

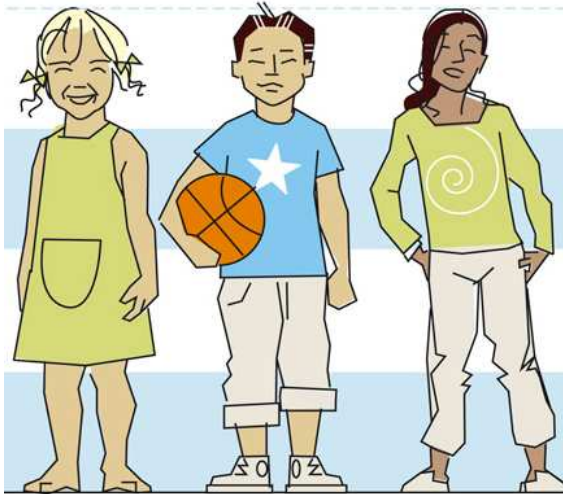
# **The balance of vehicle and CRS protection for the older children in child restraints**



# Objective

Identify the balance of vehicle protection and child restraint protection enabling the optimal real world safety for the children of different sizes.

-focusing children from 4 years and above.



Major safety issues using adult restraints:

- Size and proportions
- Pelvic development

# Development of belt-positioning boosters



World first 1978



Built-in booster 1990



2-stage built-in booster 2007

# Protection of belt-positioning boosters

A booster cushion offers essential protection to a child in frontal impacts and puts the child into a better position and protection in side impacts

*(Durbin et al. JAMA 2003, Jakobsson et al. ESV 2005 & 2007, Arbogast et al. Pediatrics 2009)*

No clear evidence of difference in the safety performance of backless versus high-back boosters, based on real world data *(Arbogast et al. Pediatrics 2009)*

For side impacts, this could potentially be explained by that the vehicle offers the main protection, by:

- the influence of a forward acceleration component *(Henary et al. Injury Prevention 2007, Maltese et al. Stapp 2007, Arbogast et al. TIP 2005)*
- the influence of pre-braking on initial sitting postures *(Stockman et al. TIP 2012)*
- the influence of wide head supports on initial sitting postures *(Andersson et al. AAAM 2010)*



## Example of sitting posture after braking event of 1g



# Child kinematics at braking events, 1g

135-150cm  
- seat belt only



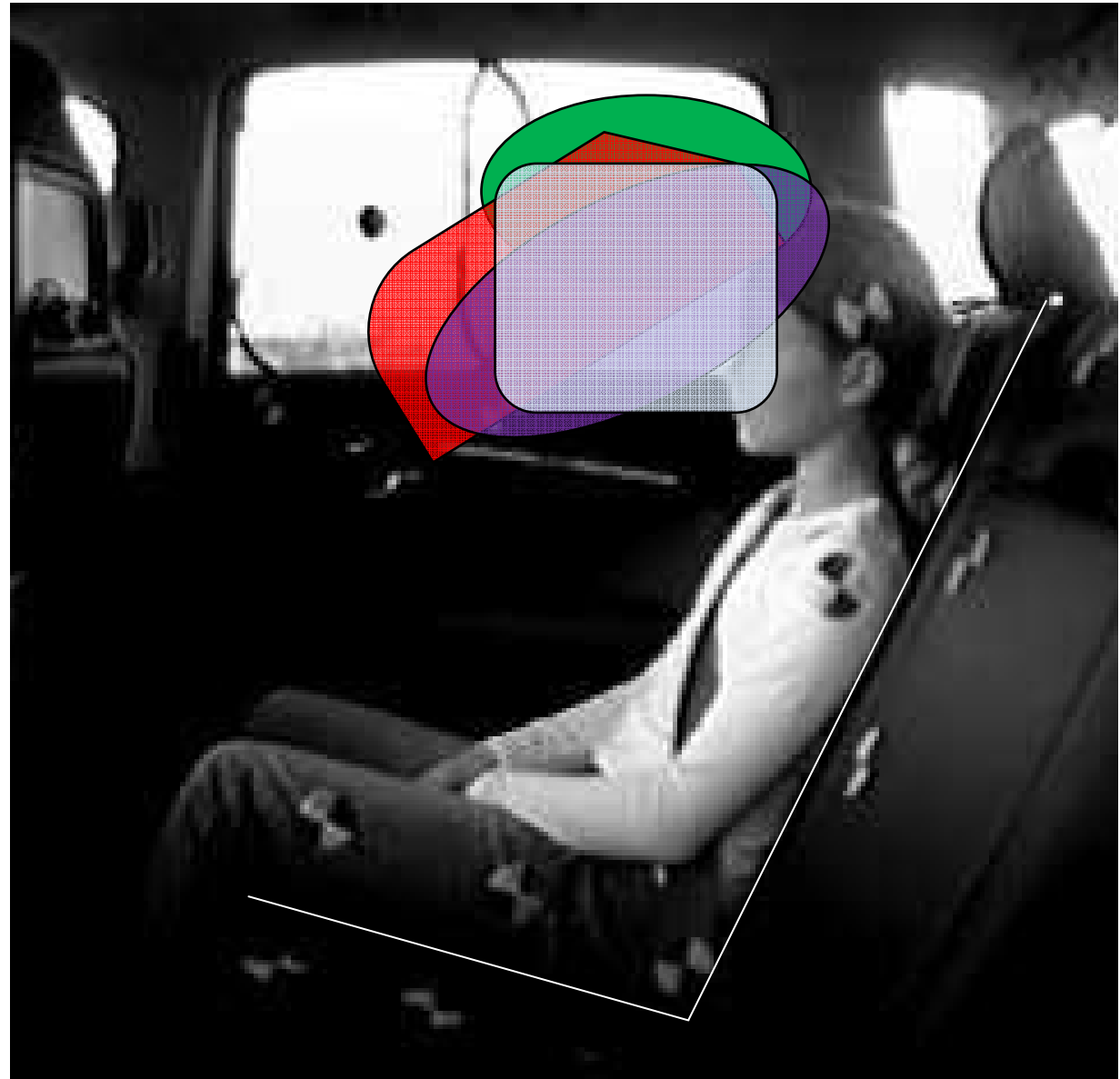
135-150cm



105-125cm



105-125cm



(Stockman et al. TIP 2012)

# Sitting postures for 3-6y during riding in the rear seat



- Shoulder-to-booster back contact during an average of 45% of riding time in the seat with the large head side supports compared to 75% in the seat with the small head side supports.
- The children in the study were seated with the head in front of the front edge of the head side supports more than half the time, in both boosters.

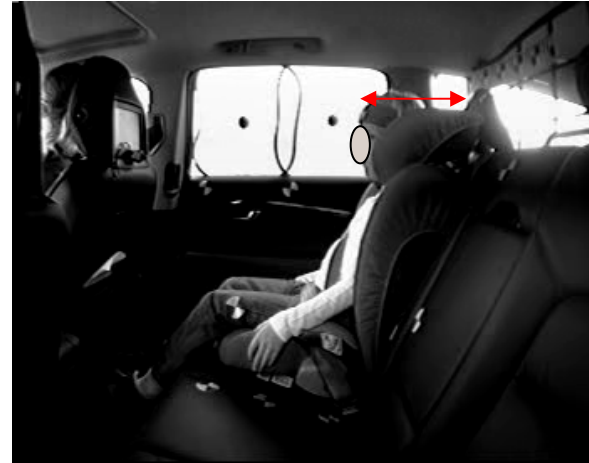


*(Andersson et al. AAAM 2010)*

# The backrest positions the head more forward



Child 6 yo – 123 cm, rear seat of Volvo XC70



Child 7 yo – 133 cm, rear seat of Renault Grand Espace



# Potential effects of a booster seat as compared to a booster cushion

- The backrest positions the child's head forward.
  - A child is more prone to lean forward when riding in booster with pronounced head supports (due to visibility).
  - During emergency braking, the child's head will move forward 15-20cm.
- Decreased distance to potential head impact areas in case of a subsequent **frontal impact**.
- High likelihood of head passing in front of head supports in case of subsequent **side impact**.
- !! It is not evident that a backrest with head side supports offers protection for the child in real world situations and could for the largest children even be a hazard.



# Benefits of a booster backrest

- Decreases the booster cushion length, beneficial for the smallest children.
- Helps keep the shoulder belt in position.
- Provides sleeping support.
- Helps support the child laterally.



# Steering event



Booster cushion



Booster with backrest

*(Bohman et al. AAAM 2011)*

# Shoulder belt far out on shoulder, child in high-back booster



## Protection principles



# Built-in booster and seat belts with pretensioner and progressive load limiter



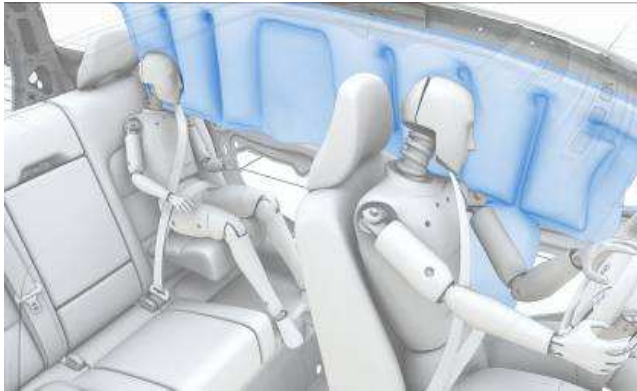
## 2-stage built-in booster cushion



**Encourages usage –  
Utilizes vehicle protection**

Performance

- Seating position/belt fit
- Reduce risk of misuse
- Pretensioner and progressive seat belt load limiter
- Inflatable Curtain coverage area



Usage

- Availability/ease of use
- Acceptance from older children
- Comfort



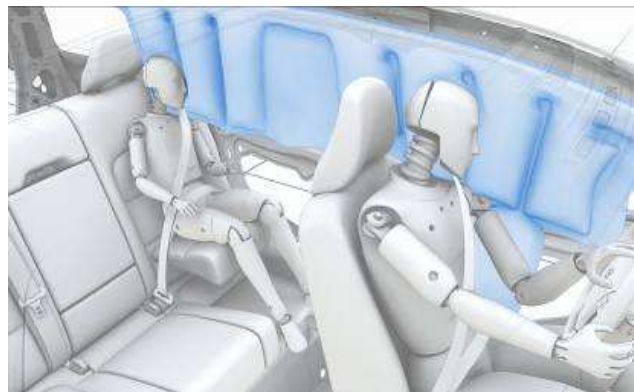
*(Jakobsson et al. ESV 2007)*

# Protection principles

As for an adult, a large child gains protection by having a tight connection to the vehicle.

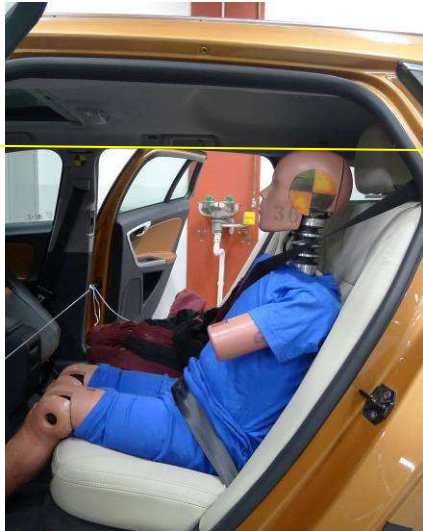
As for an adult, a child's head will be protected by the vehicle side structure, incl. IC.

- The sitting height of a SIDII (small female sized ATD) is approximately similar to a child of 130 cm using a booster raising the child 10 cm.

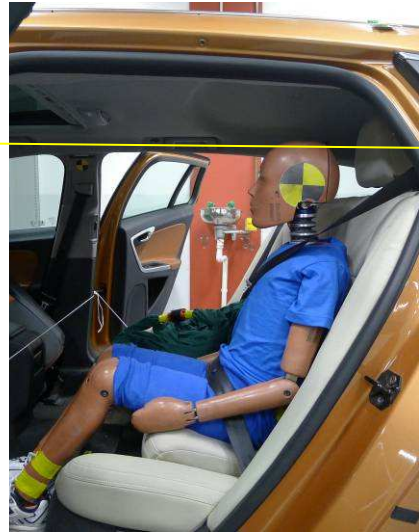




# Comparison SIDIIIs and HIII10y



SIDIIs

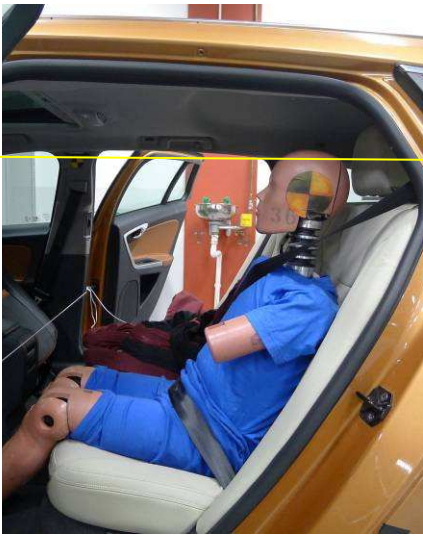


HIII10y using  
Volvo built-in  
booster (1st stage)

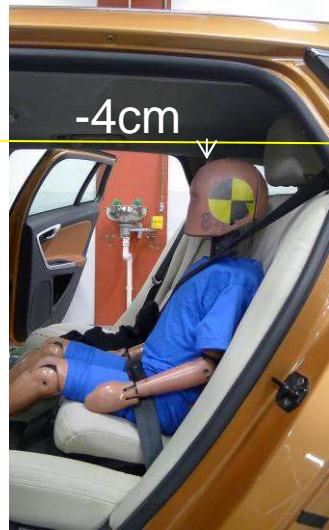


HIII10y using  
Volvo booster seat  
(similar to Britax  
KidPlus)

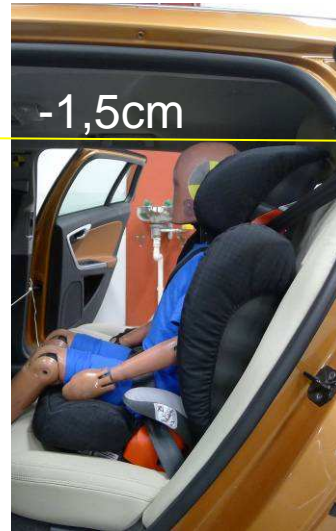
# Comparison SIDIIIs and HIII6y



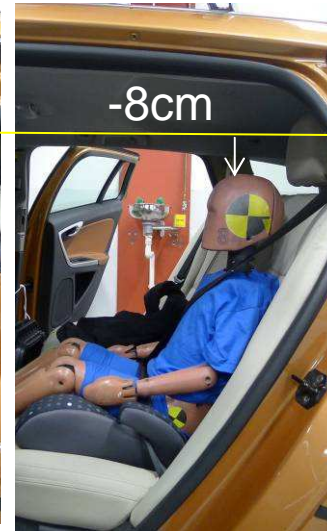
SIDIIs



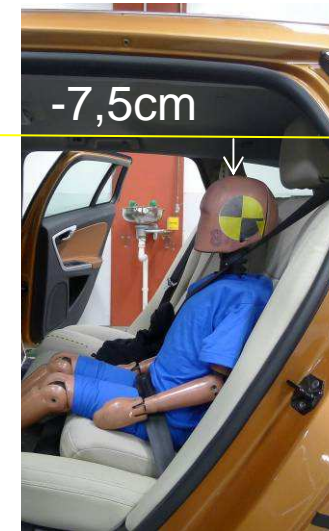
HIII6y using  
Volvo built-in  
booster  
(2nd stage)



HIII6y using  
Volvo booster  
seat (similar to  
Britax KidPlus)



HIII6y using  
Volvo  
booster  
cushion



HIII6y using  
Volvo built-in  
booster (1st  
stage)

# Summary

- Children aged 4-10(-140cm) benefit from the vehicle safety systems, given they are raised in position using boosters.
- Add-on child restraints should be balanced to the in-vehicle safety design.
- The primary effect of the backrest part of the high back booster is to help position the child.
- For children approx >130cm a booster cushion (without backrest) together with the 3pt belt should be used as their primary restraint.
- For shorter children the benefit of a backrest is depending on the vehicle used and the behaviour of the child during the specific trip.



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