



Safe & Sound

Paving the Way

**CChIPS | Center for Child Injury Prevention Studies
2015 Annual Report**

Partnering for Safety

A Message from Our Directors



Kristy Arbogast, PhD, John H. Bolte IV, PhD, and Flaura Winston, MD, PhD, co-directors, CChIPS

Strong science, relevant research, collaboration and passion. These values pave the way to preventing injuries and keeping children safe and sound at the Center for Child Injury Prevention Studies (CChIPS). This year we mark 10 years of evidence, cultivated in nearly 100 research projects, that provides our field with knowledge to engineer and innovate effective prevention solutions that will save lives.

With partner research sites at The Children's Hospital of Philadelphia (CHOP) Research Institute and The Ohio State University (OSU), CChIPS is proud to mark its 10 year anniversary in 2015. Through a unique partnership with our Industry Advisory Board (IAB) comprising 22 member organizations, our researchers pinpoint and assess the causes of injuries to children and young adults, while our IAB keeps their research actionable and relevant. On behalf of the IAB and our dedicated team of researchers, we are excited to share research highlights and summary updates from the past year in this annual report.

Founded in March 2005 with a grant from the National Science Foundation (NSF), CChIPS is one of nearly 80 Industry/University Cooperative Research Centers (I/UCRC) funded by NSF in the country and the only one focused on preventing child and young adult injuries. The lead academic site of CChIPS is housed within the larger Center for Injury Research and Prevention (CIRP), a Center of Emphasis at CHOP. Through its annual Advances in Child Injury Prevention (ACIP) Conference held in Plymouth, MI, CChIPS discusses new developments in child injury science with professionals from industry, government, and research organizations. ACIP brings together experts from academic, policy and advocacy institutions to share their latest research on occupant safety and other road traffic injury topics related to children and adolescents.

CChIPS also spreads its important mission and message of child injury prevention worldwide. Over the past year, Center faculty and investigators presented at:

- Researchers Forum of Or Yarak , Tel Aviv, Israel
- Royal Academy of Medicine of Ireland, Dublin, Ireland
- International Society for Research on Internet Interventions, Valencia, Spain
- Japanese Society of Automotive Engineers Forum on Automotive Safety, Yokohama, Japan
- Protection of Children in Cars International Conference, Munich, Germany
- International Research Council on the Biomechanics of Injury Conference, Berlin, Germany
- 1st International Conference on Children's Car Safety Technology, Shanghai, China
- Association for the Advancement of Automotive Medicine (AAAM) meeting, Munich, Germany

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CChIPS is also committed to the ongoing engagement of its stakeholders and to the translation of rigorous science into action with measurable impact. To that end, CChIPS, through its parent center CIRP, utilizes a team of outreach and communication experts with more than a decade of expertise and demonstrable success at turning traffic safety research findings into policy advocacy, education, and awareness initiatives. Their efforts focus on translating CChIPS research findings into appropriate messages and resources designed to reach our stakeholders. Digital communication strategies include the cchips.research.chop.edu website, a CIRP LinkedIn group with over 200 members, a Twitter presence through CChIPS Director Flaura Winston's [@safetymd](https://twitter.com/safetymd) account (which has over 2,700 followers), and CChIPS-focused blog articles in CIRP's *Research in Action* blog.

The success of CChIPS, as exhibited in this report, shows the tremendous impact industry, academia, nonprofits, and government can achieve when working collaboratively toward mutual goals.

A Unique Approach to Child Safety Research

Hosted by The Children's Hospital of Philadelphia Research Institute, with a second site at The Ohio State University, CChIPS is driven by a public health imperative to reduce child injury. Scientific advances made by CChIPS investigators provide commercial opportunities for the Center's industry members. These incentives combine to give CChIPS its unique dual mission – advancing research and development (R&D) while taking explicit action to apply R&D for societal benefit. Notably, this mission is executed within a challenging, highly regulated environment that requires a rigorous scientific foundation. Our researchers work side by side with industry members to conduct translational research that is relevant to industry. This synergistic collaboration is ideal for generating ideas for new research projects and sharing expertise and resources.

The fundamental idea behind our work is that children are not small adults (mechanically, psychologically, developmentally, and socially). Therefore, child injury deserves to be examined and understood as a distinct branch of science. As automotive design and our understanding of consumer behavior become increasingly complex, enhanced research, product development, and educational efforts are necessary to further child safety. Over the past 10 years CChIPS has conducted approximately 92 projects with researchers partnering with leading automotive manufacturers, restraint suppliers, insurance providers, and government agencies to translate their findings into tangible innovations in safety technology and public education programs.

The CChIPS research method applies the broad and diverse backgrounds of its investigators to create and implement novel integrated approaches. For example, child crash injury-related

research uses Biomechanical Epidemiology, an approach developed by CChIPS investigators, whereby engineering questions are answered with the rigorous methods used for clinical research studies. Currently, the majority of CChIPS research is focused on preventing road traffic injuries and deaths. Areas of research include:

- injury biomechanics, mechanisms, and tolerance
- technological solutions (design, development, and testing)
- how humans interact and behave in relation to safety technology
- safety promotion and education
- the evaluation of safety devices and behavior modification programs

In 2015, the NSF awarded CChIPS a five-year, Phase III continuation grant, following a successful first 10 years of funding through Phase I and II NSF grants. During the next five years, CChIPS leadership and the IAB will continue a proactive focus on the emerging safety needs of children and the long-term sustainability of our Center so that we can continue to provide the scientific foundation for protecting children. To learn more about CChIPS or to sponsor research with CChIPS investigators, visit cchips.research.chop.edu or e-mail Eve Weiss, MS, CChIPS managing director, at weisse2@email.chop.edu.

CChIPS Mission Statement

The CChIPS mission is to advance the safety of children, youth, and young adults by facilitating scientific inquiry into childhood and young adult injuries and to translate these findings into commercial applications and educational programs for preventing future injuries.

The CChIPS Project Year

Day-to-Day Functions and the Role of the IAB

CChIPS members play an integral role beyond sponsorship; they work closely with faculty to set the CChIPS research agenda, provide mentorship to investigators and promote the research findings and capabilities of CChIPS within their organizations. In their role, members provide the crucial link between academia and the real world to ensure that the safety of children, youth and young adults is an important consideration in design and testing and that CChIPS research is relevant and translated into innovative, practical solutions that improve safety. Representatives from the member companies form the Center's Industry Advisory Board (IAB). The IAB selects a Chair and Secretary to serve for a two-year term. IAB meetings are held twice a year, in spring (to select the research portfolio for the upcoming year and hear results from projects funded in the previous year) and in the fall (to review progress and provide insights to the current year's research portfolio and to select ideas for proposal submissions for the subsequent year). A formal process of proposal submissions involves extensive discussions with designated IAB mentors immediately preceding the annual spring meeting.

Besides selecting the research to be performed, IAB members provide valuable feedback on projects already underway, both as project mentors and as reviewers of project progress and results, and provide guidance in strategic planning for the Center.

Every membership dollar goes toward research and its dissemination. Since its inception, the CHOP Research Institute, The University of Pennsylvania, The Ohio State University, and other research facilities involved in CChIPS projects have shown their support of this important work by waiving overhead fees for member dues and for additional research projects funded by member companies as part of the CChIPS portfolio. IAB members can also rely on the CChIPS proven track record in successful research partnerships with industry and government to advance the field of child safety. In addition to regular interactions with virtually all automotive-related organizations concerned with child safety, the Center has conducted specific research projects with major original equipment manufacturers, restraint suppliers, insurance providers, child safety advocates, and government agencies, of which many are IAB members.

CChIPS membership is open to all companies, organizations, or agencies that have an interest in advancing research and development to further child and adolescent injury prevention. CChIPS faculty thank our current member companies, listed below, and invite other companies, organizations or agencies to join.

2014-2015 IAB Member Companies:

- American Honda Motor Co., Inc.
- Britax Child Safety, Inc.
- Calspan Corporation
- Childress Institute for Pediatric Trauma
- Consumer Reports
- Evenflo Company Inc.
- FCA US LLC (formerly Chrysler Group LLC)
- Federal Aviation Administration
- Ford Motor Company
- General Motors Holdings LLC
- Graco Children's Products Inc.
- Humanetics Innovative Solutions Inc.
- Minnesota HealthSolutions
- The National Highway Traffic Safety Administration
- Nissan Technical Center North America Inc.
- Realtime Technologies Inc.
- Safe Kids Worldwide
- State Farm Mutual Automobile Insurance Company
- TK Holdings Inc. (Takata Corp.)
- Toyota USA
- Transportation Research Center Inc.
- Volkswagen Group of America

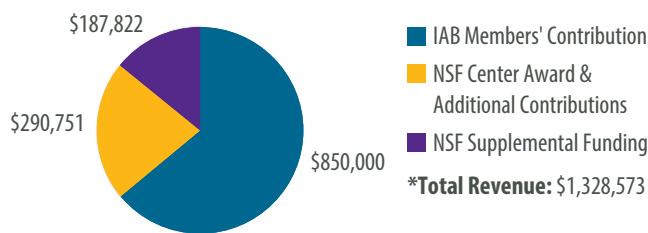
For current IAB membership, please visit
cchips.research.chop.edu.

Funding the Research

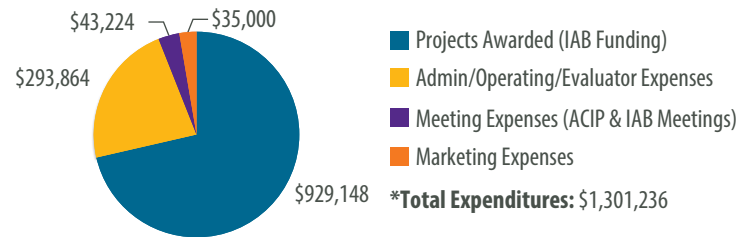


CChIPS is made possible through a grant from the National Science Foundation (NSF), as well as sponsorships from its Industry Advisory Board (IAB) members comprised of the leaders in industry, small business, nonprofits, and government agencies that engage in and value scientific research and development to improve child safety. Every year, each full voting IAB member contributes \$50,000 to support the CChIPS mission. Nonprofit organizations and small businesses are also given the opportunity to join for a reduced annual fee. Government agencies support CChIPS as non-voting members and contribute to the science as project mentors. Membership in CChIPS has fostered industry and small business commitment to the CChIPS mission and spurred innovation. To become a member or to sponsor research with CChIPS investigators, contact Eve Weiss, MS, CChIPS managing director, at weisse2@email.chop.edu.

Revenue for 2015

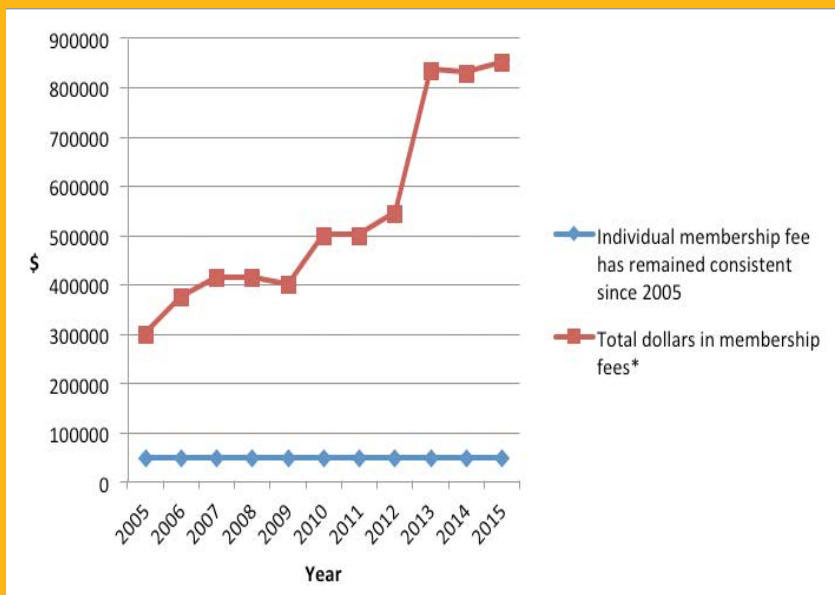


Expenditures for 2015



The Children's Hospital of Philadelphia Research Institute and The Ohio State University waive overhead expenses for CChIPS.

Return on Investment



On average since CChIPS began in 2005, each full voting Industry Advisory Board (IAB) member has contributed an annual \$50,000 membership fee as an opportunity to influence the direction of the CChIPS research agenda and to gain the benefits of leveraged research funding through a consortium model. In 2015, the combined membership fees resulted in \$850,000 available to support the CChIPS mission. Based upon the \$50,000 membership fee, this represents a 1,600% annual Return on Investment (ROI) per company.

*Membership fees only constitute a portion of total funding available for CChIPS.

Research In Action:

2014-2015 Project Highlights

Anthropometry and Properties of the 6-Year-Old Spine

Principal Investigator:

Amanda Agnew, PhD, The Ohio State University

Co-Principal Investigator:

Julie Bing, MS, The Ohio State University

Co-Principal Investigator:

Laura Boucher, PhD, The Ohio State University

Student:

Sam Goldman, The Ohio State University

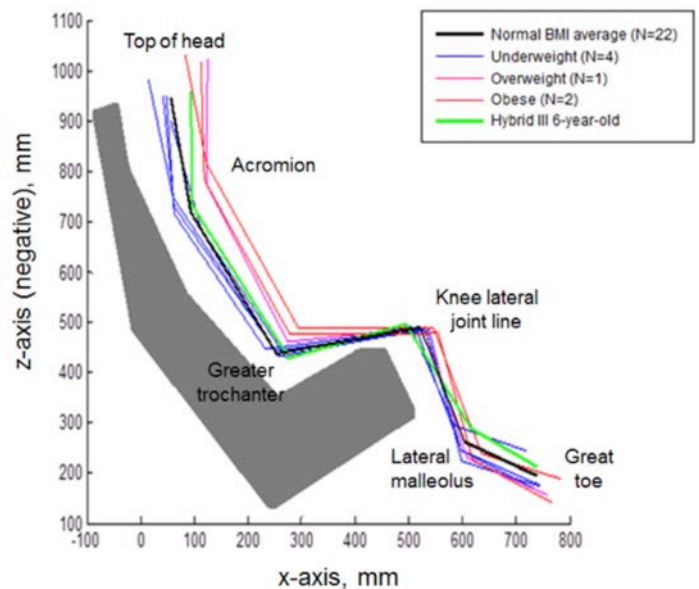
IAB Mentors:

Doug Longhitano, American Honda Motor Co., Inc.; Eric Dahle, Evenflo Company Inc.; Mark Neal, General Motors Holdings LLC; Jerry Wang, Humanetics Innovative Solutions Inc.

The use of pediatric anthropomorphic test devices (ATDs), or crash test dummies, has helped mitigate childhood death and injuries in recent decades by providing a method for testing the injury mitigation potential of safety devices. However, there is considerable room for improvement in these tools. Pediatric ATDs, especially the widely used Hybrid III (HIII) family, were developed using scaled-down adult data from the 1970's. This introduced a host of inaccuracies due to differences in both mechanical properties and anthropometry, or measurements of the human body, between adults and children. Specifically, many studies have found that the spine is too stiff and not representative of children, which leads to concentrated forces and moments in the ATD neck, and head excursion measurements in sled tests that are not representative of child kinematics.

This study aimed to better understand the anthropometry, curvature, and movement of the pediatric lumbar spine, focusing specifically on:

- Collecting anthropometric and lumbar spine range of motion data from volunteers ages 5 to 7 years
- Digitizing bony landmarks to define posture, spine curvature, and external morphology in child restraint systems (CRS), with an emphasis on the lumbar spine region
- Comparing results to pediatric computerized tomography (CT) scans to develop a meaningful picture of the entire pediatric lumbar spine



Differences in bony landmark positions for children of different sizes (as measured by body mass index) compared to the Hybrid III 6-year-old ATD.

To accomplish this, 29 youth volunteers between 5 and 7 years old were recruited. Basic anthropometric measurements were taken, and lumbar spine range of motion testing was completed using standard clinical methods. While the child was seated in a CRS, the locations of several bony landmarks were digitized using a FARO arm. Differences in anthropometry and posture were stratified by body mass index (BMI). Comparisons were made among the group of volunteers, a HIII 6-year-old ATD, and a separate cohort of supine lumbopelvic CT scans from 16 age-matched subjects.

The results quantified several important differences between pediatric volunteers and the 6-year-old HIII ATD. The ATD matched the volunteer cohort in terms of basic proportions and breadths but tended to be slightly above average in several measures of circumference. When seated in a semi-reclined CRS, the head and torso of the ATD tended to pitch further upright than the normal population of volunteers and imitated the more erect spine angles of obese and overweight subjects. Ranges of motion of the ATD spine were below those of volunteers. The CT cohort in the supine position exhibited greater lumbar spine curvature and more anterior pelvic tilt than the volunteer cohort in the semi-reclined position. Additionally, the 6-year-old HIII ATD had a more vertical and erect posture than the volunteer cohort while seated in a semi-reclined CRS.

A considerable amount of variation exists in anthropometric parameters, even within children of the same age group. The data presented here contribute to the growing base of knowledge for proper design and improvement of pediatric ATDs and computer models, which are critical tools for advancing child safety in motor vehicle crashes. Results of this study can contribute to more effective modeling scenarios, ATD design, and the evaluation of injury criteria.

Quantifying Children's Posture in the Rear Seat – A Naturalistic Study (Year 3)

Principal Investigator:

Kristy Arbogast, PhD, The Children's Hospital of Philadelphia

Project Team Members:

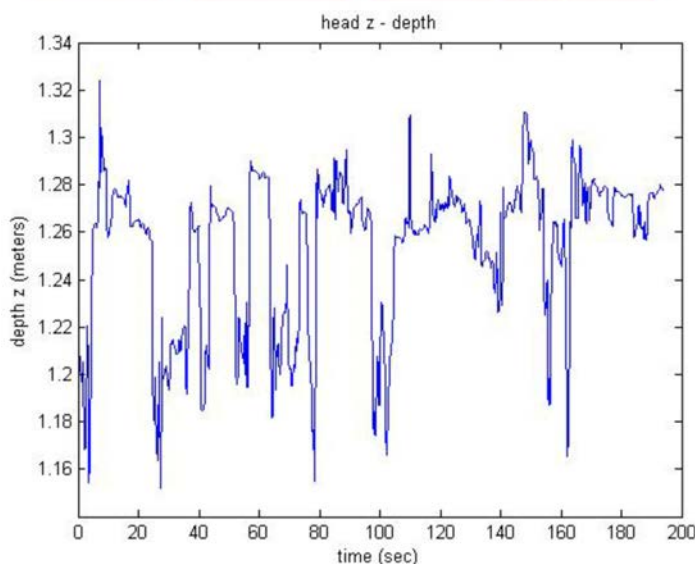
Katarina Bohman, PhD, SAFER, Autoliv Research; Judith Charlton, PhD, Monash University; Jinyong Kim, PhD, The Children's Hospital of Philadelphia; Sjaan Koppel, PhD, Monash University; Helen Loeb, PhD, The Children's Hospital of Philadelphia; Byoung-Keon Park, PhD, University of Michigan; Matthew Reed, PhD, University of Michigan; Mats Svensson, PhD, SAFER, Chalmers University of Technology

Students:

Gretchen Baker, University of Kansas; Suzanne Cross, MS, Monash University; Johnny Kuo, MS, Monash University; Christian Parker, Drexel University; Isabelle Stockman, MS, Chalmers University of Technology

IAB Mentors:

Audrey Eagle, FCA US LLC; Agnes Kim, Ford Motor Company; Julie Kleinert, General Motors Holdings LLC; Mark LaPlante, Graco Children's Products Inc.; Sara Seifert, Minnesota HealthSolutions; Steve Roberson, State Farm Mutual Automobile Insurance Company; Hiromasa Tanji, TK Holdings Inc.; Schuyler St. Lawrence, Toyota USA



At top: A single image from one time point displays raw depth data from the Kinect system. The view is from the front seat looking back at three children positioned across the second row. The blue dot represents the location of the center-seated child's head as identified by Kinect's skeletal tracking system. Below: This graph shows the fore-aft distance of the center-seated child's head throughout the trip as logged by Kinect's skeletal tracking system.

Previous research has highlighted the tendency for children to move substantially out of position when restrained in a motor vehicle, not only in response to vehicle dynamics, but also of their own volition. Of particular interest are the circumstances that lead to extreme head positions for rear-seated child occupants to identify whether these circumstances are modifiable. In 2012-2013 and 2013-2014 funding years, CChIPS has supported CHOP's effort in a large multidisciplinary collaboration of engineers and behavioral scientists led by Monash University in Melbourne, Australia to quantify differences between optimal posture and position of child occupants in the rear seat and actual position and posture through a large scale naturalistic study. CChIPS funded the development of the initial methodology to implement a Microsoft Xbox Kinect Sensor™ in the study vehicles to measure head position. This support continued through the 2014-2015 funding year to develop and test several analytical algorithms that leveraged the quantitative details of the Kinect data.

In Year 3, the team evaluated the built-in algorithm's ability to collect accurate data on the position of the head on a random sample of 5 percent of trips. Additionally, in part due to the limitations of the skeletal tracking algorithm, a second approach was developed to find images of extreme head motion. This approach compared the depth profile of a given image to a reference image. These images – defined as extreme motion candidates – were reviewed manually to confirm they indeed represented extreme head motion. Once confirmed, the x, y, z coordinates of the head were extracted from the Kinect data.

Naturalistic data collection was completed in November 2014 with 42 families enrolled and approximately 1,200 trips taken using the study vehicle. Skeleton data were recorded on 714 trips (60 percent success rate), and 1.5 million Kinect images in color and 3D format were made available for analysis. The validation study determined that for 41 percent of these images, the skeletal prediction of the head location was accurate. Though less accurate than expected, the size of the dataset suggests a significant amount of skeletal tracking data remains valuable to analyze. Precise 3D accelerometer data from the Kinect sensor was recorded as well on 492 trips, enabling the research team to study the impact of the dynamics of the car on the child's position and posture.

Ongoing support recognizes that this line of research is a critical next step to understand how to protect rear-seat occupants in actual real-world scenarios – those dominated by less-than-ideal occupant positioning. Future work will quantify head position and lead to the development of countermeasures to recognize and correct sub-optimal positions to improve rear-seat occupant protection.

Evaluation of Side Impacts with a Frontal Component for Children in Child Restraint Systems

Principal Investigator:

Kristy Arbogast, PhD, The Children's Hospital of Philadelphia

Project Team Members:

Hans W. Hauschild, MS, Medical College of Wisconsin; **Bruce Kaufmann, MD**, Children's Hospital of Wisconsin & Medical College of Wisconsin; **Matthew R. Maltese, PhD**, The Children's Hospital of Philadelphia; **Frank A. Pintar, PhD**, Medical College of Wisconsin; **Narayan Yoganandan, PhD**, Medical College of Wisconsin

Students:

Paul Gromowski, MS, Medical College of Wisconsin; **John R. Humm**, Medical College of Wisconsin

IAB Mentors:

Mike Kulig, Calspan Corporation; **Eric Dahle**, Evenflo Company Inc.; **Audrey Eagle**, FCA US LLC; **Agnes Kim**, Ford Motor Company; **Julie Kleinert**, General Motors Holdings LLC; **Mark LaPlante**, Graco Children's Products Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Hiromasa Tanji**, TK Holdings Inc.; **Schuyler St. Lawrence**, Toyota USA



Image of a sled test showing the FF CRS rotating and tipping towards the impact direction, facilitating the ATD head to rotate around the FF CRS side wing.

Side-impact collisions are the second most common crash mode, accounting for 26 percent of fatal crashes for all occupants, and 40 percent of fatalities to children between 0 and 8 years of age. As such, the National Highway Traffic Safety Administration has identified child restraint systems (CRS) protection in a near-side configuration as a safety priority. Few studies have examined the injury potential to children in side-impact crashes in positions other than the near-side position, such as center seating locations, because they are generally considered safest for the pediatric occupant. For the center- or far-side seated CRS in particular, the potential of CRS to yaw or roll into intruding vehicle components (especially in small-size vehicles) has

not been addressed. This line of research is intended to spur development of safety improvements for children in side impacts and is in alignment with recent efforts to meet the safety needs of adults seated in front row positions, during side impacts that are far side to the occupant.

This project aimed to quantify the kinematics and injury potential for anthropomorphic test devices (ATDs) representing a 3-year-old occupant in a far- or center- seated position in an oblique side-impact crash. The project test series examined the influence of side-impact protection features, such as side wings, of a forward-facing CRS (FF CRS), vehicle seat type, and tether routing.

Sled tests were conducted utilizing a Q3s dummy positioned in a FF CRS with large side wings that were removed. The CRS were attached via Lower Anchors and Tethers for Children (LATCH) on two different vehicle seat fixtures – a small SUV rear bench seat with a fixed head restraint, and a minivan rear bucket seat with an adjustable head restraint. The vehicle seats were secured to the sled at 20 degrees from lateral.

Results indicated the side wings have little influence on head excursions and ATD response. Researchers observed primary differences in head response between the two vehicle seat fixtures due to the vehicle seat head restraint design. The bench seat integrated head restraint forced the top tether to be routed over the head restraint. Due to the lateral crash forces, the tether moved laterally off the head restraint reducing webbing tension and increasing head excursion (477 mm median). In contrast, when the tether was routed under the bucket seat's adjustable head restraint, it maintained a tight attachment and helped control head excursion (393 mm median).

This testing illustrated relevant side-impact crash circumstances where side wings do not provide the desired head containment for a 3-year-old ATD seated far-side or center in a FF CRS. In a center or far-side seating configuration, the absence of a door structure immediately adjacent to the CRS may allow the rotation and tipping of the FF CRS towards the impact side and the roll-out of the head around the side wing structure. Results suggest other prevention measures, in the form of alternative side-impact structure design, FF CRS vehicle attachment, or a combination of safety technology provided by both the vehicle and the FF CRS and the vehicle, may be necessary to protect children in oblique side impact crashes.

Quantifying CRS Fit in the Vehicle Seat Environment – Digitization Approach (Year 2)

Principal Investigator:

Aditya Belwadi, PhD, The Children’s Hospital of Philadelphia

Student:

Richard Hanna, MS, Drexel University

IAB Mentors:

Doug Longhitano, American Honda Motor Co., Inc.; Keith Nagelski, Britax Child Safety, Inc.; Eric Dahle, Evenflo Company Inc.; Audrey Eagle, FCA US LLC; Julie Kleinert, General Motors Holdings LLC; Mark La Plante, Graco Children’s Products Inc.; John Combest, Nissan Technical Center North America Inc.; Schuyler St. Lawrence, Toyota USA; Barbara Birkenshaw, Volkswagen Group of America; Uwe Meissner, Technical Advisor

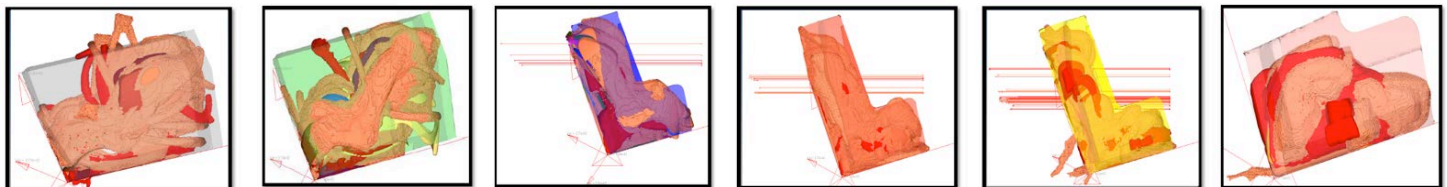


Fig. 1: Smallest RF Surrogate

Fig. 2: Largest RF Surrogate

Fig. 3: Smallest FF Surrogate

Fig. 4: Largest FF Surrogate

Fig. 5: HBB Surrogate

Fig. 6: LBB Surrogate

The above images depict virtual surrogate models, from rear-facing child restraints (RF) in Year 1 extended to forward-facing child restraints (FF), high-back boosters (HBB) and low-back boosters (LBB) updated for Year 2.

The challenges and frustration faced by many parents and caregivers in installing child restraint systems (CRS) has been well-documented, both scientifically and in the lay media. This multi-year CCHIPS project aims to alleviate this problem before it begins, by allowing vehicle manufacturers to understand the breadth of CRS dimensions and to take them into account when designing new vehicles.

Year 1 of this project developed a methodology for CRS digitization by creating a virtual surrogate of a small rear-facing CRS – a volume-encompassing CRS to aid designers in assessing space and fitment during the design phase. This was accomplished by using the Microsoft Xbox Kinect Sensor™ to scan 72 CRS, including rear-facing, forward-facing, high-back boosters, and low-back boosters, to represent 252 CRS commercially available as of April 2013.

In Year 2, researchers again utilized the Kinect Sensor in conjunction with ReconstructMe, which used the real-world imaging data read by the Kinect to create a three-dimensional shell file. This file was then imported into Hypermesh, a high-performance finite element pre-processor, for clean-up and full-model construction. Finally, a “shrink wrapping” process in Hypermesh was used to create a single, final shell that encompassed the

model and yielded an accurate virtual CRS. The same shrink-wrapping process was then used to combine multiple CRS into virtual surrogates to represent groups of CRS on the market according to size, shape and geometry.

Six virtual surrogates were developed based on the combination of scanned and original equipment manufacturer CRS virtual models. Additional CRS were scanned in Year 2, resulting in a total of 48 rear-facing seat models representative of 81 on the market, 69 forward-facing seat models representative of 104 on the market, and 35 high-back booster and 22 low-back booster models included over the duration of Year 1 and Year 2 of this project.

Through two years of development, the virtual surrogate has been proven to be an effective tool in assessing CRS-to-vehicle fitment. Feedback from both vehicle and CRS manufacturers have further helped transform these models from amorphous “blobs” to “surrogates,” accurately representing the volume of child seats. The next phase of this project will expand the virtual surrogate development to include additional seat types and sizes. Additional data on seat recline angles and belt paths will be added to aid fitment assessment.

Side Air Bag Interaction with Children Seated in the Vehicle Environment (Years 1 & 2)

Principal Investigator:

Aditya Belwadi, PhD, The Children's Hospital of Philadelphia

Project Team Members:

Kristy Arbogast, PhD, The Children's Hospital of Philadelphia

Matthew R. Maltese, PhD, The Children's Hospital of Philadelphia

Students:

Alicia Abrazinsky, Drexel University; **Ryan Garvin**, Drexel University;

Richard Hanna, MS, Drexel University; **Todd Hullfish**, Drexel University

IAB Mentors:

Doug Longhitano, American Honda Motor Co., Inc.; **Chris Mampe**, American Honda Motor Co., Inc.; **Keith Nagelski**, Britax Child Safety, Inc.; **Eric Dahle**, Evenflo Company Inc.; **Neeharika Anantharaju**, FCA US LLC; **Guy Nusholtz**, FCA US LLC; **Julie Kleinert**, General Motors Holdings LLC; **Mark La Plante**, Graco Children's Products Inc.; **Schuyler St. Lawrence**, Toyota USA; **Uwe Meissner**, Technical Advisor



A Hybrid III 6-year-old ATD seated in a high-back booster seat restrained with a lap-and-shoulder belt is subjected to side-impact testing.

The prevention of injury in side-impact crashes is of particular importance for pediatric motor vehicle occupants. The incidence of fatality in side-impact crashes is 30 percent, compared to 17 percent in frontal-impact crashes. Significant injury has been found to occur in 41 percent of side-impact crashes versus 15 percent of frontal-impact crashes and 3 percent of rear-impact crashes involving a child occupant. This line of research aimed to assess whether side curtain air bags (roof-side rail-mounted) provide a protective benefit in side-impact crashes for rear-seated children in child restraint systems (CRS).

Year 1 determined the incidence of injuries in motor vehicle crashes to pediatric occupants seated near-side to a deploying side curtain air bag. Researchers conducted a preliminary analysis of a series of cases identified from the National Automotive Sampling System- Crashworthiness Data System (NASS-CDS) and the Crash Injury Research and Engineering Network (CIREN) involving passengers ages 15 or younger who were near-side to a deployed air bag in crashes from 1998 to 2012. These analyses estimated exposure and determined injury contact maps.

In Year 2, the team sought to understand the effect of pediatric occupant seating posture using anthropomorphic test devices (ATDs), or crash test dummies. The 6-year-old Hybrid

III and Q6s ATD were restrained in belt-positioning boosters in side-impact crashes with and without exposure to side curtain air bag deployment. Researchers conducted a series of side-impact sled tests using a novel testing apparatus designed to replicate intrusion profiles and crash speeds seen in full-vehicle crashes. The apparatus included a door fixture mounted on an acceleration sled that could be deformed by four pneumatically actuated cylinders.

The sled tests revealed that side curtain air bags protected the head as indicated by reduced head acceleration and lateral head excursion as compared to tests without them. However, there was a slight increase in peak pelvic acceleration measured in ATDs that interacted with a side curtain air bag. This increase can be attributed to differences in the kinematics between the head/chest and pelvis, due to late engagement of the pelvis with the intruding door trim while the head was being supported by the air bag.

This line of research provides insight into the role of side curtain air bags in mitigating injury to rear-seated children in side-impact crashes, with an emphasis on those in belt-positioning booster seats. These data can be used by vehicle and child seat manufacturers to further enhance occupant safety.

Optimization of Recline Angle in Rear-facing Child Restraint Systems

Principal Investigator:

John H. Bolte IV, PhD, The Ohio State University

Project Team Member:

Julie Bing, MS, The Ohio State University

IAB Mentors:

Keith Nagelski, Britax Child Safety, Inc.; Eric Dahle, Evenflo Company Inc.;

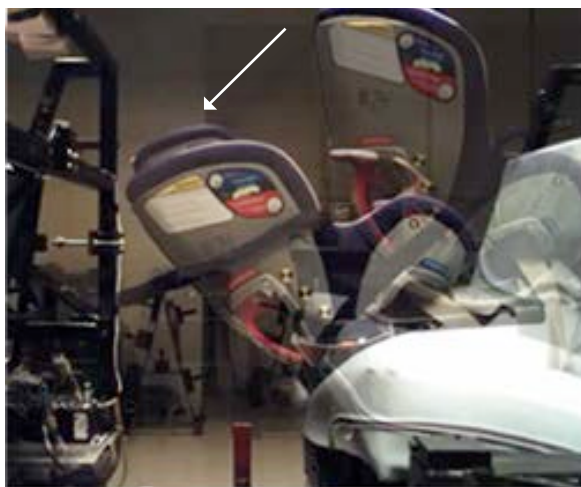
Mark LaPlante, Graco Children's Products Inc.

Rear-facing child restraint systems (RF CRS) are recommended for children from birth until they physically outgrow the weight or height limits of the restraint, which typically happens around 2 years of age. RF CRS are designed to absorb and distribute crash forces through the child's back and into the CRS, yet it is difficult to establish an ideal recline angle (defined as the angle the CRS seat back is from vertical) due to the variety of ages and sizes of RF CRS occupants. The goal of this project was to optimize the recline angle of RF CRS in frontal crashes to provide ideal crash safety while considering the differing physiological needs of children in various stages of development.

After reviewing published medical data, recline angles were identified that were considered safe with respect to bradycardia and apnea risk in normal transport for newborns, particularly those born prematurely (37 weeks and earlier). In order to determine the optimal recline angle that balanced safety during normal transport and occupant protection during collisions, researchers conducted frontal sled tests on a vehicle bench seat to examine the responses of anthropomorphic test devices (ATDs), or crash test dummies, ranging from newborn to 3-year-old, across a range of RF CRS recline angles. Both CRS kinematics and ATD injury criteria were measured. Investigators considered real-world CRS misuse data to recreate realistic scenarios, such as CRS recline angles which are too upright and/or CRS with loose harness straps.

The sled test data indicated that CRS which initially positioned the ATD in a more horizontal recline position tended to result in lower head injury measures, larger chest accelerations, and greater recline angles at the point of maximum rotation as compared to CRS which positioned the ATD initially in more upright seated positions. Of these variables, the initial recline position most significantly influenced the maximum recline angle of the CRS; however, the effect on head injury measures and chest accelerations was not as significant. Larger ATDs experienced higher neck tensions than smaller ATDs possibly because of their greater head mass. Neck tension did not appear to vary according to initial recline angle.

It is important to note that this study was conducted on a sled test with a bench seat that had no vehicle interior. Results of this study suggest that more reclined initial positions could result in more horizontal recline angles at the point of maximum rotation and/or forward movement of the CRS in the event of a crash thereby increasing injury risk. Future work should consider how the kinematics of the CRS may interact with a vehicle's interior and potentially increase the risk of injury. While smaller infants who are born prematurely (before 37 weeks) require a more reclined angle to prevent bradycardia and/or apnea, as children grow older but remain rear-facing, considerations should be made to seat toddlers in a more upright rear-facing position to prevent CRS over-rotation and to decrease the risk of contact with the vehicle's interior.



(a) Upright initial position



(b) Reclined initial position

Video frames show the initial position and point of maximum rotation overlaid for RF CRS initially installed in their most upright setting (a) and their most reclined setting (b).

Association Between NCAP Ratings and Real-world Rear Seat Occupant Risk of Injury

Principal Investigator:

Allison Curry, PhD, MPH, The Children's Hospital of Philadelphia

Project Team Members:

Dennis R. Durbin, MD, MSCE, The Children's Hospital of Philadelphia
 Siobhan Gruschow, MPH, MEd, The Children's Hospital of Philadelphia
 Kristina B. Metzger, PhD, MPH, Independent Consultant

Students:

Sayaka Ogawa, Drexel University; **Kassandra Pickel**, Drexel University

IAB Mentors:

Michelle Tsai, Consumer Reports; Lan Xu, FCA US LLC; Agnes Kim, Ford Motor Company; Steve Rouhana, Ford Motor Company; Steve Roberson, State Farm Mutual Automobile Insurance Company; Hiromasa Tanji, TK Holdings Inc.; Schuyler St. Lawrence, Toyota USA

Many consumers utilize the National Highway Traffic Safety Administration's US New Car Assessment Program (NCAP) "star ratings" to compare the safety of new vehicles. The ratings are based on evaluations of injury risk as measured by anthropomorphic test devices (ATDs), or crash test dummies, and range from 1 star (greater than average risk) to 5 stars (less than average risk).

Little is known about whether NCAP ratings predict real-world risk of injury to restrained rear seat occupants. Currently, only the side-impact barrier and pole tests include an ATD in the rear seat and no existing full vehicle crash test includes a rear-seated child-size ATD. This project examined how NCAP's current rating system predicts risk of serious injury among restrained rear-seat occupants in real-world crashes.

Crash-involved vehicles, model years 2004-2013, were identified in the National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) database. Using data on make, model year, body type, and other identifying information, 95 percent of the vehicles in NASS-CDS were matched to a specific vehicle in NCAP. The resultant database was analyzed to examine associations between vehicle ratings and rear-seat occupant injury risk. Data were limited to restrained occupants, and injuries were defined as injuries with an Abbreviated Injury Scale (AIS) score of 2 or greater.

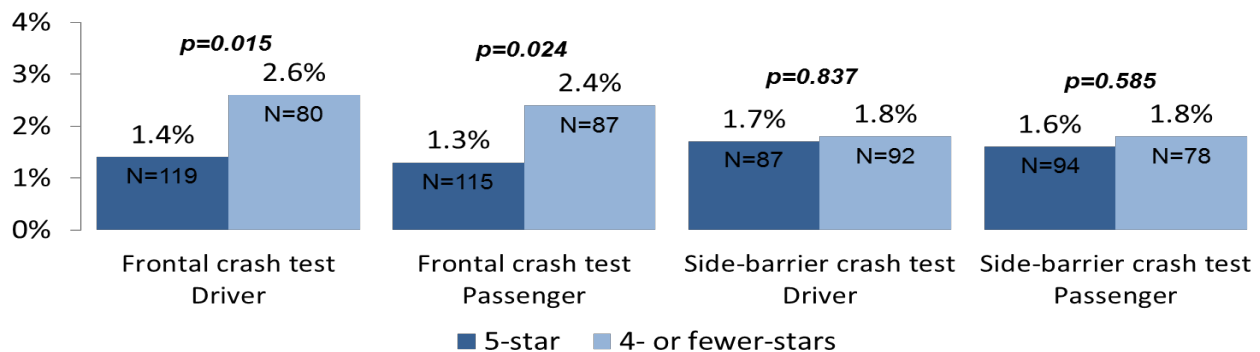
The 18,218 vehicles represented an estimated 6 million vehicles with over 9 million occupants. The injury risk for restrained rear-seat occupants was:

- **Lower** in vehicles with a 5-star driver rating in frontal-impact tests (1.4 percent) than with 4- or fewer-stars (2.6 percent)
- **Lower** in vehicles with a 5-star passenger rating in frontal-impact tests (1.3 percent) than with 4- or fewer-stars (2.4 percent)

Conversely, side-impact driver and passenger crash tests were **not** associated with rear-seat occupant injury risk (driver test: 1.7 percent for 5 star vs. 1.8 percent for 1 to 4 stars; passenger test: 1.6 percent for 5 stars vs 1.8 percent for 1 to 4 stars).

The findings indicate current frontal-impact test procedures provide some degree of discrimination in real-world rear-seat injury risk among vehicles with a 5-star rating compared to fewer than 5 stars. However, there is no evidence that vehicles with a 5-star side-impact passenger rating, the only crash test to include a rear-seat ATD, demonstrate lower risks of rear-seat injury than vehicles with fewer than 5 stars. These results support prioritizing modifications to NCAP's program that specifically evaluate rear-seat injury risk to all restrained occupants.

Risk of AIS≥2 Injury among Restrained Rear Row Occupants in All Crashes, by 2004-2010 Crash Test Star Ratings, (NASS-CDS, 2003-2012)



The risk of injury in real world crashes for restrained rear row occupants was lower in vehicles with 5-star driver and passenger ratings in frontal crash tests. There is no association, however, among rear row occupant injury risk and vehicles' star ratings in side-barrier crash tests

The Promise of Digital Communication Technology to Advance Car Seat Installation (Year 1)

Principal Investigator:

Linda Fleisher, PhD, MPH, The Children's Hospital of Philadelphia

Project Team Members:

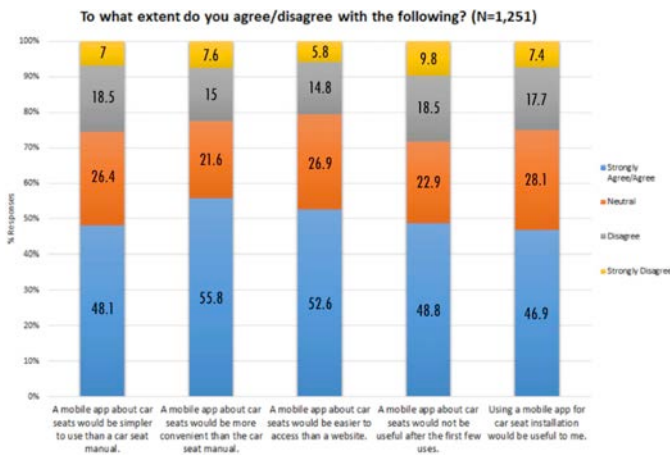
Katherine Halkyard, MPH, The Children's Hospital of Philadelphia
 Jessica Mirman, PhD, The Children's Hospital of Philadelphia
 Flora Winston, MD, PhD, The Children's Hospital of Philadelphia
 Mark Zonfrillo, MD, MSCE, The Children's Hospital of Philadelphia

Students:

Marisol Norris, MA, Drexel University; Jacqueline Omorogbe, Temple University;
 Niti Vora, Drexel University; Chris Sullivan, MPH, Temple University

IAB Mentors:

Ken Wittenaur, Britax Child Safety, Inc.; Michelle Tsai, Consumer Reports;
 John Bachner, Graco Children's Products Inc.; Lorrie Walker, Safe Kids Worldwide



This chart highlights the perceptions of parents and caregivers regarding the value of a mobile app to improve the installation and proper use of CRS.

Misuse of child restraint systems (CRS) through improper installation or inappropriate use continues to be a major contributor to child fatalities in motor vehicle collisions. Addressing misuse is an important step toward injury prevention, as prior research conducted at CHOP indicates that most caregivers do not install CRS correctly, regardless of their confidence in doing so.

This formative Phase I research project aimed to gain insights into the use of both manufacturer's user manuals and online information by parents and other caregivers for information on appropriate CRS installation, to understand perceptions about the use of smartphone applications to support improved installation, and to lay a foundation for the development of a mobile, smartphone-based tool prototype specifically geared to support parents and caretakers in these efforts.

Researchers used a mixed-methods approach to investigate the perceptions of parents and caretakers, including conducting focus groups and a national survey to understand information needs, installation challenges, and perceptions of using new smartphone or Web technology for information delivery. Additionally, investigators observed and debriefed parents and caregivers who reviewed a prototype of a mobile smartphone-based tool designed to provide information about installation and other CRS safety resources, such as local car seat inspection site locations and the Safe Kids Worldwide installation checklist.

Twenty-one caregivers of children treated at urban, suburban and rural practices participated in the focus groups, and 1,322 participated in the online national survey. In addition to reporting that CRS are physically difficult to install, caregivers showed general confusion and lack of knowledge about the appropriate time points in a child's development continuum to switch CRS, use of car seat check programs, national resources, and how to check to ensure that the child is in the proper seat and that the CRS is being used correctly.

Participant responses revealed a potential opportunity for a mobile tool to support the CRS installation process. All caregivers owned a mobile device, and over 90 percent owned smartphones, with most using their phones to access the Internet. Caregivers generally go online to find information about CRS, using social media, Google search, news media, and CRS manufacturer websites. Caregivers indicated that they would use a CRS installation application during each phase of their child's CRS transition. When asked for top suggestions for the tool, they suggested installation videos, troubleshooting tools, car seat check clinic finders, and tools to find the right CRS for their child.

These findings support the need for a mobile tool to assist caregivers in CRS installation. Next steps for this project include further development and testing of a mobile tool in a randomized trial to evaluate its effectiveness in improving CRS installation and use.

Dynamic Strength of Top Tether Anchorages in Various Anchor Locations

Principal Investigator:

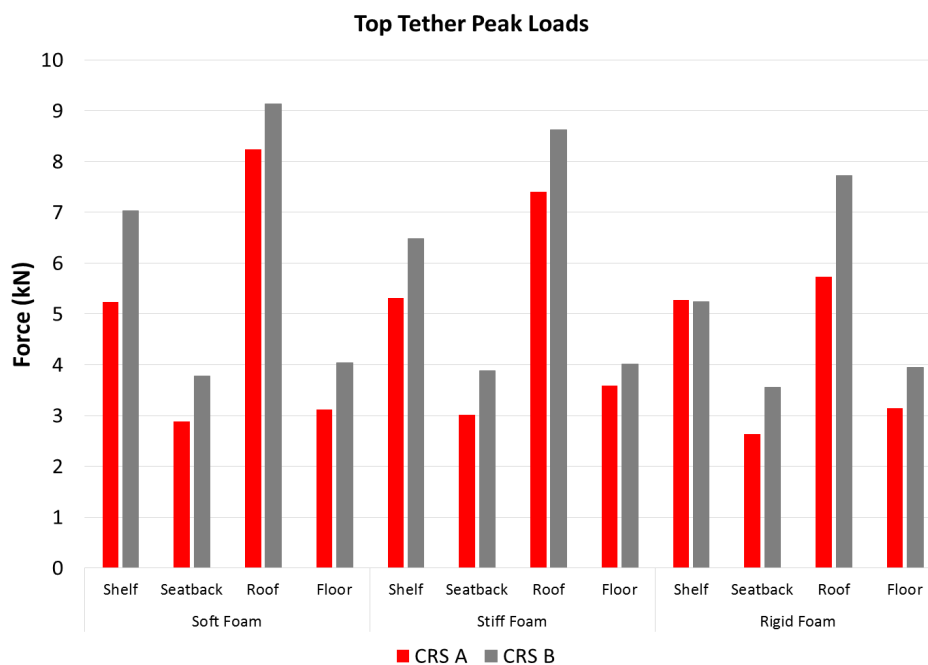
Yun Seok Kang, PhD, The Ohio State University

Students:

Jordan Majstorovic, BS, The Ohio State University

IAB Mentors:

Keith Nagelski, Britax Child Safety, Inc; Michelle Tsai, Consumer Reports; Terry Emerson, Dorel Juvenile Group; Eric Dahle, Evenflo Company Inc.; Audrey Eagle, FCA US LLC; Julie Kleinert, General Motors Holdings LLC; Mark La Plante, Graco Children's Products Inc.



This chart shows how top tether peak loads respond to differing configurations of top tether location (shelf, seatback, or roof), CRS type (A or B), and seat foam stiffness (soft, stiff, or rigid).

The traditional method of attaching child restraint systems (CRS) to vehicle seats has been with an adult seat belt; however, studies have shown this method has resulted in frequent child restraint misuse, such as loose fitting and/or incorrect routing of the seat belt. In response, Lower Anchors and Tethers for Children (LATCH) was developed as a standardized method of attaching CRS to vehicle seats. The top tether is an important component of the LATCH system as it offers an additional attachment for a forward-facing CRS (FF CRS) to the vehicle seat or structure.

The Federal Motor Vehicle Safety Standard (FMVSS) No. 225 evaluates the strength of the top tether anchor, in conjunction with the lower anchors, during a quasi-static loading test. A weakness to this loading evaluation is that the dynamic conditions of a motor vehicle crash are not taken into account, and the top tether anchor is not evaluated independently from the lower anchors. The study aimed to further understand the dynamic loads experienced at the top tether anchor and the effect of various other parameters on these loads.

A finite element (FE) sled test environment simulating frontal crashes (conducted at 48 kilometers per hour) was constructed utilizing the FMVSS No. 213 test bench, a FF CRS, and a Hybrid III 6-year-old anthropomorphic test device (ATD), or crash test dummy.

The CRS was secured to the bench with the flexible LATCH system, and LATCH anchor loads and ATD kinematics were recorded for each simulation. A parametric study was performed with varied top tether anchor location, CRS, and bench seat foam stiffness. Four top tether anchor locations, two CRS, and three seat foams were featured, resulting in a total of 24 simulation scenarios. Two additional parametric studies were performed observing the effect of top tether angle and top tether anchor location offsets on top tether anchor loads.

Top tether peak loads, which can be used for evaluating the strength of the anchorage or connector of the tether, varied by top tether anchor locations as follows (ordered from highest to lowest peak loads): 1) roof, 2) shelf, 3) floor, 4) seatback. This ordering held true regardless of the seat foam stiffness and CRS used in the simulation. Across anchor locations, the top tether angle determined the amount of CRS rotation, which affected the amount of top tether/seatback interaction and CRS/seat pan interaction. Additionally, there was not a strong correlation between top tether loads and ATD head kinematics. The results of this study provide a valuable foundation for vehicle and CRS manufacturers to utilize in optimizing the LATCH system.

Effectiveness of Top Tether on Angular Kinematics of CRS and ATD in Side Impacts

Principal Investigator:

Yun Seok Kang, PhD, The Ohio State University

Student:

Jordan Majstorovic, BS, The Ohio State University

IAB Mentors:

Keith Nagelski, Britax Child Safety, Inc.; Eric Dahle, Evenflo Company Inc.; Agnes Kim, Ford Motor Company; Julie Kleinert, General Motors Holdings LLC; Kendal Fowler, Graco Children's Products Inc.; Jerry Wang, Humanetics Innovative Solutions Inc.; Hiromasa Tanji, TK Holdings Inc.; Uwe Meissner, Technical Advisor

Side impacts are less frequent than frontal impacts; but, given a side impact, the risk of injury is greater. Among side impacts, those far-side and near-side pose different injury risks, and age-appropriate child restraint systems (CRS) have been proven effective in reducing these risks in the event of a motor vehicle collision. The effectiveness of the CRS comes from its ability to distribute forces over the shoulders and hips of the child, while reducing head and chest excursion.

The Lower Anchors and Tethers for Children (LATCH) system is a standardized method of attaching child restraints to vehicle seats. The top tether is a critical component when LATCH is used to install forward-facing CRS. Its effectiveness during frontal impacts has been well-documented, showing the ability to reduce head excursion, chest acceleration, and lower neck loads. Less is known, however, about the top tether's effects during side-impact conditions. Previous research studies analyzed sled tests and finite element simulations in an effort to understand these effects, but had critical limitations. Some only collected limited data using anthropomorphic test devices (ATDs), or crash test dummies, while others only explored a few test conditions.

This study looked to further understand the effects of the top tether in side impacts. A series of near-side and far-side impact sled tests were performed with the Q3s dummy. Two CRS, the Evenflo Triumph and Symphony, and two impact direction angles, lateral

(9°) and oblique (30°), were featured. Each scenario was performed with the presence and absence of the top tether. Q3s responses were recorded, and Head Injury Criteria (HIC15) and Brain Injury Criteria (BrIC) values were calculated. Additionally, CRS angular kinematics were recorded and correlated to the Q3s responses.

For far-side impacts, the top tether increased resultant head accelerations by approximately 8 to 38 percent, and HIC15 values by approximately 20 to 140 percent. However, the top tether was effective in preventing lateral head excursion. For near-side impacts, the top tether resulted in less than a 10 percent increase in resultant head acceleration and HIC15 in the lateral impact direction. For oblique impacts, the top tether increased HIC15 by 17.3 percent for the Triumph and decreased it by 19.5 percent for the Symphony. This difference can be attributed to the design of the seats. The Symphony has side wings to provide extra padding during side impacts; the Triumph does not. Researchers observed noticeably larger Q3s head responses during the near-side impacts than during the far-side impacts. Additionally, the top tether proved beneficial in preventing forward and lateral CRS rotation and reducing lower anchor loads. These results provide critical insight into the effects of the top tether in various side-impact conditions and can aid CRS manufacturers in optimizing the design of child restraints that benefit from top tether usage.



Video capture from a sled test of a far-side impact in which no top tether was used in the installation.

Exploration of the Effect of Positive Reinforcement on Teen Driving Behavior

Principal Investigator:

Yi-Ching Lee, PhD, The Children's Hospital of Philadelphia

Project Team Member:

Aditya Belwadi, PhD, The Children's Hospital of Philadelphia

Students:

Celia Cheng, Drexel University; Leif Malm, Drexel University;

Molly Tiedeken, Drexel University

IAB Mentors:

Doug Longhitano, American Honda Motor Co., Inc.; Chuck Thomas, American Honda Motor Co., Inc.; Mary Beaubien, FCA US LLC; Joseph Lenneman, FCA US LLC; Steve Rouhana, Ford Motor Company; Louis Tijerina, Ford Motor Company; MaryAnn Beebe, General Motors Holdings LLC; Dan Glaser, General Motors Holdings LLC; Sara Seifert, Minnesota HealthSolutions; Noelle LaVoie, Parallel Consulting; Clayne Woodbury, Realtime Technologies Inc.; Steve Roberson, State Farm Mutual Automobile Insurance Company

Research has shown that novice driver crashes decline sharply during the first 6 to 24 months of driving, regardless of the age at which driving begins. Additionally, the relative proportion of speeding-related crashes to all crashes decreases as driver age increases. These patterns indicate that the accumulation of experience during the initial years of driving play a critical role in the decline of crash risk. During the early, high-risk period, opportunities exist to enhance experience and improve safe driving behaviors among novice drivers through continued training and educational efforts beyond licensure.

In-vehicle monitoring systems could provide such continued learning opportunities, yet little is known about how to best provide this training and education. The objectives of this study were to: 1) better understand young drivers' perceptions, preferences, and reactions to receiving support and feedback from in-vehicle monitoring systems, and 2) quantify any behavioral changes upon receiving feedback.



A depiction of one of the experimental drives where participants followed a hilly road while interacting with other vehicles and receiving occasional auditory feedback. These simulated road configurations allowed the research team to examine how drivers adjust their vehicle control behaviors upon receiving positive reinforcements or warnings.

To address the goals of this project, a series of three studies were performed:

- **Study #1:** Researchers identified 17 in-vehicle monitoring apps (iPhone and Android platforms) designed to monitor driver behavior and then systematically evaluated the technologies on a specified driving route. This field evaluation provided insightful information on the range of currently available features and their functionality.
- **Study #2:** Based on the field evaluation results, individual interviews were conducted with 18 young novice drivers exploring their attitudes towards in-vehicle monitoring systems. Results indicated that these drivers were open to receiving feedback, especially when delivered live, in auditory format, and linked to rewards such as earning small monetary bonuses for good driving behavior.
- **Study #3:** Incorporating findings from the interviews, a driving simulator experiment was designed to deliver real-time, auditory feedback (with both positive and negative messages) to 17 participants about their speeding behaviors. Behaviorally, no significant changes were observed when participants received live, auditory feedback.

The results of this study indicate that although positive reinforcement techniques are attractive and have potential to change speed management behaviors, further testing and refinement of reinforcement techniques are needed.

Understanding and Predicting Human Driving Behaviors via Machine Learning Models (Year 2)

Co-Principal Investigator:

Yi-Ching Lee, PhD, The Children's Hospital of Philadelphia

Co-Principal Investigator:

Santiago Ontañón, PhD, Drexel University

Project Team Members:

Avelino J. Gonzalez, PhD, University of Central Florida;

Flaura Winston, MD, PhD, The Children's Hospital of Philadelphia

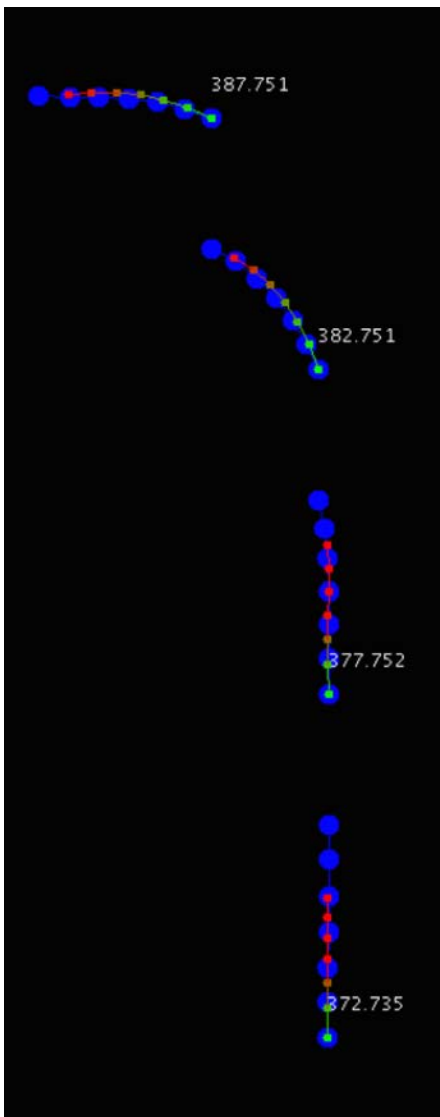
Students:

Celia Cheng, Drexel University; Sam Snodgrass, Drexel University;

Molly Tiedeken, Drexel University

IAB Mentors:

Doug Longhitano, American Honda Motor Co., Inc.; Tim Hsu, FCA US LLC



This indirect model can be used to predict accurate long-term driving behaviors. The figure shows four predictions, in four different situations. For each prediction, two trajectories are shown: The blue dots represent the trajectory that the driver actually took, while the red dots show the predicted trajectory by our model.

Among teen drivers, speed management is a significant factor that contributes to crashes. To better understand how technology can help reduce crash risk, this study used driving simulators to analyze and learn a human behavior – speed management – using a technique called machine learning. Such techniques are used to create predictive driving models that may be incorporated into smart-car or in-vehicle monitoring systems. The long-term goal of this research was to fully understand young drivers' risky behaviors in order to advance safety awareness and management of driving risks.

In phase one of the study, researchers determined the feasibility of using computational approaches to automatically model speed management. Results suggest that modeling was effective at predicting vehicle control behaviors up to one second into the future. These predictions were consistent with the skill proficiency and crash likelihood ratings given by a professional driving education instructor.

Drawing on phase one results, the objectives of phase two were to determine: (1) which parameters of modeling techniques were most suitable for producing predictions of unsafe and dangerous speed management behaviors, and (2) the effect of feedback on behavioral changes in speed management in subsequent simulator drives.

Researchers upgraded the machine learning modeling techniques, including testing and comparing machine learning approaches for accuracy and scalability; improving model accuracy; reducing prediction errors; and redesigning the feedback interface. In parallel, researchers developed and tested driving scenarios in the driving simulator to best align with the collection of training and testing scenarios for the machine learning modeling work. The driving contexts were programmed in a specific way and presented in a specific order so that the machine learning models could capture participants' driving styles in various driving contexts. This ensured that the models had sufficient training data with which to output predictions on how each driver would perform in new driving scenarios.

The third component of the project involved collecting data from young drivers. Drivers in the feedback condition received model predictions as feedback half-way through a study visit. Drivers in the control condition did not receive any feedback. This allowed researchers to examine the effect of receiving feedback on subsequent driving behaviors in similar or different driving contexts.

Preliminary results show that the indirect model (depicted at left) outperforms all other modeling approaches. This work paves the way for future in-vehicle machine learning systems that can provide drivers with real-time monitoring and feedback to help reduce crash risk.

Pediatric Brain Injury Assessment in Real World Crashes (Year 2)

Principal Investigator:

Matthew R. Maltese, PhD, The Children's Hospital of Philadelphia

Project Team Members:

Kristy Arbogast, PhD, The Children's Hospital of Philadelphia

Susan Margulies, PhD, The University of Pennsylvania

Students:

Sriram Moparthy, BS, The Children's Hospital of Philadelphia

Christopher Polster, BS, The Children's Hospital of Philadelphia

IAB Mentors:

Eric Dahle, Evenflo Company Inc.; **Guy Nusholtz**, FCA US LLC; **Steve Rouhana**, Ford Motor Company; **Mark Neal**, General Motors Holdings LLC; **John Combest**, Nissan Technical Center North America Inc.; **Hiromasa Tanji**, TK Holdings Inc.; **Ann Mallory**, Transportation Research Center Inc.; **Uwe Meissner**, Technical Advisor

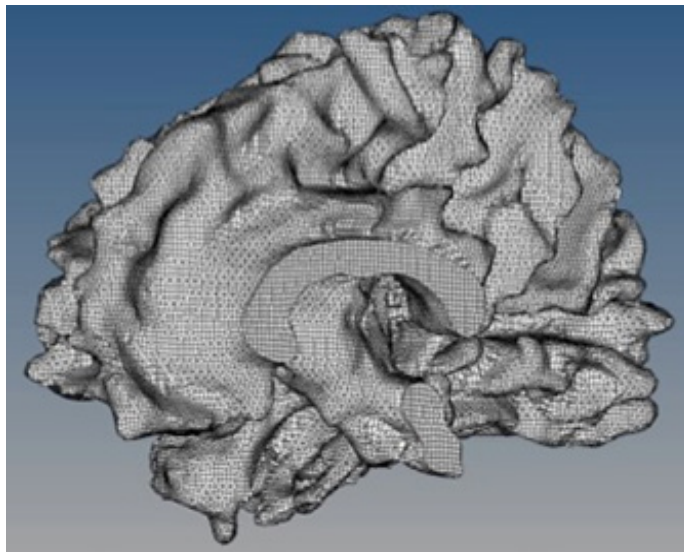
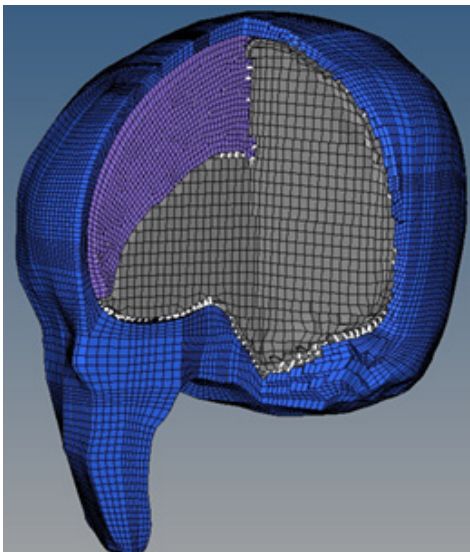
Finite element (FE) modeling is a design tool that allows vehicle manufacturers to digitally develop safety systems and vehicle structures and to simulate crashes in the computer environment without the constraints of engineering materials, associated costs, and production time. This line of research aims to improve the FE model design tools available to engineers as they develop motor vehicle safety systems that mitigate traumatic brain injuries (TBI) in children. TBI, the most common serious injury sustained by children in motor vehicle crashes, can lead to neuropsychological effects, including altered behavior, diminished academic achievement, and increased family strain. Hospitalization costs associated with pediatric TBI are estimated to exceed \$1 billion annually.

Specifically, researchers aimed to develop an FE model of the pre-adolescent human brain and skull and to demonstrate its usefulness in predicting brain deformation during real-world crash reconstructions.

In Year 1 of this project, researchers developed an FE model of the 6-year-old human brain that used an MRI averaging process to combine 26 individual segmented MRI brain scans. Recent analyses of previously published animal data showed enhanced

axonal injury prediction when only the white matter is examined; thus, in Year 2, researchers added distinct regions of gray and white matter. This brain model was then integrated with a skull model of the 6-year-old human based on published geometric and material data and was tested for predicting brain deformation during rapid rotation reconstructions. In these reconstructions, the FE brain model was rotated in each of the three anatomical planes: sagittal, axial, and coronal. Results showed that the axial and sagittal rotation directions had the highest strains.

This project delivers a pre-adolescent FE brain and skull model to the research and engineering community. This model may be used by other researchers to design and evaluate safety systems for the pre-adolescent age range, including assessing brain injury potential in pedestrian crash tests or designing side curtain air bags for children. This research lays a foundation to elucidate the biomechanics of pediatric TBI and to improve the capability and accuracy of the computer modeling tools available to the automotive safety research and engineering community.



Left image: Cutout of the 6-year-old pediatric human brain and skull finite element model. **Right image:** Right half of the finite element model showing distinct regions of white matter.

Dynamic Comparison of Large Omni-directional Child ATD to Pediatric Volunteers

Principal Investigator:

Thomas Seacrist, MBE, The Children's Hospital of Philadelphia

Project Team Member:

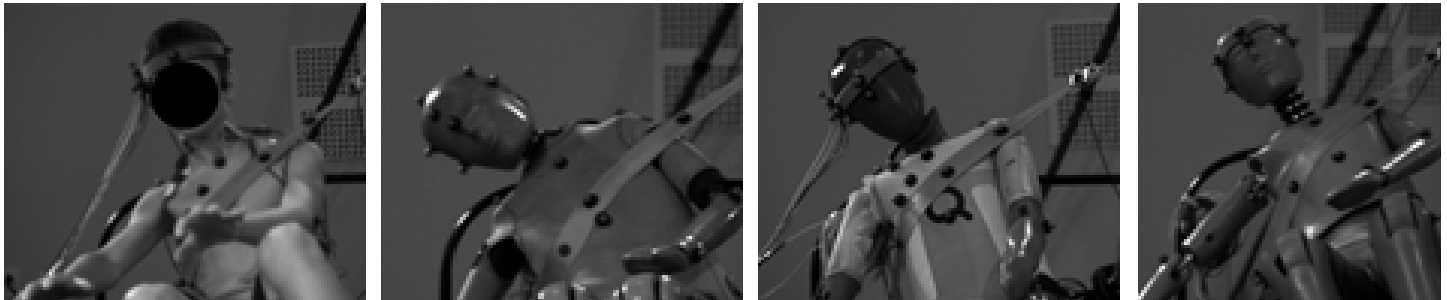
Caitlin Locey, BS, The Children's Hospital of Philadelphia

Student:

Gretchen Baker, University of Kansas

IAB Mentor:

Jason Stammen, National Highway Traffic Safety Administration



A comparison of volunteer-ATD response in low-speed oblique impacts, featuring left to right: an 11-year-old human volunteer, the LODC, the Q10, and the HIII 10.

Research has shown that the head is the most commonly injured body region among children in motor vehicle crashes. To better mitigate these injuries, pediatric anthropomorphic test devices (ATDs), or crash test dummies, must mimic pediatric motion and internal forces as well as accurately predict injury potential during a crash. Previous studies of pediatric ATDs have shown an overestimation of upper neck loads and injury risk due to limited biofidelity of the ATDs. Recently, a large omni-directional child (LODC) ATD has been developed in an effort to improve biofidelity through a more realistic shoulder construction, softer cervicothoracic junction, and a multi-segmented, more flexible thoracic spine compared to the Hybrid III 10-year-old dummy. This study sought to evaluate the influence of these modifications on LODC neck loading by comparing its response to previously collected child volunteer data in low-speed sled tests.

Low-speed (<4g) sled tests were conducted with the LODC, which was restrained using a 3-point seat belt. Photo-reflective targets were placed on important anatomic landmarks, such as head top, and were captured using a 3D near infrared tracking system. Variables considered were shear force (Fx), axial force (Fz), and bending moment (My) about the upper neck. These parameters were calculated using standard equations

of motion. These data were then compared to previous data from 9- to 11-year-old pediatric volunteers, the Hybrid III 10, and the Q10 that were tested utilizing similar methods.

The LODC significantly underestimated mean shear force compared to the HIII 10, Q10 and volunteers. The LODC also underestimated axial force compared to the volunteers, yet was closer to volunteer levels than both the HIII 10 and Q10. These differences are likely due to the LODC's greater flexibility, especially in the thoracic region of the spine. A shift in force distribution from shear to axial was displayed, likely due to greater head rotation displayed by the LODC than the HIII 10 or Q10 ATDs.

The LODC has the potential to address one of the primary biofidelity issues with the current pediatric ATDs – the rigid thoracic spine. As continuous improvements are made to ATDs, future work should continue to investigate the acceleration and loading of pediatric ATDs in comparison to human volunteers; these data provide valuable information on the biofidelity of the recently developed LODC that have led to newer iterations.

Investigating Injuries in Pediatric Occupants for Use in Automatic Crash Notification (Year 2)

Principal Investigator:

Joel Stitzel, PhD, Wake Forest University School of Medicine

Co-Principal Investigator:

Andrea Doud, MD, Wake Forest University School of Medicine

Project Team Members:

Ryan Barnard, MS, Wake Forest University School of Medicine

Jennifer Talton, MS, Wake Forest University School of Medicine

Ashley Weaver, PhD, Wake Forest University School of Medicine

Student:

Samantha Schoell, MS, Wake Forest University School of Medicine

IAB Mentors:

Agnes Kim, Ford Motor Company; Christina Mullen, State Farm Mutual Automobile Insurance Company; Dan Robertson, Toyota USA; Uwe Meissner, Technical Advisor

In children seriously injured in motor vehicle crashes (MVC), providing prompt and accurate field triage to designated trauma centers (TC) improves outcomes. Advanced Automatic Crash Notification (AACN) systems are designed to improve the speed and accuracy of field triage decisions, but their algorithms have been developed only for adults.

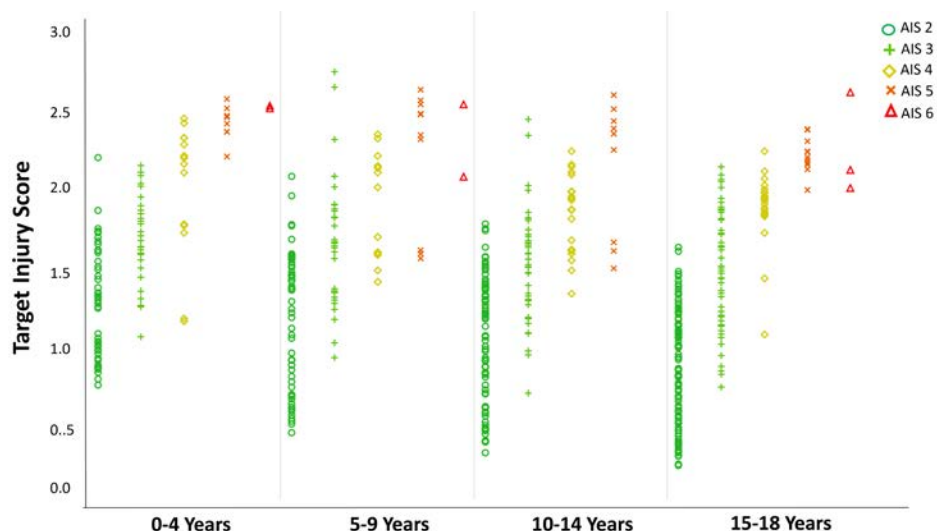
The long-term goal of this project is to create a pediatric-specific AACN algorithm that uses a comprehensive scoring system to predict the risk that a child in a MVC is severely injured and requires treatment at a designated TC. Year 1 of this project evaluated the most common injuries occurring in children and characterized them across different developmental groups.

Year 2 of the project focused on refining the injury patterns to create a better understanding of the pediatric injuries described in the first phase. Researchers performed a retrospective review of injuries to occupants 19 years old and under in crashes contained within the 2000-2011 National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) dataset. Results from logistic regression models predicting 18 key injury types were compared to determine which metrics should be used as co-variables in a pediatric AACN algorithm. Injury patterns were then used to create developmental groupings that discriminated between pattern

categories. Researchers conducted advanced data mining and statistical analysis of several large national databases and survey data to define the severity, time sensitivity, and predictability of the most frequently occurring MVC-induced injuries within each developmental group, which were then combined to create age specific Target Injury Scores (TIS) for the most common MVC-induced pediatric injuries.

The results from this current study reveal that age alone provides the best predictive power with respect to injury patterns. Researchers established four pediatric age groups using injury patterns to differentiate between injury types (0-4; 5-9; 10-14; 15-18). Analyses showed that younger children were at increased odds of sustaining Abbreviated Injury Scale (AIS) 2+ and 3+ head injuries and AIS 3+ spinal injuries. Older children were at increased odds of sustaining chest wall fractures, AIS 3+ abdominal injuries, and AIS 2+ upper and lower extremity injuries. Overall, TIS values decreased with increasing age, and increasing AIS severity correlated with increasing TIS within each age group.

Injury patterns change as children grow and develop, and age proved to have the best predictive power. Triage may be improved with the use of age-adjusted TIS values to help discriminate between those children who require TC care and those who can be safely managed at a non-TC. Year 3 will utilize these scores to create age-specific AACN algorithms.



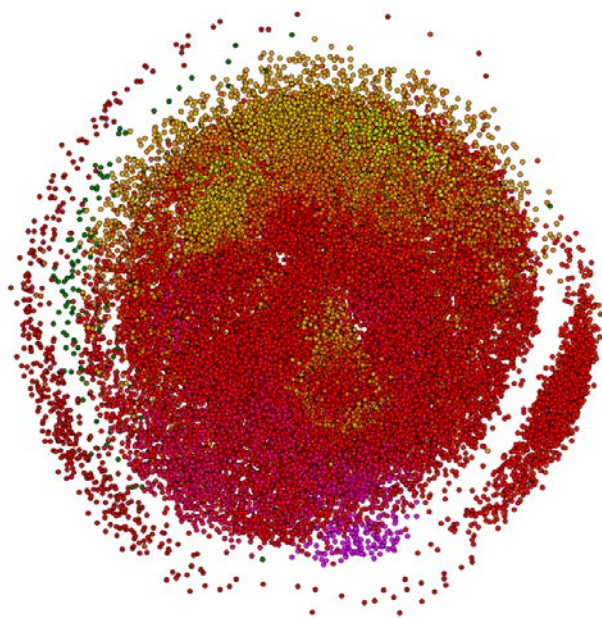
This chart describes the target injury scores for the top 95 percent most frequent MVC-induced injuries, stratified by age and AIS severity level.

Supplemental Research Funding

CORBI: Modeling, Visualization, and Understanding of Large Data Sets

The NSF created the Collaborative Opportunity for Research Between I/UCRCs (CORBI) as a funding mechanism to foster cooperative research among these Centers. CChIPS is partnering with the Center for Visual and Decision Informatics (CVDI), established by The University of Louisiana at Lafayette and Drexel University, to research and develop next generation visual and decision support data analysis tools. The main goal of this project is to improve the understanding of how to analyze large amounts of data and increase the capabilities of both CChIPS and CVDI IAB members to perform this task. Investigators are exploring a new avenue of research to analyze datasets containing behavioral, sequenced information, such as data recorded from specific individuals performing complex tasks, like driving a car or browsing a website.

In these scenarios, instances of behavior cannot be visualized independently. Investigators plan to develop a new family of techniques for the analysis of teen driver behavior, since teen drivers are the age group at highest risk for serious and fatal crashes. The techniques produced for data visualization have the potential to provide IAB members with added insights that will result in new and improved commercial products, such as in-vehicle monitoring systems to further driver safety. These new insights will not only foster the economic competitiveness of the IAB members, but also contribute to child injury prevention by generating new understanding of the main causes of motor vehicle crashes among young adult drivers.



Two-dimensional visualization of 15 minutes of driving behavior. Each dot represents a different time instant and color indicates the different actions performed by the driver (e.g., right turn, left turn, acceleration, and braking).

Innovative Managing Director

Now in its third year, CChIPS' Innovative Managing Director (IMD) supplement has opened up opportunities to explore new collaborations, new lines of inquiry, and new avenues to strengthen the Center's long-term sustainability. Eve Weiss, MS, holds the title of IMD but works in tandem with her team at CHOP and OSU to pursue ways to facilitate the growth and stability of the Center, including broadening its research focus and bringing in new industry members to foster that growth. For example, Ms. Weiss, along with other CIRP and CChIPS leaders, has generated new research ideas with colleagues at state and regional Highway Safety Offices to promote pedestrian safety and to reduce the rates of injury and death from motor vehicle crashes. Ms. Weiss works in partnership with CChIPS co-directors in aligning and embedding new information into technological advances through our industry members. NSF's continued support of the IMD into its third and final year provides evidence of the ongoing success, productivity and value generated by the Center's innovative management practices and collaborative relationships with industry and academia that have been developed and tested since CChIPS' inception.

Research Sponsorship Opportunities for IAB Members Outside of CChIPS

CChIPS member companies often have research questions that, while in line with the CChIPS mission, may be bigger in scope or more specific or applied than the typical CChIPS research project. In this context, the member company can sponsor research directly with CChIPS' academic partners and their investigators. As these projects do not have shared mentorship across all IAB members, these research relationships facilitate a one-to-one interaction between the sponsor and the investigative team; this provides an opportunity to more closely shape the scope of work to their particular industry needs. Several IAB companies have worked closely with CChIPS investigators over the years and include: TK Holdings Inc. (CHOP), Transportation Research Center Inc. and The National Highway Traffic Safety Administration (OSU), State Farm Mutual Automobile Insurance Company (CHOP), Minnesota HealthSolutions (CHOP), and Toyota USA (CHOP and Wake Forest University). Much has been contributed to the scientific fund of knowledge from these projects, leading to improved protection of children and youth in motor vehicle crashes and representing yet another way to leverage the collaboration and passion of the CChIPS model.

Preparing Future Industry Scientists

Training students is a vital part of the CChIPS mission. We are committed to creating a diverse, internationally competitive, and globally engaged science and engineering workforce with a focus on injury prevention. Our rigorous, meaningful research projects and talented investigators and IAB members allow us to attract a diverse pool of talented students. These students also bring fresh ideas and energy to our studies. To date, over 100 students have played key roles in CChIPS research projects. This past year, two CChIPS students received doctoral degrees and another received a master's degree.



Each spring the second CChIPS site, The Ohio State University, hosts the Injury Biomechanics Symposium (IBS), where students from universities around the world are invited to present their research projects. The aim of the IBS is simple—to provide student researchers with a welcoming, non-threatening platform to present their research and to have meaningful conversations with experts in the field and industry partners. The 11th Annual Injury Biomechanics Symposium, held in May 2015, had more than 115 attendees, featuring 23 student presenters from 14 universities, including several projects associated with CChIPS.



Gretchen Baker and her fellow IBS student presenters.

"Having the opportunity to attend and present research at the IBS in May 2015 was a wonderful experience. As an undergraduate Engineering student, the IBS provided a student-focused and encouraging environment to make connections with other Engineering students, faculty, and professionals in the field. Attending the IBS helped to solidify my decision to pursue a PhD focused on injury biomechanics after I graduate from the University of Kansas. I'm excited to continue a career in a field where engineering, medicine, industry, and public health cooperate to produce innovations that impact the lives and safety of people. Seeing the variety of research presented at IBS helped me to see the impact injury biomechanics research can have and realize my passion for this research."

– Gretchen Baker, CChIPS Research Experiences for Undergraduates (REU) student, 2014-2015

What's Next From CChIPS

The CChIPS IAB has provided continuation funding to multiple projects to deepen its understanding of scientific questions of interest to industry and academia. Many of CChIPS' 2015-2016 projects are continuing work from previous years, including:

- Kristy Arbogast is in Year 2 of her Evaluation of Side Impacts with a Frontal Component for Children in CRS (Year 1 is detailed on page 7 of this report).
- Aditya Belwadi is in Year 3 of his study, Quantifying CRS Fit in Vehicle Seat Environment: Digitization Approach (see page 8 of this report for information about Year 2).
- Yi-Ching Lee is in Year 3 of her project, Machine Learning Techniques: Online Prediction of Driving Behavior and Generation of Customized Feedback (see page 16 for a summary of Year 2 results).
- Matthew Maltese continues the third year of his study, Pediatric Brain Injury Assessment in Real World Crashes (see page 17 for Year 2).
- Joel Stitzel is in Year 3 of Advanced Automatic Crash Notification for Children (see page 19 for Year 2).

For a sneak peek of next year's 2015-2016 research projects, please visit CChIPS' newly expanded website!



New projects for the 2015-2016 project year explore topics such as the compatibility of belt-positioning booster seats in vehicles, dynamic top tether loads in various anchor locations in side impacts, a comparison of teen and adult naturalistic car-following patterns, and an assessment of the interaction of inflatable seatbelts and pediatric ATDs installed in aircraft seats.

To learn more about the entire research portfolio for 2015-2016, please see our website! cchips.research.chop.edu.

Our Collaborators

The Center for Child Injury Prevention Studies (CChIPS) would like to thank the Industry Advisory Board (IAB) members, our member companies, and the National Science Foundation (NSF) for their generous support and insight.

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Editors

Lindsey Mitros
Eve Weiss

Graphic Designer

Melissa LaVigne

CCHIPS LEADERSHIP TEAM

Flaura Winston
Kristy Arbogast
John Bolte
Eve Weiss
Patricia Corwin
Ayana Bradshaw



 The Children's Hospital *of* Philadelphia[®]
RESEARCH INSTITUTE



THE OHIO STATE UNIVERSITY
WEXNER MEDICAL CENTER

3535 Market Street, Suite 1150, Philadelphia, P.A. 19104 • 215-590-3118 • cchips.research.chop.edu

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