



Safe and Sound

The Center for Child Injury Prevention Studies 2013 & 2014 Annual Reports

Center for Child
Injury Prevention Studies



The Children's Hospital of Philadelphia®
RESEARCH INSTITUTE



THE OHIO STATE UNIVERSITY
CENTER FOR CHILD INJURY
PREVENTION STUDIES

Partnering for Safety

A Message from Our Directors



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

Safe and sound. That's what parents hope for and our Center works toward. The Center for Child Injury Prevention Studies (CChIPS), with partner research sites at The Children's Hospital of Philadelphia (CHOP) Research Institute and The Ohio State University, is proud of its achievements in 2014. Through a unique partnership with our Industry Advisory Board (IAB) comprised of representatives from 21 member organizations, our researchers are pinpointing and assessing the causes of injuries to children and young adults. With this knowledge, we can prevent injuries and engineer solutions that save children's lives. On behalf of the IAB and our dedicated team of researchers, we are excited to share research highlights and summary updates from CChIPS' past two years in this annual report.

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Founded in March 2005 with a grant from the National Science Foundation (NSF), CChIPS is one of over 70 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. Primarily through its annual Advances in Child Injury Prevention (ACIP) Conference, CChIPS continues to share the latest research on occupant safety and other road traffic injury issues for children and adolescents with professionals from industry, government, and research organizations. In May 2014 more than 100 attendees from 43 organizations came to Plymouth, MI to hear a dozen presentations from experts at CHOP, The Ohio State University, the University of Michigan Transportation Research Institute, the National Highway Traffic Safety Administration, Wayne State University, and Wake Forest University.

CChIPS also spreads its important mission and message of child injury prevention worldwide. Center faculty and investigators presented at the Or Yarok Road Safety Conference in Israel; the Japanese Society of Automotive Engineers Forum on Automotive Safety in Yokohama, Japan; the Protection of Children in Cars International Conference in Munich; the Monash Injury Research Institute in Melbourne, Australia; the Enhanced Safety of Vehicles Conference in Seoul, South Korea; the International Research Council on the Biomechanics of Injury Conference in Gothenburg, Sweden; and the Association for the Advancement of Automotive Medicine meeting in Quebec City, Quebec. CChIPS also employs digital communication strategies to share information. Our expanding and evolving digital presence now includes the cchips.research.chop.edu website (which went live in April 2013 and had more than 1,600 user sessions in its first year), a CChIPS LinkedIn group with 130 members, a Twitter presence through CChIPS Director Flora Winston's [@safetymd](https://twitter.com/safetymd) account (which has over 2,400 followers), and 11 CChIPS-focused blog articles on CHOP's Center for Injury Research and Prevention's [Research in Action](#) blog.

In 2013, CChIPS received a three-year supplemental grant from the NSF to support the role of a Managing Director. Tasked with the long-term sustainability of the Center, Eve Weiss, MS, accepted the challenge when appointed to the position. She is facilitating further growth of the Center by broadening its research focus and bringing in new industry members to foster that growth. The grant provides evidence of the ongoing success, productivity and value generated by the Center's innovative management practices and collaborative relationships with industry and academia.

The success of CChIPS 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 takes a unique approach to child safety research. 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 consumer behavior become increasingly complex, enhanced research, product development, and education efforts are necessary to further child safety. Over the past nine years CChIPS has conducted approximately 80 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. 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 to injury (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

Historically, CChIPS' emphasis has been in the field of Automotive Safety. In 2013, CChIPS leadership, along with the Industry Advisory Board (IAB), voted to expand the research portfolio with the addition of two other thrusts, Sports Injury Biomechanics and Pediatric Trauma Care. These two new thrusts are currently in their infancy but will continue to grow as relevant industry partners are identified. 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

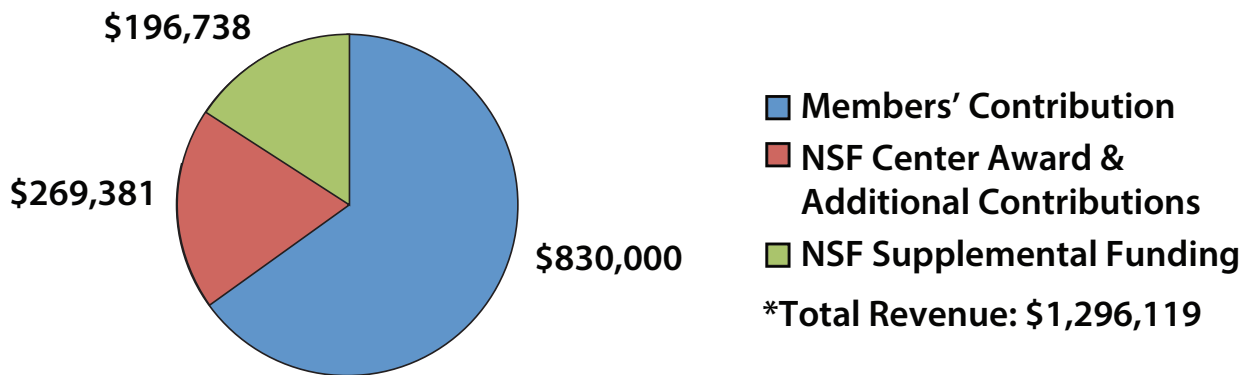
The CChIPS mission is to advance the safety of children, youth, and young adults by facilitating scientific inquiry into childhood and young adult injuries and to translate these findings into commercial applications and educational programs for preventing future injuries.

Funding the Research

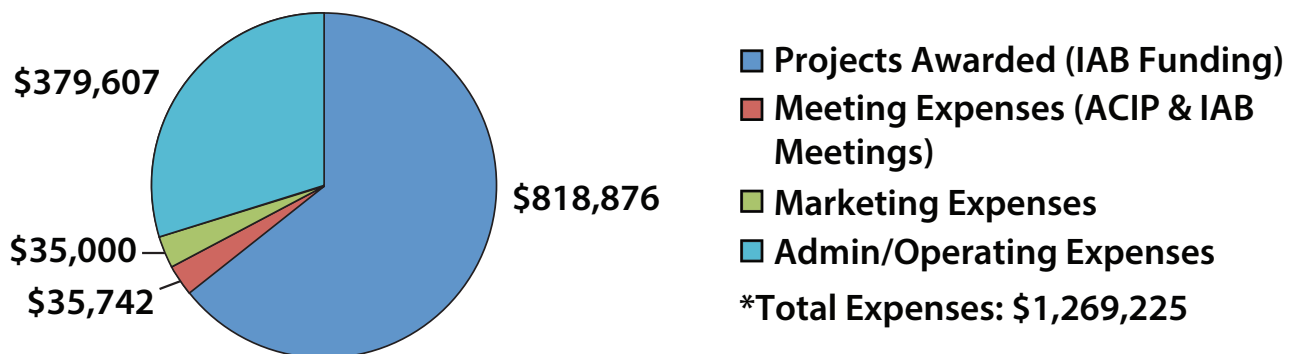
CChIPS is made possible through a grant from the National Science Foundation (NSF), as well as sponsorships from its Industry Advisory Board (IAB) member companies, comprised of industry, nonprofits, and government, that engage in scientific research and development to improve child safety. Every year, each full voting IAB member contributes \$50,000 to support the CChIPS mission. Non-voting government and nonprofit organizations and small businesses are also given the opportunity to join for a reduced annual fee. 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 2014



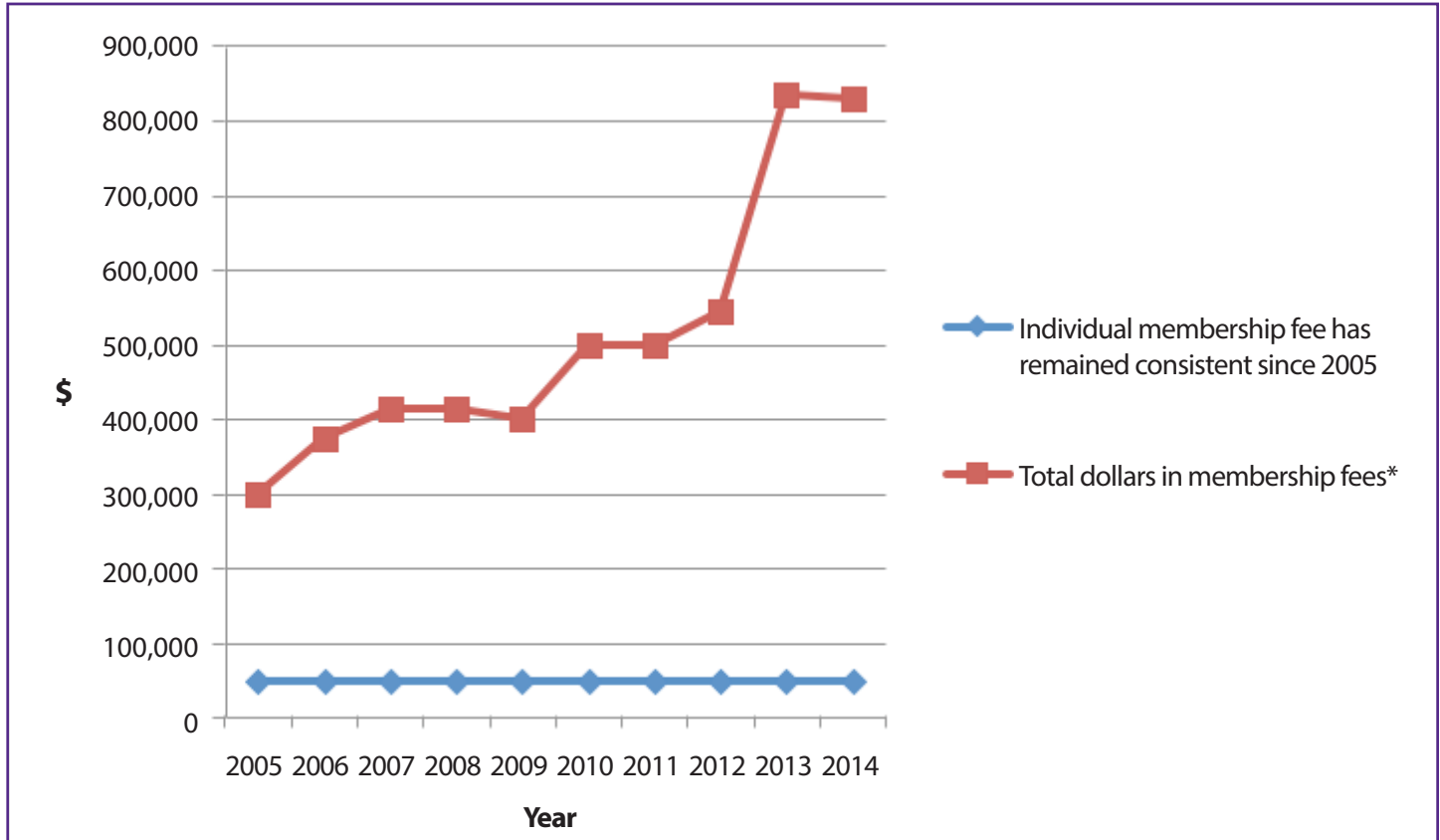
Expenditures for 2014



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

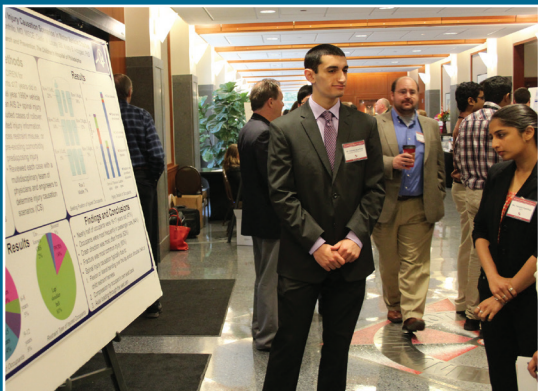
Return on Investment

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. In 2014, the combined membership fees resulted in \$830,000 available to support the mission of CChIPS. Based upon the \$50,000 membership fee, this represents a 1,560% annual Return on Investment (ROI) per company.



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

Preparing Future Industry Scientists



Research Experiences for Undergraduates (REU) student Steven Scarfone of The University of Pennsylvania presents CChIPS research at The Ohio State University Injury Biomechanics Symposium.

Training students is an important 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 75 students have played key roles in CChIPS research projects.

Each spring The Ohio State University hosts the Injury Biomechanics Symposium where students from universities around the world are invited to present their research projects. The 10th Annual Injury Biomechanics Symposium, held in May 2014, featured 25 students representing 13 universities from around the world. It was the largest symposium yet, as over 130 attendees enjoyed the student presentations, which included five projects associated with CChIPS.

Research In Action: 2012-2013 Project Highlights

Quantifying CRS Fit in the Vehicle Seat Environment – Dimensional Comparison Approach (Year 1)

Co-Principal Investigator:

Amanda Agnew, PhD, The Ohio State University

Co-Principal Investigator:

Julie Bing, MS, The Ohio State University

Project Team Member:

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

Students:

Colleen Mismas, The Ohio State University; Kevin Soong, The Ohio State University

IAB Mentors:

Ron Burton, Transportation Research Center Inc.; Audrey Eagle, Chrysler Group LLC; Keith Nagelski, Britax Child Safety, Inc.; Eric Dahle, Evenflo Company Inc.; Doug Longhitano, American Honda Motor Co., Inc.; Julie Kleinert, General Motors Holdings LLC



Several of the dimensions measured on each CRS are shown above.

Current estimates of the prevalence of misuse of child restraint systems (CRS) are as high as 94 percent, which can lead to an increased risk of injury or death for child occupants. Although the majority of CRS misuse is attributed to consumer installation errors, physical incompatibilities between CRS and vehicle models may also cause or exacerbate problems in the installation process. While all CRS on the U.S. market comply with the federal standard for dynamic testing requirements under FMVSS 213, it remains unclear which child restraint features are the best fit for certain vehicle environments.

This study aimed to collect quantitative and descriptive data on a large set of CRS and vehicles currently on the road, to identify factors that influence compatibility between CRS and vehicles, and to use this information to provide benchmark data for CRS/vehicle manufacturers and consumers. Detailed dimensional data were collected from 59 CRS, which included 31 rear-facing (RF) and 28 forward-facing (FF) seats. The researchers collected 37 data points (including outer dimensions, information about the belt path, recline angle, top tether, and type of LATCH hooks) from each CRS. In addition, they documented the dimensions and features of the second-row seats of 61 vehicles representing 27 different manufacturers, with 76 data points collected for each vehicle, as well as the space available in the seat, the contours of the seat pan and seat back, the locations of seat belt and LATCH anchors, and clearance space relative to the front row of seats and vehicle ceiling.

Following data collection, key dimensions were compared in order to identify the following most frequent points of incompatibility:

- Seat pan angle for RF CRS: 42 percent of RF CRS cannot naturally sit within the required angle range on vehicle seats.
- Width of CRS compared to width of vehicle seat: 37 percent of CRS do not fit between the vehicle seat's side bolsters and require the CRS base to sit on top of the side bolsters.
- Height of seat back for FF CRS: 34 percent of FF CRS have interference with the vehicle's head restraint in their seat position.
- Clearance space behind front row seats for RF CRS: 27 percent of RF CRS cannot fit comfortably behind the front row vehicle seats.

There are many implications for the use of these data. The information will be made available for CRS and vehicle manufacturers to use as a benchmark for design decisions. For a more immediate impact, the results of this study can also be used in educational materials to guide caregivers in choosing a CRS for their vehicle. These data provide an important resource to help improve the CRS installation process, to lower the rate of CRS misuse, and, ultimately, to reduce the rate of child injury and death when motor vehicle crashes occur.

Quantifying CRS Fit in the Vehicle Seat Environment – Digitization Approach (Year 1)

Principal Investigator:

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

Student:

Daniel Martinez, Drexel University

In the design of automotive interiors, engineers must take into consideration the accommodation of add-on restraint products such as child restraint systems (CRS). The evolving nature of CRS design (and an increasing amount of CRS options for consumers) puts pressure on vehicle manufacturers to keep their vehicle seats and occupant space compatible. For vehicle manufacturers, it is important to understand the breadth of CRS dimensions so that this balance can be successfully negotiated.

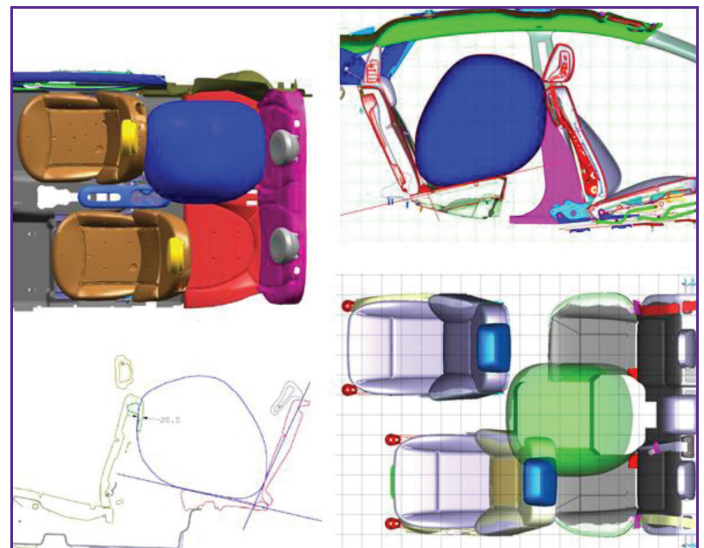
To this end, this phase of the project developed a methodology for digitization of CRS. This created a virtual surrogate of a small rear-facing CRS -- a volume encompassing CRS to aid designers in assessing space and fitment during the design phase of the vehicle rather than an “aftermarket” assessment, which has typically been the standard. The researchers placed 72 CRS (rear-facing, forward-facing, high-back boosters, and low-back boosters representing 252 CRS commercially available as of April 2013) on a flat table and used an optical scanner to get the 3D surface geometry. They also leveraged the capabilities of the Microsoft Xbox Kinect Sensor™ for this purpose as a cost-effective alternative to more expensive technology. In this first year, a subset of these scans, involving small rear-facing CRS, were then adjusted to a predefined vehicle seat orientation and overlaid to create a “virtual surrogate” of a small rear-facing CRS.

The drawings in several electronic formats were made available to vehicle and CRS manufacturers that are members of CChIPS to conduct a “virtual fitment” study in their design environment to evaluate interference and compatibility. The virtual surrogate was installed in both outboard and center seating positions of a sub-compact passenger car, compact sedan and compact SUV in various combinations of fore-aft positions of the front seat.

IAB Mentors:

Audrey Eagle, Chrysler Group LLC; **Eric Dahle**, Evenflo Company Inc.; **Julie Kleinert**, General Motors Holdings LLC; **Keith Nagelski**, Britax Child Safety, Inc.; **John Bachner**, Graco Children’s Products Inc.; **Rajiv Menon and Terry Emerson**, Dorel Juvenile Group; **Barbara Birkenshaw**, Volkswagen Group of America; **Doug Longhitano**, American Honda Motor Co., Inc.; **Schuyler St. Lawrence**, Toyota Motor North America Inc.; **Eric Eisenworth**, Ford Motor Company; **Michelle Tsai**, Consumer Reports

Initial vehicle and CRS manufacturer feedback of this process indicated several points: 1) that the rear-facing virtual surrogate accurately predicts the interferences seen in typical physical installations of these child seats in most seating conditions; and 2) that there is a need to expand the surrogate to include larger rear-facing CRS, convertible CRS, and forward-facing CRS and both high/low back boosters. These items will be addressed in Year 2 (2014-2015) of this Digitization Approach project.



Virtual installation of the “surrogate” (in blue/green) in a sub-compact sedan.

Research In Action: 2012-2013 Project Highlights

Development and Validation of a Biofidelic Pediatric ATD Lower Extremity

Principal Investigator:

Amanda Agnew, PhD, The Ohio State University

Project Team Member:

Yun Seok Kang, PhD, The Ohio State University

Student:

Laura Boucher, PhD, The Ohio State University

IAB Mentors:

Doug Longhitano, American Honda Motor Co., Inc.;

Rodney Rudd, National Highway Traffic Safety Administration

As vehicle safety continues to improve, life-threatening injuries from motor vehicle crashes are declining. This progress increases the need for injury research to expand beyond the brain and other vital organs to include injuries that can lead to long-term disabilities such as those to the lower extremity. Limited research has been conducted into the biomechanics of pediatric lower extremity injury. Recent testing conducted by The Ohio State University (OSU) of child interactions with knee-bolster air bags raised questions regarding the extent to which the lower extremities of pediatric anthropomorphic test devices (ATDs) are “human-like” (i.e., biofidelic). This identified a specific need for a tibia load cell to accurately measure forces and an ATD ankle with accurate range of motion and stiffness.

The current version of the Hybrid III 6-year-old ATD has a simple clevis joint at the ankle, which severely compromises the accuracy of the joint’s response and may create unrealistic responses at other points in the limb. Using previously collected child volunteer data from OSU’s lab, a new 6-year-old ATD lower extremity (ATD-LE) was designed, which included a tibia load cell and a more biofidelic ankle joint with range of motion stops and stiffness bumpers.

The aim of this study was to validate the new ATD-LE, and the process included two phases: a biofidelity assessment and knee bolster air bag tests. The biofidelity assessment compared leg and foot anthropometry (measurements of the human body), ankle range of motion, and ankle stiffness between the ATD-LE and previously collected volunteer data.

The second phase of validation evaluated the response of the ATD-LE by recreating the knee-bolster air bag tests previously conducted by OSU researchers in 2011. Four configurations were used for the knee-bolster air bag tests:



Results demonstrated that the anthropometry of the new ATD-LE was representative of the 6-year-old child. However, range of motion measurements revealed differences between the ATD-LE and volunteers. The knee bolster air bag tests demonstrated that the ATD-LE functioned well in all scenarios and indicated that the condition most likely to be injurious was the third configuration, which caused the air bag to hit the bottom of the foot, resulting in both axial loading and forced dorsiflexion of the ankle. When evaluated separately, peak tibia forces and moments did not exceed injury threshold, but when evaluated together (tibia index), the relative risk of producing a fracture was above the injury threshold.

The results of this study demonstrated that ankle biofidelity in the 6-year-old ATD is improving but still requires some modification to more closely represent the 6-year-old ankle. Improving the accuracy of ankle range of motion will help to ensure proper force transmission through the ankle. A properly instrumented pediatric ATD will not only allow for advances in automotive safety and the manufacturing of safer child restraint systems, but also give researchers the opportunity to directly measure the effects of optimal and suboptimal positioning of the child with a more accurate picture of the forces experienced by the lower extremity.

Quantifying Children's Posture in the Rear Seat: A Naturalistic Study (Years 1 & 2)

Principal Investigator:

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

Project Team Members:

Helen Loeb, PhD, The Children's Hospital of Philadelphia;

Judith Charlton, PhD, Monash University;

Katarina Bohman, PhD, SAFER, Chalmers University;

Mats Svensson, PhD, SAFER, Chalmers University

Students:

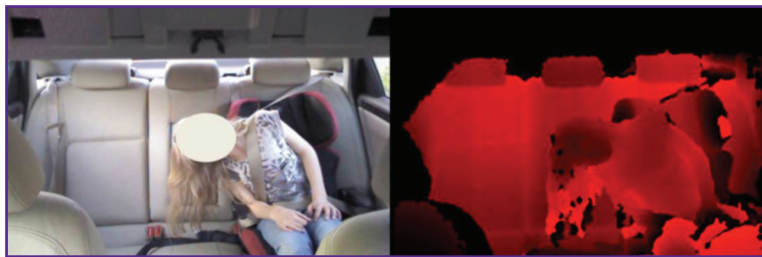
Suzanne Cross, Monash University; Johnny Kuo, Monash University; Isabelle Stockman, Chalmers University

IAB Mentors:

John Combest, Nissan Technical Center North America Inc.;

Schuyler St. Lawrence, Toyota Motor North America Inc.;

Kevin Kramer, Minnesota HealthSolutions; Uwe Meissner, Technical Advisor



Kinect™ software is used to capture a child's position and posture.

Vehicle and restraint safety devices have largely been optimized through laboratory testing programs using anthropomorphic test devices (ATDs), or crash test dummies, intended to mimic the human occupant. Most testing protocols evaluate restraint performance with ATDs placed in ideal positions (for example, perfectly upright against the seat back) and the majority of restraints perform very well under those conditions. Unfortunately, recent real world evidence has suggested that ideal test conditions do not always reflect actual conditions and despite being seated in the correct restraint system for their age and size, an unacceptable number of children are injured or killed in motor vehicle crashes. A potential solution lies in the study of the naturalistic behaviors of passengers. For child occupants, however, there have been only a few isolated efforts to describe position and postural changes using naturalistic, observational methods.

The aims of this project were to develop and test an innovative data collection and analysis method to determine the naturalistic positions of child occupants while restrained in cars. In collaboration with Monash University in Melbourne, Australia, a naturalistic observation study of children in cars will be completed by the end of 2014, with data collected from 48 Melbourne families. Two study vehicles were fitted with a set of discrete video cameras, a recording system, and a vehicle data acquisition unit, providing a comprehensive view of the child occupants. In addition, one of the vehicles was also fitted with an RGB camera and depth sensor to provide 3D motion capture of the rear seat outboard occupants. The researchers leveraged the capabilities of the Microsoft Xbox Kinect Sensor™ for this purpose as a cost-effective alternative to more expensive technology. Participant families were asked to use the study vehicle for all driving trips over a period of two weeks.

At the beginning of the observation period, participants were asked to complete a mandatory Participant Briefing and Training Session to familiarize themselves with the vehicle and its video-recording equipment. Participants also completed an online survey to gather basic demographic information, types of child restraint use and general driver information, such as number of years driving, amount of driving experience and crash history. Upon completion of the observation period, participants were asked to complete a second online survey that addressed general child restraint safety and legislation awareness, driver and child travel behaviors, and beliefs regarding child restraints and common vehicle travel.

The primary objective of the data analysis is to quantify how often and to what degree the child occupant is in a non-ideal position. The upcoming third year of this study will see a continuation of naturalistic data collection and analysis of data, as well as sled tests to explore injury consequences of postures observed in the naturalistic study.

Research In Action: 2012-2013 Project Highlights

Kinematics of Rear Seat Child Occupants in Small Overlap Crashes

Principal Investigator:

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

Project Team Members:

Caitlin Locey, BS, The Children's Hospital of Philadelphia;
Rachel Hammond, MS, The Children's Hospital of Philadelphia;
Aditya Belwadi, PhD, The Children's Hospital of Philadelphia;
Chris Sherwood, MS, Insurance Institute for Highway Safety

IAB Mentors:

Eric Dahle, Evenflo Company Inc.; Julie Kleinert, General Motors Holdings LLC; Rodney Rudd, National Highway Traffic Safety Administration; John Combest, Nissan Technical Center North America Inc.; Kazuo Higuchi, TK Holdings Inc.; Schuyler St. Lawrence, Toyota Motor North America Inc.; Richard Bandstra, Volkswagen Group of America



A post-test photo from the full vehicle small overlap crash testing (photo courtesy of the Insurance Institute for Highway Safety).

Small overlap crashes occur when the primary crash damage comes from a frontal crash but the damage is outside the longitudinal structures of the vehicle. These types of crashes have received recent interest as a crash dynamic that results in high likelihood of injury to both drivers and passengers. Over the past several years, the National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS) have developed extensive test programs to study this crash dynamic, finding significant lateral motion of the vehicle and, therefore, the driver. However, there has been no research into the kinematics of rear seat occupants for this type of crash. Therefore, this study sought to understand injury risks for rear-seated occupants in small overlap crashes through field data analysis and full-scale crash testing.

Using data from NHTSA's National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) from 2000-2010, injury risk for rear seat occupants in small overlap crashes was calculated. Results suggest that rear seat occupants may be at higher risk in this crash dynamic than front seat occupants – a finding at odds with the conventional understanding that the rear seat has increased protection for its occupants. In addition, head injuries were the most common significant injury sustained by young children.

The second phase of this project explored the kinematics of the rear seat occupant in small overlap crashes in partnership with IIHS through a full-scale crash test of a mid-size sedan. The IIHS small overlap test protocol consists of a moving vehicle striking a rigid, stationary barrier at 64 km/h, with a 25 percent overlap of vehicle and the barrier. In the left rear seat was a lap-shoulder belt restrained Hybrid III 5th percentile female anthropomorphic test device (ATD) and a backless booster seated Hybrid III 6-year-old in the right rear. During the crash, the 5th percentile female submarined as slack was introduced into the lap belt through deformation of the seat belt anchors. However, even with the submarining, the ATD's head contacted the vehicle door just below the windowsill. The 6-year-old moved substantially inboard, particularly on rebound, suggesting the restraint system was not fully able to control the kinematics.

The kinematics of the 5th percentile female were further explored through computational modeling. By positioning this occupant in a realistic position and posture, the simulation demonstrated contact between the ATD head and the intruding vehicle door, providing support for the injury causation scenario observed in real world crashes.

This study provides the first in-depth examination of the rear-seat passenger environment in small overlap crashes and is an important step toward understanding rear seat head injury mitigation. By quantifying the injury risk, vehicle dynamics and associated kinematics of rear seat child occupants in this crash dynamic, manufacturers now have a better understanding of the circumstances that lead to a substantial proportion of serious head injuries and fatalities.

Injury Risk and Causation Scenarios of Children Involved in Rollover Crashes

Principal Investigator:

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

Project Team Members:

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Caitlin Locey, BS, The Children's Hospital of Philadelphia;
Matthew R. Maltese, PhD, The Children's Hospital of Philadelphia

Students:

Jessica Harrington, University of Delaware; Christine Evangelista, Elizabethtown College; Todd Hullfish, Drexel University

IAB Mentors:

Mark Neal and Steve Cassatta, General Motors Holdings LLC; Doug Longhitano, American Honda Motor Co., Inc.; Uwe Meissner, Technical Advisor; Steve Ridella, National Highway Traffic Safety Administration; Schuyler St. Lawrence, Toyota Motor North America Inc.



This finite element model depicts a rollover with two quarter turns.

Although rollover crashes account for only about 3 percent of crashes, they are the cause of more than 33 percent of all motor vehicle-related fatalities and have the highest fatality risk of all crash types in the United States. Very limited pediatric-specific data related to rollover crashes currently exists, despite the importance of evaluating injury causation, particularly with data from crashes involving the current fleet.

The objectives of this project were: 1) to examine available real world data regarding children in rollover crashes, calculate injury risk, determine injury patterns and causation, and identify areas of occupants' contact with the vehicle in order to guide development of injury mitigation technology, and 2) to evaluate the feasibility of using computer models to aid in pediatric rollover research. To provide a contemporary analysis of rollover crashes involving children, researchers queried the National Automotive Sampling System's Crashworthiness Data System (NASS-CDS) and the Crash Injury Research and Engineering Network (CIREN) from case years 1998 through 2012. Rollover crashes for passenger vehicles of model year 1998 or newer with at least one restrained occupant (excluding drivers) between 0 and 19 years of age were included. Using the NASS-CDS dataset, univariate and multi-variate logistic regression models of injuries with an Abbreviated Injury Scale maximum score (MAIS) of 2+ or 3+ were used to examine the relationship between the key factors of the crash and the injury outcomes for the vehicle occupants. From the CIREN dataset, vehicle components that served as contact points (such as the roof or a vehicle door) and details of the occupant's injuries were used to develop contact maps.

The NASS-CDS study cohort consisted of 1,033 occupants weighted to represent 285,703 occupants. Risk analysis indicated that children restrained in forward-facing child restraint systems or booster seats were less likely to sustain an MAIS 2+ injury than occupants restrained with a lap and shoulder belt in a rollover crash. This supports the protective effect of supplemental child restraint systems for younger occupants. The abdomen was the most commonly injured body region at the MAIS 2+ level, while the head was most common at the MAIS 3+ level, followed by the thorax and spine. Of the 20 CIREN cases that met the inclusion criteria, 15 had one or more injuries attributed to contact with some part of the vehicle structure. The CIREN analyses revealed that the head was the most common seriously injured body region, primarily due to contact with the roof side rail and/or vehicle interior. This finding was true for both adolescents and younger child passengers in outboard seating positions.

The final phase of this project involved reconstructing an exemplar CIREN case using computational modeling techniques. The objective of the modeling effort was to understand the effect of a rollover crash on restrained pediatric occupant kinematics. The analysis was performed in two stages: 1) vehicle-to-vehicle dynamics and deformations were reconstructed, and 2) simulation of the occupant kinematics and associated impact with the vehicle interior was conducted. This line of research can ultimately provide vehicle and restraint system manufacturers with data needed to develop rollover injury-mitigation systems specifically for children.

Research In Action: 2012-2013 Project Highlights

Analysis of Child Comfort in Forward-facing Versus Rear-facing Child Restraint Systems

Principal Investigator:

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

Project Team Member:

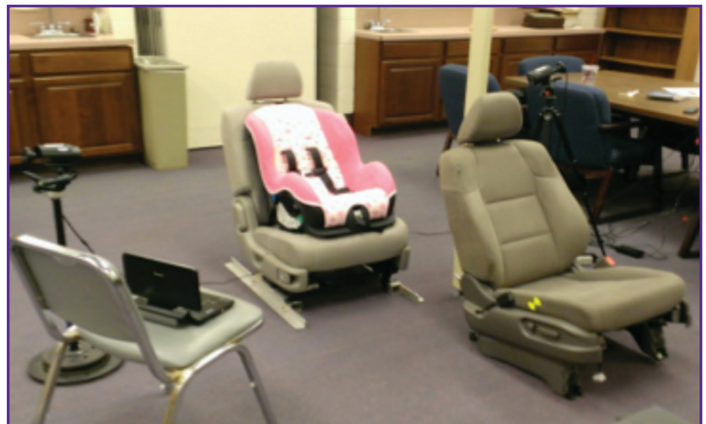
Julie Bing, MS, The Ohio State University

Students:

Meagan Ita, The Ohio State University; Yeonsu Ryu, The Ohio State University

IAB Mentors:

Keith Nagelski and Ken Wittenauer, Britax Child Safety, Inc.; Eric Dahle, Evenflo Company Inc.; Sara Seifert, Minnesota HealthSolutions; Uwe Meissner, Technical Advisor



Equipment setup for laboratory trial of FF CRS.

According to the most recent best practice recommendations from the American Academy of Pediatrics (AAP), rear-facing child restraint systems (RF CRS) are the safest method of restraint for children under the age of two. Most currently available RF CRS accommodate children up to at least 35 pounds, and many newer models are rated for even higher occupant weights. Although the recommendations state that children should ride in a RF CRS until the upper weight or height limit of the CRS is reached, parents often transition their children to forward-facing (FF) CRS before the recommended physical milestones. Recent research indicates that while RF CRS usage rates are increasing with time, only 18.2 percent of toddlers between 12 and 23 months old were restrained in RF CRS in 2012. A primary reason for premature transition to FF CRS is concern over children's comfort in RF CRS as their legs grow longer and the RF orientation appears more cramped. This study aimed to quantify the comfort levels of children near two years old in FF versus RF CRS.

The study consisted of an indoor laboratory session, where 23 2-year-old children were observed during trial periods in RF and FF CRS. Since the children's caregivers make the final decisions regarding CRS usage and orientation, their perceptions of their children's comfort are very important. Along with qualitative questions, parent participants were asked to observe their children's movements/behavior and to rate their physical comfort every 5 minutes throughout each 20 minute interval using a pain rating scale.

Parental feedback confirmed that the parents considered the RF CRS less comfortable than FF CRS. However, unbiased observation of the children's movements in both CRS orientations revealed no significant difference in comfort levels between the two configurations. Children's behavior and movements (n=3) were also monitored during real car rides in each orientation using a small camera installed in the vehicle. Again, no obvious differences in comfort were observed between RF and FF configurations.

The results of this study support adherence to the AAP guidelines, as RF CRS do not appear to cause discomfort in children at the upper age and size range for these restraints. By better understanding the comfort of 2-year-old children in each orientation, parents can become educated on the importance of safety over their perceptions of comfort. In addition, this study allows pediatricians and Child Passenger Safety technicians to be better armed with data to respond to this common parental concern.

Serious Teen Crashes: Identification of the Most Common Scenarios and Factors

Co-Principal Investigator:

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

Co-Principal Investigator:

Catherine McDonald, PhD, RN, The University of Pennsylvania

Project Team Members:

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Despite the societal burden of motor vehicle crashes, how and why teens get into crashes has not been well understood on a scientific level. This study allowed CChIPS researchers to analyze data from the National Highway Traffic Safety Administration's (NHTSA) National Motor Vehicle Crash Causation Survey (NMVCCS) to determine the leading scenarios of serious crashes among teen drivers and the primary causal factors leading up to those crashes.

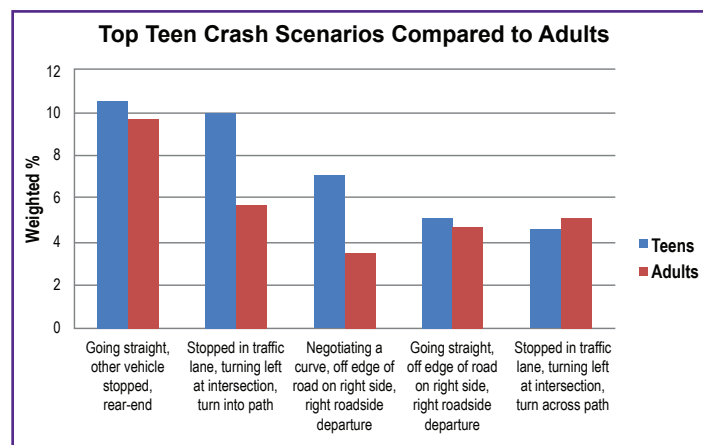
The multidisciplinary team documented the five most frequent crash scenarios for teen drivers involved in serious motor vehicle crashes from 2005-2007: rear-end crashes, two types of left turn intersection crashes that occurred when the teen was turning left into or across the path of another vehicle, and two types of running-off-the-road events that occurred after either negotiating a curve or after going straight. These five crash scenarios accounted for 37.3 percent of teen (ages 16-19) and 28.7 percent of adult (ages 35-54) serious crashes in that time period. Rear-end and left turn intersection crashes were primarily due to recognition errors, which include poor driver surveillance and distraction, and decision errors, which include following too closely and traveling too fast for conditions. The majority of run-off-road events, however, resulted from decision errors or poor driver performance (e.g., overcompensating) or from non-performance errors (e.g., fatigue).

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This table indicates the top five teen crash scenarios, accounting for 37.3 percent of serious teen driver crashes.

This research is helping to identify how and why teen drivers get into serious motor vehicle crashes. By identifying the most frequent crash scenarios and causal factors leading up to a crash, this study provides key information that may help ensure that crash avoidance technology, behavioral interventions, educational programs, driving simulation scenarios, and legislation target the most common and modifiable risk factors for teen crashes. Engineers had previously focused development of driver assistance technology on the performance of adult drivers. Now, with this research, they have the knowledge needed to target crash prevention efforts specifically toward young drivers—the group at highest risk.

Research In Action: 2012-2013 Project Highlights

Effects of Peer Passengers on Teen Driver's Interactions with Stressful Traffic Events

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A teen driver completes a testing protocol using the CChIPS driving simulator.

The combination of teen drivers and peer passengers presents a unique challenge to roadway safety. Inexperienced teen drivers have not yet mastered essential driving skills and may not know how to safely manage their passengers. Additionally, peer passengers may not know how to help the driver and, as a result, become a source of distraction and a risk-promoting factor. This study examined the effect of working relationships (i.e. cooperative, individualistic, and competitive) on driver-passenger social interactions in a driving simulator using observational and self-report methods.

The research team experimentally induced the type of working relationship between two participants (who are friends) via a pre-drive social interaction task (a challenging math problem) by having them work on the task cooperatively, competing against each other, or individually. The two participants, one as the driver and the other as the passenger, then drove in the simulator and had to navigate to various places together. Their verbal communications were recorded during the navigation task as well as the driving behaviors. The transcribed audio data were used to code the nature of conversations and attitudes of driver and passenger in the following categories: Agreement – passenger and driver agreed with route; Disagreement – passenger told the driver a different route or argued with him; Critique – passenger pointed out flawed driving or wrong routes; Helpful – passenger pointed out directions to the target; Neutral – neither in agreement or disagreement, no consensus; and Unsure – driver and passenger were unsure as to which path they should take.

The results indicated that pairs of participants assigned to the cooperation condition produced more 'helpful' comments compared to pairs in the competition condition during navigation. In the cooperation condition, the drivers felt less worked-up upon driving and navigating to a destination, and the passengers felt less strongly about needing the drivers to be good navigators. Pairs who were asked to compete against each other for solving the math problems made more neutral comments during navigation. Pairs who were asked to work on the math problems individually showed similar patterns of conversations with the pairs in the cooperative condition. These findings suggest that this type of experimental manipulation may be useful for examining driver-passenger interactions among teens, and those interactions between driver-passenger pairs prior to driving do carry over to in-vehicle social dynamics. More research is needed to further examine driver-passenger interactions and how differences in these interactions may be associated with safety outcomes.

Dynamic Comparison of Pediatric and the Small Female ATDs to Size-matched Pediatric Volunteers (Years 1 & 2)

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Because children are not simply “small adults,” the mitigation of injuries from motor vehicle crashes requires biofidelic pediatric anthropomorphic test devices (ATDs), or child crash test dummies, to effectively design and evaluate automotive safety systems. Previous CChIPS research evaluated the biofidelity of pediatric ATDs by comparing their response in frontal crashes to similar tests of restrained 6- to 14-year-old pediatric human volunteers. Although frontal crashes are most common, side impact crashes have a higher mortality and injury burden for rear seat occupants. Far-side impacts in particular account for 43 percent of Abbreviated Injury Scale (AIS) 3+ injuries and 25 percent of lateral impact fatalities. Therefore, there is a growing need to evaluate the biofidelity of the pediatric ATDs in far-side impacts by comparing them to biomechanical response data from real children, which is extremely limited in the literature. Through additional funding by CChIPS member TK Holdings Inc., CChIPS researchers have collected data on the kinematics and kinetics of restrained pediatric human volunteers, ages 9 to 14 years, in low-speed lateral and oblique far-side sled tests.

The current study leveraged this previous work and had the following aims: 1) to expand the age range of lateral and oblique far-side pediatric volunteer data collection to include 6- to 8-year-olds, and 2) to continue the current line of ATD comparison research. Specifically, this includes comparisons between pediatric ATDs and age matched pediatric volunteers ages 6 to 14 years in lateral and oblique loading conditions.

Low-speed, far-side oblique and lateral sled tests were conducted using the Hybrid III and Q-series 6 and 10-year-old side impact ATDs, as well as the SID-IIIs and WorldSID 5th percentile female. The ATDs were restrained by a lap and shoulder belt equipped with a pre-crash belt pre-tightener and photo-reflective targets were attached to the head, spine, shoulders, and sternum.

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The ATD data were compared with previously collected 9- to 14-year-old volunteer data and newly collected 6- to 8-year-old volunteer data tested with similar methods. Metrics of comparison included head, spine and torso excursion, seat belt and seat pan reaction loads, belt-to-torso angle, and shoulder belt slip-out.

In general, the ATDs overestimated lateral excursion in both impact directions and underestimated forward excursion of the head and neck in oblique impacts compared to the pediatric volunteers. Additionally, the effect of belt pre-tightening on occupant kinematics was greater for the ATDs than the volunteers. Overall, the findings suggest that the pediatric ATDs exhibit sub-optimal biofidelity under these loading conditions. Additionally, though some metrics were statistically similar between the ATDs, no particular ATD was substantially more biofidelic than another.

To our knowledge, this is the first study to evaluate the biofidelity of the 6- and 10-year-old pediatric ATDs in side impacts by comparing their response to child volunteers. These data provide insight into the biofidelity of the pediatric ATDs in far-side impacts and have important implications for the design and evaluation of low-speed countermeasures.



This image shows the kinematic comparison of the Q6s ATD (top) and exemplar 6-year-old volunteer (bottom) at initial position, mid-motion, and maximum excursion in a lateral low-speed impact. At mid-motion, the Q6s exhibited lateral head rotation, whereas the volunteer's head remained upright.

Research In Action: 2012-2013 Project Highlights

Child Restraint System Misuse Nationally and in Full-vehicle Crash Tests (Year 2)

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Child restraint systems (CRS) significantly reduce the risk of injury for children in motor vehicle crashes. Observational studies of consumer CRS use behavior show that up to 94 percent of child restraints are improperly used, commonly referred to as "misuse." The term misuse covers the broad range of improper use of a CRS, which can include incorrect CRS selection, CRS-to-vehicle attachment, and occupant-to-CRS harnessing.

This project aimed to identify injury potential from CRS misuse conditions, using both real-world and crash test data. In the first phase, researchers analyzed Safe Kids USA Child Passenger Safety Checklist forms, which are used at over 8,000 car seat inspection stations nationally. They examined approximately 10,000 forms collected from 4/1/2012-6/30/2012, providing robust information on misuse and allowing researchers to capture the most common types of installation errors. Using a strict definition of misuse, nearly 75 percent of rear-facing and forward-facing seats were misused upon initial inspection at car seat checkpoints.

The second phase of the study involved a series of full-scale frontal vehicle crash tests with a CRS, conducted and funded by Transport Canada. Focusing on rear-facing CRS, three broad categories of misuse were considered: 1) improper restraint selection or placement in the vehicle; 2) incorrect or loose CRS-to-vehicle attachment; and 3) incorrect or loose restraint of the child in the CRS. Testing was conducted in the second row seat of passenger vehicles undergoing full frontal rigid barrier crash tests at approximately 25 and 30 mph. Two identical child restraints with instrumented CRABI 12 month or Q3 3-year-old crash test dummies were installed in each of the rear outboard positions of the test vehicles: one child restraint was "correctly installed" as per manufacturer instructions behind the driver seat; a second, identical child restraint was "incorrectly installed" behind the right front passenger seat to characterize one or more of the common 'real-world' misuse conditions. The resulting video images of the crash testing demonstrated a variety of potential injury scenarios.

By better understanding the current prevalence and types of misuse, and how misuse correlates to injury potential, both the crash and real-world data examined in this study have practical implications for the field. This information can inform and improve educational campaigns to consumers and provide a foundation for CRS and vehicle modifications that will continue to improve child safety in motor vehicles.



Freeze frame views of a rear-facing CRS installed in a forward-facing direction.

Research In Action: 2013-2014 Project Highlights

An Assessment of Injury for Pediatric Motor Vehicle Occupants with Premature or Delayed Graduation from Forward-facing to Booster Restraint

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Several observational studies within the United States and internationally have revealed a trend of “premature graduation,” or children who were transitioned from forward-facing child restraint systems (FF CRS) to belt-positioning boosters (BPB) before reaching the recommended booster seat age or weight. The objective of this study was to perform an updated examination to evaluate injury risk for several age, height, and weight criteria for FF CRS and booster seated occupants to quantify the injury risk associated with prematurely graduating.

Using data from the National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) for crash years 2002-2012, the premature or delayed graduation of 1,478 child occupants was assessed. Injury risk (AIS2+) for “premature graduation” BPB occupants (i.e. small/young children in BPB) was compared to occupants of the same age, weight, or height in a FF CRS and appropriately aged and sized occupants in a BPB. Similarly, injury risk for “delayed graduation” FF CRS occupants (i.e. those who remained in their FF CRS beyond traditional transition ages or sizes) was compared to occupants of the same age, weight, or height in a BPB and appropriately aged and sized occupants in a FF CRS.

There were no detectable patterns in relative injury risk among the comparison groups. Those with delayed graduation (older/heavier children in FF CRS) appeared to have a slightly lower injury risk than those of comparable age or size in BPB; however, these differences were not statistically significant. Overall, the risk of injury was very low for all restraint conditions, indicating that CRS offer excellent protective benefit in the event of a crash.

In addition to the NASS analyses, detailed crash investigation information was gathered from the Crash Injury Research and Engineering Network (CIREN) database maintained by NHTSA. The CIREN database was queried for all AIS 2+ injured occupants using a FF CRS or BPB. Cases were defined as “premature graduation,” “delayed graduation,” or “age-and-size appropriate” users based on age, weight, and height criteria. Each case was retrospectively reviewed to determine injury causation scenarios for “premature graduation” BPB-seated occupants and “delayed graduation” FF CRS-seated occupants. Misuse for these cases was examined in detail. Misuse of the CRS for those who were restrained in FF CRS with delayed graduation (i.e. larger children in FF CRS) was critical to the injury causation.

This analysis provides insight into the issue of graduation between child restraint types, rather than graduation between a CRS and the vehicle lap and shoulder belt, which has previously been the focus of research. The findings ultimately can be used to educate consumers when deciding when to transition their children.

Research In Action: 2013-2014 Project Highlights

Understanding and Predicting Human Driving Behaviors via Machine Learning Models

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Co-Principal Investigator:

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Poor speed management is a key factor in teen driver crashes. In order to inform new training and technology to reduce teen crash risk due to poor speed management, a more complete understanding of this complex driving behavior is needed. This study determined the feasibility of using computational approaches to automatically model speed management, as an example of human driving behavior.

The project utilized a subset of an existing dataset from the development of a Simulated Driving Assessment. This Assessment included driving scenarios and situations that reflected the most common crash configurations among young drivers as identified in the results of the National Motor Vehicle Crash Causation Survey (NMVCCS). The dataset contained behavioral and eye-tracking data from four simulator drives, a driver education instructor's subjective ratings of driving behaviors, images from three video cameras, and self-report measures from the teen participants.

Data from 17 novice teen drivers (licensed for less than 90 days) were analyzed using three modeling techniques. The modeling techniques predicted the behavior of the driver at the same instant, as represented by a given sample, and the future behavior of the driver. Additionally, a certified driver education instructor reviewed video recordings of the participant's simulator drives and evaluated each participant's crash likelihood and driving skill levels in comparison to all drivers, as well as teenage drivers.



The driving simulator used as part of the Simulated Driving Assessment.

The results of this study showed the potential for certain modeling techniques to accurately predict driver behavior at the present time as well as 1 second into the future. There are several implications for this research, including conducting further analysis to understand the differences between teen and adult driving behavior and the causes for crashes. There is also the potential for using validated modeling techniques to provide feedback to drivers for training and educational purposes. Eventually, these techniques might possibly be integrated into in-vehicle monitoring systems that can predict both driver behavior and skill level and thus provide personalized assistance.

Comparing FMVSS 213 Sled Test to the Full-scale Vehicle Crash Environment (Year 3)

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Child restraint systems (CRS) provide an adaptive interface between a developing child and the vehicle seat, limiting the child's risk for injury or death in the event of a crash. The most common method used to evaluate the dynamic performance of a CRS is a sled test, where a crash sled containing a restrained pediatric anthropomorphic test device (ATD), or crash test dummy, reproduces a crash pulse similar to what is observed in a full-scale vehicle crash. The regulation that governs evaluations of child restraint performance is known as FMVSS 213.

While the ability to run such sled tests and estimate injury potential is essential for the CRS design process, development and implementation of federal regulations has revealed many opportunities to refine the sled test methodology. The long-term goal of this line of research is to influence CRS design and safety by developing a method to provide data-driven assessment of the ability of the regulatory sled test to mimic actual vehicle crashes. Prior research under this project showed clear differences in the kinematics of both the ATD and the child restraint when exposed to identical crash pulses between the FMVSS 213 bench and actual rear seats from a representative passenger car, SUV, and minivan, each mounted on an acceleration sled.

Given these differences, the testing, simulations, and analysis conducted in this phase of research focused on the differences in booster seat performance on vehicle seats compared to the FMVSS 213 bench. There were two distinct tasks in this phase: 1) developing a Finite Element (FE) model of the FMVSS 213 bench with a booster seat and 2) providing a cost-efficient platform to evaluate bench characteristics. As part of the FE model validation process, high rate belt, harness and tether webbing experiments and foam experiments were generated that are proving valuable to the industry. Tether anchor location was varied parametrically in the model to include locations attached to the floor, the roof and the package shelf, and results were compared to matched sled test data. Head and chest acceleration were sensitive to tether anchor location, but head and knee excursion changed minimally across the locations.

Task 2 involved physical sled tests and the examination of retractor vs. no retractor on various kinematic and kinetic ATD metrics and injury criteria. As mentioned above, in year 1 of the project, substantial differences were observed between the booster head excursion on the vehicle seats as compared to the FMVSS 213 bench. It was hypothesized that these differences were due to retractors on the vehicle seat belts, which allow for a certain amount of belt payout during loading, while the seat belt on FMVSS 213 bench clamps the shoulder belt restricting payout. The sled tests revealed head excursion was greater in the retractor condition. The FE model developed in Task 1 was used to confirm these findings.

This body of research provides important insight into the capacity of the FMVSS 213 bench to replicate real-world crash scenarios. Because sled tests are vital to the design and validation of CRS, improvements to the testing protocol based on these analyses may yield increased safety benefits for children in actual motor vehicle crashes.

Research In Action: 2013-2014 Project Highlights

Pediatric Brain Injury Assessment in Real World Crashes

Principal Investigator:

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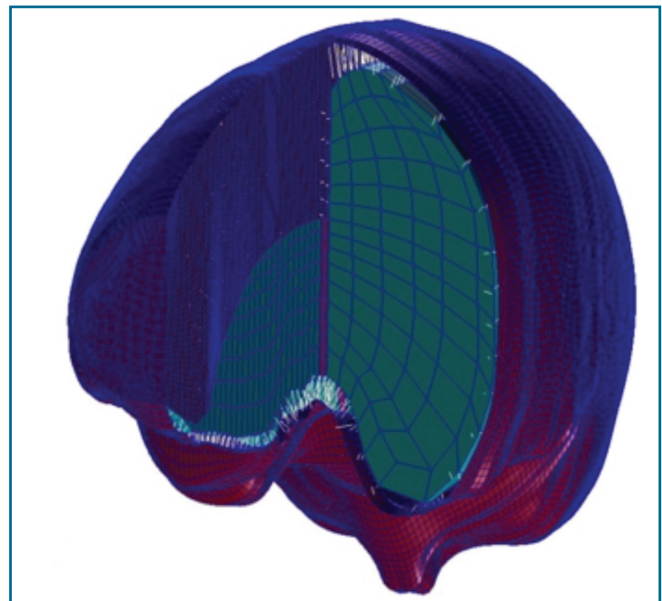
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Traumatic brain injuries (TBI) are the most common serious injuries sustained by children in motor vehicle crashes, both as vehicle occupants and pedestrians. A child's risk of head injuries increases with age -- appropriately restrained pre-adolescents (ages 8- to 12-years-old) have nearly twice the risk for head injury as toddlers (ages 1- to 3-years-old) in frontal and side impact crashes. This project utilized finite element (FE) modeling to create a model of the pediatric 6-year-old human brain and skull with a long-term goal to improve the design tools available to engineers as they develop motor vehicle safety systems that mitigate TBI in children.

A pediatric 6-year-old human brain and skull FE model was developed based upon an average MRI scan template from the McConnell Brain Imaging Center of the Montreal Neurological Institute at McGill University. The usefulness of the model was then demonstrated in predicting brain deformation during rapid rotation reconstructions. The FE brain model was rotated in each of the three anatomical planes (sagittal rotations, axial rotations, and coronal rotations); results showed that the axial rotation direction had the highest strains. As part of a previous project funded by the National Highway Traffic Safety Administration (NHTSA), six real-world crashes were reconstructed with seat belt restrained rear-row pediatric occupants in the age and size range of the 6-year-old occupant in order to yield a range of likely head angular and linear acceleration time histories from each case. In the current project, these head acceleration time histories were used as the input to the FE brain model in order to translate global head kinematics to brain mechanics.



Cutout of pediatric 6-year-old brain and skull finite element model.

Four separate car crash reconstructions were chosen that represented a variety of crash conditions (frontal and side impact), with a range of occupant ages (6 to 10 years), and mild to moderate brain injury (Abbreviated Injury Scale maximum score of 2 to 5). Results showed that the two reconstructions with diffuse axonal injury had the highest strain. The next phase of this research will involve further development of the 6-year-old FE brain model by adding a deformable skull, and then using this new brain model to answer key questions in pediatric head injury mitigation that are most relevant to pediatric pedestrian and booster-seated occupant safety.

Motor Vehicle Crash-related Injury Causation Scenarios for Disabling Injuries in Children

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Motor vehicle crashes (MVCs) are the most common mechanism of spinal injury in children, and spinal cord injuries result in the most residual physical disability in children. This study aimed to expand upon knowledge of the patterns of injuries and their associated causation scenarios for restrained child occupants in MVCs to gain insight into how loads of the crash and restraint system are transferred to the spinal column.

A case series of crash investigations were identified from the Crash Injury Research and Engineering Network (CIREN) database, operated by the National Highway Traffic Safety Administration (NHTSA). CIREN obtains detailed crash investigation data from crashes involving a sample of patients admitted to a network of level-one trauma centers in the U.S. Cases included child occupants under 18 years old with at least one AIS 2+ spinal injury from vehicles model year 1990 and newer. Only patients properly restrained in a harness child restraint system, belt-positioning booster seat, or lap and shoulder belt were included. Rollover crashes were excluded, as were occupants with pre-existing co-morbidities contributing to spinal injury or with limited injury information.

A multi-disciplinary Case Review Team studied 42 cases meeting the inclusion criteria to determine injury causation scenarios. The case review process included review of crash conditions, restraint and occupant characteristics, occupant injuries, and occupant contact points within the vehicle. Data summaries included estimates of the vehicle dynamics and occupant kinematics during the crash, and detailed descriptions of the injuries by body region, type of injury, and severity.

The cases included 97 distinct AIS 2+ spinal injuries, with fracture as the most common injury type (80 percent). Spinal injuries predominantly occurred in high-speed frontal crashes of passenger cars with front-row teenage occupants who sustained non-fatal vertebral fractures from flexion over the belt or harness or direct contact from the vehicle interior. The majority of the crashes (62 percent) were frontal and at a relatively high speed, with an average delta V (the instantaneous change in velocity, an accepted measure of crash severity) of 51 km/h.

The results of this study align with prior work showing that occupants who are restrained and in non-rollover crashes with spinal trauma sustain mostly vertebral fractures and relatively few cord injuries. Although these fractures are less disabling than cord injuries, they still result in hospitalization and measurable morbidity. Because these crashes were predominantly high-speed and involved teenage occupants, there are important implications for prevention strategies and countermeasures. Future work should focus on additional means to further mitigate MVC-related spinal trauma in children while continuing to limit head excursion and resultant injuries.

Research In Action: 2013-2014 Project Highlights

Linking Adolescents' Medical and Traffic Data: Creation of a Unique Database

Principal Investigator:

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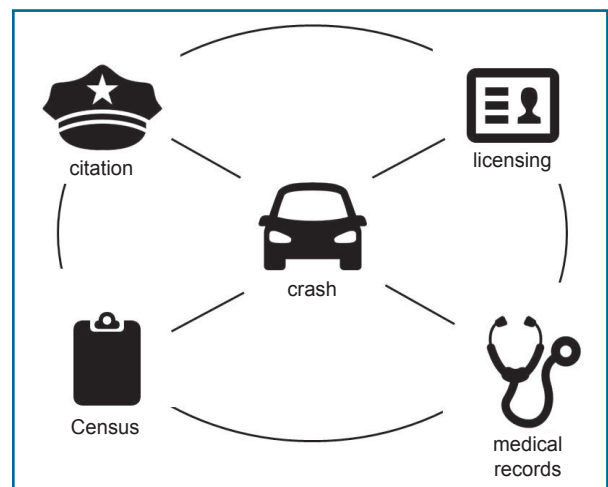
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By linking crash data of teen drivers to their licensing information, citation data, Census data, and childhood electronic medical records, researchers can generate a more complete assessment of teen drivers' relevant history and experiences on the road.

Although state- and national-level crash report data have been invaluable to the traffic safety community, current limitations preclude traffic safety researchers from placing a teen driver's crash event in the context of relevant previous or future experiences and events. Linking traffic safety data to other available data sources — licensing databases, hospital medical records, Emergency Medical Service records, and/or vital statistics databases — uniquely extends the richness and value of crash data. This project aimed to develop and refine methods to link patient medical data from The Children's Hospital of Philadelphia (CHOP) to New Jersey's (NJ) traffic safety data, to execute the linkage for a sample of adolescents from CHOP's NJ primary care and subspecialty care practices, and to assess the quality of the linkage.

A methodology was developed to individually link adolescents' medical information from CHOP NJ primary and subspecialty care practices to their detailed driving record — including history of licensing, citations, and crashes. This linkage was performed for 65,149 NJ residents who were: 1) born between 1987 through 1994 (i.e., 17 years old at some point between 2004 and 2011); 2) patients at one of CHOP's primary care or subspecialty care practices located in NJ; and 3) whose last known address was in NJ.

Among the population of 65,149 adolescents, 53,323 (81.85 percent) were linked with a unique license record, surpassing expectations set for each year of birth. This linkage rate was achieved using six linkage phases, each utilizing distinct and fairly stringent linkage criteria. Multiple methods were utilized to assess the quality of the linkage; each demonstrated high-quality results. The estimated true match rate was 99.81 percent, and the estimated false non-match rate was 1.99 percent. Additionally, the majority of CHOP records linked with a license record (99.67 percent) had matching values for gender in the two sources.

There are many potential applications for future traffic safety research using this linked database, including work that examines the association between medical conditions (such as Autism Spectrum Disorder, Attention-Deficit/Hyperactivity Disorder, and concussion) and licensing and crash outcomes. The long-term goal of this line of research is to establish the scientific foundation for the development of evidence-based interventions that tailor the licensing and learning-to-drive process to, and ensure safe driving behaviors among, adolescents with these conditions.

Advanced Automatic Crash Notification for Child Occupants

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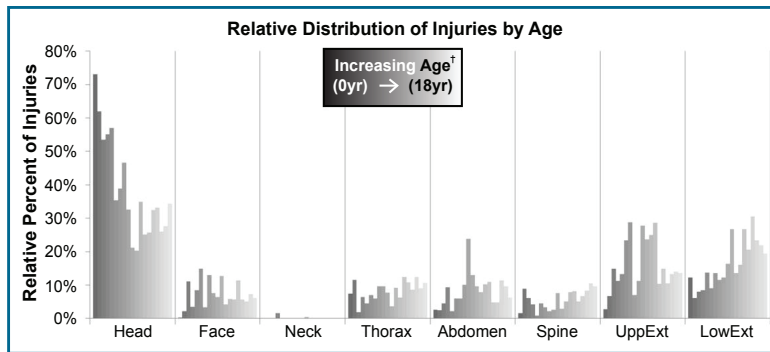
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Jerry Wang, Humanetics Innovative Solutions Inc.;

Julie Kleinert, General Motors Holdings LLC;

Christina Mullen, State Farm Mutual Automobile Insurance Company;

Uwe Meissner, Technical Advisor; Michelle Caldwell, Childress Institute for Pediatric Trauma



This chart represents the relative percentages of child injuries involving specific body regions by age in the NASS-CDS 2000-2011 dataset.

Because children are not simply “small adults,” the management of their unique injuries at trauma centers (TCs) must be approached differently. One of the most important factors in the treatment of traumatic injuries is the process of trauma triage, which involves transporting the “right patient” to the “right place” at the “right time.” However, trauma triage algorithms remain varied and stand to improve with the use of Advanced Automatic Crash Notification (AACN), which utilizes information retrieved by a vehicle’s Event Data Recorder to predict the severity of injuries sustained by occupants and subsequently alert first responders to the event in real time. Though several research groups have developed AACN algorithms for adults, none have yet been developed for children. Given children’s constant growth and development, there is a need for a pediatric-specific AACN system that can adjust its injury risk prediction based upon their developmental stage.

The long-term goal of this project is to create a pediatric-specific AACN algorithm that uses a more comprehensive scoring system than the Abbreviated Injury Scale (AIS) to predict the risk that a child in a motor vehicle crash (MVC) is severely injured and requires treatment at a designated TC. Year 1 of this project focused on: quantification of the patterns of injuries among pediatric MVC occupants as they grow in age, height and weight; and preliminary assessment of the severity, time sensitivity and predictability of the most common injuries sustained among MVC occupants in different pediatric age groups.

The research team conducted a retrospective review of occupants 0-18 years of age with injuries of AIS 2+ severity using the National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) 2000-2011 dataset to determine the most common MVC-induced injuries occurring in each developmental group. The results of the analysis showed that injury patterns change as children grow and develop. In general, the odds of head injury significantly decreased during development, while the odds of spinal injury, thoracic wall fracture and lower extremity fracture increased during development. Given the uniqueness of the different stages of pediatric development, age groupings (0-4, 5-9, 10-14 and 15-18 years) were established to allow for the creation of more specific algorithms within each developmental group. Having a system that links an age group with relative risk of various injury types will have important implications for clinicians, improving time, cost-effectiveness and, most importantly, pediatric patient care.

Research In Action: 2013-2014 Project Highlights

Comparison of Q3s ATD Biomechanical Responses to Pediatric Volunteers

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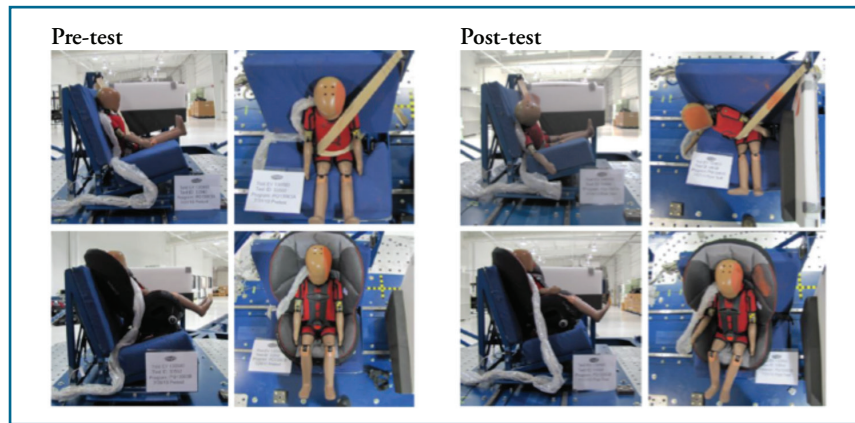
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IAB Mentors:

Eric Dahle, Evenflo Company Inc.; Jerry Wang, Humanetics Innovative Solutions Inc.; Steve Rouhana, Ford Motor Company; Keith Nagelski, Britax Child Safety, Inc.; Ron Burton, Transportation Research Center Inc.



These photos show examples of pre- (left) and post-test (right) pictures with a three-point seat belt (top) and CRS (bottom). The post-test pictures were taken after lateral impacts at the high speed condition.

Improvements to the design of child restraint systems (CRS) are dependent upon new testing protocols to better understand how children's bodies respond during crashes and how CRS can best protect them. Under Federal Motor Vehicle Safety Standard (FMVSS) 213, all CRS sold in the U.S. must meet a dynamic testing requirement in frontal collisions. New side impact requirements to FMVSS 213 have been proposed by the National Highway Traffic Safety Administration (NHTSA) but are dependent upon an adequately biofidelic pediatric side impact anthropomorphic test device (ATD), or crash test dummy. The 3-year-old targeted Q3s ATD is one of the first side impact specific pediatric ATDs that is emerging as a tool to fill this need. This study utilized existing pediatric volunteer data to evaluate the Q3s, which was also subjected to higher severity impacts to compare overall kinematics and kinetics.

Previously conducted experiments were replicated in order to make a direct comparison between the Q3s and pediatric volunteer data from 4- to 7-year-olds (shoulder tests) and 6- to 8-year-olds (low speed sled tests). Force-deflection data were captured during quasi-static shoulder tests of the Q3s through manual displacement of the shoulder joint. Low-speed far-side sled tests, as well as low, medium, and high-speed sled tests using a Takata bench setup, were conducted with the Q3s at lateral (90°) and oblique (60°) impacts. In testing, the Q3s ATD exhibited greater shoulder stiffness than pediatric volunteers, which may affect loads seen by the Q3s head, torso, and neck during side impact. In low-speed sled testing, the Q3s kinematics displayed rigid body translational motion of the torso followed by independent lateral bending of the head, suggesting cervical and thoracic spine rigidity compared to pediatric volunteers.

While ATDs have been compared to volunteer responses in frontal impacts, this study is the first to extend ATD to pediatric volunteer comparison methods to the Q3s ATD, and among the first to extend these methods to side impacts. These results provide an important step toward ATD pediatric biofidelity evaluation by comparison to volunteer data. Even at low severity impacts, there are important differences in the biomechanical responses of children compared to the Q3s. Identifying, understanding, and making improvements based on these differences will lead to more biofidelic pediatric ATDs and, ultimately, save more children's lives.

Supplemental Research Funding

Research Experiences for Undergraduates

Since 2011, CChIPS has hosted a National Science Foundation Research Experiences for Undergraduates (REU) site for Injury Science. In 2013, the third and final year of the grant, 364 students applied for nine internships. The selected students spent the summer working side-by-side with Center for Injury Research and Prevention (CIRP) researchers.

Partnering with The University of Pennsylvania, CIRP's 10-week REU program provided a diverse group of student scholars from schools across the country with mentorship and hands-on research experience in the fields of Engineering, Behavioral Science, and Epidemiology. Each student was paired with a CIRP mentor to work on specific projects and also received formal training in research ethics, research methodology, and the presentation of research findings.

Looking Beyond Catastrophic Brain Injury to Mild Traumatic Brain Injury

Led by Kristy Arbogast, PhD, co-director of CIRP and CChIPS, this sports injury prevention study examined the accuracy of helmet-based sensors on youth hockey players in measuring head acceleration with the long-term goal to quantify head biomechanics and correlate with neurocognitive deficits across a typical season. This project has evaluated the accuracy of two different types of sensors that can be integrated in helmets to measure global head kinematics. These results represent the first comprehensive evaluation of this technology and have been influential in defining the foundational science of this field. Linking head biomechanics to clinical outcomes will allow scientists to understand how head movements relate to the risk of concussion. This research is being conducted in collaboration with CChIPS members Toyota North America Inc. and the National Highway Traffic Safety Administration, as well as SAFER, the Vehicle and Traffic Safety Centre at Chalmers University in Gothenburg, Sweden.

Global Venture Fund

The Global Venture Fund Supplement provided support for CChIPS to promote new international collaborations, to leverage expertise, specialized skills, and resources of a foreign collaborator, and to provide U.S. students with international research experiences. Researchers explored a potential collaboration with a large multi-national technology corporation with a significant presence in India, to better understand road traffic injury in that nation – particularly understanding safety behaviors of their large Indian workforce while traveling to and from work or during personal time.

CChIPS researchers conducted a systematic assessment of available electronic resources linked to health risk assessment road safety focal areas and conducted focus groups with the corporation's employees about perceptions and practices relating to road traffic safety. The research team presented recommendations for future activities and collaborations to reduce road traffic injury and death among employees and their families. The team developed a Web-based Road Safety Resources database with the aim of better understanding road traffic safety behaviors and helping to design future interventions to reduce injury and death in India.

New Research Tool for CChIPS Investigators and Collaborators

Through National Science Foundation funding, the Digital Health team at CIRP has designed and developed a digital health evaluation platform that can be used to conduct online studies of apps and websites providing the evidence of their impact and value. The platform can be a tool that app developers use to prove their value to app purchasers (which may include hospitals and healthcare systems). The platform includes study design and management tools, user tracking, deployment of online surveys and integration with other data sources to provide a comprehensive evaluation platform. Over the next year, this tool will be used and refined through implementation with several projects, with a goal to make it available to CChIPS investigators as an effective study management tool.

Synergy In Motion

CChIPS members play an integral role beyond sponsorship; they work closely with faculty to set the CChIPS research agenda and provide mentorship to investigators. Representatives from the member companies form the Center's Industry Advisory Board (IAB). Membership is open to all companies, organizations, or federal agencies that have an interest in advancing research and development to further child and adolescent injury prevention. 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 involving extensive discussions with designated IAB mentors immediately precedes the annual spring meeting. At that meeting, the Board votes on the proposals, ranking them based on points allotted.

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

Every membership dollar goes toward research and its dissemination. The CHOP Research Institute, The University of Pennsylvania, The Ohio State University, and other research facilities involved in CChIPS projects waive overhead fees to make this vital work possible. IAB members also can rely on CChIPS' proven track record in successful research partnerships with Industry and government. 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, and government agencies.

2013-2014 IAB Member Companies:

- American Honda Motor Co., Inc.
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- Consumer Reports
- Dorel Juvenile Group
- Evenflo Company Inc.
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- Humanetics Innovative Solutions Inc.
- Minnesota HealthSolutions
- The National Highway Traffic Safety Administration
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- State Farm Mutual Automobile Insurance Company
- TK Holdings Inc. (Takata Corp.)
- Toyota Motor North America Inc.
- Transportation Research Center Inc.
- Volkswagen Group of America

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

Center for Child Injury Prevention Studies

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.

Our vital work would also not be possible without the generosity of our academic, corporate, and government collaborators. Many thanks to The Children's Hospital of Philadelphia, The Ohio State University, The University of Pennsylvania, as well as our collaborators at Chalmers University of Technology/SAFER, Drexel University, the Insurance Institute for Highway Safety, Monash University, Rowan University, Safe Kids Worldwide, Transport Canada, Wake Forest University, and Wayne State University for providing CChIPS with forward-thinking scientists committed to making the world a safer place for children and adolescents.

Acknowledgements

This report was produced by the Center for Child Injury Prevention Studies (CChIPS) at The Children's Hospital of Philadelphia and the Research Communications Department of CHOP's Research Institute.

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