# What Are the Most Important Features on Infant Car Seats to Prevent Injuries: A Systematic Qualitative Review

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## INTRODUCTION

*Child Passenger Safety* (1) recommends 4 evidence-based approaches for best practice of pediatric safety in the adolescent:

1. rear-facing child safety seats for as long as possible during infancy into prematurity,
2. forward facing car safety seats once they outgrow the rear- facing all the way unto four years of age.
3. belt-positioning booster seats once they outgrow the forward facing booster seat until they have reached a nominal height of 4'9" or 8 years of age.
4. lap and shoulder seat belts once they outgrow the booster seats.

The study of biomechanical aspects in pediatric studies that directly affect injuries related to automobile accidents was the main topic of research conducted in these studies.

## OBJECTIVES

Because there are many different variables to consider while gathering data on the problem, an important step is to have an Anthropomorphic Test Dummy (ATD). *Pediatric Head Contours and Inertial Properties for ATD Design* (4) used "a large sample of 185 clinical CT scans and a small sample of 14 high-resolution CT scans taken of 'Post-mortem Human Subjects' (PMHSs)", to develop averages of head and skull contours from an age range of 1 month to 120 months. These scans provided:

- The information needed to find the "inertial and morphometric properties of the pediatric head."
- This study is important for reducing pediatric head injuries (6) because the average head and skull contours can be used to study injury by implementing them in FEMs and to provide the shape of ATDs.

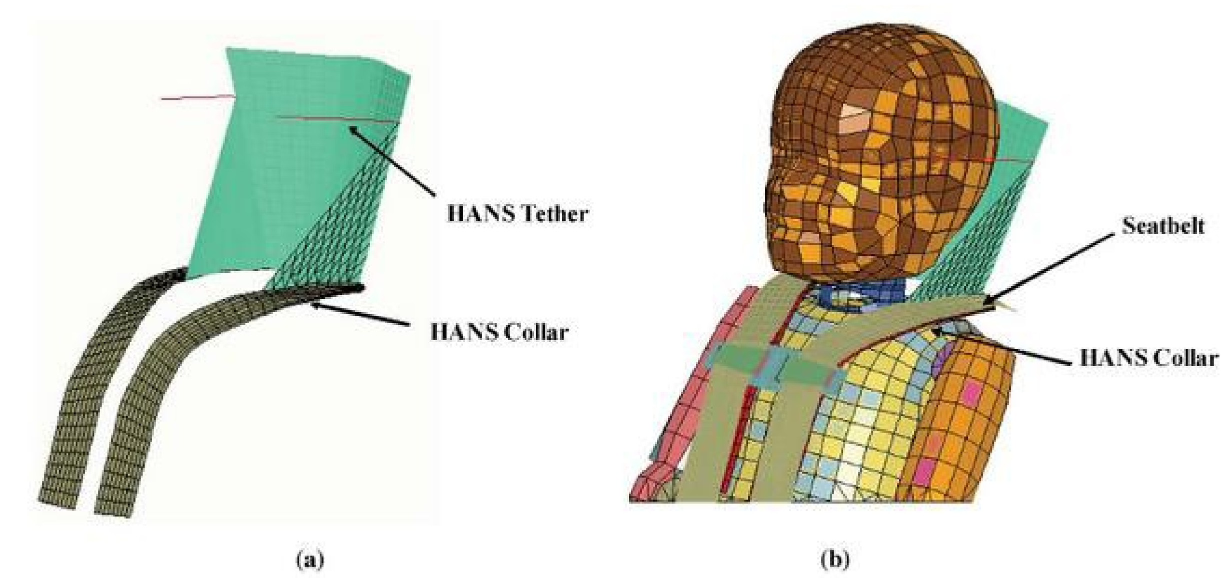
*Head Impact Mechanisms of a Child Occupant Seated in a Child Restraint System as Determined by Impact Testing*(3):

- Side impact collisions had a significantly higher risk of head injury in forward-facing child restraint systems (CRS).
- Head injury was the most frequent among all injuries to children restrained in a CRS.
- The purpose of his testing was to "understand the mechanisms that lead to a child's head making contact with the side structure of the vehicle interior in side collisions." (3) Data collected from crash tests using pediatric ATDs provide reference points to how effective certain features of a CRS are, as well as demonstrating how injuries occur in a wide range of situations.

## MATERIALS & METHODS

*Design and Fabrication of the Child Head and Neck Support Prototype for Child Car Seats* (5) describes:

- Potential design processes as well as materials to be used for prototyping specifically the head and neck support feature of a CRS.




Reference: *Countermeasures to Mitigate Head and Neck Injuries to Toddlers…*

- The models shown in the article are SolidWorks 3D models and are made from Ethylene Vinyl Acetate (EVA) Foam. "Ethylene Vinyl Acetate (EVA) Foam Blocks is great hard foam that withstands a substantial amount of weight and gravity compared to other types of foam." This material was used to absorb and dissipate the energy from impact, making sure there was minimal risk to the child occupant.

A HANS tether was created and attached to a Computer-simulated Hybrid III child dummy in order to simulate impact collisions and display the critical variables associated within these systems. Frontal-impact, near-side impact, and a forty-five degree impact were simulated in this particular study. The age range for a child in this simulation would be around age three to five.

## RESULTS

Point of contact maps were displayed in the articles to give a clear visualization as to which section of the car was most frequently struck by the child during impact collision. Head Impact Contact Points for Restrained Child Occupants specifically queried the Crash Injury Research and Engineering Network (CIREN) to find these case studies with criteria of an AIS2+ head and/or face injury to determine which point of contact is made, which positions in the car made these points of contact and looked at different forms of child restraints to make an accurate determination. "...efforts to mitigate head injuries for these occupants would greatly improve their overall safety." (3).

The researchers ran simulations in SolidWorks and found that the increasing thickness of foam towards the outer side and back ends of the model absorbed most of the stress caused by an impact. The prototype was designed to support a 2.5 to 3-year-old child from the 50th percentile.

This table details the data analysis conducted in these studies and compares the results with emphasis on the LATCH and ISOFIX systems specifically. Any study conducted without greater than thirty participants was deemed statistically insignificant.

Table 3. Summary of Studies Referenced in the Research

| Author, Year | Objective | Statistically Significant | Methods | Results |
|---|---|---|---|---|
| Williams JR, O'Donel CA, Leiss PJ, 2015 | Explore the effects of different installation methods of common RFCRS in use with the Lower Anchor and Tethers for Children (LATCH) system | Yes, ATDs were used for this study | Rear-end Collision, Sled Test | LATCH does not provide equal protection from head injuries to lap and shoulder belts when used with RFCRS in rear impact collisions |
| Kapoor T, Altenhof W, Howard A, et al., 2010 | A pediatric study to determine whether head & neck safety devices reduce forces directly attributed to impact collisions using datum points and their reflections from the standard axis | Yes, because 185 pediatric studies were used (AIS2+ traumatic head and neck injuries) | FEM modeling, CIREN database used for the studies conducted | ISOFIX and LATCH devices as well as HNSDs greatly reduced forces of impact as well as reducing deflection from the standard axis |
| Yoshida R, Okada H, Nomura M, Mizuno K, Tanaka Y, Hosokawa N, 2011 | The purpose of this research is to understand the mechanisms that lead to a child's head making contact with the side structure of the vehicle interior in side collisions. | No, there was no population count specified | SUV-to-small car side oblique test, sled tests | During the test, the dummy head contacted the side window, which led to a high HIC, even though the child was seated in the CRS in a standard posture |
| Arbogast KB, Wozniak S, Locey CM, Maltese MR, Zonfrillo MR, 2012 | A pediatric case study was put together in order to determine which sections of the car contributed to the injuries sustained in these AIS2+ or greater head and or face injury. | No, only 21 cases were included in the overall study even though 49 were originally screened from the CIREN database | CIREN database was used along with criteria to limit studies in order to collect the data | A contact point map was determined using these case studies to determine where in the car these pediatric studies sustained their head impact points |

Table 1. Summary of peak values of various injury parameters observed for the Hybrid III 3-year-old child dummy in the absence and presence of the head and neck device for the frontal impact.

| | Flexible LATCH | | Rigid ISOFIX | |
|---|---|---|---|---|
| | No HANS | HANS | No HANS | HANS |
| Resultant head acceleration (g's) | 59.5 | 76.4 | 47.9 | 52.8 |
| Resultant chest acceleration (g's) | 59.2 | 66.2 | 41.9 | 50.8 |
| Head injury criteria ($HIC_{15}$) | 304.7 | 326.6 | 173.4 | 189.8 |
| Head injury criteria ($HIC_{36}$) | 325.2 | 445.7 | 174.2 | 242.9 |
| Resultant upper neck force (N) | 2284.2 | 1136 | 1937.7 | 1231.9 |
| Resultant lower neck force (N) | 1473.9 | 1638 | 976 | 1100 |
| Resultant upper neck moment (N · m) | 33.2 | 34.2 | 26.8 | 26.2 |
| Resultant lower neck moment (N · m) | 148.9 | 57.2 | 148.4 | 47.2 |
| Forward head excursion (mm) | 235 | 187 | 209 | 155 |

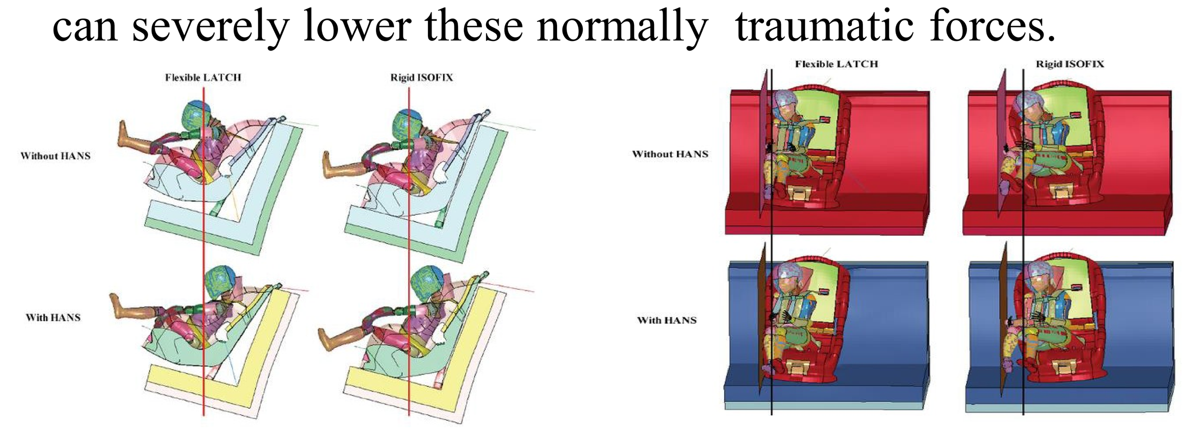
Table 4. Summary of peak values of various injury parameters observed for the Hybrid III 3-year-old child dummy in the absence and presence of the head and neck device for the near-side impact.

| | Flexible LATCH | | Rigid ISOFIX | |
|---|---|---|---|---|
| | No HANS | HANS | No HANS | HANS |
| Resultant head acceleration (g's) | 60.6 | 70.8 | 48.4 | 53.3 |
| Resultant chest acceleration (g's) | 80.5 | 73.4 | 42 | 39 |
| Head injury criteria ($HIC_{15}$) | 239 | 395 | 172.4 | 218 |
| Head injury criteria ($HIC_{36}$) | 147.4 | 217.4 | 174.6 | 207.6 |
| Resultant upper neck force (N) | 1449.6 | 1879.5 | 1117 | 1190 |
| Resultant lower neck force (N) | 1770 | 2100 | 986 | 1154 |
| Resultant upper neck moment (N · m) | 102.6 | 76 | 56.5 | 26.9 |
| Resultant lower neck moment (N · m) | 193.9 | 166 | 134.3 | 80.2 |
| Lateral head displacement (mm) | 213 | 205 | 169 | 153 |

Reference: *Countermeasures to Mitigate Head and Neck Injuries to Toddlers…*

## CONCLUSIONS

A concerted study was done on the effect of Head and Neck Safety Devices (HNSDs) and reported major reduction in both forces and moment of inertia of both head and neck in crashes involving children. *Countermeasures to mitigate head and neck injuries to toddlers in frontal and lateral vehicle crash conditions* (2) used Finite Elemental Modeling paired with derived kinematic equations to accurately determine these values. Furthermore, when a lower anchorage and tether (LATCH) as well as a rigid ISOFIX system were included in the studies these values continued to decrease with less overall movement of the child restraint system effectively "absorbing" the impact of the collision by moving along with the vehicle during the collision. These HNSDs can be effective in reducing the impact sustained during collision and paired with the ISOFIX system and LATCH can severely lower these normally traumatic forces.



Reference: *Countermeasures to Mitigate Head and Neck Injuries to Toddlers…*

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