CChIPS | Center for Child Injury Prevention Studies

SAFE AND SOUND

PAVING THE WAY

2022

Annual Report

CChIPS Center for Child Injury Prevention Studies

Children's Hospital of Philadelphia RESEARCH INSTITUTE

THE OHIO STATE UNIVERSITY WEXNER MEDICAL CENTER

PARTNERING FOR SAFETY

Welcome to the CChIPS 2021-2022 Project Year!

The Center for Child Injury Prevention Studies (CChIPS) takes a unique approach to child safety research. For 17 years, CChIPS has been a hub of innovation and collaboration for industry members and academic researchers committed to improving the safety of children and adolescents.

A Message From Our Directors

Julie Mansfield, PhD, Kristy Arbogast, PhD,
Flaura Winston, MD, PhD, co-directors, CChIPS

Founded in 2005 with a grant from the National Science Foundation (NSF), CChIPS' unique partnership includes research sites at the Children's Hospital of Philadelphia (CHOP) Research Institute and The Ohio State University (OSU). Our Industry Advisory Board (IAB) comprises 15 member organizations from industry, advocacy, and government agencies.

In 2021-2022 the IAB funded 10 research projects across the Center's five-domain research agenda. In this Annual Report, you will find highlights of conversations held with our principal investigators about their CChIPS projects, discussing a range of topics including project aims, results, and industry relevance. We hope this format allows the expertise, passion, and dedication of our research scientists to shine through. These conversations also illuminate just how important a role our IAB members play in the research process and the industry-academic collaborative spirit that makes CChIPS research so unique. As an added benefit, IAB members have access to the full technical research reports that contain more detailed data and analyses.

In addition, CChIPS – through its parent center at CHOP, the Center for Injury Research and Prevention (CIRP) – 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 social media, email blasts, and the cchips.research.chop.edu and injury.research.chop.edu websites. The two websites garnered over 200,000 page views in calendar year 2021. Read more about CChIPS' digital communication efforts on Page 17 of this report.

The Center's research portfolio continues to cover our core areas of focus: child passenger safety, pediatric and young adult biomechanics, and young driver safety. Our efforts are also evolving to address current challenges and emerging issues in child and young adult injury prevention – such as protection of occupants in future mobility modes like autonomous vehicles – as guided by science and our IAB member companies. We are proud to be a driving force behind innovative research that continues to push the envelope in working to improve child and adolescent safety.

In addition to this Annual Report, our CChIPS scientists continue to share research at numerous professional conferences throughout the world. The 2021-2022 project year brought the return of in-person conferences, and CChIPS research was shared at key conferences, such as the Association for the Advancement of Automotive Medicine, the Automotive Safety Council, the SAE Government/Industry Meeting, and the SAE World Congress Experience. Look for our researchers at similar venues as we turn the page to 2023. We look forward to discussing mutual interests in protecting children, youth and young adults on our roads.

We are pleased to share our achievements over this past year and in years to come, as together, we improve the safety of our roads for youth.

IAB MEMBER COMPANIES (2021-2022)

◆ Founding IAB Member Company

★ 2022 ACIP Conference* Presenting Sponsor

★ 2022 ACIP Conference* Silver Sponsor

* Each year, CChIPS hosts the Advances in Child Injury Prevention (ACIP) Conference that convenes child occupant safety professionals from industry, government, and organizations involved in research and development, product design, and safety policy and regulation to hear the latest research in traffic safety for children and adolescents. In June 2022, we convened an audience of 30 organizations and shared wide-ranging results from CChIPS research, engaging in dynamic discussion with key stakeholders throughout the industry. The next ACIP Conference will be held in June 2023. For more information on ACIP, please visit https://cchips.research.chop.edu/events.

CChIPS Mission Statement

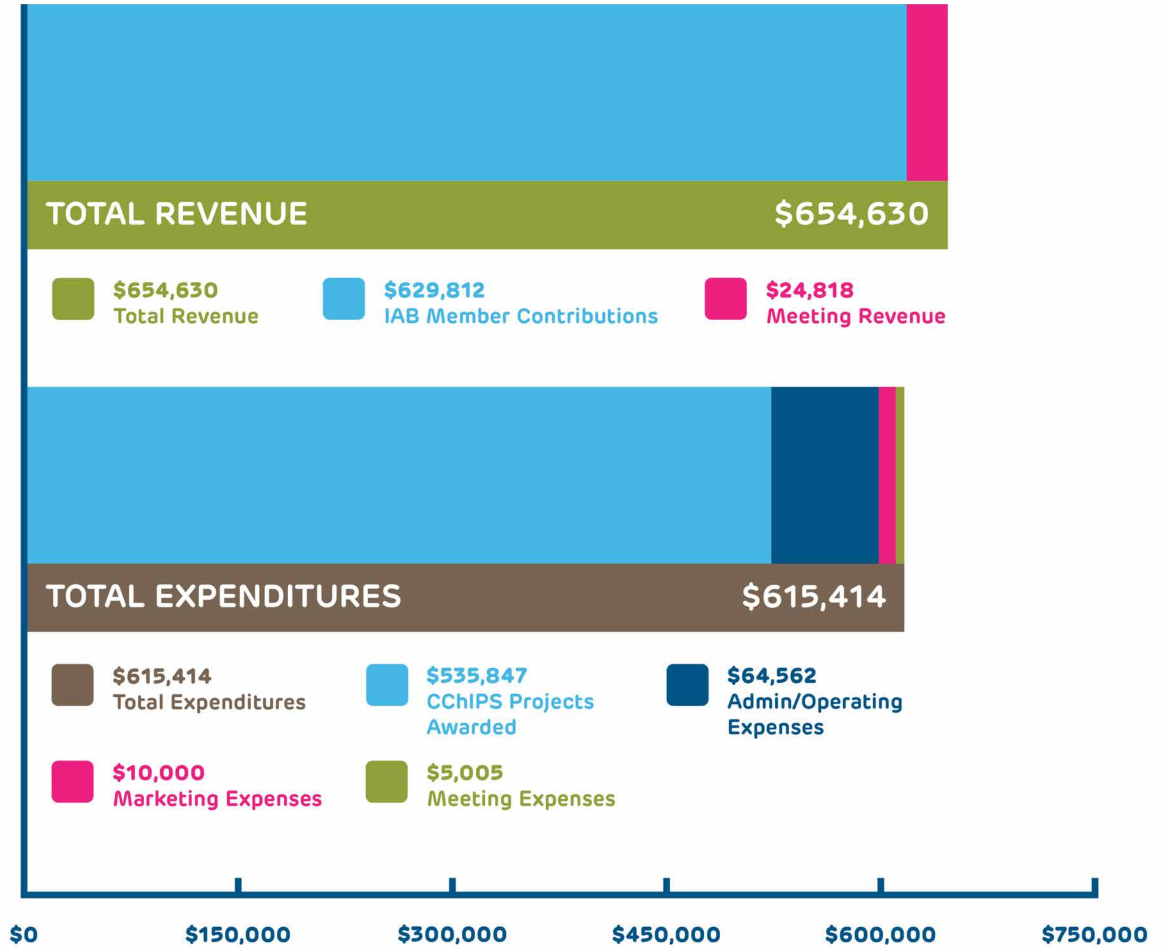
The CChIPS mission is to advance the safety of children, youth, and young adults by facilitating scientific inquiry into childhood and young adult injuries and to translate these findings into commercial applications and educational programs for preventing future injuries.

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

FUNDING THE RESEARCH

CChIPS is made possible through 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. For the 2021-2022 project year, each full voting IAB member contributed $65,000 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. All members contribute to the science as project mentors. Membership in CChIPS has fostered industry and small business commitment to the CChIPS mission and spurred innovation and collaboration. To become a member or to sponsor research with CChIPS investigators, please contact us at cchips@chop.edu.

REVENUE & EXPENDITURES FOR 2022



HOW DO WE CALCULATE THE CCHIPS ROI?

The CChIPS Industry Advisory Board (IAB) has three different membership types tied to varying annual fees:

Large Business	Government/Nonprofit	Small Business
$65,000	$28,750	$17,250

15 Members

$629,812 in research funds
excluding supplemental funds

The research pool funded 11 projects in 2021-2022, which fall within five interest areas. Projects are often categorized in more than one area.

Interest Area	Projects	Value
Child Restraint Design and Performance	8 Projects	$683,996*
Consumer/Driver Behavior	5 Projects	$420,242*
Crash Avoidance & Autonomous Vehicles	2 Projects	$181,914*
Vehicle Restraint Performance	6 Projects	$505,336*
Dummy Biofidelity	3 Projects	$241,375*

What Does the CChIPS ROI Look Like for One Member?

In 2021-2022, a large business with an interest in vehicle restraint performance contributed $65,000 for access to research valued at $505,336.

* These values include the cost of individual projects coupled with the institutional indirect rates from academic partners to more accurately represent the actual cost of conducting research.

RESEARCH IN ACTION:

2021-2022 Project Highlights

To make the CChIPS research portfolio more accessible to a broad audience with a range of professional backgrounds and expertise, we asked our principal investigators to tell us about their projects. We hope you enjoy the highlights from these conversations. Full abstracts for each project are available on the CChIPS website. Detailed technical reports are made available to IAB member companies, and findings from the majority of projects are published in the peer-reviewed literature.

PROJECT INTEREST AREAS

The CChIPS research portfolio can be categorized by the five interest areas below.
Look for these icons next to each project summary.

Dummy Biofidelity/Human Body Models

Vehicle Restraint Performance

Child Restraint Design and Performance

Consumer/Driver Behavior

Crash Avoidance & Autonomous Vehicles

GLOSSARY OF COMMONLY USED TERMS

ATD – anthropomorphic test device; also known as a crash test dummy

CRS – child restraint systems; including rear- or forward-facing car seats and belt-positioning booster seats

FMVSS 213 – Federal Motor Vehicle Safety Standard used to certify child restraints

LATCH – Lower Anchors and Tethers for Children; a standardized method of attaching child restraints to motor vehicles

NHTSA – National Highway Traffic Safety Administration; an agency of the US Department of Transportation dedicated to saving lives, preventing injuries, and reducing economic costs due to road traffic crashes

LODC – Large omni-directional child dummy, representing approximately a 10-year-old child

MEG – Magnetoencephalography, an advanced imaging method that allows measurement of brain functioning

REU – Research Experiences for Undergraduates summer internship program, sponsored by the National Science Foundation

EFFECTS OF TEMPERATURE AND HUMIDITY ON DYNAMIC TEST COMPONENTS

Principal Investigator:
John Bolte, PhD, The Ohio State University

Co-Investigator:
Julie Mansfield, PhD, The Ohio State University

Student:
Rosalie Connell, BSE, The Ohio State University

IAB Mentors:
Mark LaPlante, Graco Children's Products Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Curt Hartenstein**, Iron Mountains; **Erin Hutter**, National Highway Traffic Safety Administration; **Uwe Meissner**, Technical Advisor

WHAT WAS THE PURPOSE OF THIS PROJECT?

This project examined the foam cushion used on the federal compliance test bench, in FMVSS 213, used by all CRS manufacturers to crash test their products. NHTSA is in the process of replacing the polyurethane foam cushion with a new formulation that better represents the modern vehicle fleet. However, there are little data currently available to understand the mechanical properties of this new foam and how it might vary with respect to temperature and humidity in testing facilities. The goal of this study was to better understand how the ambient environment might influence stiffness properties of the test bench foam and, therefore, crash test outcomes.

HOW WAS THE RESEARCH CONDUCTED?

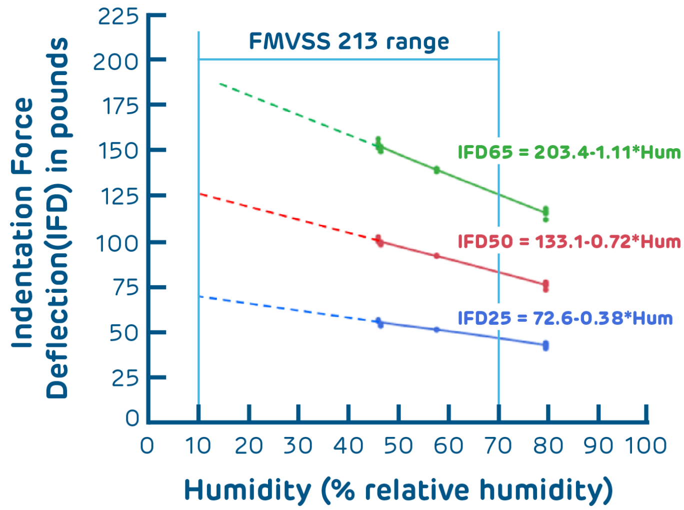
We obtained 25 samples of the newly formulated foam and placed them for at least 24 hours in a climate chamber set to a specific temperature (ranging from 32.9 to 86.0°F) and humidity (ranging from 46.0 to 86.2% relative humidity). We then conducted quasistatic indentation force deflection tests in a universal testing machine by compressing each sample by 25%, 50%, and 65% of its original height, recording the corresponding force at each of those indentations to quantify the stiffness of the foam.

WHAT WERE THE FINDINGS AND WAS ANYTHING SURPRISING?

We found that the stiffness of the foam was sensitive to both temperature and humidity over the ranges tested. Something that surprised us was how large of a role the humidity played. Under current FMVSS 213 standards, NHTSA specifies that crash testing should be conducted at relative humidity between 10% and 70%. We found that there was quite a range in stiffness within that 10% to 70% range. Based on these results, we would recommend that the humidity range be tightened, which may ultimately produce more repeatable results.

HOW ARE THESE RESULTS APPLICABLE TO INDUSTRY MEMBERS?

Our results complement testing that NHTSA is currently conducting and can help CRS manufacturers better understand how their crash test results might vary with respect to ambient conditions, especially across different test facilities in different geographic climates.



The indentation forces of the newly proposed FMVSS 213 test bench foam varied considerably with respect to humidity for all three indentation levels. The solid lines model the data over the humidity range tested in this study, and the dashed lines show the extrapolation of the results over the current FMVSS 213 humidity range of 10 to 70% relative humidity.

CRS FIT IN AIRCRAFT

Principal Investigator:
John Bolte, PhD, The Ohio State University

Co-Investigator:
Julie Mansfield, PhD, The Ohio State University

IAB Mentors:
Emily Thomas, Consumer Reports; **Joseph Pellettiere**, Federal Aviation Administration; **Mark LaPlante**, Graco Children's Products Inc.; **Josh Gazaway**, Graco Children's Products Inc; **Susan Mostofizadeh**, American Honda Motor Co., Inc.; **Nick Rydberg**, Minnesota HealthSolutions

WHAT WAS THE PURPOSE OF THIS PROJECT?

The Federal Aviation Administration (FAA) encourages the use of aircraft-approved CRS. However, as established through prior CChIPS research led by Aimee Palumbo, PhD, MPH, caregivers often encounter challenges installing CRS on aircraft seats. The broad objective of this study was to quantify the specific compatibility concerns between CRS and aircraft seats to ultimately facilitate higher rates of CRS use on aircraft.

HOW WAS THE RESEARCH CONDUCTED?

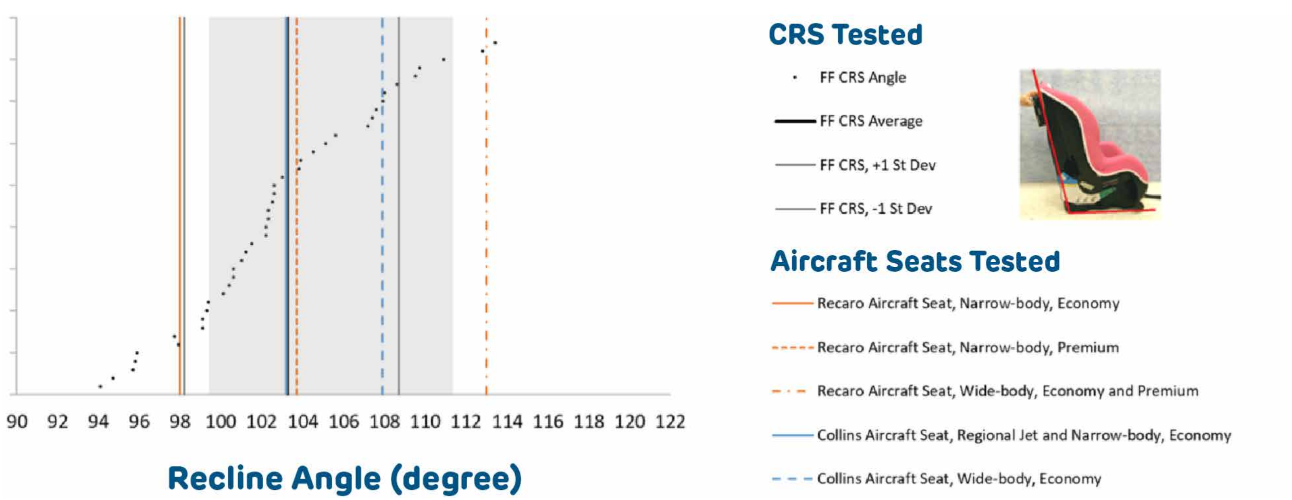
Through a collaboration with the SAE Aircraft Seat Committee, we obtained the physical dimensions of nine different aircraft seats, which represented economy and premium seats on regional jets, narrow body aircraft, and wide body aircraft. From prior CChIPS studies, we had measurements from 56 CRS models and 111 vehicle seats. We compared the dimensions to see which CRS would fit into which aircraft seats and compared the aircraft seat dimensions to vehicle seat dimensions.

WHAT WERE THE FINDINGS?

We found that the width of the aircraft seats and the pitch dimension, or the forward space between each row of seats, presented challenges with installing rear-facing CRS in aircraft seats. This was especially true for larger convertible or 3-in-1 CRS. We also found that aircraft seats are flatter and a little shorter in seat bottom length than vehicle seats. All the dimensions and measurements were provided to the CChIPS IAB members to use as benchmark data so aircraft seat and CRS manufacturers can better understand how their products work together.

WHAT'S NEXT?

We hope that by creating this comprehensive database of dimensions we can shed more light on how CRS designed to keep children safe in vehicles can also be used to keep children safe when traveling by air. We hope that these data, and the discussions and collaborations to follow, can help to move the needle in encouraging caregivers to use CRS when traveling on aircraft.



This image shows the distribution of seat back angles for forward-facing (FF) CRS (with respect to horizontal, black dots) compared to the seat back angles of aircraft seats (with respect to the seat pan, orange and blue lines). Most aircraft seats fall within +/- 1 standard deviation of the corresponding FF CRS angles.

SHOULDER BELT INTERACTION FOR BOOSTER-SEATED ATDS

Principal Investigator:

John Bolte, PhD, The Ohio State University

Co-Investigators:

Gretchen Baker, PhD, The Ohio State University;
Julie Mansfield, PhD, The Ohio State University

IAB Mentors:

Jonathan Gondek, Calspan Corporation; **Michael Kulig**, Calspan Corporation; **Jennifer Stockburger**, Consumer Reports; **Emily Thomas**, Consumer Reports; **Amanda Taylor**, Federal Aviation Administration; **Josh Gazaway**, Graco Children's Products Inc.; **Mark LaPlante**, Graco Children's Products Inc.; **Marianne LeClaire**, Graco Children's Products Inc.; **Nick Reaves**, Graco Children's Products, Inc.; **Kyle Mason**, Iron Mountains; **Bill Lanz**, American Honda Motor Co., Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Nick Rydberg**, Minnesota HealthSolutions; **Jason Stammen**, National Highway Traffic Safety Administration; **Steve Gerhart**, Nuna Baby Essentials, Inc.; **Schuyler St. Lawrence**, Toyota USA; **Paul Gaudreau**, UPPAbaby; **Uwe Meissner**, Technical Advisor

WHAT WAS THE PURPOSE OF THIS PROJECT?

This project built upon previous CChIPS work where we developed new ways to measure seat belt fit for children. We found a lack of contact between the shoulder belt and the lower torso on some booster seats, which we call belt gap, and we observed differences in belt gap among various booster seat designs. This study took the next step to investigate how variation in belt gap relates to differences in crash outcomes. To do this, we tested three ATDs on six different booster seats, which varied in their initial belt gap, in two crash scenarios: frontal and 15 degrees from the frontal direction. We primarily looked at the following outcomes: head acceleration and displacement, chest acceleration and deflection, axial shoulder rotation, axial thoracic spine rotation, and lumbar spine moments.

WHAT DID YOU FIND?

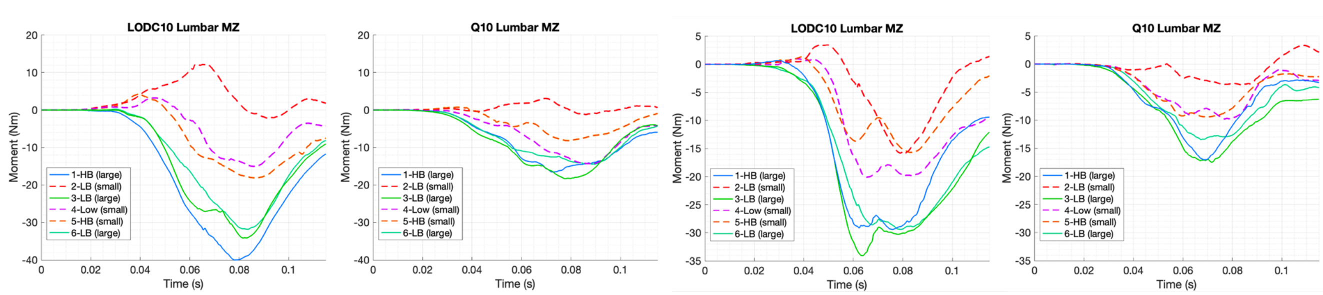
We found generally similar results across the six booster seats in terms of head and chest metrics. However, the ATDs on boosters which had less initial contact between the shoulder belt and lower torso tended to rotate more around their spine, particularly in the lumbar area. We also saw more rotation in the shoulders and thoracic spine for the ATDs restrained in these booster seats. This increase in spinal and shoulder rotation may suggest an increased risk of the seat belt slipping off the shoulder. This trend was observed in both frontal and oblique crash directions.

WHAT ARE THE INDUSTRY IMPLICATIONS?

This research can be applied to other scenarios of occupant protection, such as adult occupants restrained by three-point seat belts. The more we understand the relationships between initial fit of the seat belt, posture, and how occupants respond during a crash, crash outcomes will improve for all occupants.

WHAT'S NEXT?

In follow-up work, we hope to fully tease out the individual influences of each variable (such as initial belt gap and the amount of boost provided by the booster seat) by conducting either additional physical testing (with more seats) or using computational models (simulations) with a simplified booster scenario and examine the effect as each variable is modified parametrically.



This graph shows the lumbar spine movement about the vertical axis (MZ) over time for the LODC 10-year-old for frontal sled tests (left) and 15° oblique (second from left) sled tests and the lumbar spine movement about the vertical axis (MZ) over time for the Q-series 10-year-old ATDs for frontal sled tests (second from right) and 15° oblique sled tests (right). Booster seats with smaller initial belt gap are represented in dashes lines, while larger gap booster seats are represented in solid lines. Booster seats included those with backs (HB), backless (LB), and low-profile (Low).

MOTION OF RECLINED BOOSTER-SEATED CHILDREN DURING SLED-SIMULATED LATERAL OBLIQUE PRE-CRASH SCENARIOS

Principal Investigator:
Valentina Graci, PhD, Children's Hospital of Philadelphia and Drexel University

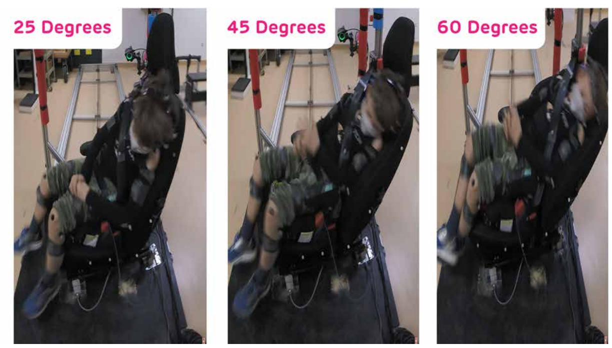
Co-Investigators:
Kristy Arbogast, PhD, Children's Hospital of Philadelphia;
John Bolte, PhD, The Ohio State University;
Madeline Griffith, MS, Children's Hospital of Philadelphia;
Yun Seok Kang, PhD, The Ohio State University;
Thomas Seacrist, MBE, Children's Hospital of Philadelphia

Student:
John Burns, BS, University of Pennsylvania

IAB Mentors:
Suzanne Johansson, General Motors Holdings LLC; **Mark LaPlante**, Graco Children's Products Inc.; **Marianne LeClaire**, Graco Children's Products Inc.; **Joseph Webb**, Graco Children's Products, Inc.; **Susan Mostofizadeh**, American Honda Motor Co., Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Steve Gerhart**, Nuna Baby Essentials, Inc.; **Schuyler St. Lawrence**, Toyota USA; **Uwe Meissner**, Technical Advisor

WHAT WAS THE PURPOSE OF THIS PROJECT?

This is the first project to examine child human volunteers in reclined vehicle seating configurations, which we expect to be more common in autonomous vehicles. With this study we aimed to understand the role of reclined seatback angles in influencing the motion of booster-seated children when exposed to a pre-crash scenario, such as a lateral oblique swerve. All the current research on reclined occupants is done on adults, but we can't just transfer what we've learned about keeping reclined adults safe in autonomous cars to children. We need to learn how to specifically protect children. This research can help.



Instrumented booster-seated child participant on a reclined vehicle seat.

WHAT DID YOU FIND?

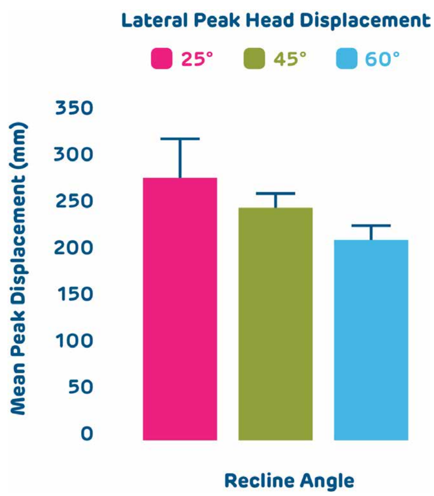
We tested two types of low back booster seats on 6 children (3 females and 3 males) and found that both boosters are effective in preventing submarining (when the occupant slides under the seat belt) in the reclined seating configurations. We had hypothesized that this might be more common when the seat back is reclined, so the absence of submarining is an important discovery.

WERE ANY OF THE RESULTS SURPRISING?

We discovered that children move less during lateral oblique swerves when the seatback is reclined compared to the upright position. This means that reclined seating configurations can lead to better positioning of children within the shoulder belt in lateral-oblique pre-crash maneuvers. Usually, occupants flex laterally when the seat is in the upright position; but, in the 60-degree reclined seatback angle, which corresponds to a severe recline position, children do not flex but roll slightly on the side. It is important to note that in these tests, the shoulder belt position simulated is attached to the vehicle seat and not to the C-pillar of the vehicle.

WHAT'S NEXT?

This study highlights a potential countermeasure – the booster seat - to prevent submarining in reclined passengers. We need to investigate how a booster-like solution can be implemented for small adults who have been found to be prone to submarining in reclined seating configurations.



Means and standard deviations of child lateral head motion: As seatback angle increases, the lateral motion of the head decreases ($p<0.002$).

UNDERSTANDING RECLINED SMALL OCCUPANTS' KINEMATICS IN FRONTAL CRASHES BY TESTING THE LODC

Principal Investigator:

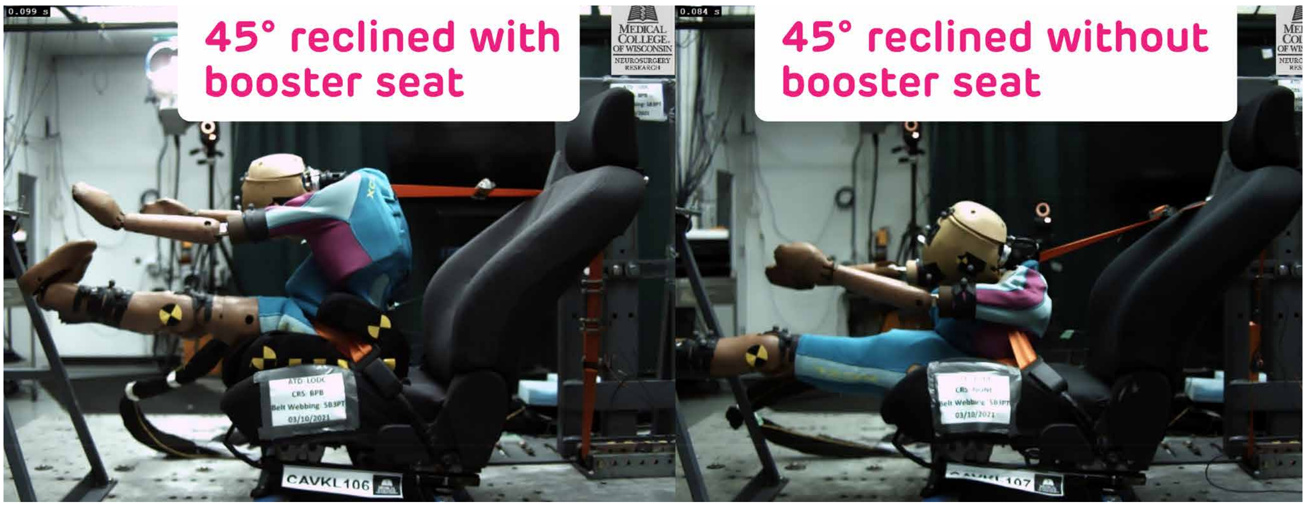
Valentina Graci, PhD, Children's Hospital of Philadelphia and Drexel University

Co-Investigators:

Hans Werner Hauschild, MS, Medical College of Wisconsin; **John Humm, PhD**, Medical College of Wisconsin; **Jalaj Maheshwari, MSE**, Children's Hospital of Philadelphia

IAB Mentors:

Allison Schmidt, Britax Child Safety Inc.; **Michael Kulig**, Calspan Corporation; **Suzanne Johansson**, General Motors Holdings LLC; **Susan Mostofizadeh**, American Honda Motor Co., Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Mladen Humer**, Lear Corporation; **Jason Stammen**, National Highway Traffic Safety Administration; **Schuyler St. Lawrence**, Toyota USA; **Uwe Meissner**, Technical Advisor



Test images at peak forward head displacement for the 45° (moderate) reclined condition with the booster seat (left) and without the booster seat (right).

WHAT WAS THE PURPOSE OF THIS PROJECT?

This project aimed to characterize the kinematics and kinetics of reclined child occupants with and without booster seats in frontal crashes by using the LODC ATD that was recently developed by NHTSA. We chose the LODC for this study because of its adjustability and flexible spine, which is ideal for examining reclined postures in vehicles.

HOW WAS THE RESEARCH CONDUCTED?

The LODC was tested in 12 simulated full frontal vehicle crashes, with and without low back booster seats, at the Medical College of Wisconsin. Three reclined seatback angles were compared: nominal (25°), moderate (45°), and severe (60°). We also examined scenarios with and without a pre-pretensioner seat belt. 3D motion capture and sensor data, including accelerometers, angular rate sensors, and load cells were used to measure the LODC response.

WHAT DID YOU FIND?

The booster seat prevented submarining (when the child slides under the seat belt) in all reclined seatback angles. However, we found that the compressive forces on the lumbar spine increased with the increase in recline angle and the presence of the booster seat. However, we don't know if those forces can cause injury because our field does not have an injury risk curve for the pediatric lumbar spine to place these values in context.

WHAT'S NEXT?

These results lead to future research questions focused on modification of the vehicle seat pan to mitigate these forces. It would be great to extend this research to also examine the ATD response with reclined seatbacks when restrained in a high back booster, as well as other crash directions.

NATURALISTIC SEATING POSTURES IN FRONTAL IMPACTS – TRANSLATING THE EFFECT OF ATD SEATING POSTURE TO BOOSTER CRS SLED TESTING USING THE Q6 ATD

Principal Investigator:
Jalaj Maheshwari, MSE, Children's Hospital of Philadelphia

Co-Investigators:
Gretchen Baker, PhD, The Ohio State University;
Madeline Griffith, MSE, Children's Hospital of Philadelphia;
Julie Mansfield, PhD, The Ohio State University;
Declan Patton, PhD, Children's Hospital of Philadelphia

IAB Mentors:
Jonathan Gondek, Calspan Corporation; **Emily Thomas**, Consumer Reports; **Suzanne Johansson**, General Motors Holdings LLC; **Mark LaPlante**, Graco Children's Products Inc.; **Marianne LeClaire**, Graco Children's Products Inc.; **Susan Mostofizadeh**, American Honda Motor Co., Inc.; **Bill Lanz**, American Honda Motor Co., Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Schuyler St. Lawrence**, Toyota USA; **Uwe Meissner**, Technical Advisor

WHAT WAS THE PURPOSE OF THIS PROJECT?

Most standard testing for child safety seats or vehicles is conducted in an ideal configuration – with the ATDs seated upright in a very rigid sitting posture. But real-world data suggests that children don't sit like that and instead take various postures across a trip for comfort and to engage in numerous activities while riding. These postural changes can alter the seat belt routing, resulting in non-ideal seat belt placement across the child. Further, due to different booster seat designs, the seat belt routing may be further affected. Therefore, it's important to assess occupant protection in these naturalistic seating postures, specifically how seat belt fit would change in those postures and how booster seats with varying static belt fit could affect dynamic crash performance when the occupant is positioned this way.

HOW WAS THE RESEARCH CONDUCTED?

We positioned the Q6 ATD on two booster seats (each with different static belt fit metrics) in three seating postures: standard reference, leaning forward, and leaning inboard. Prior naturalistic studies have shown that these postures are most observed in children. We collected belt fit metrics such as shoulder belt score (lateral distance between the suprasternale and inboard edge of the shoulder belt), lap belt score (distance in the sagittal plane between the superior edge of the lap belt and the anterior superior iliac spine (ASIS), gap size (3D distance between the shoulder belt and torso), gap length (distance along shoulder belt in gap region), and percentage torso contact (percent of shoulder belt length along the torso that is in contact with the torso). We then performed 12 frontal impact sled tests, recorded kinetic and kinematic measures, and conducted statistical analysis across conditions.

WHAT DID YOU FIND?

Static belt fit does affect dynamic crash test performance. The booster seat with more inboard shoulder belt, more inferior lap belt, and larger gap size had relatively better kinetics and kinematics than the other conditions with greater outboard shoulder belt, superior lap belt, and smaller gap size.

WERE ANY OF THE RESULTS SURPRISING?

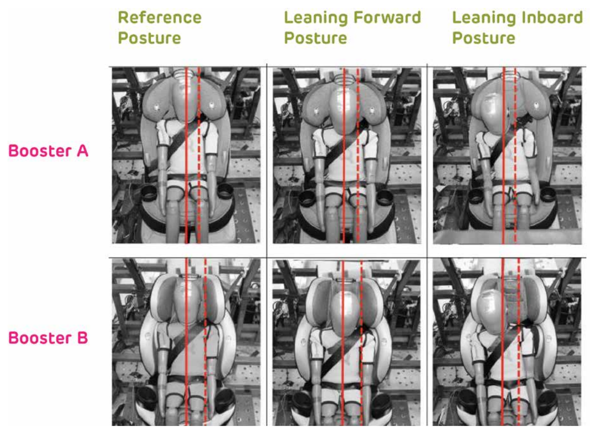
Even small differences in static belt fit resulted in statistically significantly better kinematic and kinetic performance. The booster seat with slightly better belt fit had significantly lower head and chest acceleration, HIC15 (an objective measure of head injury severity), neck tensile force, abdominal pressure, and higher ASIS force and moment. Additionally, the better belt fit booster had lower forward head excursion and chest deflection.

WHAT ARE THE INDUSTRY IMPLICATIONS?

These data will help guide booster seat design improvements to provide comprehensive child occupant protection in all types of seating scenarios.

WHAT'S NEXT?

We need to assess the relationship of static belt fit with dynamic sled test performance across a range of belt fit metrics in frontal, oblique, and side impacts. There's a lot of work to be done that builds from here.



This figure highlights the variation in initial static belt positioning over the Q6 ATD's torso when the ATD was positioned in each booster seat and seating posture. The solid red lines represent the center of the ATD's torso, while the dashed red lines represent the position of the center of the shoulder belt on the ATD's shoulder.

USABILITY AND STABILITY OF EUROPEAN VS. TRADITIONAL BELT ROUTING FOR NO-BASE INFANT CRS

Principal Investigator:
Julie Mansfield, PhD, The Ohio State University

IAB Mentors:
Michael Block, Consumer Reports; **Emily Thomas**, Consumer Reports; **Suzanne Johansson**, General Motors Holdings, LLC; **Mark LaPlante**, Graco Children's Products Inc.; **Marianne LeClaire**, Graco Children's Products Inc.; **Kelly Seagren**, Graco Children's Products Inc.; **Joseph Webb**, Graco Children's Products Inc.; **Emily Burton**, American Honda Motor Co., Inc.; **Steve Gerhart**, Nuna Baby; **Anita Sabapathy**, UPPAbaby; **Uwe Meissner**, Technical Advisor

WHAT WAS THE PURPOSE OF THIS PROJECT?

Infant CRS can be installed without the base using two different methods: 1) using primarily the lap belt and routing the shoulder belt directly up to the retractor known as the traditional belt path or 2) using the lap belt and additionally wrapping the shoulder belt around the back of the infant carrier, known as the European belt path. Some CRS models require or prefer a certain installation method, while others allow both. Little is known about whether caregivers can accurately complete each of these installation options and whether these CRS fit into US vehicles.

HOW WAS THE RESEARCH CONDUCTED?

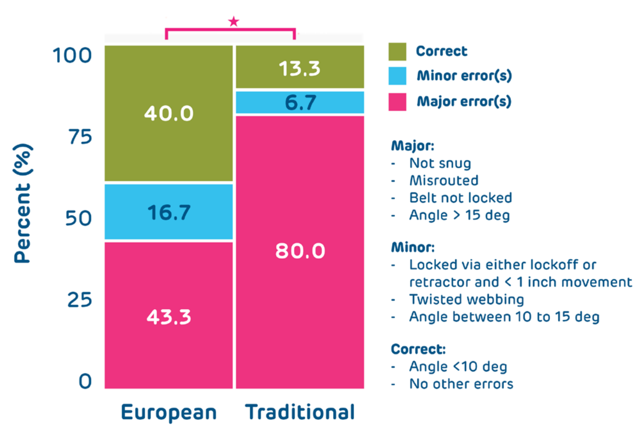
There were three different aims and methods for this project. For Aim 1, we looked at compatibility by comparing key measurements from a convenience sample of 30 vehicles to corresponding dimensions of 10 CRS. For Aim 2, we studied consumer usability by recruiting 30 caregivers from the community to install CRS using each method and tracked their errors. For Aim 3, we analyzed the stability of each installation method (that is, its ability to stay upright without lateral or rotational shifting) during real-world driving. Misuse conditions were compared to correct installations.

WHAT WERE THE FINDINGS AND WAS ANYTHING SURPRISING?

In terms of compatibility, the primary focus was confirming that the height of the seat belt buckle fit underneath the infant CRS belt guide and ensuring the seat belt was long enough to route around the back of the CRS. We found generally good compatibility across the field. For Aim 2, overall misuse rates were similar to those reported in child safety literature. However, caregivers had fewer major errors using the European belt path (43.3%) compared to the traditional belt path (80.0%). This was surprising because the European belt path has a few additional steps, which we thought may lead to more errors. Interestingly, 100% of the installations completed using the European method had the seat belt locked correctly. This is because the belt needed to be extended to nearly its maximum length to fit around the European belt path. Additionally, most users recognized that the European belt path provided a more stable installation and felt it was safer than the traditional belt path. For Aim 3, the European belt path appeared to create a more stable installation compared to the traditional method, especially when misuses were present.

HOW ARE THESE RESULTS APPLICABLE TO INDUSTRY MEMBERS?

We hope that the industry sponsors can use this information to help prioritize which installation method is recommended to caregivers. Considering all three aims, there is evidence that the European belt path is a feasible and practical option for caregivers that provides more stability.



The traditional belt path had a higher rate of major errors compared to the European belt path (80.0% vs. 43.3%).

LOAD LEG COMPATIBILITY WITH VEHICLES

Principal Investigator:
Julie Mansfield, PhD, The Ohio State University

IAB Mentors:
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WHAT WAS THE PURPOSE OF THIS PROJECT?

A load leg, also called a support leg, on a CRS extends from the base of the child seat down to the vehicle floor and braces the CRS against the floor during a crash. Previous CChIPS studies by Declan Patton, PhD and others have found that using a load leg can significantly reduce head and neck injury risks. The objective of this study was to look at different vehicle and CRS geometries to provide benchmark data to ensure that CRS with load legs will be compatible with current US vehicles.

HOW WAS THE RESEARCH CONDUCTED?

We compared measurements of 105 seating positions from 51 vehicles of model year 2015 to 2020 with measurements from 10 different CRS with load legs currently available in the US. We then selected three different CRS models to directly install into 42 different vehicle seating positions, resulting in 126 total installations of CRS with load legs, to assess if our prediction measurements could be validated.

WHAT WERE THE FINDINGS?

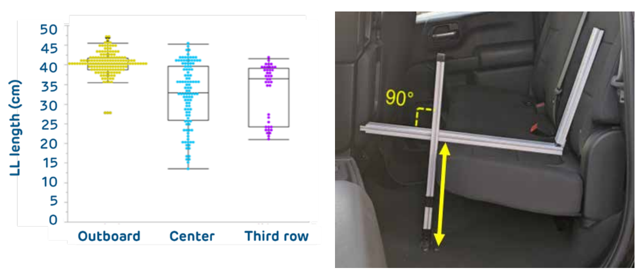
We assembled a database of measurements from the 105 different seating positions, looking at both outboard and center seating positions. As expected, we found that the center seating positions created more difficulty due to the variation in the floor contours and the center consoles protruding rearward from the front row seats. We also found installation challenges related to plastic trim on the floor of the vehicle; in those instances, additional information would be needed from the manufacturer of both the CRS and the vehicle to confirm that a load leg installation is allowed.

WAS ANYTHING SURPRISING?

The amount of variation in load leg design across the 10 CRS models currently available on the US market was most surprising. Some load legs were designed to be positioned at the same angle in every vehicle, regardless of the seat pan angle. On other CRS models, the angle of the load leg varied according to the vehicle seat pan angle. We expected to see a lot of variation in the vehicles' center seats, which was confirmed by our quantitative data.

HOW ARE THESE RESULTS APPLICABLE TO INDUSTRY MEMBERS?

We hope that these benchmark measurements will be valuable to industry members designing load legs and conducting in-house crash testing, particularly in the absence of a federal standard for a floor on the FMVSS 213 test bench.



These data show the predicted load leg length requirements for the full set of vehicles calculated from the seat height, seat pan angle, and length of CRS base. Note the wide range of required lengths for the center seat position, owing to the variability in vehicle floor contours in that seat position.

INTERACTIONS BETWEEN REAR-FACING CRS AND THE FRONT ROW SEATBACK IN FRONTAL IMPACT SLED TESTS

Principal Investigator:

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Co-Investigators:

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WHAT WAS THE PURPOSE OF THIS PROJECT?

This was a continuation of prior CChIPS work looking at rear-facing CRS with a support leg, which is also called a load leg. Our previous work used sled testing to look at CRS with a support leg using a blocker plate in front of the CRS to represent a front row seatback. Using this test setup, we found a reduction in head injury metrics in frontal crashes when support legs were used. The current project studied how rear-facing CRS with a support leg interact with an actual front row seat.

HOW WAS THE RESEARCH CONDUCTED?

The front row seat was set to three positions. The "touch" position moved the front row seat rearward until it just contacted the rear-facing CRS. The "brace" position translated the front row seat 20 millimeters aftward from the touch position, which simulated a front row passenger moving their seat afterwards so that the CRS was braced against the front row seat. The "gap" position translated the front row seat 50 millimeters forward from the touch position, leaving space between the CRS and the front row seat. We conducted 12 total tests: two CRS models – an infant-only CRS with an 18-month-old ATD and a convertible CRS with a 3-year-old ATD – installed rear-facing in the three positions with and without a support leg.

WHAT WERE THE FINDINGS?

The 18-month-old ATD in the rear-facing infant CRS had the lowest head injury metrics for the touch and gap conditions. In contrast, the 3-year-old ATD in the rear-facing convertible CRS had the lowest head injury metrics for the brace condition. These results can be attributed to the shape and design of each CRS and how the ATD's head fits within the CRS. However, because only two CRS models were tested, additional research is needed to understand whether these results are representative of the large variety of CRS designs available.

In addition, we found that the tests with a support leg were associated with significantly lower head acceleration, indicating a lower likelihood of injury when a support leg was used. This supports our previous findings that a support leg reduces head injury metrics.

HOW ARE THESE RESULTS APPLICABLE TO INDUSTRY MEMBERS?

In the absence of a federal safety standard in the US pertaining to support legs, these results can help CRS manufacturers to establish or refine testing and recommendations. Our findings are also relevant for vehicle manufacturers in terms of front row seat design, specifically the interaction between pediatric occupants and vehicle seats. There may be some avenues to reduce head injury metrics through front row seat design.

An 18-month-old ATD seated in a rear-facing infant CRS with support leg installed in the test buck.

NEW INSIGHTS FOR THE AUTO INDUSTRY: IDENTIFYING KEY EYE-TRACKING METRICS ASSOCIATED WITH COGNITIVE CONTROL WHILE DRIVING, VALIDATED BY MEG NEUROIMAGING

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WHAT WAS THE PURPOSE OF THIS PROJECT?

Following our prior CChIPS project that integrated eye-tracking technology into our MEG+Driving+Eye-Tracking paradigm, we wanted to test the hypothesis that eye-tracking metrics are associated with increased cognitive control during simulated driving. As a first step, we aimed to establish the analytical pipeline for processing and analyzing the eye-tracking data we now are collecting and to see if we can detect differences in eye-tracking behaviors related to driving performance.

WHAT METHODS DID YOU USE?

We used custom-built driving scenarios that include driving tasks requiring different levels of cognitive control over behavior, paired with MEG neuroimaging, along with eye-tracking recording. We time-synced the MEG recording with the eye-tracking recording and used event markers in the driving scenario to align brain and eye responses with specific driving events (such as accelerating and braking in response to traffic light changes). We compared typically developing teens and teens with autistic spectrum disorder (ASD) in a small pilot-test sample.

WHAT DID YOU FIND?

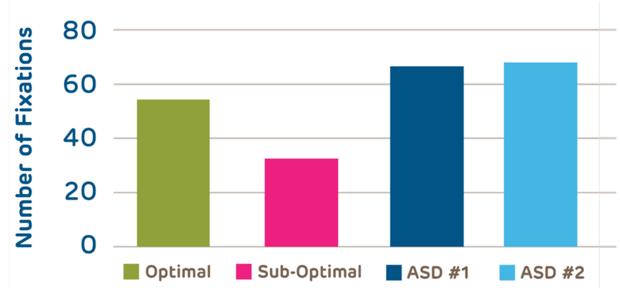
This MEG+Driving+Eye-Tracking paradigm can detect differences in scanning behavior, even during a basic braking task. We observed three distinct eye-tracking behaviors: the "optimal driver" scans widely, the "sub-optimal driver" scans more centrally, and the "driver with ASD" is overattentive. (See graph.) The differences observed between periods of driving with cognitive control versus no cognitive control with the "optimal driver" suggests that eye-tracking could be used to measure cognitive control brain responses.

WHAT ARE THE INDUSTRY IMPLICATIONS?

Auto manufacturers may want to consider incorporating eye-tracking technology in their in-vehicle monitoring systems to measure cognition during driving, specifically for teen drivers.

WHAT'S NEXT?

We're excited to collect more data in a larger sample and with a more challenging driving scenario to verify that these findings are consistent across individuals and groups (which is the goal of our CChIPS 2022-2023 project).



The mean (±SE) number of fixations (i.e., periods of time when the eyes are focused on an object of interest) exhibited by teen drivers over 20 repetitive trials during a basic intersection braking task. Drivers with ASD exhibited more fixations compared to "optimal" and "sub-optimal" typically-developing drivers, which is reflective of adolescents with ASD exhibiting "over-attention" to objects on the roadway (Ting Chee et al. 2019).

PREPARING FUTURE INDUSTRY SCIENTISTS

Research Experiences for Undergraduates (REU)

The Center for Injury Research and Prevention (CIRP) at CHOP (the administrative home of CChIPS) hosts an NSF-supported Injury Science REU site, with an emphasis on providing research experiences to students who are underrepresented in research: American Indian/Alaskan Native, Black, and Latinx students, women, students with disabilities, and students from STEM-limited schools with minimal internship opportunities and no available doctorate program. In our 10th summer offering this program, we received over 200 applications for 8 REU internship positions for Summer 2022. After a hybrid program in 2021, this year we offered a fully on-site program that included interactive workshops, seminars, and journal clubs. In addition, REU students were invited to participate in the CHOP Research Institute's Summer Scientific Research Colloquium, which included several virtual sessions designed for students to learn about scientific disciplines and research career paths. While the 10-week REU program concluded in August, some students elected to continue at CIRP, working on research projects remotely into the fall. Please contact us if you would like to meet with these talented students or are interested in sponsorship to extend this program to more students.

Injury Biomechanics Symposium

The CChIPS site at The Ohio State University is housed within the Injury Biomechanics Research Center (IBRC). The IBRC has been a leader in student development in injury biomechanics via the annual Injury Biomechanics Symposium (IBS). In its 17th year, 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 May 2022, it hosted the annual symposium as a hybrid in-person and virtual event. The event had over 150 registered attendees, including 26 student presenters from 12 universities, including four international universities. The speakers covered a range of topics, such as biomechanics of the head and brain, spine, and lower extremities, epidemiology, and pediatric sports injuries. Five student presenters from OSU shared their research: Jordan Reddington, Nathan Kebede, Matthew Isaksson, Mara Van Meter, and Angelo Marcallini. They were joined by CHOP student presenters from the University of Pennsylvania: Colin Huber and John J. Burns III.

CChIPS Digital Communications

The Outreach team at the Center for Injury Research and Prevention at CHOP deploys a range of digital communications strategies to promote CChIPS research and investigators:

- **Updated CChIPS Website.** In December 2020, following a comprehensive redesign process, CChIPS re-launched the cchips.research.chop.edu website. The website includes a summary of each of CChIPS's 180+ projects organized by project year, a database of peer-reviewed publications based on CChIPS-funded projects and organized by year and topic area, a listing of current CChIPS IAB membership, and more.

In 2021, the CChIPS website had a 52% increase in visits compared to 2020.

- **Blog Posts.** CChIPS research is featured on CIRP's highly viewed *Research In Action* blog. During the 2021-2022 project year, there were 10 CChIPS blogs which received 1,648 views. View a list of all CChIPS-relevant posts at cchips.research.chop.edu/blog.
- **YouTube Videos.** During the 2019-2020 project year, a marketing video for CChIPS was developed. Over the past year, the Outreach team has used the full-length video and associated interviews to develop shorter, social media-friendly videos on specific areas of CChIPS research including computational modeling and transporting children in autonomous vehicles. The videos are available in a CChIPS playlist on CIRP's Injury Research in Action YouTube channel at youtube.com/InjuryResearchInAction.

CChIPS: A Unique Consortium

The Center for Child Injury Prevention Studies (CChIPS) would like to thank the Industry Advisory Board (IAB) representatives and our member companies for their generous support and insight. We would also like to acknowledge the National Science Foundation (NSF) for providing the support and infrastructure to establish CChIPS in 2005.

Our vital work would also not be possible without the generosity of our academic, corporate, and government collaborators. Many thanks to Children's Hospital of Philadelphia; The Ohio State University; The University of Pennsylvania; and Drexel 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 Children's Hospital of Philadelphia (CHOP) and the Creative Services Department of the Children's Hospital of Philadelphia Research Institute.

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Members of CChIPS leadership, the Industry Advisory Board (IAB), and Principal Investigators at the Spring IAB Meeting in Philadelphia, March 2022. Due to pandemic-related restrictions and challenges, this marked the first in-person CChIPS IAB meeting in two and a half years.

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