How rear-facing CRS work in rear-impact crashes

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Research Engineer

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Rear-facing orientation is safest for children
Studied extensively for frontal and side impacts
Background

Frontal impact

Forward-facing

Rear-facing
What happens when crash forces are reversed in a rear impact?
- RF child is facing the direction of impact
Objective 1:
Literature Review
• **Frequency** of rear impacts

- Frontal: 53.5%
- Side: 20.1%
- Rear: 25.4%
- Noncollision/Rollovers: 0.5%
- Other/Unknown: 0.5%

Data from 5,982,000 crashes
(NHTSA Traffic Safety Facts, 2014)
• **Injuries** in rear impacts: Adults

Data from 72,605 adult, front row occupants in 54,080 crashes (excludes rollovers) (Burnett et al. 2004)
Literature: Children

- Jakobsson et al. 2005: Volvo crash database
  - Includes 454 children in rear-facing CRS
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No rear-facing children suffered injuries more than AIS 1 in side or rear impacts!
Jakobsson et al. 2005: Volvo crash database
- Includes 454 children in rear-facing CRS

No rear-facing children suffered injuries more than AIS 1 in side or rear impacts!

“The rearward-facing child seats are designed primarily for frontal impacts, however the outcome for side and rear-end impacts indicates a good performance also in these situations.”

--Jakobsson et al. 2005
• Langwieder et al. 1999: Institute for Vehicle Safety (IFV) study in Germany. Small sample size of 42 rear-facing children.

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**Literature: Children**


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“Hence, rearward facing infant carriers have a low risk of injury in rear-end collisions.”

--Langwieder et al. 1999
• Representative and random sample of minor, serious, and fatal crashes in the US
• Includes about 5,000 crashes per year
• Years 2002-2015:
  – 39 rear-facing children in rear impact crashes

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ΔV 30 kph, head injuries
ΔV 62 kph, severe intrusion
• Rear impacts appear to be low risk for children, even those in RF CRS.
• However, sample sizes for children are small.
Objective 2:
Sled testing
Sled testing: Methods

Sedan seat

Four CRS models
Sled testing: Methods

Target:
ECE R44 corridor (UNECE, 2011) 
(European standard)

Actual:
Peak velocity: $18.4 \pm 0.1$ mph
Peak g’s: $17.5 \pm 0.1$ g

~80$^{th}$ percentile in terms of rear impact severity
Handle stowed  

Handle upright  

Anti-rebound bar

Lowest neck loads  
(tension and compression)

All trials for this CRS:
Low Head Injury Criteria (HIC15) near 32-38 (injury threshold is 389 (Mertz et al. 2016))
Chest acceleration near 31-32 g (injury threshold is 60 g (NHTSA, 2011))
Handle stowed

Handle upright

No base

Head contacts head restraint, HIC15=39

Head contacts handle, HIC15=62

Neck tension similar to other trials! Slightly more shear, but less compression.

HIC15 injury threshold = 389 (Mertz et al. 2016)
Sled testing

12-month-old  3-year-old

Higher neck compression, flexion moment, and extension moment (but still below injury thresholds)

Very similar HIC15 values (16 and 19) with injury thresholds of 389 and 568 (Mertz et al. 2016)
Sled testing

No tether

Swedish style tether

- Notably higher neck tension, shear, and extension moment (but still below injury thresholds)
- Slightly higher HIC15 and chest resultant acceleration (much below thresholds)
Sled testing: Limitations

- One moderate severity crash pulse
- Small sample size (no repeated tests)
- One vehicle seat model
  - Influence of head restraint design?
- All CRS were tightly installed
  - Influence of loose installation?
- Biofidelity of pediatric ATDs, especially neck
Objective 3:
Communication with Caregivers
“If a child is rear-facing and you get hit from behind, isn’t that the same as a forward-facing child in a frontal crash?”
“If a child is rear-facing and you get hit from behind, isn’t that the same as a forward-facing child in a frontal crash?”

First off—This is a really great question!
“If a child is rear-facing and you get hit from behind, isn’t that the same as a forward-facing child in a frontal crash?”

First off—This is a really great question!

No, it’s not the same:

RF CRS interact with the vehicle seat to absorb crash forces.

FF CRS rely primarily on the five-point harness to restrain the occupant.
Communication with caregivers

Forward-facing in frontal impact
Communication with caregivers

Forward-facing in frontal impact

Frontal impact
Communication with caregivers

Forward-facing in frontal impact

Occupant projects out of CRS

CRS is stationary

Frontal impact
Forward-facing in frontal impact

Occupant projects out of CRS

CRS is stationary

Torso engages **quickly**, head continues forward.
Communication with caregivers

Forward-facing in frontal impact

- CRS is stationary
- Occupant projects out of CRS
- Torso engages **quickly**, head continues forward.

Rear-facing in rear impact

- CRS interacts with vehicle seat.

Frontal impact

Rear impact
Communication with caregivers

Forward-facing in frontal impact

- CRS is stationary
- Occupant projects out of CRS
- Torso engages **quickly**, head continues forward.

Rear-facing in rear impact

- CRS interacts with vehicle seat.
- Torso engages **slowly**, head stays aligned.
Conclusions: Rear impacts

• Rear-facing CRS have features to mitigate forces in rear impacts
  – This crash mode is different than a forward-facing CRS in a frontal impact.
• These data are insufficient to conclude whether RF or FF is safer in a rear impact scenario.
• Ultimately, these conclusions align with best practice recommendations to keep children rear-facing.
• More results in publication: SAE International 2018
The authors would like to acknowledge the National Science Foundation (NSF) Center for Child Injury Prevention Studies at the Children’s Hospital of Philadelphia (CHOP) and the Ohio State University (OSU) for sponsoring this study and its Industry Advisory Board (IAB) members for their support, valuable input and advice. The views presented are those of the authors and not necessarily the views of CHOP, OSU, the NSF, or the IAB members.

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Acknowledgments
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Julie.Mansfield@osumc.edu

Injury Biomechanics Research Center:
www.ibrc.osu.edu

Center for Child Injury Prevention Studies (CChIPS):
www.cchips.research/chop.edu

Buckle Up with Brutus (Caregiver-oriented):
www.buckleup.osu.edu
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References


