Safe & Sound
Paving the Way

CChIPS | Center for Child Injury Prevention Studies

2016 Annual Report

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

The Ohio State University
WEXNER MEDICAL CENTER

Partnering for Safety

A Message from Our Directors

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

Through strong science, relevant research, collaboration and passion, the Center for Child Injury Prevention Studies (CChIPS) continues to pave the road to preventing injuries and keeping children safe and sound. As we embark on the 11th year of our National Science Foundation (NSF)-founded Center, we remain committed to these values. Our unique partnership includes research sites at The Children's Hospital of Philadelphia (CHOP) Research Institute and The Ohio State University (OSU), and our Industry Advisory Board (IAB) comprises 20 member organizations from industry, advocacy, and government agencies. In this collaborative setting, our researchers pinpoint and assess the causes of injuries to children and young adults, while our IAB keeps the research actionable, relevant, and market-driven. 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.

In 2015-2016, the IAB funded 16 research projects, bringing the Center's 11-year total to more than 120 completed projects across the Center's five-domain research agenda. This multitude of research projects has fostered the development of multiple lines of research, including data linkage; human volunteer testing; driving simulator research; child passenger safety; and naturalistic driving behavioral research.

This year, our Center greatly expanded our naturalistic driving behavioral research portfolio. With generous matching support from CHOP and partial funding from the IAB, CChIPS acquired a large dataset of teen and adult driving and crash/near-crash data from the Strategic Highway Research Program 2 (SHRP2), collected as part of a federal research effort and managed by the Virginia Tech Transportation Institute. The initial analysis of SHRP2 data is adding to the Center's understanding of how crashes occur, including the driving behaviors that led to them. The acquisition of these innovative data has enabled our team to seek new ways to investigate and prevent injury to young adults on our roads. Read about CChIPS' first line of study utilizing this unique dataset on Page 14.

The procurement of SHRP2 data is just one example of how CChIPS creates opportunities for its members and scientists to pursue their shared research goals. The Center model provides another unique mechanism for IAB members to undertake projects of particular interest to their companies, thus providing opportunities to contribute project-specific research funds above and beyond their membership fees. To learn more about the individual contributions of our members, see our IAB Member Spotlight on Page 3.

CChIPS prioritizes sharing new developments in child injury science with professionals from industry, government, and research organizations. Its annual Advances in Child Injury Prevention (ACIP) Conference held in Plymouth, MI is one of the primary mechanisms for presenting CChIPS research to external audiences. At the most recent ACIP conference in November 2015, attendees from over 40 companies came to hear experts from academic, policy, and advocacy institutions share their latest research on occupant safety and other road traffic injury topics related to children and adolescents. These topics included: how side air bags interact with rear-seated children in car seats; the use of finite element models in traffic crash reconstruction; and how state child passenger safety laws predict child restraint use.

CChIPS also spreads its important mission and message of child injury prevention worldwide. Over the past year, Center faculty and investigators presented at the Protection of Children in Cars Annual Conference in Munich, Germany and the 11th World Congress on Brain Injury in The Hague, the Netherlands.

The Center's research portfolio is continually evolving to address current challenges and emerging issues. 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 at CHOP, the Center for Injury Research and Prevention – utilizes a team of outreach and communication experts who focus on translating CChIPS research findings into appropriate messages and materials designed to reach target audiences. This includes digital communication strategies to share information such as the cchips.research.chop.edu website, which saw a 128 percent increase in visits in calendar year 2015.

This synergy has fostered robust growth at our Center over its first decade, and now, as we enter the second decade, we continue to pursue this important work with an eye toward sustainability and fiscal strength. We look forward to sharing many more achievements with you in the future.

A Unique Approach to Child Safety Research

Since 2005, CChIPS has been a hub of innovation and collaboration for industry members and academic researchers committed to improving the safety of children and adolescents.

The Children's Hospital of Philadelphia (CHOP) CHOP was established in 2005 as the original academic site of CChIPS. CHOP is one of the country's leading pediatric hospitals and is a world class research institution. CChIPS at CHOP runs administratively under the auspices of the Center for Injury Research and Prevention (CIRP), a Center of Emphasis at the CHOP Research Institute. Additionally, CHOP-based CChIPS faculty share an academic affiliation with The University of Pennsylvania.

The Ohio State University (OSU) The Injury Biomechanics Research Center at OSU was added as a second research site in 2010. The Center, comprised of the Injury Biomechanics Research Lab and Skeletal Biology Research Lab, brings to CChIPS an interdisciplinary team of engineers, anatomists, physicians, computer modelers and technicians with expertise on mechanisms of injury and injury thresholds of the human body.

National Science Foundation (NSF) The NSF, created by the US Congress in 1950, is the only federal agency with a mission that supports all fields of fundamental science and engineering. In March 2005, CChIPS was founded by an NSF grant as an Industry/University Cooperative Research Center (I/UCRC). It remains the only I/UCRC dedicated to child and young adult injury prevention, of the nearly 80 in the country. The NSF provides annual funds for the Center's administrative costs, as well as programmatic oversight.

Industry Advisory Board (IAB) Comprised of industry, nonprofit, and government members, the IAB funds research, establishes investigative priorities, and advises on strategic direction. IAB members meet twice annually to review the research portfolio and vote on new projects. They also volunteer to serve as mentors to the research investigators, providing guidance and critical insight throughout the life of each project.

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

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. This ensures 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 involving extensive discussions between faculty and IAB mentors immediately precedes the annual spring meeting.

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 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 on Page 4, and invite other companies, organizations, or agencies to join.

IAB Member Spotlight

As part of the CChIPS model, IAB members may contribute funds above and beyond their membership fees to conduct additional research projects, the findings of which are shared among all Center membership. Several IAB members have taken advantage of this opportunity. State Farm Mutual Automobile Insurance Company is supporting the ongoing project *Active Safety Systems and Teen Drivers: Impressions, Perceived Need, and Intervention Preferences*. Toyota USA contributed a second CChIPS membership to the research funding pool in order to continue supporting external investigators from Wake Forest University in their multi-year project, *Advanced Automatic Crash Notification for Children* (see Page 17).

Two additional member companies have worked closely with CChIPS faculty on other sponsored research efforts. Minnesota HealthSolutions has partnered with CHOP's Dr. Aditya Belwadi on innovative advancements in child restraint design with funding from the federal Small Business Innovation Research program. TK Holdings (Takata Corp.) continues its long-standing support of the human volunteer pediatric biomechanics research led by CHOP's Dr. Kristy Arbogast.

The Center greatly values these generous contributions, which allow its researchers to pursue important work in the arena of child injury prevention.

Be Part of a Safer Future

Additional partnerships are needed to successfully and efficiently reduce the burden of child injury. CChIPS looks to broaden its membership by adding new companies and other organizations vested in child safety. The Center also seeks to expand its scientific collaboration by linking with new academic partners. If your organization is interested in being part of this exciting movement to address a significant societal problem, please contact us at cchips@email.chop.edu.

Visit our website at cchips.research.chop.edu to learn about CChIPS' entire portfolio of research, spanning 11 years and over 120 projects.

IAB Member Companies

britax ◆★
Consumer Reports
evenflo
FCA – Fiat Chrysler Automobiles ★
Federal Aviation Administration
GM ★
Graco
Honda – The Power of Dreams ★
Humanetics – Innovative Solutions
Lear Corporation
MHS
NHTSA
Nissan ◆★
Realtime technologies, inc – simulation, vehicle dynamics, human factors
Safe Kids Worldwide
State Farm ◆
Takata ◆★
Toyota ◆★
TRC ★
VW ◆★

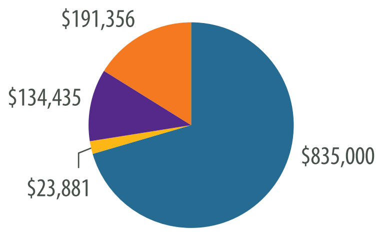
◆ Founding IAB Member Company ★ 2015 ACIP Conference Sponsor – Gold ★ 2015 ACIP Conference Sponsor – Silver

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

Funding the Research

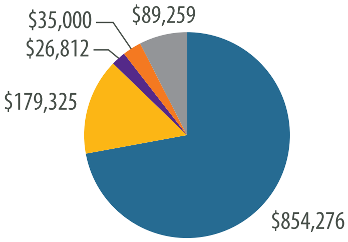
CChIPS is made possible through a grant from the National Science Foundation (NSF), as well as sponsorships from its Industry Advisory Board (IAB) members comprised of the leaders in industry, small business, nonprofits, and government agencies that engage in and value scientific research and development 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 2016



***Total Revenue:** $1,184,672

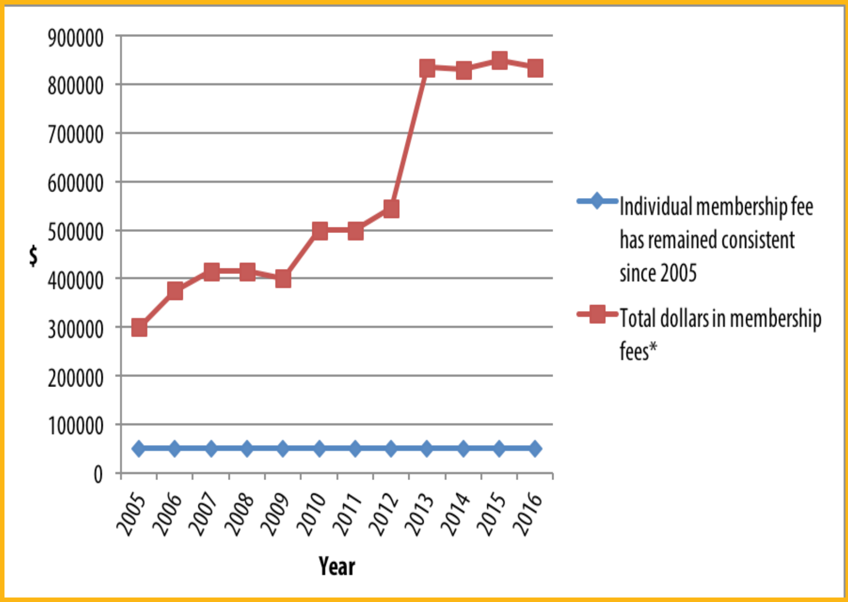
Expenditures for 2016



***Total Expenditures:** $1,184,672

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

Return on Investment



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

Since CChIPS began in 2005, each full voting 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 2016, the combined membership fees resulted in $835,000 available to support the CChIPS mission. Based upon the $50,000 membership fee, this represents a 1,670% annual Return on Investment (ROI) per company.

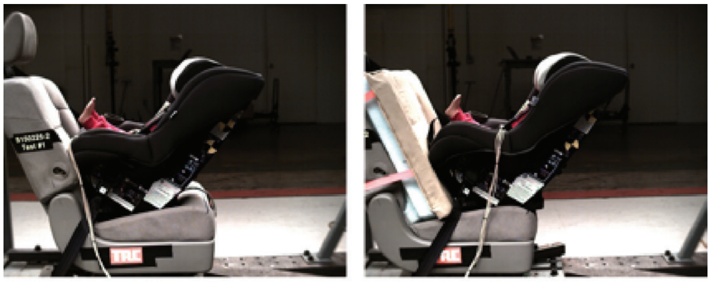
Quantifying CRS Fit in the Vehicle Seat Environment – Focusing on Incompatibilities

Co-Principal Investigator:
Julie Bing, MS, The Ohio State University

Co-Principal Investigator:
Amanda Agnew, PhD, The Ohio State University

IAB Mentors:
Keith Nagelski, Britax Child Safety Inc.; **Eric Dahle**, Evenflo Company Inc.; **Julie Kleinert**, General Motors Holdings LLC; **William Conway**, Graco Children's Products Inc.; **Drew Kitchens**, Graco Children's Products Inc.; **Mark LaPlante**, Graco Children's Products Inc.; **Uwe Meissner**, Technical Advisor

At left: Each RF CRS was first installed without any additional items. The yellow line represents the manufacturer's level-to-ground line (outside of the target range).
At right: The same CRS re-installed with a rolled towel to correct the angle.



Control Overhang

The sled test conditions for the control trial vs. the overhang trial. The spacer in the photo on the right effectively shortened the seat pan length so that 20 percent of the CRS base was overhanging the front edge of the vehicle seat. When the spacer was inserted, the vehicle seat was slid backwards an equal amount on its slider track so that all seat belt anchors were in the same position relative to the new seat bight.

Wide varieties of child restraint systems (CRS) and vehicle interior designs suggest that not every CRS can fit seamlessly into every vehicle. Previous work has identified specific areas of incompatibility between a large portion of CRS and vehicles available on the US market. With these areas of concern identified, more detailed information is now required to support manufacturers' improvement efforts and to help define priority levels for each potential incompatibility. The long-term objective of this study was to improve fitment between CRS and vehicle models by establishing the frequency, severity, and consequences of various incompatibilities.

Phase 1 of this study aimed to document a large number of physical CRS installations in vehicles to develop detailed descriptions of compatibility challenges and further validate methods to predict these scenarios. To this end, 10 common convertible CRS were installed in the outboard and center positions of 10 common family vehicles. Rear-facing (RF) and forward-facing (FF) modes were evaluated for each CRS, and all were installed using both Lower Anchors and Tethers for Children (LATCH) and seat belt methods. Quantitative and qualitative data were collected from each of the 632 completed installations.

In Phase 2, sled tests were performed to investigate the consequences of common incompatibilities on occupant safety. Frontal sled tests were conducted with RF CRS installed on second-row vehicle seats to determine if performance was affected by:

a) using pool noodles to achieve proper base angle
b) allowing the front edge of the CRS base to "overhang" the front edge of the vehicle

Overall, installations could be completed according to the manufacturers' instructions for 98.4 percent of RF CRS installations and 95.9 percent of FF CRS installations. Three out of the 10 RF CRS installed in vehicles demonstrated consistent inability to achieve proper base angle without the use of a rolled towel or pool noodle. This incompatibility was generally well predicted by the previous external evaluations of both CRS and vehicle seat pan angles. Eight frontal sled tests of convertible CRS in RF mode indicated no reduction in performance caused by either pool noodle installations or front edge overhang compared to control trials. Slightly more lateral rotation of the CRS was observed in RF CRS installations with front edge overhang compared to control trials, but all other kinematic and injury values were not significantly different.

The majority of CRS installations could be completed according to manufacturers' instructions, although some exhibited minor issues or required after-market items to aid in angle alignment. Pilot sled testing did not reveal any major causes for concern regarding pool noodle usage or front edge overhang for one model of RF CRS.

Evaluation of Side Impacts with a Frontal Component for Children in CRS (Year 2)

Principal Investigator:
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Project Team Members:
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IAB Mentors:
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Recent advances in child occupant protection have focused on mitigating fatalities and injuries to children in child restraint systems (CRS) in side-impact or oblique crashes. Although those in near-side seating positions have the highest injury and fatality risk in side-impact scenarios, injuries still occur to occupants seated center or far-side. For these occupants, the most common body region of injury is the head and neck, most frequently caused by head contact with the vehicle interior.

In the first year of this line of study, researchers observed the far-side seated forward-facing (FF) CRS yaw and roll in the oblique impact mode, leading to substantial head excursion of the anthropomorphic test device (ATD), or crash test dummy. This excursion was of the magnitude to lead to potential impact with a vehicle's intruding components during a side-impact crash. The tests also suggested the tether can provide value in mitigating head excursion and pointed to the need for a more detailed look at the role of the tether. Based on the Year 1 findings, an extension of this work for a second year used a series of sled tests to explore the role of the tether and intrusion on the kinematics and injury potential of a 3-year-old occupant seated in the center seat in oblique side impacts.

Sled tests were conducted utilizing a Q3s ATD positioned in a FF CRS. CRS were attached to a rear seat from a small SUV via Lower Anchors and Tethers for Children (LATCH) flexible webbing in the center seating position; tests were conducted with and without the tether. The vehicle seat was secured to the sled at both 30 and 10 degrees from pure lateral, with a simulated intruded door secured left of the CRS – on the near side of the crash. 3D motion cameras collected ATD head excursion data and head accelerations, head rotational velocities, and neck loads, as well as webbing and tether loads.

All tests without a tether resulted in head to door contact, with the head rolling out of the FF CRS side wings and making contact with the intruded door halfway between the top of the door and the top of the armrest. The tether reduced excursion and head injury values, indicating its importance for potentially preventing injury in side impacts to children seated center or far-side. In addition to elevated head injury metrics, neck injury metrics were above existing thresholds.

These results point to the need for further research examining potential CRS attachment design and vehicle interior protection countermeasures to limit head and neck injury, including ways to better contain the head in oblique crashes. Additional padding or inflatable curtains below the vehicle's window sill also may help better protect small occupants, including children.

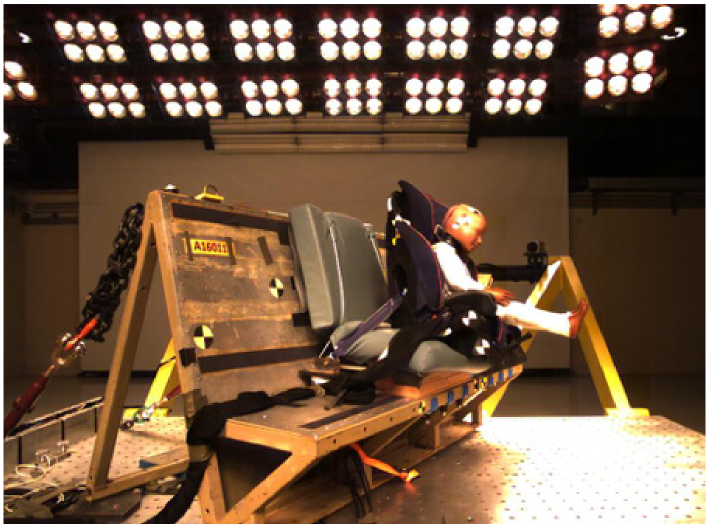
High-speed video frame at maximum head excursion, for the FF CRS tested in the untethered condition.
Note CRS yawing and tipping and ATD lateral excursion and head impact with the simulated intruded door.

Evaluation of Interaction of Inflatable Seat Belts with CRS Installed in Aircraft Seats in Oblique Impact Sled Tests

Principal Investigator:
Aditya Belwadi, PhD, The Children's Hospital of Philadelphia

Project Team Member:
Hans W. Hauschild, MS, Medical College of Wisconsin

IAB Mentor:
Amanda Taylor, Federal Aviation Administration



Sled test of a forward-facing CRS installed using a deactivated inflatable seat belt and Hybrid III 3-year-old ATD.

Federal Aviation Administration (FAA) regulations allow children younger than two years of age to ride unrestrained; however, the FAA strongly recommends that all children who fly, regardless of age, should be restrained in the appropriate child restraint system (CRS) for their weight and size attached to the aircraft seat by the aircraft seat belt.

The methods and fixtures used to certify child restraints under automotive regulation Federal Motor Vehicle Safety Standard 213 may not effectively measure CRS performance in an airplane seat. Compounding this, aircraft passenger seats continue to evolve, with the latest development being a partially enclosed (pod) seat that is oriented obliquely with respect to the aircraft centerline, presenting an off-axis loading condition.

The long-term objective of this line of research is to evaluate the effectiveness of advanced restraint systems and aircraft seats for pediatric occupants and their ability to mitigate injury during various modes of impact. The aim of the current study was to evaluate the interaction of an inflatable aircraft seat belt with rear-facing (RF) and forward-facing (FF) CRS installed on aircraft seats in oblique sled tests.

Six static installation evaluations and 17 dynamic oblique sled tests were performed. Seven RF and 10 FF CRS were attached to a FAA rigid couch, configured to reflect the typical oblique aircraft seat configuration. CRSs were mounted via a 2-point lap belt of two designs - with a deactivated inflatable air bag and with a standard aircraft lap belt. A Q1 anthropomorphic test device (ATD), or crash test dummy, representing a 1-year-old, and a Hybrid III 3-year-old ATD were secured to the CRS using the 5-point harness system. Occupant kinetics, including head, chest and pelvic accelerations, along with kinematics captured via high-speed camera were evaluated against standard Injury Assessment Reference Values (IARV) for injury thresholds. Eleven out of the 17 tests were run with the addition of a sidewall or an armrest to evaluate the likelihood of head contact.

In static testing, the thickness of the inflatable seat belt proved challenging during installation of the RF CRSs, particularly if the CRS had a base. In this scenario, the belt could not be routed, and this scenario was therefore not tested dynamically. In dynamic testing, installation of the CRS via the inflatable seat belt resulted in head, chest and neck accelerations, as well as Head Injury Criterion (HIC) values below the IARVs. No significant differences were noted between the inflatable belt and a standard lap belt. Neck Injury Criterion was greater than 1.0 for all test conditions but was not significantly different across seat belt type. There was no visible head strike with the armrest or the side cabin wall in any of the tests.

The test data can be used by the FAA to develop further policies on using CRSs in aircraft seats, especially when installed using inflatable seat belts.

Quantifying CRS Fit in Vehicle Seat Environment: Digitization Approach (Year 3)

Principal Investigator:
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Richard Hanna, Drexel University

IAB Mentors:
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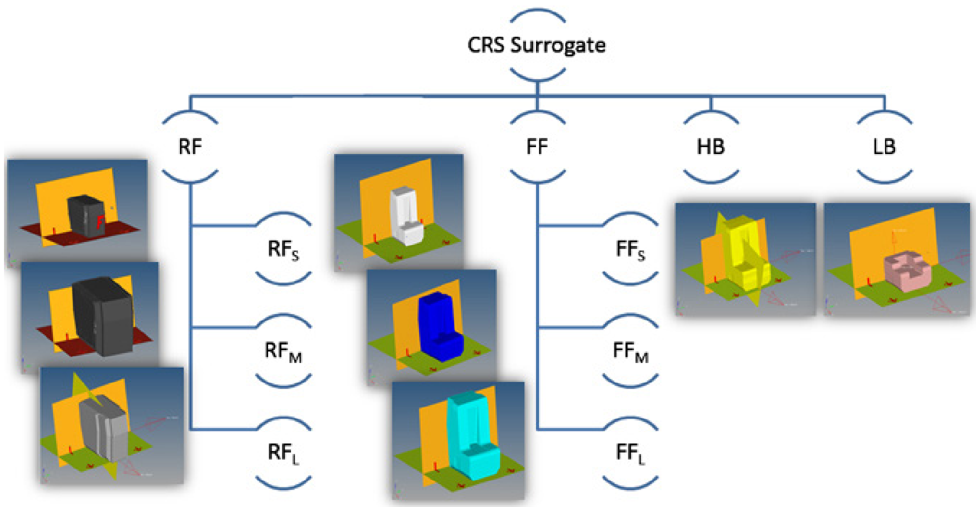


CChIPS Virtual Surrogate Models: Three each of RF (Small, Medium and Large), FF (Small, Medium and Large) and one each of HB and LB were developed.

Automotive interior design optimization must balance the design of the vehicle seat and occupant space for safety, comfort and aesthetics with the accommodation of add-on restraint products such as child restraint systems (CRS). Because CRS design is constantly changing, particularly with the introduction of CRS side impact protection and emphasis on ease of installation, the onus is on vehicle manufacturers to keep vehicle seats and occupant space compatible.

This multi-year line of research aims to allow vehicle manufacturers to better understand the breadth of CRS dimensions and to take them into account when designing new vehicles. In Year 1, a methodology was developed using the Microsoft Xbox Kinect™ Sensor to scan commercially available CRS to create a volume-encompassing virtual surrogate of a small rear-facing (RF) CRS. Additional CRS were scanned in Year 2, resulting in a total of 48 RF seat models representative of 81 on the market, 69 forward-facing (FF) seat models representative of 104 on the market, and 35 high-back booster (HB) and 22 low-back booster (LB) models included over the duration of this project.

In Year 3, 28 additional CRS were scanned using the Kinect™ Sensor along with 22 OEM drawings to represent over 293 CRS on the market as of March 2016. Further, 18 vehicle model scans were conducted to place the CRS surrogates in the context of an actual vehicle installation. The relevant scanned drawings were then overlapped for installation on an exemplar vehicle seat pan and seat back angle to create virtual surrogates of small, medium and large RF, FF, HB, and LB CRS models. The models included all of the seat belt paths, orientation denotation and level to ground markings and were made available to CChIPS IAB vehicle and CRS manufacturers as finite element models and surface data sets. Vehicle and CRS manufacturers provided detailed feedback on the utility and accuracy of the surrogates.

Year 3 concludes this broad line of work to quantify and characterize the shapes and volumes of a significant number of CRS (293 in total) on the US market. The virtual surrogates can be used by both the vehicle and CRS manufacturers to assess fitment in the design environment early on in their production cycle. The ultimate goal is that this will translate into designs that lead to better CRS-to-vehicle compatibility, less misuse and enhanced occupant safety.

Compatibility of Belt-positioning Boosters in Vehicles

Principal Investigator:

Julie Bing, MS, The Ohio State University

Student:

Laura Jurewicz, The Ohio State University

IAB Mentors:

Angela Manning, American Honda Motor Co. Inc.; **Keith Nagelski**, Britax Child Safety Inc.; **Eric Dahle**, Evenflo Company Inc.; **Julie Kleinert**, General Motors Holdings LLC; **Jason Carpenter**, Graco Children's Products Inc.; **Mark La Plante**, Graco Children's Products Inc.; **Tim Patrizi**, Graco Children's Products Inc.; **John Combest**, Nissan Technical Center North America Inc.; **Barbara Birkenshaw**, Volkswagen Group of America; **Uwe Meissner**, Technical Advisor

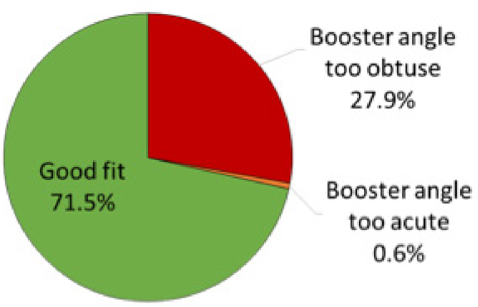
Belt-positioning boosters are effective at preventing injuries to children, but the incorrect use of boosters is a persistent problem. Many efforts have been made to address the booster misuse issue, including legislation and educational campaigns. However, little research has examined the booster's compatibility with the vehicle seat, and incompatibility may be a contributing factor for high booster misuse rates. This study aimed to increase proper belt-positioning booster usage by better understanding the physical factors involved with installation and to develop a resource for benchmark booster/vehicle seat dimensions to help guide industry in design decisions.

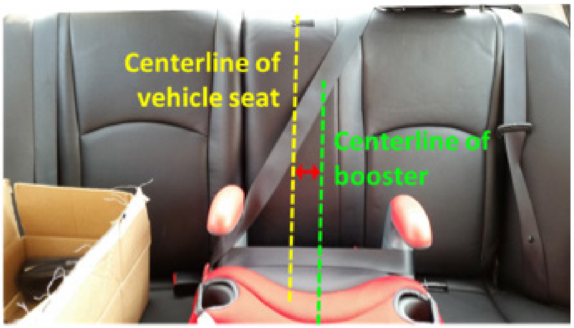
Comprehensive measurements were collected from 40 boosters and 95 seating positions from 50 modern vehicles, which included both left outboard and center seating positions in the rear row(s). Key dimensions of each booster were compared to corresponding dimensions in vehicles to predict the rate of incompatibilities across all 3,800 potential booster/vehicle combinations. To validate the results, 72 physical booster installations were completed, and the rate of predicted incompatibilities within this subset was compared to the actual incompatibilities observed during installation. From the validation data, tolerances and correction factors were determined for each fit criterion, and the accuracy, sensitivity, and specificity of all predictions were calculated.

The interaction between the base of the booster and the vehicle seat belt buckle was found to be the most common predicted incompatibility, at a rate of 14.6 percent of outboard installations and 65.3 percent of center installations. This can result in the booster being pushed off-center from the intended seating position by 2 to 15 cm.

Head restraint interference was predicted in 22.8 percent to 29.1 percent of high back booster installations, depending on the position of the booster's adjustable head support. Vehicle head restraints with gently sloping surfaces along their bottom edge were more accommodating of booster seats, as compared to head restraints with sharply protruding bottom edges. Mismatches between booster back angles compared to vehicle seat back angles occurred in 28.5 percent of predicted combinations. As evidenced in the graphic below at left, the overwhelming majority of angle incompatibilities resulted from the seat back to seat bottom angle of the boosters being more obtuse than the vehicle seats.

This study quantified some of the more common incompatibilities between boosters and vehicles, which may complicate booster usage for typical caregivers. These data can serve as a critical reference for industry design decisions, including prioritization of specific problem areas.





At left: 27.9 percent of the booster installations were predicted to have too obtuse a seat back to seat bottom angle compared to the vehicle seat.
At right: Seat belt anchors which are too close together can push the booster off-center from the intended position (pictured); this scenario had a predicted occurrence rate of 65.3 percent in the center positions of rear seats.

Defining Anterior-Posterior Motion of the Shoulder Girdle

Principal Investigator:

Laura C. Boucher, PhD, ATC, The Ohio State University

Project Team Members:

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

Students:

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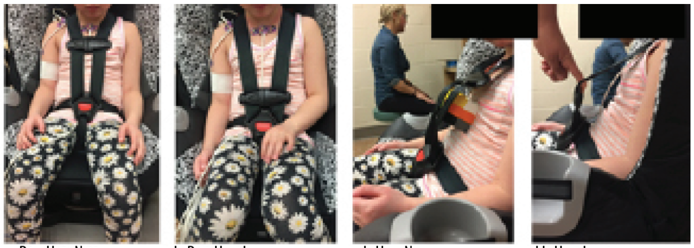
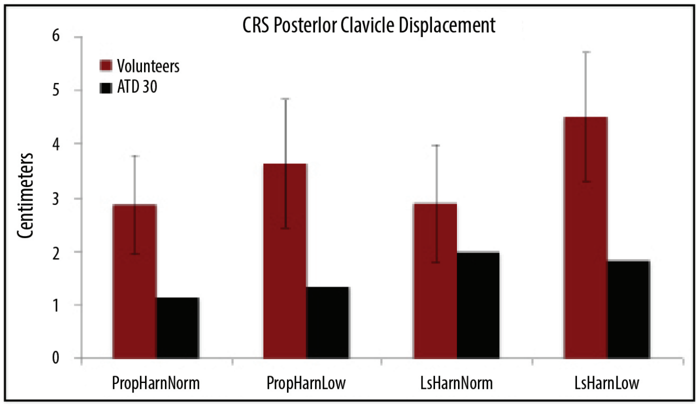
IAB Mentors:

Eric Dahle, Evenflo Company Inc.; **Phil Przybylo**, Evenflo Company Inc.; **Jack Jensen**, General Motors Holdings LLC; **Taft Jones**, Graco Children's Products Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **John Combest**, Nissan Technical Center North America Inc.; **Hiromasa Tanji**, TK Holdings Inc.; **Jason Gainey**, Volkswagen Group of America



a. PropHarnNorm b. PropHarnLow c. LsHarnNorm d.LsHarnLow

Proper Harness — Normal Clip, Low Clip | **Loose Harness** — Normal Clip, Low Clip



The 3-year-old ATD under-predicts the amount of quasi-static clavicle movement compared to volunteers in correct and incorrect CRS harness and chest clip conditions. **Top:** Images of the four CRS conditions tested in the study, where PropHarnNorm = proper harness tightness and chest clip position; PropHarnLow = proper harness tightness with low chest clip position; LsHarnNorm = loose harness with proper chest clip position; and LsHarnLow = loose harness with low chest clip position. **Bottom:** Clavicle displacement results for each CRS condition depicting that the volunteers (red) had greater movement compared to the ATD (black).

In a motor vehicle crash, serious injuries to the thorax and head are in part related to displacement and motion of the shoulder girdle. Currently, the shoulder complex of the 3-year-old anthropomorphic test device (ATD), or crash test dummy, may not fully capture the movement of the child caused by the interaction with the child restraint system (CRS) harness. By understanding how the shoulder and clavicle move, we can better predict the kinematics of the child and the relation to injuries to the thorax, cervical spine, and head.

This study aimed to quantify the amount of anterior and posterior displacement in the clavicle and T1 vertebra and the role of chest clip position and harness tightness on CRS-restrained children.

Data were collected from 23 children, 2-4 years old, after obtaining IRB approval and parental consent. Skin-mounted motion capture markers were placed on each child's sternum, spinous process of T1, distal end of the right clavicle, right acromion process (of scapula), and right deltoid tubercle (of humerus). Anatomical segments were digitized using 3D motion capture software. Following instrumentation, each child was seated and asked to stretch as far as he or she could while holding on to a hand-strap connected to a dynamometer. The maximum anterior and posterior passive clavicle displacement was then quantified.

Children were then placed in a 5-point CRS and asked to stretch forward, while clavicle and T1 displacements were measured in four CRS conditions: proper harness tightness and chest clip position, proper harness tightness with low chest clip position, loose harness with proper chest clip position, and loose harness with low chest clip position. Each CRS testing condition was repeated three times. Measures of anthropometry and maximum anterior and posterior clavicle displacement, across the four CRS scenarios, were repeated using a 3-year-old ATD for comparison.

The anthropometry of the volunteers was similar to the ATD in most measurements, including height, weight, chest circumference, arm circumference, and seated height. Results indicated that maximum anterior and posterior displacement of the distal clavicle was 2.0 cm and 3.2 cm, respectively, for the volunteers. The ATD moved significantly less, with anterior displacement of 1.4 cm and posterior displacement of 0.4 cm. Volunteer data from the CRS conditions revealed that clavicle displacement and T1 displacement in all conditions was significantly greater than the ATD. Interestingly, the position of the chest clip appeared to play a large role in the amount of displacement possible, even if the harness was loose.

These data provide the first glimpse into the amount and the ratio of anterior and posterior movement of the clavicle and how the clavicle and T1 move in different CRS conditions. These data may benefit future 3-year-old ATD shoulder designs or influence computer models. Understanding clavicular movement relative to chest clip position will help to better predict the effect of impacts on thorax, cervical spine, and head excursion in motor vehicle crashes.

Validation and Reliability Testing of a New Hybrid III 6-Year-Old Lower Extremity

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Previous CChIPS-sponsored research has succeeded in collecting data directly from a pediatric population to help inform the design and development of a prototype 6-year-old Hybrid III anthropomorphic test device lower extremity (ATD-LE). The resulting ATD-LE has a tibia load cell and a more biofidelic ankle.

Based on results from the first project using the new prototype ATD-LE in static and dynamic assessments, the objectives of this project were to:

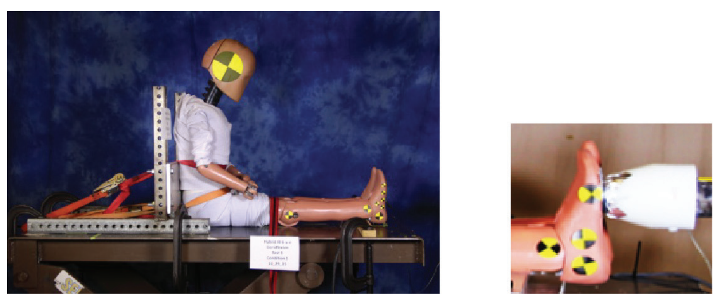
1) Evaluate the repeatability of the tibia force, tibia moment, range of motion (ROM), and stiffness of the new prototype ankle (ATD-LE) across a range of loading conditions

2) Quantify the injury response of the ATD-LE by performing knee bolster air bag (KBA) tests and compare the injury responses between the updated ATD-LE and the previous prototype.

In Aim I, a pneumatic ram impactor was used to evaluate the repeatability of the ankle in response to various loading parameters at 1.3 meters/second (m/s) without shoes, and 2.3 m/s with and without shoes. The tibia force transmission, bending moment, ankle ROM, and stiffness was quantified and evaluated for consistency. In Aim II, a dynamics assessment of the KBA in out-of-position scenarios took place using the same protocol as in previous research. The ATD was positioned in a front seat to mimic three "worst case scenarios," including toes on the mid-dashboard, toes on the lower dashboard, and feet flat on floor. The impact responses in the femur and tibia were collected and compared with published injury threshold values. Results were then compared to the previous ATD-LE KBA tests using an earlier prototype.

Results of the ram impact testing indicated repeatable responses; tibia load, tibia moment, and ankle ROM had a maximum coefficient of variance of 2.7 percent. Calculated ankle stiffness was not as repeatable, with a maximum coefficient of variance of 15.6 percent. Interestingly, the repeatability tests performed with shoes resulted in decreased tibia force and moments, suggesting that the shoes absorbed force during the impact. The KBA test results placed the prototype ATD-LE in a realistic dynamic environment and indicated that the toes on lower dashboard position was the most injurious due to the high bending moments in the tibia, above injury threshold.

This work has demonstrated continued improvement in the biofidelity of the ATD-LE, indicating positive steps towards validating the new design of the Hybrid III 6-year-old ATD ankle. The device allows researchers to collect data that were previously difficult to capture, thus providing new information which may lead to injury reduction and help advance the safety of children.



At left: The set-up for the repeatability tests is pictured. **At right:** The ram impactor making contact with the ATD-LE.

Machine Learning Techniques: Online Prediction of Driving Behavior and Generation of Customized Feedback via Machine Learning Models (Year 3)

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The simulator lab, housing a Pontiac G6 driver seat, LCD panels allowing for a 160 degree field of view, active pedals and steering system, and a rich audio environment.

Machine learning is an analytic technique that shows promise in providing algorithms to help predict and manage certain teen driver behaviors that can contribute to crash risk, including speed management. In this multi-year study, researchers aimed to create a real-time feedback system to help teen drivers improve their speed management skills.

In Phase 1 of the study, researchers determined the feasibility of using machine learning-based computational approaches to automatically model speed management in a driving simulator. Their findings suggest that modeling was effective at predicting vehicle control behaviors up to one second in the future. These predictions matched the skill proficiency and crash likelihood ratings given by a professional driving education instructor. In Phase 2 of the study, researchers evaluated the effectiveness of providing customized feedback from these machine learning models to young drivers and found that one of the models tested can be used to accurately predict long-term driving behaviors.

While promising, these results were not obtained in real-time but rather through off-line processing of completed drives. Therefore, Phase 3 of the study aimed to make this technology closer to real life by exploring machine learning models that could make predictions in real time, as the teen participants were driving in the simulator. The objectives were to: (1) develop new machine learning algorithms for updating models and generating predictions in real-time, (2) update the data collection infrastructure to allow real-time transfer of driving simulator data, (3) design effective feedback mechanisms to generate predictions and examine the effect of such feedback on driver behaviors, and (4) explore the feasibility of incorporating additional data sources, such as physiological measurements and eye-tracking data.

The study team successfully created a mechanism to receive real-time data from the driving simulator to train machine learning models using this data, to make predictions of participants' driving behavior, and to provide feedback about speed management to participants while driving in the simulator. The four drives used in this project contained a variety of road configurations, terrains, road conditions, and speed limit zones. While data analysis is ongoing, this work will help to inform the development of interventions to help teen drivers develop crucial speed management skills, a major factor contributing to crashes. It also shows great potential in preventing other dangerous driving behaviors via personalized feedback models.

The researchers envision a future where real-time feedback via machine learning techniques will be part of in-vehicle assistance systems that can track driver performance and provide meaningful, adaptive guidance to novice drivers to enhance safety.

Driving Analytics: Comparison of Teen and Adult Naturalistic Car-following Patterns

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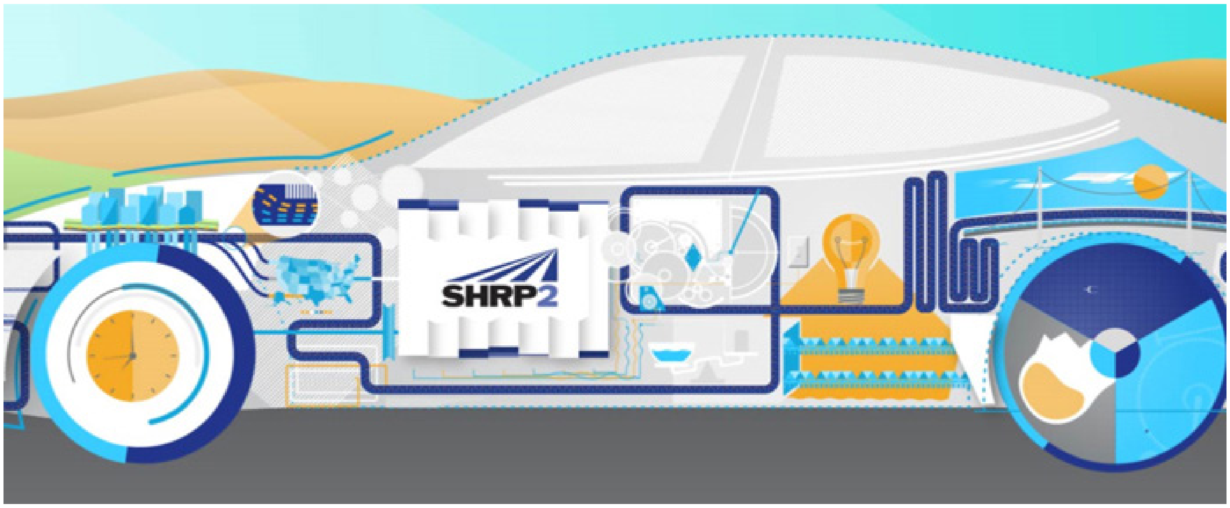
Motor vehicle crash (MVC) rates for teen and adult drivers are traditionally based upon fatal crashes, police-reported crashes, and estimated miles driven (EMD). Yet, nearly 30 percent of all crashes–particularly those that do not result in injury or death–are not reported to police. Teen drivers are much more likely to crash than adults; according to the Insurance Institute for Highway Safety, in 2014 the risk of MVCs per miles driven was nearly three times greater among 16- to 19-year-olds than among any other age group.

Naturalistic driving studies offer a unique opportunity to measure crash rates inclusive of all crashes, not only those reported to police, and to provide an exact quantification of miles driven among study participants. In this study, investigators used the Strategic Highway Research Program 2 (SHRP2), a large-scale naturalistic driving database administered by the Virginia Tech Transportation Institute, to study motor vehicle crashes. Over 3,000 volunteer drivers had their vehicles fitted with cameras, radar, and other sensors to capture data as they drove.

For this project, investigators analyzed 353 crashes involving 549 novice 16- to 19-year-old drivers and 185 crashes involving 591 experienced 35- to 54-year-old drivers.

Scene videos were reviewed for all events to identify rear-end striking crashes, and dynamic variables, such as acceleration and velocity, were analyzed for rear-end striking events. The investigators compared crash rates, crash severity, and impact velocity between novice teen drivers and experienced adult drivers. The teen group crash rate was more than seven times higher than the adult group, with 12.8 rear-end striking crashes occurring per 1 million miles driven for novice teens compared to 1.8 rear-end striking crashes occurring per 1 million miles driven for experienced adult drivers.

Further analysis of the SHRP2 dataset is needed to determine why novice teens experience rear-end striking crashes at such a high rate as compared to experienced adult drivers. To our knowledge, this is the first study to compare rear-end striking crash rates between teens and adults using a large-scale naturalistic driving database. This new knowledge of drivers' reactions in emergency situations will help manufacturers design Active Safety systems, such as Forward Collision Warnings or Brake Assist systems, such as Dynamic Brake Support and Crash Imminent Brake systems, to address the braking deficits of newly licensed teen drivers.



This analysis used logged SHRP2 data of 1,000 actual motor vehicle crashes and near crashes to understand in-depth why teen drivers crash.

Pediatric Brain Injury Assessment in Real World Crashes (Year 3)

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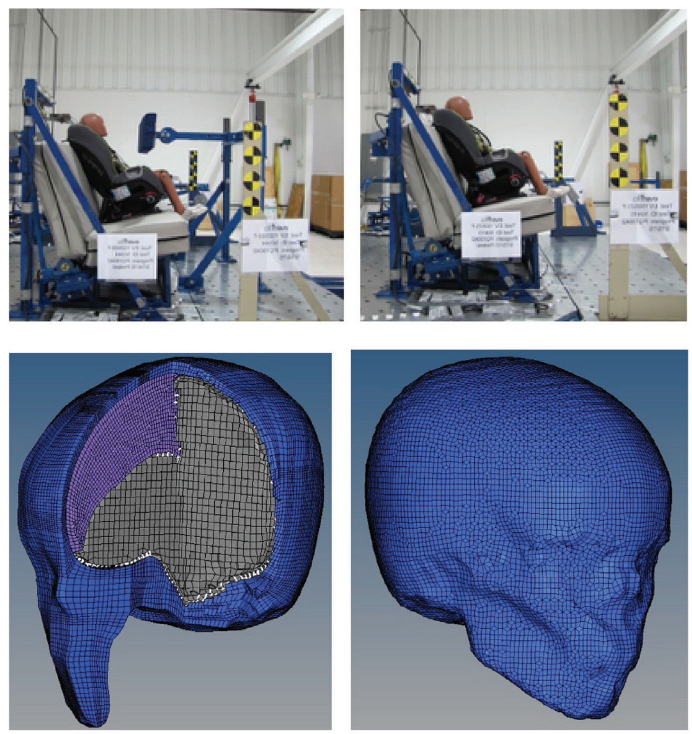
Traumatic brain injuries (TBI) are the most common serious injuries sustained by children in motor vehicle crashes (MVCs), both as vehicle occupants and as pedestrians. Brain injuries are commonly associated with evidence of head contact with the vehicle interior, intruding door, or other exogenous sources in MVCs. To protect the brain, the Head Injury Criterion (HIC) was developed principally from direct head contact impact experiments with cadaver skulls. Child restraint system (CRS) performance standards and due care testing are implemented via a frontal impact sled test, anthropomorphic test devices (ATDs), also known as crash test dummies, and the HIC. But, because no head contact to exogenous structures occurs in these sled tests, the validity of the HIC is questionable. This research aimed to determine the relationship between HIC score and brain injury in head acceleration events with and without direct contact to the head.

Unlike skull fracture or other orthopedic injuries, understanding the complex relationship between impact biomechanics, physiology, and resulting brain injury requires a living organism (i.e., an animal model of TBI). Recently, University of Pennsylvania researchers have developed and refined an anesthetized porcine model of pre-adolescent TBI. This model reproduces the constellation of lesions and physiology that constitute human moderate-to-severe TBI and plays an essential role in validating the use of a finite element model (FEM) of the brain to predict brain injury.

In this study, investigators developed FEMs of the human brain at 1 year, 3 years, and 6 years to investigate brain injury potential in head acceleration events with and without head impact. Sled tests were conducted with and without head contact that produce similar HICs, and investigators compared brain tissue strain and strain rate for contact and non-contact events. Sled test results showed that the FE brain-estimated brain injury potential is greater when head contact occurs. More specifically, brain tissue maximum principal strain increased from 8 percent to 42 percent, and maximum principal strain rate increased from 242 percent to 582 percent in head contact cases compared with HIC- matched non-head contact cases.

This project delivers robust and useful 1-year-old, 3-year-old, and 6-year-old FE brain and skull models to the research and engineering community and highlights important differences in injury potential in contact and non-contact head impact scenarios.



At top: A sled test with (left) and without (right) the simulated vehicle interior structure (SVIS) set-up.
At bottom: Cutout of final finite element 6-year-old model (left) and finite element skull mesh (right).

Effect of ATD Certification Specification Variance on Full-scale Sled Testing Performance

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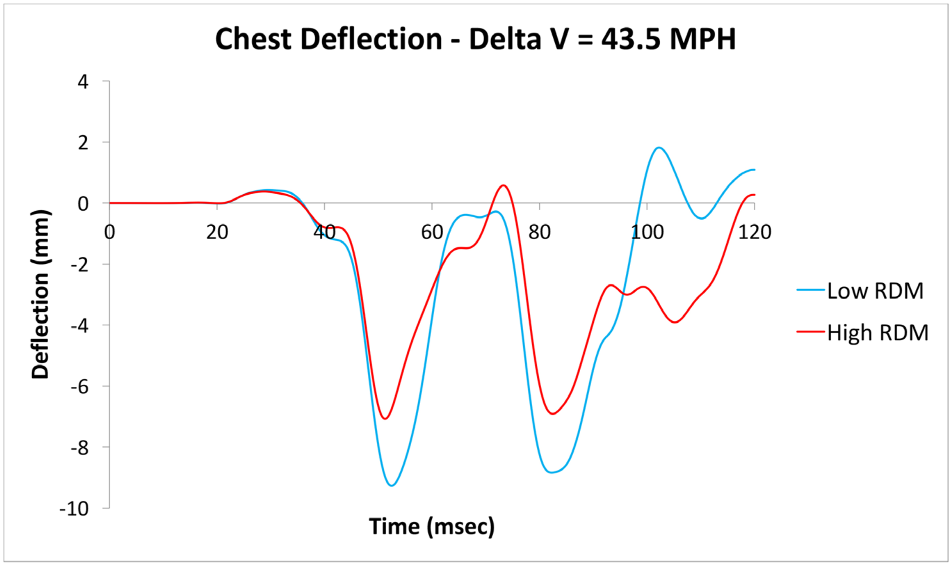
The anthropomorphic test device (ATD), or crash test dummy, is widely used to develop crash safety systems and designed to be biofidelic (humanlike) for a prescribed collision condition. To ensure biofidelic reliability, an ATD is required to pass certification tests for biomechanical response within a specific allowable range. To date, it is unknown how this allowable range influences the ATD's kinematic/kinetic response in full-scale crash or sled testing. For example, the chest certification procedure for the Hybrid III ATD has an upper range and lower range of allowable chest deflection, but it is unknown how an ATD's full-scale sled test response at the upper end of the certification range compares to one at the lower end. This study was conducted to answer that question by determining the effects of variance in chest certification test performance on injury metrics and kinematics in simulated frontal sled tests.

Investigators used a finite element model (FEM) of the Hybrid III 6-year-old ATD to simulate the pendulum impact chest certification test procedure. To produce simulations with deflection responses at the extreme ends of the certification corridor, the rib damping material (RDM) thickness and material properties were parametrically varied within the regulatory drawing package limits. Two FEMs were then created – one at the higher and one at the lower chest certification window boundaries. To determine the effect of chest certification variance on injury metrics in frontal impacts, the two models were restrained within a harness child restraint system on the FMVSS 213 test bench and varying severities of frontal crash acceleration pulses were simulated.

Results show a higher chest deflection response for the Low RDM model as compared to the High RDM model in all frontal crash simulations, leading to a difference in head acceleration of as much as 40 percent. The High RDM model also recorded a greater Head Injury Criterion (HIC) value than the Low RDM model at speeds of 33.5 mph and 43.5 mph; however, at 38.5 mph the Low model recorded a higher HIC value.

Results showed that the Hybrid III 6-year-old model was insensitive to changes in deflection when fine-tuning RDM material properties but was sensitive when the RDM thickness was varied within the specifications of the ATD drawing packages. These findings indicate that variance in chest certification test response could significantly affect the kinematics and injury severity of a 6-year-old occupant involved in a frontal crash.

Future research might aim to develop models that calibrate at the extreme ends of the certification corridor for three body regions (head, chest, and knee) to study how this affects injury kinematics in a frontal crash at various sled pulses.



Chest deflection differences in models with high (red) and low (blue) rib damping material thicknesses.

Advanced Automatic Crash Notification for Children (Year 3)

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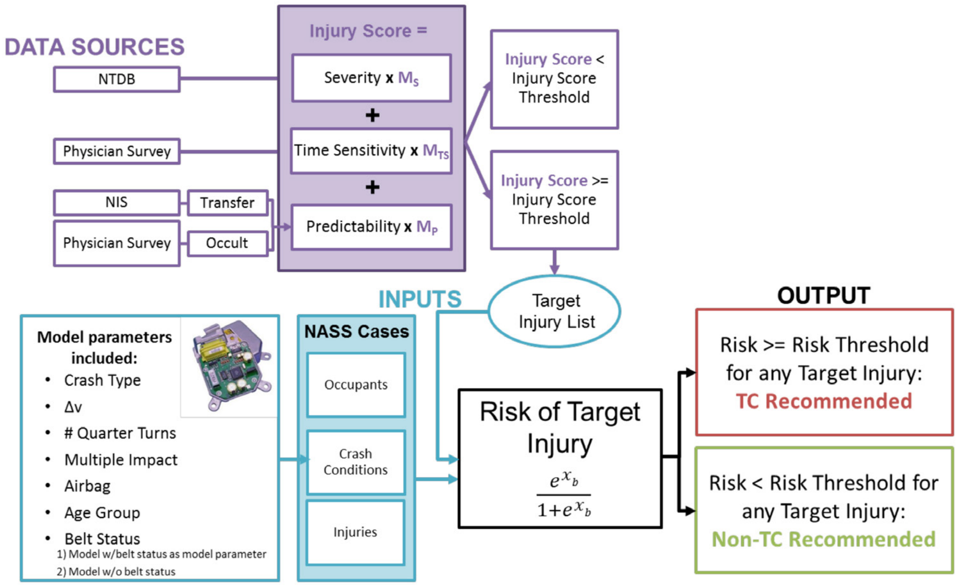
Motor vehicle crashes (MVCs) remain a leading cause of death and disability in children worldwide. Prompt field triage of seriously injured children to designated trauma centers (TCs) can improve outcomes, and these decisions can be streamlined with the use of Advanced Automatic Crash Notification (AACN) systems to improve speed and accuracy.

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 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 delineated the specific ways in which the incidence of these injuries change as children grow and develop, while Year 2 focused on refining the injury patterns to create a better understanding of the pediatric injuries described in the first phase.

In Year 3, a list of injuries associated with a pediatric patient's need for Level I/II TC treatment known as the Target Injury List was determined using an approach based on three facets of injury: severity, time sensitivity, and predictability. The inputs used to create the pediatric-specific AACN algorithm include the Target Injury List and 11,632 MVC occupants from the National Automotive Sampling System-Crashworthiness Data System 2000-2011. The algorithm uses multivariable logistic regression to predict an occupant's risk of sustaining an injury on the Target Injury List from various crash-related input variables. Two separate versions of the algorithm were developed: one with belt status as a model parameter and one with no belt status included. The pediatric-specific AACN was optimized in order to minimize under triage (UT) and over triage (OT) rates with the goal of producing UT rates < 5 percent and OT rates < 50 percent, as recommended by the American College of Surgeons.

For the algorithm with belt status included as a model parameter, the OT rates were <50 percent for all crash modes. The UT rates for this algorithm were <5 percent for frontal, near, and far side crashes. For the algorithm with belt status not included as a model parameter, the OT rates were <50 percent for all crash modes. The UT rates for this algorithm were <5 percent for near and far side crashes.

The AACN algorithm developed in this study will aid emergency personnel in making the correct triage decision for a pediatric occupant after a MVC and, once incorporated into the trauma triage network, can reduce response times, increase triage efficiency, and improve overall patient outcomes.



This graphic provides a visual overview of the Pediatric Advanced Automatic Crash Notification (AACN) Algorithm, where MP = predictability score multiplier; Ms = severity score multiplier; MTS = time sensitivity score multiplier; NASS-CDS = National Automotive Sampling System - Crashworthiness Data System; NIS = Nationwide Inpatient Sample; NTDB = National Trauma Data Bank; and TC = trauma center.

Differences in Injury Outcomes in Children Versus Adults

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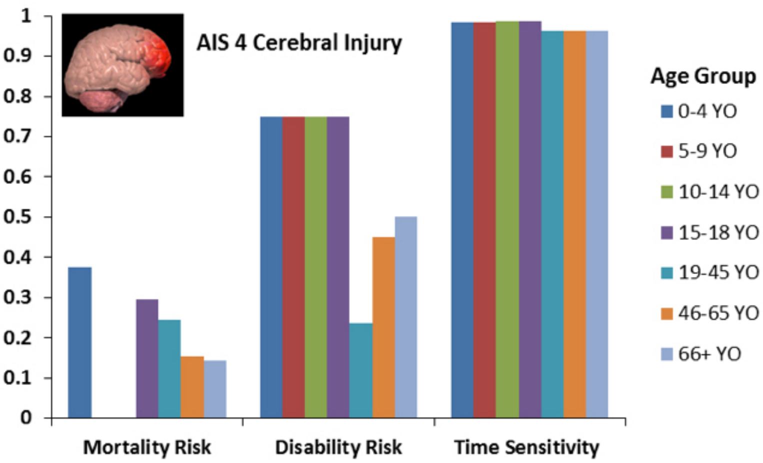


Maximum-AIS adjusted Mortality Risk (MR^{MAIS}), Maximum-AIS adjusted Disability Risk (DR^{MAIS}), and Time Sensitivity by age group for an AIS 4 cerebral injury. Risk ranges from 0 (0 percent mortality/disability/time sensitivity) to 1 (100 percent mortality/disability/time sensitivity).

The Abbreviated Injury Scale (AIS) is considered the global system of choice for injury data collection and has become the basis for a number of derivative scales in use. However, the AIS is largely based on mortality risk, and there may be age-specific differences in injury outcomes. Such differences may become evident by quantifying time sensitivity (a measure associated with the urgency with which an injury should be treated), mortality risk (a measure of the associated mortality and threat to life of an injury), and disability risk (a measure of the associated disability of an injury). No prior study has identified pediatric-specific injuries that vary in these three measures and this could inform future pediatric-specific modifications to the AIS. Therefore, this study aimed to identify the specific injuries that result in varying levels of time sensitivity, mortality risk, and disability risk in children, when compared to adults.

The top 95 percent most frequently occurring AIS 3, 4, and 5 injuries in motor vehicle crashes (MVCs) were identified using the National Automotive Sampling System–Crashworthiness Data System (NASS-CDS) years 2000-2011. Time sensitivity was quantified using expert physician survey data (n=164 experts/n= 12,152 responses) in which physicians were asked to determine whether a particular injury should go to a Level I/II trauma center and the urgency with which that injury required treatment. Time sensitivity was quantified for the pediatric age groups of 0-4 years, 5-9 years, 10-14 years, and 15-18 years and an adult age group of 19+. Mortality risk and a co-injury adjusted mortality risk were calculated using the National Trauma Data Bank (NTDB) years 2002-2011 for the pediatric age groups (18 and under) and years 2002-2006 for the adult age groups of 19-45 years, 46-65 years, and 66+ years. Disability risk and a co-injury adjusted disability risk (DR^{MAIS}) were calculated using NTDB years 2002-2006 for a pediatric age group of 7-18 years and the adult age groups of 19-45 years, 46-65 years, and 66+ years. All three metrics were compared between pediatric age groups versus adult age groups to determine age-specific differences in injury outcomes.

An analysis focusing on MVC head injuries and disability revealed that the pediatric population possessed higher DR^{MAIS} values for brain stem injuries as well as loss of consciousness injuries compared to the adult age groups. Older adults possessed higher co-injury adjusted disability values for contusion/hemorrhage injuries, epidural hemorrhage, intracerebral hemorrhage, skull fracture, and subdural/subarachnoid hemorrhage compared to pediatric patients, adults, and middle adults.

This study demonstrates that there are age-related differences in time sensitivity, mortality risk, and disability risk and, therefore, injury outcomes. Information regarding these metrics is especially crucial for at-risk populations of pediatric patients, as disability and injury outcomes can result in loss of quality life years. These metrics could be used to supplement the assessment of injuries using AIS, especially for injuries that do not necessarily lead to death. In addition, understanding age-related differences in injury outcomes could inform future age-specific modifications to AIS including creation of a pediatric-specific AIS.

Supplemental Research Funding

Quantifying Children's Posture in the Rear Seat: A Naturalistic Study (Year 4)

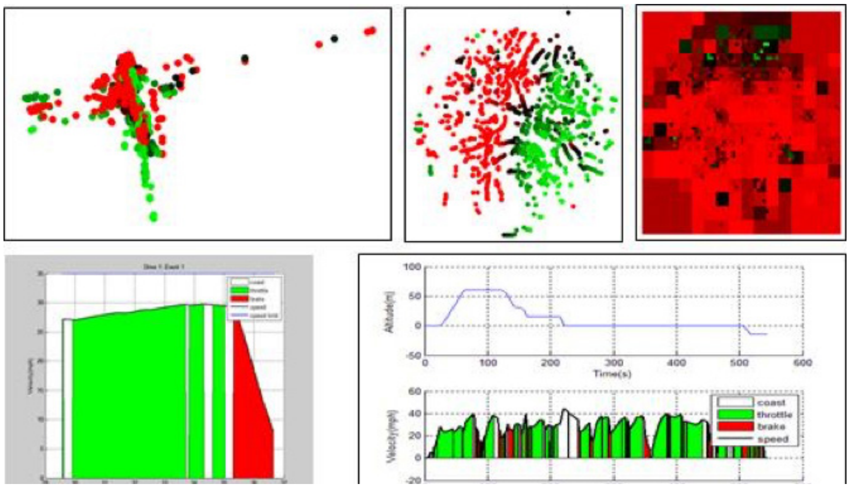
Led by CHOP's Kristy Arbogast, PhD in partnership with Monash University, this was the fourth and final year of a project that was funded by CChIPS for the first three years. The study was conceived in response to the fact that most test protocols evaluating the performance of vehicles and child restraint systems (CRS) utilize anthropomorphic test devices (ATDs) placed in ideal positions (e.g., ATD against seat back, perfectly upright). Under these conditions, the majority of CRS perform very well. Recent real-world evidence has suggested, however, that the 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 die or are seriously injured in real world crashes. Naturalistic driving studies, where cameras and other data acquisition systems are placed in a vehicle used by participants during their regular transportation, offer the ability to collect position and posture data of occupants in a real world setting.

A study vehicle was instrumented with a data acquisition system to measure vehicle dynamics, a set of video cameras and a Microsoft Xbox Kinect™ Sensor providing 3D motion capture of the rear seat child occupants. Families used this study vehicle for two weeks during normal driving scenarios. In this phase of the project, the head position of restrained child occupants was quantified using the Kinect™ data throughout normal, everyday driving trips. Eighteen participant families used the vehicle for all driving trips over two weeks. As restraint type moved from more to less restraint (forward-facing CRS to booster seat to seat belt), the range of fore-aft head position increased: 218mm, 244mm, and 340 mm on average respectively. This observation was also true for left-right movement – for every seat position. These data can lead to solutions for optimal protection for occupants who assume positions that differ from prescribed, optimal testing positions.

Research Experiences for Undergraduates (REU)

NSF's REU program provides research experiences to undergraduate students, focusing on minorities, students with disabilities, and students from Science, Technology, Engineering and Math (STEM)-limited schools with few internship opportunities and no available doctorate program. In 2016, the Center for Injury Research and Prevention (CIRP) at CHOP was awarded a second, three-year REU Injury Science Site grant to develop a diverse, internationally competitive, and globally engaged science and engineering workforce with a focus on pediatric injury prevention. During winter/spring 2016, 318 students applied for eight REU internships for summer 2016. This cohort also included two additional students: one funded by an NSF REU supplement grant and one by the Drexel University STAR (Students Tackling Advanced Research) Scholars Program. The diverse group of student scholars selected from schools across the country spent the summer working with CIRP researchers, receiving mentorship and hands-on research experience in the fields of Engineering, Behavioral Science, and Epidemiology. Students also received formal training in research ethics, research methodology, and the presentation of research findings. Many of these students worked on CChIPS projects with CChIPS faculty.

CORBI: Modeling, Visualization, and Understanding of Large Datasets (Year 2)



Visualization of vehicle control data. Plotting data in 2- and 3-D space (top three figures), as well as over time (bottom figures) and color coding variables help highlight patterns among variables and hidden relationships.

The Collaborative Opportunity for Research Between I/UCRCs (CORBI) was established by the NSF as a funding mechanism to foster cooperative research among these Centers. In Year 2 of a CORBI project partnership between CChIPS and the Center for Visual and Decision Informatics (CVDI), established by The University of Louisiana at Lafayette and Drexel University, researchers focused on developing the next generation of visual and decision support data analysis tools. This project was designed to address a great challenge in today's research world–how large datasets, such as those collected during naturalistic driving studies, are analyzed and understood.

Over two years, 9 million total data points were collected from 32 participants, each completing four 10-minute drives in a driving simulator. Half of the participants received feedback on their speed management behaviors after the second drive in the simulator; the other half of the participants did not. This feedback mechanism used participants' own driving data collected from their first drive and created a machine-learning driving model for each participant. Then the driving model made individualized predictions on speeding-related behaviors via an interactive interface. After comparing the driving behaviors in the third drive (post-feedback) between participants in the feedback condition and the control condition, findings suggest that participants in the feedback condition slowed down and handled the car more smoothly.

Drawing appropriate conclusions from this data required robust analysis and visualization tools. Ultimately, these early promising results point to the benefit of feedback for teen drivers, as well as the utility of data visualization techniques for analyzing and gaining insight into child injury prevention data, specifically teen driver vehicle data. This approach also has the potential to be used in other domains such as medical and clinical applications, social media, and basic science.

Preparing Future Industry Scientists

The CChIPS site at The Ohio State University has been a leader in student development in injury biomechanics via the annual Injury Biomechanics Symposium (IBS). The IBS stimulates and rewards strong injury biomechanics research among trainees by providing a welcoming atmosphere for novice researchers to present original work in a non-threatening environment. In June 2016, it hosted more than 130 attendees, including 26 student presenters from 13 universities. Among the presenters was CHOP student-intern Todd Hullfish, who presented his CChIPS-funded project (see project summary below). CChIPS Co-Director Kristy Arbogast, PhD was a featured guest speaker on the topic of the biomechanics of youth concussion.

The Amount of Muscle Force Recruited During Braking in Young Adults

Led by undergraduate student Todd Hullfish under the mentorship of CHOP's Aditya Belwadi, PhD, this project was designed in response to recent interest in modeling the pre-crash phase of automotive crashes. Feedback control has been used to model occupant responses using Human Body Models (HBM). However, driver postural responses during driver initiated braking differ greatly from autonomous braking, and there is a need to accurately define the initial conditions of the car occupant during these braking scenarios. This study aimed to quantify young drivers' behavior in terms of muscular activity just before "emergency braking" situations.

Todd Hullfish presents his poster at the 2016 Injury Biomechanics Symposium at The Ohio State University.

Two young adults ages 21 and 23 years were instrumented with electrodes from an electromyography (EMG) system and put through a simulated driving experience, where muscle activity time history was synchronized and compared to the major events in the driving simulator. Results showed that the muscle activity in the leg has a direct impact on the positioning and posture of the driver and that EMG data and leg position can be used to develop advanced HBM and controllers for active safety. These results can ultimately help improve the understanding of pre-crash scenarios for young drivers and contribute to the long-term goal of aiding in the development of advanced HBM.

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' 2016-2017 projects are continuing work from previous years, including:

- Kristy Arbogast is in Year 3 of her Evaluation of Side Impacts with a Frontal Component for Children in CRS project (Year 2 is detailed on page 7 of this report).
- Helen Loeb is in Year 2 of her Driving Analytics: Comparison of Teen and Adult Naturalistic Car-following Patterns project (Year 1 is detailed on page 14 of this report).
- Joel Stitzel and Ashley Weaver are in Year 4 of their Pediatric Advanced Automatic Crash Notification project (Year 3 is detailed on page 17 of this report).
- Matthew Maltese continues his line of study into the FMVSS 213 test bench (complementary research is detailed on page 16 of this report).

For a sneak peek of next year's 2016-2017 research projects, please visit the CChIPS website!

To learn more about the entire research portfolio for 2016-2017, 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.

Out 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; Wake Forest University; Drexel University; Rowan University; the Medical College of Wisconsin; the University of Louisiana at Lafayette; Monash University; the University of Utah; the Virginia Tech Transportation Institute; and Diversified Technical Systems, Inc. for providing CChIPS with forward-thinking scientists committed to making the world a safer place for children and adolescents.

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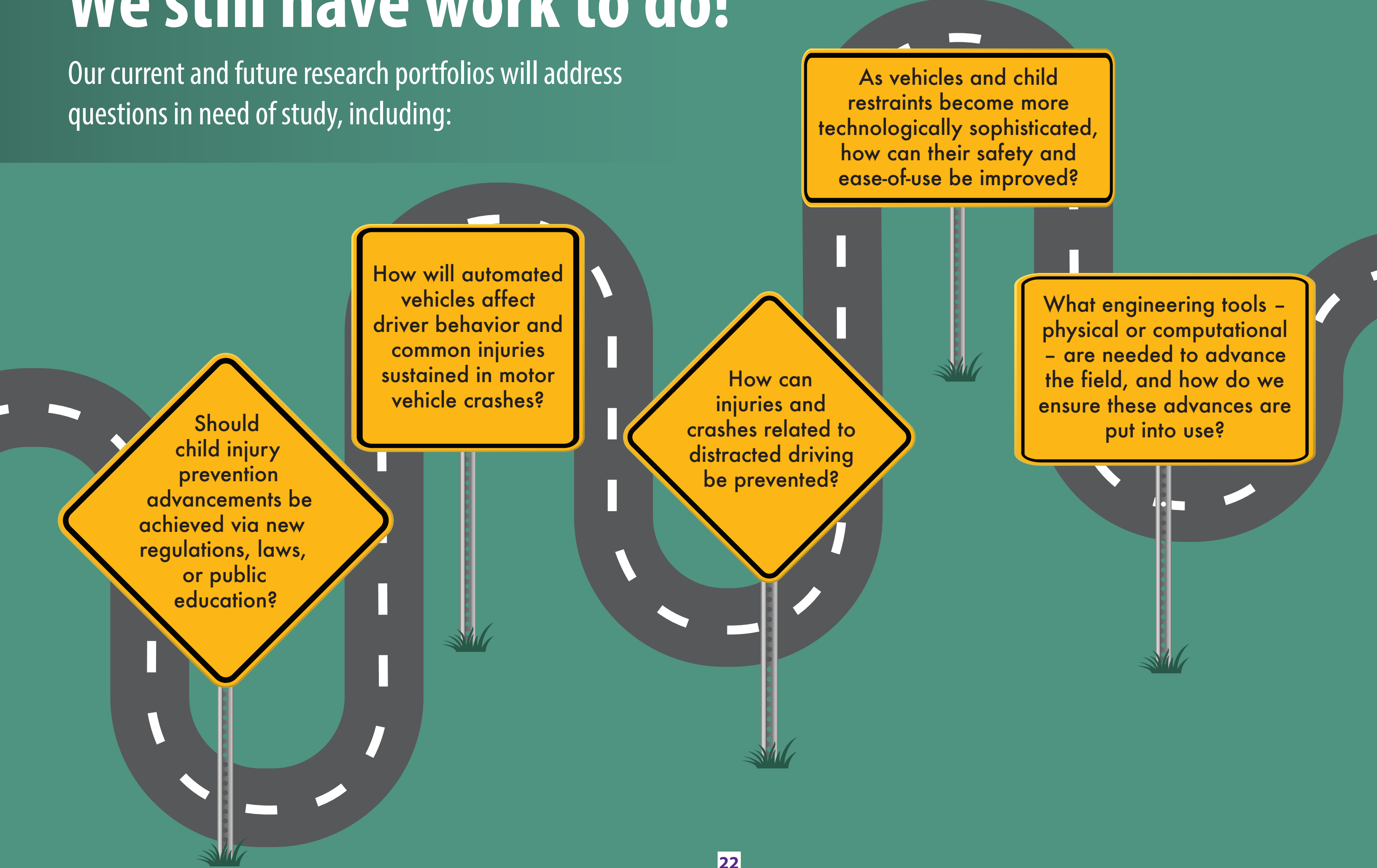
We still have work to do!

Our current and future research portfolios will address questions in need of study, including:



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We're moving! As of May 1, 2017 we'll be located at 2716 South Street, Philadelphia, PA 19146