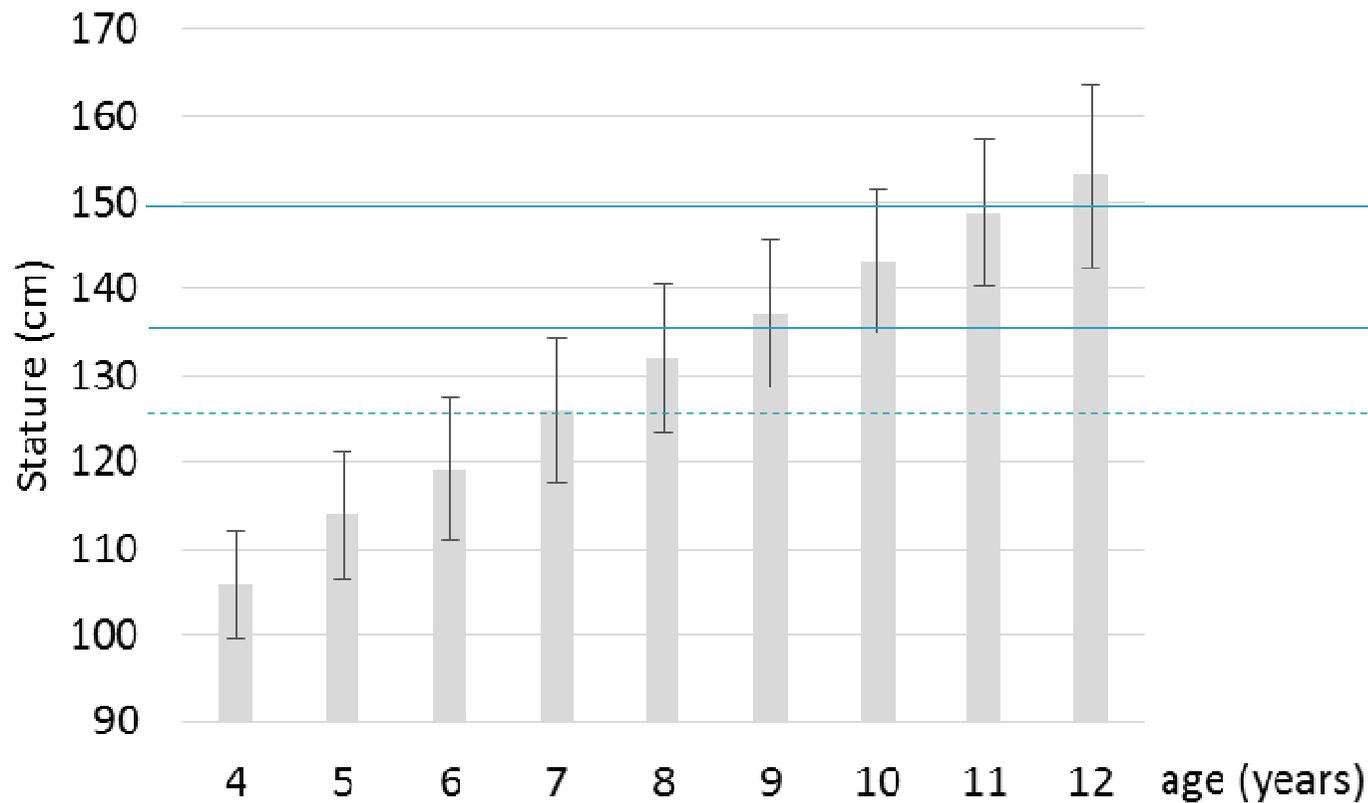
- UN ECE R129: At this stage, not possible to type approve a booster cushion due to side impact test set-up (not vehicle-like).
 - Discussions ongoing



- Amendment for UN ECE R44-04, Suppl 11
 - Effective date **2017-01-21**, new type approvals and extensions to existing type approvals
 - Booster cushions without backrest shall only be used by children with a stature > 125 cm
 - Requires booster cushions without a backrest to be permanently marked.

Age vs stature (mean +/- std dev)

Volvo Cars' Statistical Accident Database, Sweden



Law in Germany etc

Law in Sweden etc



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Swedish national research projects 2010-2017

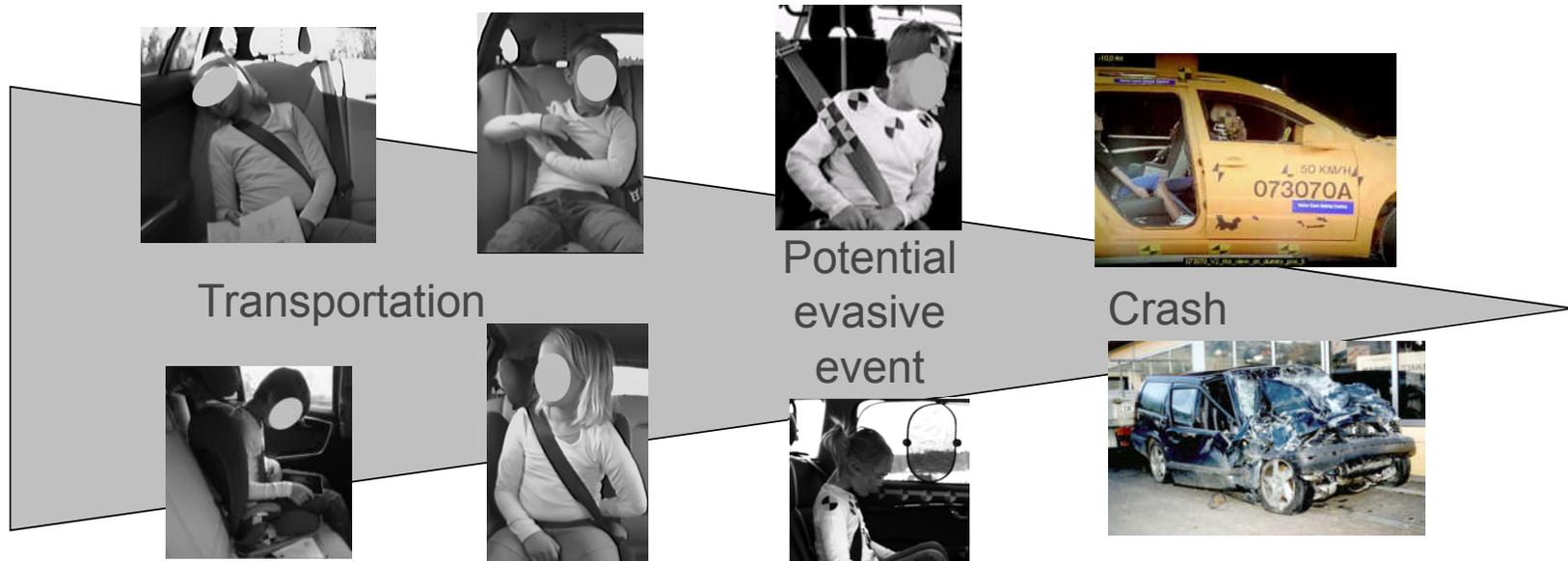
Aim and purpose

- Further enhance the safety of booster-seated children in the rear seat by identifying the real world needs, also taking restraint interaction and attitude aspects into account



- Establish guidelines for evaluation methods and protection principles
- Provide state-of-the art knowledge and contribute to setting the futures research and development needs

Real world safety



Evaluation of protection beyond standardized crash testing scenarios, including child kinematics and behavior during transportation and in potential evasive braking or steering before crash.

A multi-faceted approach

Methods

- Real world crash data
 - Driving studies with children
 - Testing and simulations
 - Crash testing and simulations
 - Low-severity / maneuver tests
 - International coordination of knowledge
- 
- Real world crash data analysis
 - Fatality trends in Sweden
 - Long-term consequences
 - Pre-crash maneuver characteristics
 - Child kinematics and behavior in cars during riding and in evasive events
 - Evaluation and development of tools
 - Evaluation of countermeasures (crash, pre-crash)
 - International dissemination

How do children sit in cars during transportation?

On-road driving studies



6 children aged 3-6



6 children aged 8-13



No booster

6 children aged 7-9

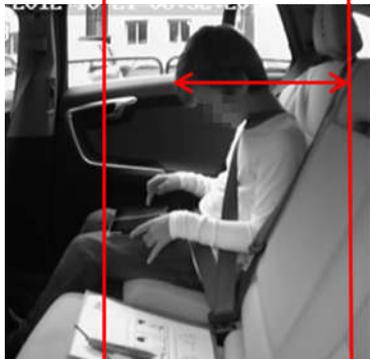


Head forward position

Booster type



Visibility



Activities

Evasive braking

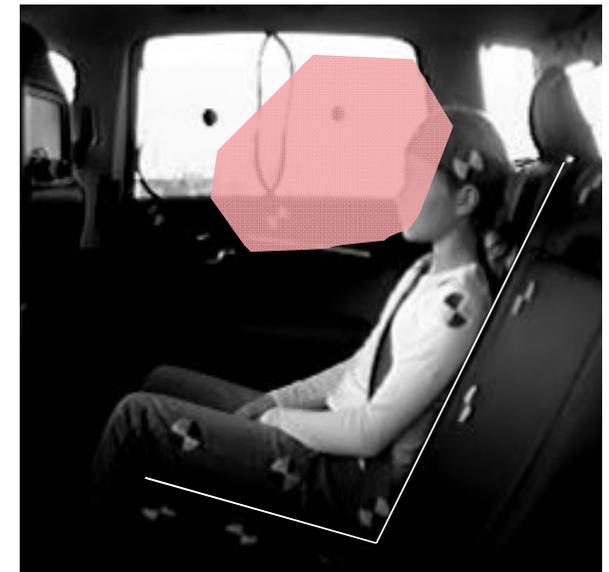


Shoulder belt on shoulder



Shoulder belt slip-off

Area of forehead positions during evasive braking, when upright initial sitting posture



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Child sidewise positions

Comfort & Activities



Evasive steering

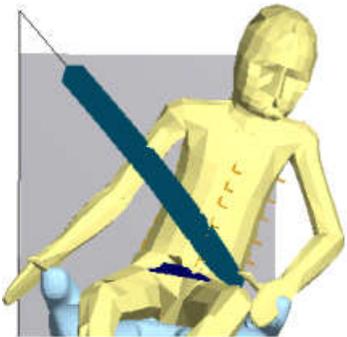


Activation of **pre**-pretensioner in evasive steering

Starting position



No activation of pre-pretensioner



Activation of pre-pretensioner



Activation of pretensioner in side impacts

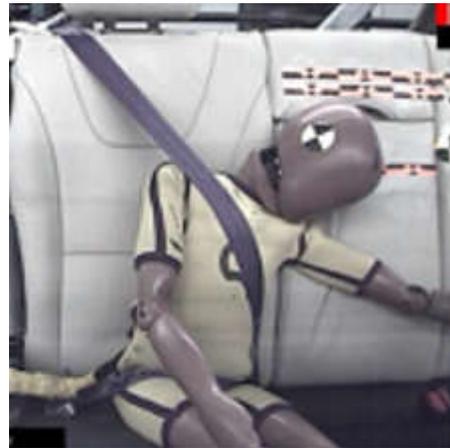
Far-side seated occupant

No activation



Integrated booster

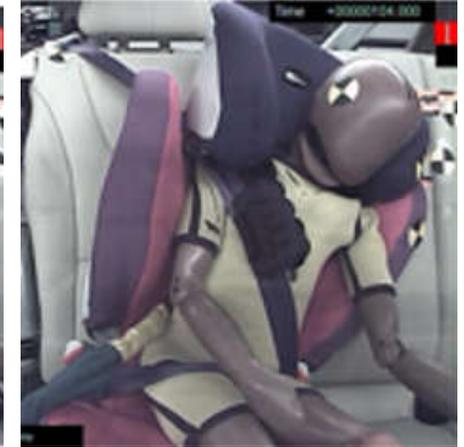
Activation of seatbelt pretensioner (pyro)



Integrated booster



Highback booster,
no ISOFIT



Highback booster,
ISOFIT

Children benefit from vehicle protection systems, given they are raised in position using a booster



Ensure good belt fit



- Vehicle and CRS should encourage “controlled” sitting postures, preferably guided by comfort, helping to restrict the variability in user positions.
- Control occupant kinematics during evasive and low severity events, which potentially precede an impact.
- Encourage designs enabling protection in real world situations for children in different user positions.

Booster usage in Volvo cars in Sweden, 2000-2013

Volvo Cars' Statistical Accident Database

- Children aged 4-12
- Stratified in two groups of observation (crash) years; 2000-2006 versus 2007-2013
- Type of restraints:
 - booster cushions 
 - high-back-booster seats 
 - integrated boosters 
 - seat belt only 
 - rearward facing child seat 
 - unrestrained

Data set

All children

age	Total	% front pass. seat	% outboard rear seat
4	145	13%	79%
5	134	15%	75%
6	116	13%	73%
7	112	14%	77%
8	146	23%	66%
9	139	22%	62%
10	160	27%	60%
11	129	30%	56%
12	154	31%	55%
	1235	21%	66%

Children of stature ≤ 135 cm

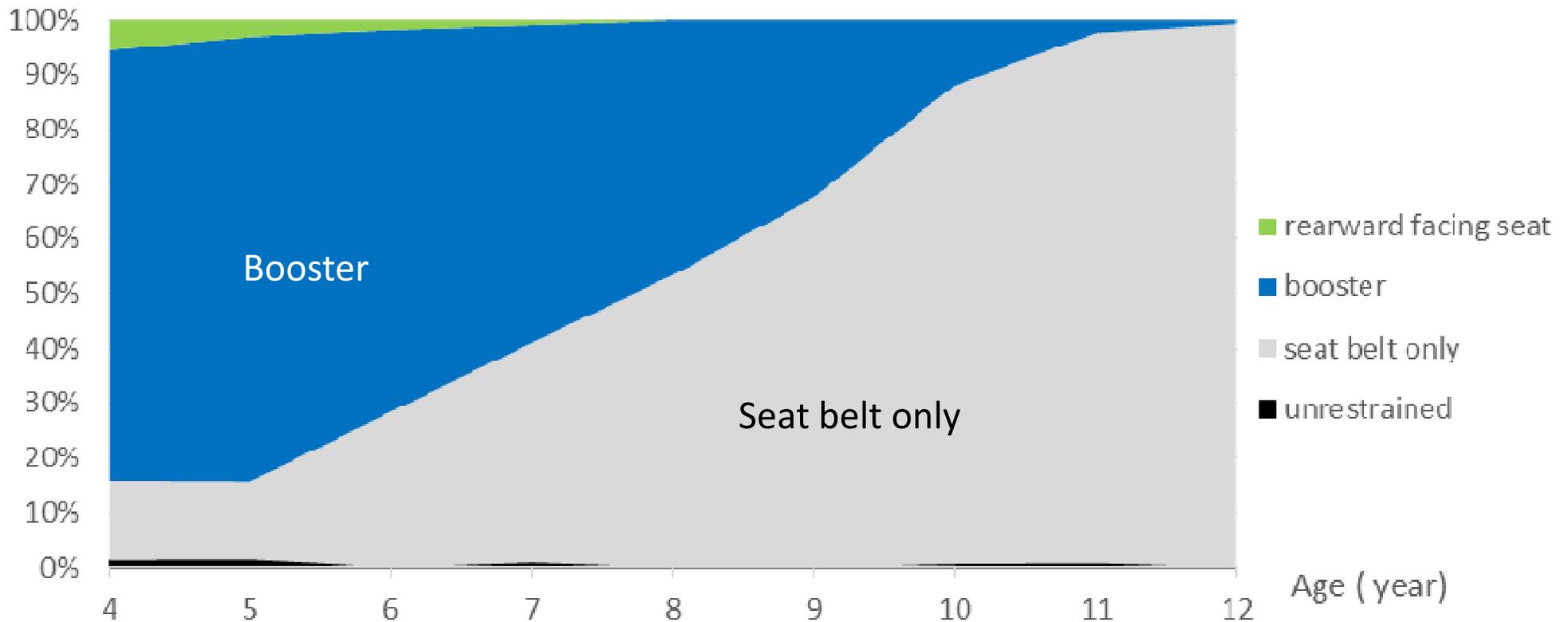
age	Total	% front pass. seat	% outboard rear seat
4	130	12%	81%
5	113	15%	74%
6	99	13%	72%
7	90	11%	79%
8	87	23%	68%
9	51	12%	67%
10	23	22%	65%
11	8	50%	50%
12	8	50%	50%
	609	16%	73%

57% ≤ 135 cm

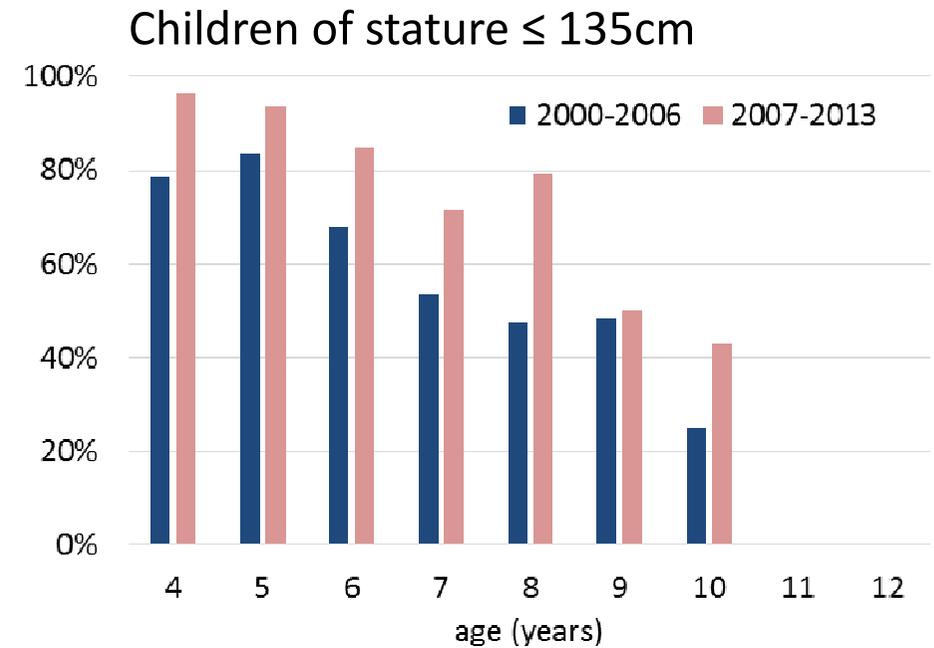
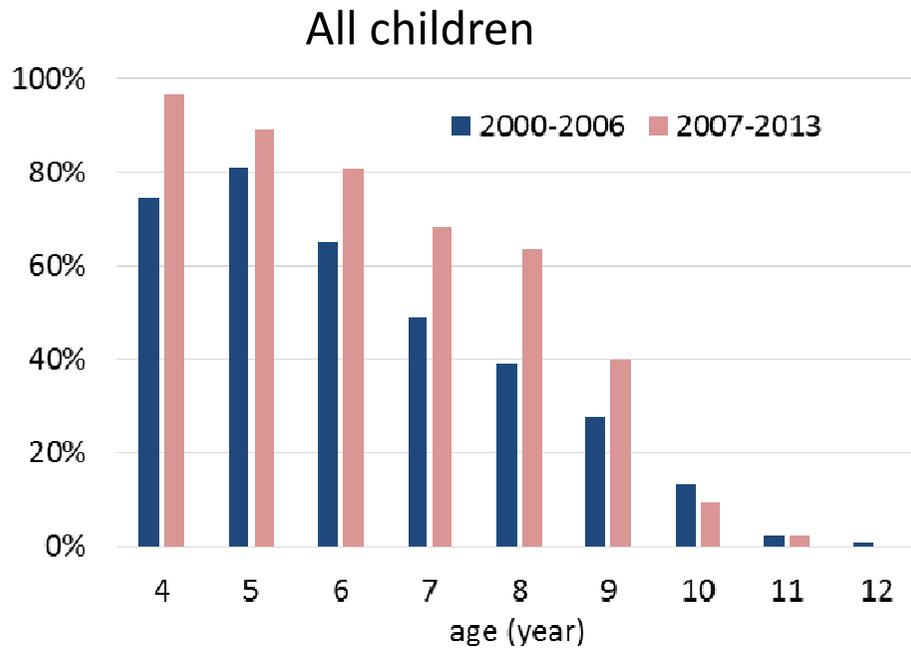
Missing data due to lack of stature information, N= 157



Restraint usage all 4-12yo, 2000-2013



Booster (incl RFCRS) usage rate per age



- Increase over time; 37% \rightarrow 51% (+39%)
- Decrease with increased age

- Increase over time; 63% \rightarrow 79% (+26%)
- **21% are not following the law!**

Boosters

- Children using boosters are well protected, irrespective of type of booster
 - no real world evidence of different level of protection when using booster cushion vs booster seat.
- The car provides protection to the child!
- Although law requires booster usage up to 135cm in Sweden, one of five children aged 4 and above are using seat belt only. Those are:
 - The majority of the 9+ year-olds
 - Approximately 20% of the 6-8 year olds
- Child occupant protection strategies should consider higher degree of car sharing / taxis and car automation.

Protection strategies?



?



Comfort cover when needed

Back to basics?



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Conclusions



- For total child safety, a priority is to increase overall booster usage rate.
- Regulation forcing children up to 135cm stature to use CRS contributes only to a limited extent.
- Necessary to understand and address the needs for the specific travel to reach high usage.
- Booster designs are important measures to encourage increased usage over the whole age range.
 - Integrated boosters and booster cushions increase relative usage among the older age group.
- The car provides protection to the child. The booster is essential to ensure good belt-fit.
- The balance of vehicle and booster protection should be in focus, not the banning of the booster cushion.

Project publications, page 1(2)

- Andersson M, Bohman K, Osvalder A-L. **Effect of booster seat design on children's choice of seating positions during naturalistic riding.** *AAAM*, 2010
- Andersson M, Arbogast KB, Pipkorn B, Lövsund P. **Characteristics of crashes involving injured children in side impacts.** *International Journal of Crashworthiness*, 16:4, 2011
- Andersson M, Pipkorn B, Lövsund P. **Parameter study for child injury mitigation in near-side impacts through FE simulations.** *Traffic Inj Prev*, Vol 13:2, 2012
- Andersson M, Pipkorn B, Lövsund P. **Rear seat child safety in near-side impacts: a modeling study of common sitting positions.** *Traffic Inj Prev*, Vol 14:2, 2013
- Arbogast K, Bostrom O, Jakobsson L, Fildes B. **Setting the future agenda for child passenger safety.** *9th Int. Conf. Prot. of Children in Cars*, 2011
- Arbogast K, Locey C, Bohman K, Seacrist TY. **Relative kinematics of the shoulder belt and the torso: Comparison of the Q10 ATD and pediatric human volunteers.** *Ircobi Conf.*, 2013
- Arbogast KB, Bohman K, Stockman I, Jakobsson L. **Child occupant protection: Latest knowledge and future opportunities – Results of a workshop in Gothenburg, Sweden.** *11th Int. Conf. Prot. of Children in Cars*, 2013
- Arbogast KB, Bohman K, Brolin K, Jakobsson L. **Child occupant protection: Latest knowledge and future opportunities – Results of a 2015 workshop in Gothenburg, Sweden.** *13th Int. Conf. Prot. of Children in Cars*, 2015
- Arbogast KB, Kim J, Loeb H, Kuo J, Koppel S, Bohman K, Charlton JL. **Naturalistic driving study of rear seat child occupants: Quantification of head position using a Kinect™ sensor.** *Traffic Inj Prev*, 17:sup1, 2016
- Baker G, Stockman I, Bohman K, Jakobsson L, Svensson M, Osvalder A-L, Wimmerstedt M. **Kinematics and shoulder belt engagement of children on belt-positioning boosters during emergency braking events.** *Ircobi Conf.*, 2017
- Baker G, Stockman I, Bohman K, Jakobsson L, Osvalder A-L, Svensson M, Wimmerstedt M. **Kinematics and shoulder belt engagement of children on belt-position boosters during evasive steering maneuvers.** *AAAM*, 2017
- Bohman K, Rosén E, Sunnevang C, Boström O. **Rear seat occupant thorax protection in near side impacts.** *AAAM*, 2009
- Bohman K, Arbogast K, Boström O. **Head injury causation scenarios for belted, rear-seated children in frontal impact.** *Traffic Inj Prev*. Vol 12:1, 2011
- Bohman K, Stockman I, Jakobsson L, Osvalder AL, Bostrom O, Arbogast KB, **Kinematics and shoulder belt position of child rear seat passengers during vehicle maneuvers.** *AAAM*, 2011



Project publications, page 2(2)

- Bohman K, Sunnevång C. **Q10 child dummy performance in side and frontal sled tests.** *10th Int. Conf. Prot. of Children in Cars*, 2012
- Bohman K, Stigson H, Krafft M. **Long-term medical consequences for child occupants 0-12 years injured in car crashes,** *Traffic Inj Prev*, Vol 15:4, 2014
- Bohman K, Jakobsson L, Stockman I. **Retention of rear seat occupants during evasive steering maneuver – effect of seatbelt pre-pretensioner.** *14th Int. Conf. Prot. of Children in Cars*, 2016
- Brolin K, Stockman I, Subramanian H, Gras L-L, Östh J. **Development of an active 6-year-old child Human Body Model for simulation of emergency events.** *Ircobi Conf.* 2015
- Carlsson A, Strandroth J, Stockman I, Bohman K, Svensson MY, Wenäll J, Gummesson M, Turbell T, Jakobsson L. **Review of child car occupant fatalities in Sweden during six decades,** *Ircobi Conf.*, 2013
- Charlton JL, Koppel S, Cross S, Rudin-Brown C, Kuo J, Arbogast KB, Loeb H, Eby D, Bohman K, Svensson M, Jakobsson L, Stockman I. **Naturalistic observation of children in cars: an international partnership.** *11th Int. Conf. Prot. of Children in Cars*, 2013
- Jakobsson L, Bohman K, Andersson M, Stockman I, Boström O, Svensson M, Svanberg H, Wimmerstedt M, Arbogast KB. **Rear seat safety in frontal to side impacts – focusing on occupants from 3yrs to small adults.** *ESV Conf.*, 2011
- Jakobsson L, Bohman K, Stockman I, Andersson M, Osvalder A-L. **Older children's sitting postures when riding in the rear seat.** *Ircobi Conf.*, 2011
- Jakobsson L, Lindman M. **Booster usage in cars 2000-2013, in Sweden.** *13th Int. Conf. Prot. of Children in Cars*, 2015
- Jakobsson L, Bohman K, Svensson M, Wimmerstedt M. **Rear seat safety for children aged 4-12: Identifying the real-world needs towards development of countermeasures,** *ESV Conf.*, Paper no. 17-0088, 2017
- Osvalder A-L, Hansson I, Stockman I, Carlsson A, Bohman K, Jakobsson L. **Older children's sitting postures, behaviour and comfort experience during ride – A comparison between an Integrated Booster Cushion and a high-back booster.** *Ircobi Conf.*, 2013
- Stockman I, Bohman K, Jakobsson L, Brolin K. **Kinematics of child volunteers and child anthropomorphic test devices during emergency braking events in real car environment,** *Traffic Inj Prev* 14:1, 2013
- Stockman I, Bohman K, Jakobsson L. **Kinematics and shoulder belt position of child anthropomorphic test devices during steering manoeuvres,** *Traffic Inj Prev*, 14:8, 2013
- Stockman I, Bohman K, Jakobsson L. **Pre-pretensioner effect on child sized dummies during run-off road events,** *ESV*, Paper no. 17-0125, 2017



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