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CPS ISSUE REPORT

ISSUE FOUR: DEVELOPING A BETTER CHILD CRASH TEST DUMMY – JANUARY 2010



The Children's Hospital *of* Philadelphia®

RESEARCH INSTITUTE

Advances in Pediatric Biomechanics



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Children are not small adults. The density, flexibility and mechanical properties of their soft tissue and bone structure change at varying rates through adolescence and young adulthood. Yet today's child crash test dummies, also known as pediatric anthropomorphic test devices (ATDs), are basically smaller versions of adult-sized dummies with little consideration for these differences in body composition.

This means that today's ATDs can be improved to more accurately show how child occupants move and respond to the forces of a vehicle crash.

Engineering researchers around the world are conducting cutting-edge work in pediatric biomechanics, which is crucial to filling the gaps in knowledge to make

more accurate child ATDs. The biomechanical engineers at the Center for Injury Research and Prevention (CIRP) at The Children's Hospital of Philadelphia (CHOP) and others are implementing novel approaches to measure how children respond to the forces of a crash and to estimate their bodies' tolerance to various types of injury.

The research is delivering the basic data we need to improve specific body regions of the pediatric ATDs and to develop innovative restraint products to make vehicles safer for children in the future. These advances will help save children's lives, prevent injuries, and reduce the economic cost of crashes involving child passengers.

HOW REAL-WORLD DATA FUELS BIOMECHANICS RESEARCH

Biomechanics researchers use a variety of laboratory methods to study and solve problems that occur in real-world crashes. Due to the changing landscape of restraint products, vehicle features, and child passenger safety (CPS) norms, it is critical that such data is up to date and scientifically rigorous in order to provide accurate evidence-based direction to government, industry, and the public on how best to protect our children. For the past decade, the Partners for Child Passenger Safety (PCPS) surveillance system at CHOP has primarily served this need. The nation's only large-scale child-focused crash surveillance system, PCPS informed new product development, test protocols and regulations, education, policy, and medical practice.

This real-world data provided the foundation for many of the biomechanics research efforts described in this report. Initial findings created new areas of investigation, leading to more detailed assessments of why child injuries occur and their consequences. Auto safety researchers and motor vehicle and restraint manufacturers have used this data to determine future biomedical research and product development priorities. For example, PCPS data was used as the basis for CHOP research in ATD development for the abdomen and spine described in this report.

PCPS concluded data collection at the end of 2007. Recognizing the continued need for a credible, high-quality data source on children in crashes, researchers at CHOP and the National Highway Traffic Safety Administration (NHTSA) are conducting pilot research to establish a new child crash surveillance data source. To be called the National Child Occupant Special Study (NCOSS), this new system leverages the robust infrastructure of the National Automotive Sampling System (NASS) to collect child-specific crash data. NCOSS will provide the platform for government, industry, and the auto safety research and advocacy community to work together to improve CPS. The data will encourage these groups to partner to achieve family-focused vehicle safety innovations such as:

- better vehicle design to address the unique safety needs of children and adolescents
- improved child restraints and booster seats to better protect children of different sizes and weights
- guidance for drivers to promote maximum safety for child passengers

With a national child crash surveillance system in place, biomechanics researchers will have the necessary foundation to continue their research for many years to come.





Photo Courtesy of Ford Motor Co.

HEAD AND BRAIN INJURY RESEARCH

Traumatic brain injury (TBI) continues to be a major health problem. Each year, 1.5 million new cases occur in the United States, resulting in 50,000 deaths. There are approximately 3.7 million people in the U.S. living with long-term disability from TBI. When children are seriously injured in motor vehicle crashes, brain and skull injuries are among the most common, regardless of age, crash direction, or type of restraint used. TBIs are responsible for one-third of all pediatric injury deaths.

Motor vehicle safety systems, including seat belts, air bags, child restraint systems (CRS), and occupant compartment padding, are key elements for reducing TBI in motor vehicle crashes. Part of developing more effective safety systems for children is acknowledging significant developmental differences across the pediatric age range. Properly restrained child passengers transition through three to four different restraint types: a rear-facing infant carrier; a forward- and/or rear-facing toddler CRS; a booster seat used with the vehicle belt system for older children; and the vehicle belt alone for preteens.

Studies have shown that when properly restrained, children and youths are much less likely to experience head injury in a crash. CHOP researchers have found that seat-belt restrained 2- to 5-year-olds are four times more likely to suffer a head injury compared to children of the same age in a CRS. In children restrained in forward-facing CRS, moderate to severe head injury ranks third as the most frequently injured body region (19 percent of injuries), after the face (21 percent) and lower extremities (28 percent). However, in general, the risk of head injury rises as children age. Understanding the factors that influence this risk is essential to reducing injury levels.

Although ATDs can accurately measure head kinematics during a crash for adults, it is difficult to prevent TBI in children due to a lack of necessary pediatric biomechanical data. Past biomechanical data for TBI primarily came from studies with animal surrogates for human adults. Now armed with immature animal models that mimic the developing brain, researchers at the University of Pennsylvania (UPenn) have discovered that infant brain tissue is stiffer and thus more resistant to deformation than toddler and adult brain tissue. Despite this stiffness, the infant brain is still more susceptible to TBI than the toddler's when exposed to an impact of equal magnitude.

The medical community has long known that the infant skull is more flexible than an adult's, due to bone softness and sutures (fibrous "joints" where the growing sections of the skull come together). Recent research conducted at UPenn confirmed this observation. In a related study at Duke University, researchers evaluated the 6-month-old ATD and found it compared well to an actual child for impacts to the top and back of the skull and forehead. It was

found, however, to be much stiffer when impacted laterally than an actual child's.

Although this data provided important insight into designing a better infant and toddler-age ATD, little data existed for children past toddler age. To begin addressing this gap, CHOP is collaborating with Susan Margulies, Ph.D., at UPenn's Department of Bioengineering, with funding from NHTSA to conduct research to develop brain injury criteria for the 6- to 10-year-old. Once the criteria are determined, a computational model can be developed to predict the likelihood of brain injury and then applied to the ATD currently available for this age group.

It is difficult to prevent traumatic brain injury in children due to a lack of necessary pediatric biomechanical data.

UNDERSTANDING THE CERVICAL SPINE'S BIOMECHANICS

Since the spine controls the trajectory or movement of the head during a crash, understanding the kinematics of the pediatric spine and ensuring that the spines of pediatric anthropomorphic test devices (ATDs) mimic real children are important areas of research.

There is a growing body of evidence that differences exist between the spinal movement of a human and that of an ATD for both children and adults. The human thoracic and cervical spine is flexible, while the ATD spine is relatively rigid. This may lead to differences in ATD head movement during crashes compared to that of humans. For pediatric ATDs these differences may be particularly important.

Because current pediatric ATDs are based on adult biomedical data “scaled down” to fit an average child’s body, they do not account for significant differences in spinal development from birth through adolescence. As children grow, the spine undergoes changes to its structure that likely lead to differences in flexibility and overall head movement compared to adults.

At birth, the cervical vertebrae are made up of several bones that do not fully fuse like those of an adult until age 4 to 6. The cervical ligaments are also much looser than an adult’s, and the facet joints, which govern the relative sliding of one vertebrae on top of another, are mostly horizontal. These structural differences can lead to substantial movement of the skeletal components of the child’s spinal column, putting the spinal cord at risk.

Further changes in the curvature of the spine usually continue throughout adolescence and young adulthood.

The effect of these developmental changes on biomechanical response has been shown in pediatric age-equivalent animals, as well as in limited numbers of pediatric human cervical spines donated to science. These studies found that as humans age, the cervical spine becomes stiffer and thus more resistant to forces that bend or apply tension and compression to it.

Measuring Cervical Spine Range of Motion in Real Children

These tissue-specimen studies are limited, however, because they cannot account for the effect of the muscles of a living subject on the biomechanical response. Studies conducted using pediatric human volunteers by researchers at CHOP sought to fill that gap, measuring age-based differences in cervical spine range of motion. In a study published in 2007, CHOP researchers quantified the active cervical spine range of motion of 3- to 12-year-olds by asking them to flex/extend, laterally bend, and laterally rotate their neck to the maximum degree possible while restraining their torso. The data showed both flexion and rotation increased slightly throughout this age range. When compared to similar data on adults, the active cervical spine range of motion for children was slightly greater.

To complement this work, CHOP researchers conducted a study to quantify how the spine bends in

response to passive muscle forces using both pediatric and adult volunteers. Volunteers were placed in passenger restraints and asked to flex their neck while relaxing the muscles surrounding it. The researchers used surface electromyography (EMG) with audio feedback to ensure the neck muscles were relaxed, tracked the motion of the head and neck using a multi-camera 3-D target tracking system, and calculated the neck flexion angle. This study showed that the neck flexion angle significantly decreased with age and that females tend to have more spinal flexion than males.

These findings were partially explained by age- and gender-based differences in head and neck size. For example, children have a relatively large head compared to their neck, which may place more weight on the neck leading to increased flexion. Since both of these human volunteer studies were conducted at slow speeds, these age-based differences may not remain when applied to a dynamic environment, such as a crash.

Recreating a Bumper Car Crash

To find out if this is indeed the case, CHOP collaborated with Rowan University, Takata Corp., and University of Virginia researchers to measure how a child’s head and spine move in a frontal crash-like impact. Since this could not be performed at real crash speeds for safety reasons, the team designed a crash sled to mimic the crash experienced by children and adults when they ride an amusement park’s bumper car ride (pictured right).

Data were collected on 20 children, ranging in age from 6 to 14, and 10 adults at the Exercise Science Research Laboratory at Rowan using motion-capture technology to track movement from external markers on volunteers' heads, necks, and spines during a bumper car's safe crash.

After accounting for differences in height and comparing the movement of their head and spine to adults, the researchers found that the children's head and spine moved further forward than the adult's, with most movement occurring at the base of the neck. They

also found that the youngest children studied experienced the most neck flexion, leading to more head rotation and perhaps increased likelihood of the head hitting the seat, window, or something else in the car. Again, the relative size of the head to the neck may explain these results. The researchers also documented flexion in the thoracic spine, an area where the ATD is particularly rigid, across all age groups.

These findings raise additional questions that need to be explored through research. Since it is not possible to study human volunteers at actual crash speeds,

further studies will be conducted using computer models to determine whether these age-based differences in spinal kinematics remain at increased speeds.

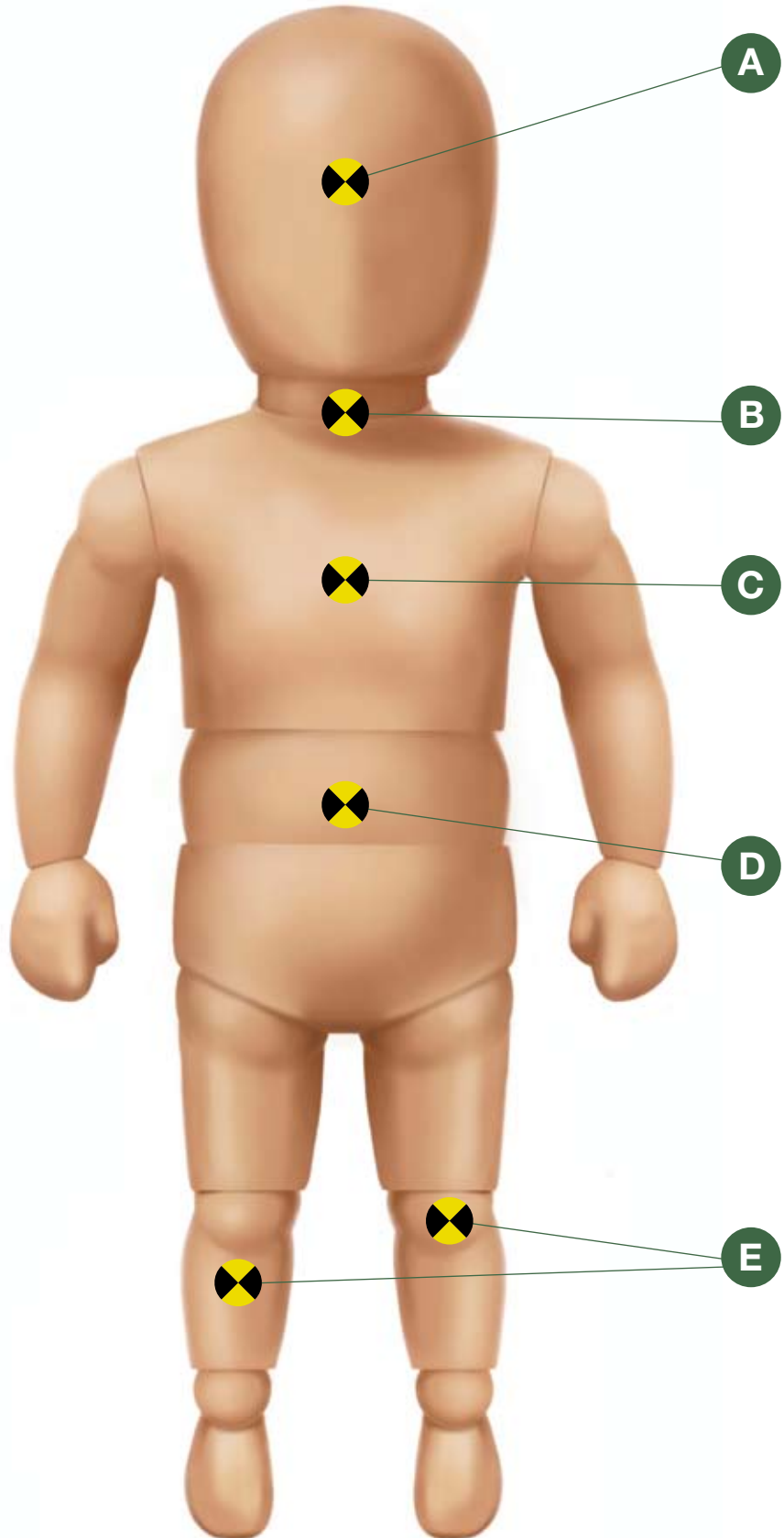
Also, since the current ATD for a 6-year-old has a relatively rigid thoracic spine, future research should study this construction based on the pediatric spinal flexion results to help inform future ATD design. If current pediatric ATDs do not adequately account for this increased flexibility, they may not accurately predict the risks of head injury to children from crashes.



Photo Courtesy of Rowan University

A BODY OF NOVEL RESEARCH

It is important to understand how children react differently to crash impacts than adults. That is why bioengineers and medical researchers are studying the pediatric body regions to help quantify how children respond to various levels of acceleration and impact. They also are working to better understand how the parts of the body interact with each other and then using computer models to extrapolate to the crash environment. Their findings are improving the tools that automobile and safety restraint manufacturers use to design safer products to reduce pediatric injuries and deaths from crashes.



A Head/Brain

- Injuries to the brain and skull are among the most common injuries sustained by children in motor vehicle crashes regardless of age, direction of crash, or type of restraint.
- The infant brain is stiffer and more resistant to deformation than toddler and adult brain tissue.
- The infant skull is more flexible than an adult's.
- Research is underway to develop child-specific brain injury criteria.

B Cervical Spine

- The biomechanics of the cervical spine are important to study because the spine governs the motion of the head.
- As children grow, the spine's structure changes in ways that influence flexibility and lead to increasing stiffness with age.
- Novel research on child and adult human volunteers has shown that the active range of motion, passive flexion, and dynamic flexion of the spine decrease with age.
- Spinal flexibility, demonstrated in humans in both the cervical and thoracic spine, should be incorporated into pediatric ATDs.

C Thorax

- The biofidelity of the ATD chest is critical because it is one of the primary load paths of a seat belt or child restraint harness.
- As children age, the ribs and the sternum structurally change; bones fuse and the ribs angle downward and twist.
- While studying chest compressions during CPR, researchers have found that the chest stiffens with age. Stiffness increases fourfold from age 8 to 40 and then decreases in seniors.

D Abdomen

- Injuries to the abdomen are the second most common sustained by children restrained in seat belts.
- Current pediatric ATDs do not have the ability to detect injuries to this body region.
- By studying the types of abdominal injuries children sustain and quantifying the tolerance of the abdomen to injury and response to seat belt loading, researchers were able to create a prototype abdomen for use in the 6-year-old ATD.

E Lower Extremities

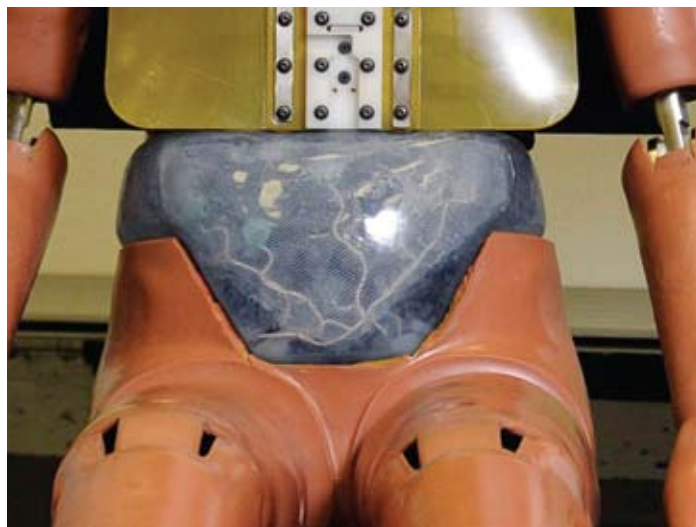
- Lower extremity injuries are common in children involved in car crashes as passengers or pedestrians.
- Though not typically life-threatening, lower extremity injuries are disabling and can directly impair normal orthopedic growth.
- Limited data currently exist on the biomechanical and physiological properties of the pediatric lower extremities. Bioengineers are hard at work defining a pediatric animal model to study injury criteria in the future.

DEVELOPING A MORE ACCURATE ABDOMEN

The national effort to encourage age-appropriate restraints for children, especially booster seat use for 4- to 8-year-olds, has been partially driven by a desire to reduce abdominal injury risk. Second only to head injuries, abdominal injuries fall under the constellation of injuries known as “seat belt syndrome,” often associated with significant healthcare costs and extended hospital stays. Although children of all ages are highly susceptible to developing seat belt syndrome, younger children are at higher risk due to poor belt fit. CHOP researchers have shown that age-appropriate restraint use is directly linked to abdominal injury risk reduction.

Current pediatric ATDs, however, have limited ability to assess abdominal injury risk in motor vehicle crashes. Neither the ATD used in U.S. regulations (Hybrid III child series) nor the ATD used in European regulations (P-series) has shown that its abdomen responds in a biofidelic manner (as it would in a real child’s body). Also, neither ATD has appropriate abdominal sensors to measure important engineering parameters, such as force and velocity, that can be used to predict the likelihood of injury to this body region.

CHOP researchers collaborated with researchers from the University of Virginia (UVA), Ford Motor Co., and Takata Corp. to fill that gap. Together they sought to improve the



This silicone-filled compressible insert uses innovative sensors to measure the amount of compression experienced by the ATD in crash environments.

Photo Courtesy of Ford Motor Co.

6-year-old ATD and its ability to determine the likelihood of abdominal injuries. This comprehensive effort involves six key steps, with the project currently in the final step:

- 1) studying real-world crashes where abdominal injuries occurred in seat-belt restrained children
- 2) measuring real children’s abdominal dimensions
- 3) defining the engineering response of a typical abdomen using an animal model
- 4) linking engineering metrics of force, velocity, and compression depth to abdominal injury
- 5) creating an abdominal insert for the Hybrid III 6-year-old ATD based on engineering and real human data
- 6) initiating a testing program to gain automotive industry acceptance of this new tool

How Do Children Sustain Abdominal Injuries?

In a review of actual crashes in which children restrained in seat belts sustained abdominal injury, CHOP researchers found that most injuries involve the seat belt directly compressing the abdomen’s internal organs, such as the liver or spleen. This can occur in several ways:

- when a child scoots forward on the soft, compressible seat cushion before a crash, creating a more horizontal lap belt angle worsened by the child moving forward and downward during the crash
- when a child places the shoulder belt behind his back, resulting in a belt geometry that may move the lap belt higher on the abdomen
- when a child is seated in a rear seat belt system that places the lap belt high on the abdomen even when both lap and shoulder belts are used and the child remains seated against the seat back

Because the pediatric pelvis is still developing, it cannot anchor the lap belt effectively. The belt tends to slide up over the abdomen where it may directly compress the internal abdominal organs against the spinal column.

Often a bruise appears on the skin of the abdomen to provide a clue as to where the injurious compression took place. A booster seat helps prevent this from happening.

A Real Child's Abdomen

To ensure that the new ATD abdomen has accurate dimensions, the researchers measured the size and shape of a representative sample of children's abdomens, internally and externally. Abdominal dimensions were measured from the CT scans (from CHOP's Radiology database) of children about the same size as the 6-year-old ATD. Digital photography was then used to measure the distance between the seat belt and key skeletal landmarks on the ribs and pelvis of 6- to 8-year-olds seated on a vehicle seat with and without a booster seat. These two approaches allowed the research team to define the dimensions of an actual child's abdomen and compare it to the structure of the existing 6-year-old ATD.

Child Abdomen Response to Seat Belt Loading

To accurately design a child ATD abdomen, researchers need to know the compressibility of a child's abdomen. They also need to know the amount and speed of compression that can be applied before injury occurs. Due to safety reasons, this research cannot be conducted on children, and suitable surrogates must be used. Researchers at UVA loaded the abdomen of anesthetized age-equivalent young pigs in a manner similar to how a child's abdomen is loaded by a seat belt. Through these tests, the researchers

were able to define how much force it takes to compress the abdomen and the depth of compression needed for injuries similar to those sustained by children in crashes to occur.

Abdominal Insert for the Child ATD

Armed with fundamental data on how abdominal injuries occur, the size of a child's abdomen, and the important biomechanical characteristics of the pediatric abdomen, the team was able to develop a new abdomen for the 6-year-old child ATD. Led by Ford Motor Co., in collaboration with Wayne State University, the researchers constructed a silicone-filled compressible insert to be used as the ATD abdomen using innovative sensors to measure the amount of compression experienced by the ATD in crash environments. At the same time, a team of researchers at the University of Michigan Transportation Research Institute were working to modify the 6-year-old ATD pelvis based on radiological studies of actual children. This joint effort led to a new advanced abdomen-pelvis that is currently undergoing an approval process through a Society of Automotive Engineers International (SAE)-sponsored task force and testing program involving more than 20 international industry, government, and research organizations.

Once approved by SAE, the new abdomen and pelvis for the 6-year-old ATD can be used to optimally protect child occupants. Novel restraint designs for children can be developed and evaluated with a tool that more accurately assesses the likelihood of abdominal injury, the second most common injury sustained by child occupants.

An ATD History*

In the late 1970s and early 1980s, P-series child ATDs were developed in Europe, while Hybrid II 3- and 6-year-old ATDs were developed in the United States.

- 1987** Development begins for child ATDs based on Hybrid III adult male
- 1992** Design for Hybrid III 3-year-old and 6-year-old begins
- 1993** Design of CRABI 6-, 12-, and 18-month-old ATDs begin
- 1993** Design of Q series ATDs begins in Europe (Q3 first, followed by Q0, Q1.5, Q6)
- 1997** Biomechanical bases and injury criteria for CRABI and Hybrid III child ATDs published
- 1997** Hybrid III 3- and 6-year-old upgraded for evaluating "Out of Position" (OOP) air bag aggressiveness testing
- 1997** Biomechanical bases for Q3 ATD published
- 2000** Design of Hybrid III 10-year-old ATD begins
- 2002** Side impact biofidelity guidelines published for pediatric side impact ATD
- 2004** Injury criteria for Hybrid III 10-year-old ATD published
- 2007** Q3 revised for side impact, Q3 biofidelity performance targets published

**Since ATD development can span four to six years or more, dates are approximate.*

About CChIPS

Several of the research efforts described in this report have been sponsored by CHOP's Center for Child Injury Prevention Studies (CChIPS). CChIPS is a National Science Foundation Industry/University Cooperative Research Center (I/UCRC) that focuses exclusively on preventing injuries to children and adolescents. Through CChIPS, researchers from CHOP and UPenn work side by side with industry members to conduct translational research that is practical to industry. Of the more than 40 I/UCRC designated centers nationwide, CChIPS is the only one that focuses solely on child injury prevention. This synergistic collaboration between industry and academia creates an ideal environment for generating ideas for new research projects and to leverage shared expertise and resources. Visit www.research.chop.edu/programs/injury/our_research/cchips.php to learn more. Industry colleagues interested in membership should contact Felicia Rowe at rowef@email.chop.edu.

DEFINING THE PEDIATRIC ATD THORAX

During a frontal crash, the seat belt compresses the chest of those buckled, causing the sternum to move toward the spine. Any adult or child ATD must accurately reproduce this chest compression to be useful to develop better restraint systems to enhance safety.

In the 1970s, researchers developing an ATD with a thorax that mimics an adult's chest compression used data from blunt impacts to the chests of adult cadavers. Since similar data did not exist for children, the design specifications for the child ATDs' thoraces were developed by scaling adult data to a child's size, not taking into account important developmental differences between the chest structure of children and adults.

As children age, the bony parts of the thorax (ribs and sternum) mature and structurally change. During childhood, the sternum is comprised of six individual bones that do not fuse together until young adulthood, adding to the chest's flexibility.

Gross geometric changes are also at play. From birth to age 2 or 3, the sternum moves downward with respect to the spine, causing the ribs to angle downward more steeply, and the shaft of the rib to twist. The connecting cartilage between the sternum and the ribs also hardens with age, likely contributing to the decrease in flexibility of the entire chest throughout the developmental process. These changes during maturation are important to consider when designing a pediatric ATD thorax because they may influence a child's response to forces

exerted on his chest in a motor vehicle crash.

Although the study of pediatric cadavers is rare, a series of thoracic impact tests on pediatric cadavers conducted by Southern Medical University in China showed a good qualitative agreement with the scaled data from adult cadavers. Important quantitative differences did emerge, however, such as the rate at which the force developed, as well as the maximum force and deflection sustained. Due to these differences, further study was recommended.

Using CPR to Collect Important Biomechanical Data

Given the small number of pediatric cadavers available for impact testing of the thorax, researchers had to find alternative ways to obtain this important biomechanical data. With funding from NHTSA, researchers at CHOP are using data collected during cardiopulmonary resuscitation (CPR) within the hospital setting to gather this information. CPR involves compressing the sternum toward the spine. Chest compression during CPR is similar in magnitude to what happens during a motor vehicle crash; it just occurs at a slower rate.

In the Emergency Department and Intensive Care Units at CHOP, clinicians use a Force-Deflection Sensor (FDS) integrated into a patient cardiac monitor-defibrillator to provide visual and audio feedback on the quality of CPR chest compressions. The FDS is placed between the hands of the person administering CPR and the sternum of

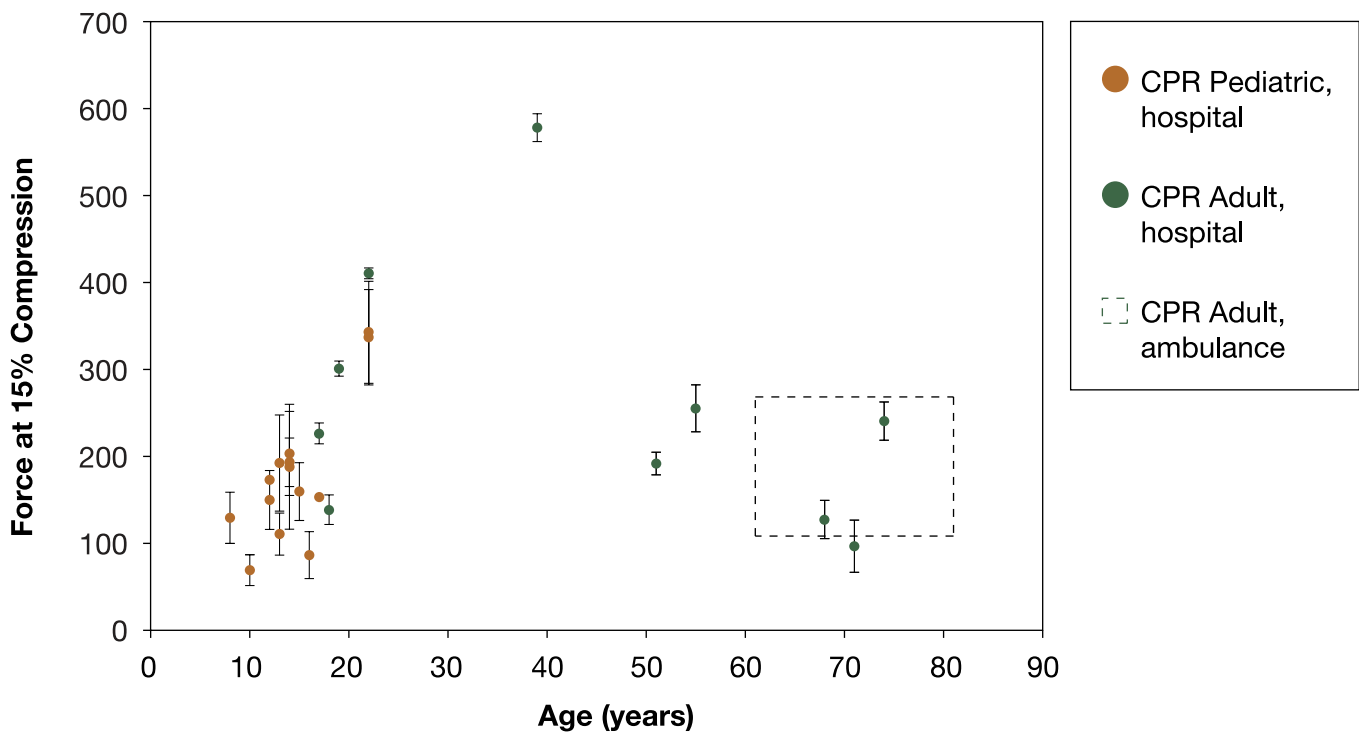
the patient, recording force and acceleration data during each compression cycle. CHOP researchers have applied this technology to assess the thoracic mechanics during CPR in a sample of pediatric subjects at CHOP and a sample of adults receiving CPR by an ambulance crew in the field. When combined with other CPR data on adults from the scientific literature, CHOP research found that the chest's stiffness increases fourfold from age 8 to 40 but falls to force levels comparable to pediatric patients after age 40. (See chart below: "Measuring Changes in the Chest's Stiffness with Age.")

More recently, CHOP researchers collaborated with Duke University and University of Virginia researchers to expose a single pediatric cadaver to seat belt forces similar to the magnitude and rate exerted in a motor vehicle crash. When compared to adult cadaver specimens that were tested in a comparable manner, the age trend similar to that demonstrated in the CPR data was seen.

What may be most important for ATD development is determining how the chest generates force to resist compression. This force can be categorized in two ways: 1. as generated by the ribs when they bend, and 2. as generated by soft tissue (lungs, heart, great vessels, etc.). In seniors, when the chest generates force to resist compression, this force is shared by the ribs and soft tissue up until the point of rib fracture when it becomes the job of the soft tissue alone. However, in children, rib fractures due to chest compression are rare. When a child's chest is compressed, resistive forces are shared by the ribs and soft tissue.

These findings highlight the dramatic differences in thoracic force-deflection properties as a function of age. Due to these differences, a child ATD's thorax may not only need to be smaller than the adult ATD's, but also possess different biomechanical properties. The studies described here are important first steps in achieving that goal.

Measuring Changes in the Chest's Stiffness With Age



The chest's stiffness changes with age, as this figure shows, increasing fourfold from age 8 to 40, and falling to force levels comparable to pediatric patients after age 40.

Source: Maltese et al, Stapp Car Crash, 2008.

THE LATEST ON THE LOWER EXTREMITIES

The lower extremities are among the most common body regions injured among children in motor vehicle crashes, in pedestrian impacts, and in situations of maltreatment. For example, when a child in a forward-facing child restraint is in a motor vehicle crash, the lower extremities are the most frequently injured. Pedestrian injuries account for 61 percent of all pediatric trauma hospital admissions, and most involve injury to the lower extremities. Fractures to the legs are the second most common presentation of child abuse, and a significant number of femoral shaft fractures have been reported in children less than 1 year of age.

Although not typically life-threatening, injuries to the lower extremities are disabling and seriously affect a child and family's quality of life. Because their bones are still



A radiological image of a pediatric femur fracture.

developing, an injury to this body region can also impair further growth. Considerable costs are associated with these types of injuries because longer periods of hospitalization are often required to treat them.

Limited data currently exist on the biomechanical and physiological properties of pediatric lower extremities that can be used to prevent, diagnose, treat, and rehabilitate these injuries. For adults, traditional biomechanical testing has utilized large test series of adult cadavers. However, with pediatric tissue, specimen supply limits the feasibility of this approach.

There have been a few biomechanical studies performed on pediatric femurs, with researchers finding that their resistance to bending forces is less than that of adults. Other limited biomechanical studies on the pediatric tibia have reported that its resistance to fracture increases during childhood and adolescence.

Animal biomechanical models have been used to understand the mechanical properties of the lower extremities. For mature animals, several previous studies demonstrate that measurements derived from noninvasive radiological methods, such as bone mineral density (BMD) assessment, relate to the mechanical and structural properties of long bones. Although these correlations are well established for mature animals, very limited data exists for immature animals, and none of these studies correlate the measurements from animals to equivalent measures in actual children.

To close this research gap, biomechanical researchers at CHOP, in collaboration with the School of Veterinary Medicine at UPenn, are implementing a novel approach to develop an age-equivalent animal model for pediatric long bones. This research will define how to correlate detailed measures in an immature animal model to similar radiological and biomechanical measurements in actual children. These data will serve as the foundation for future research that examines mechanisms of lower extremity injury and explores treatments and countermeasures, impacting the fields of biomechanics, clinical care, and nutrition and bone health.

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