Setting the Future Agenda for Child Occupant Protection: Results from a Workshop in Prato, Italy

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INTRODUCTION

Worldwide, each year nearly 400,000 people under age 25 sustain fatal injuries on the world's roads – averaging more than 1,000 deaths per day. Road traffic injuries are the second leading cause of death for 5-14 year olds representing nearly a quarter of all injury deaths. Although approximately one-third of these deaths are to pedestrians, 65 percent are to vehicle occupants. Youth are overrepresented in these mortality numbers representing 10 percent of the population but 27 percent of the traffic fatality burden (World Health Organization, 2007).

Worldwide there is incredible variability in road traffic fatality rates. Even within a region, such diversity exists. Using Europe as an example, children and adolescent motor vehicle driver/passenger deaths are over 40 times more likely in the lowest performing country (Lithuania) than in the best performing country (France) (see Figure 1). These deaths are accompanied by millions of non-fatal injuries; however, sources of injury data are scant resulting in imprecise estimates of the morbidity burden.

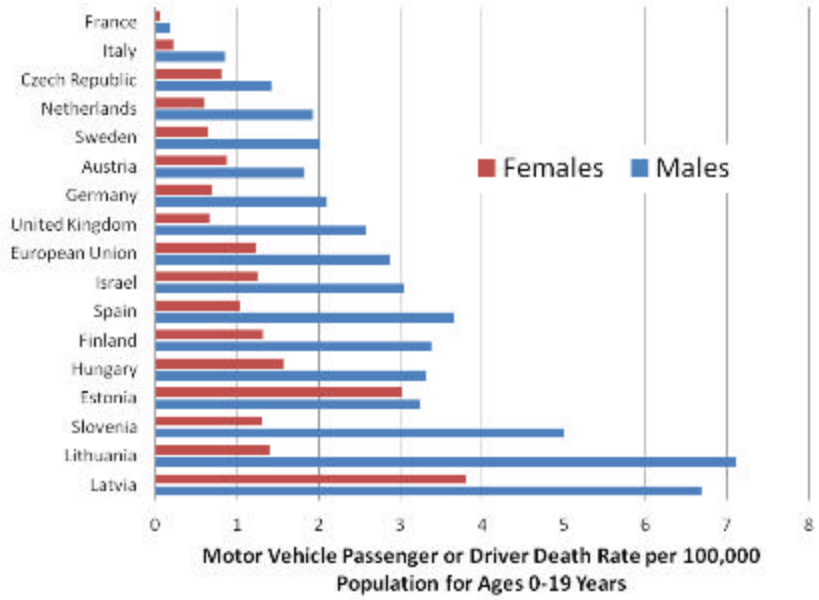

Figure 1: Motor vehicle occupant and driver mortality rates in the European region. Rate per 100,000 population 0-19 years. Source: MacKay et al, 2009. (Original source: WHO Mortality database as 3-year averages for 2003-2005 or most recent 3 years of data)

Development of solutions for traffic safety for the young (i.e., children, adolescents and young adults) is complex occupying several domains of emphasis: individual, social, vehicular, environmental and medical (see Figure 2). Change in one of these domains often alters the actions in the others and a multi-disciplinary

approach to create the scientific foundation is needed. Engineers must work in concert with behavioral scientists and epidemiologists to create a comprehensive view of injury and its mitigation (Winston et al. 1996). Epidemiologists define the magnitude of the hazard, identify risk factors for injury, and evaluate the effectiveness of interventions. Behavioral scientists examine the contribution of the human and social contexts to the injury. Biomechanical engineers apply the laws of physics and other engineering principles to systematically determine injury causation and define technology's role in mitigation to allow for new advances (e.g., products, safety standards, and test procedures). Engineers attempt to reduce the chance of crashes and their impact on the human body through thoughtfully designed environments, vehicles, and occupant protection systems.

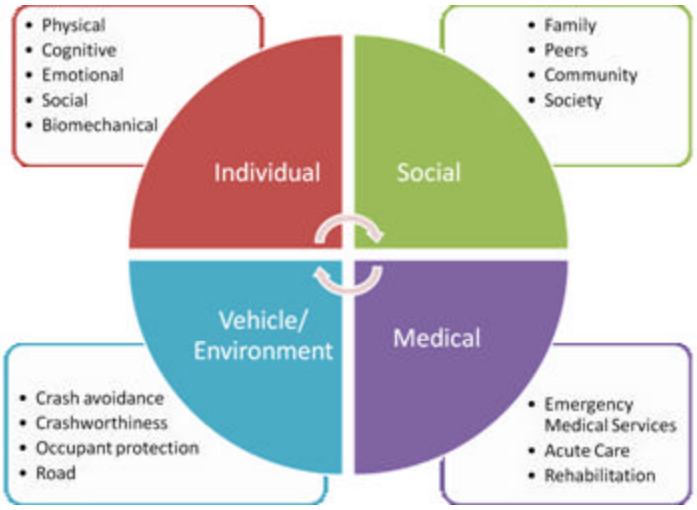

Figure 2: Domains of traffic safety solutions for youth

Effective traffic safety solutions begin with knowing the science and are rooted in data. Rigorous data can provide the scientific context and real world grounding for a diverse set of traffic safety activities. Such data provide critical evaluation and guide priority setting. However, in order to effect change, complex technical or scientific information must be translated for stakeholders such as policymakers, legislators and the lay public. To this end, collaboration between scientists and outreach and advocacy professionals is critical to convincingly "tell the story" of traffic safety.

In response to the urgent need to develop traffic safety solutions and the desire to catalyze global activities, the World Health Organization (WHO) along with the United Nations (UN) General Assembly has proclaimed 2011-2020 the Decade of Action for Road Safety, with a corresponding framework for countries and communities to increase action to save lives on the world's roads. (WHO and UN Road Safety Collaboration, 2011) This framework outlines activities that should be carried out at the local, national and global levels to stabilize and then reduce the level of road traffic injuries and fatalities worldwide by 2020 and is organized around the following five pillars (Figure 3):

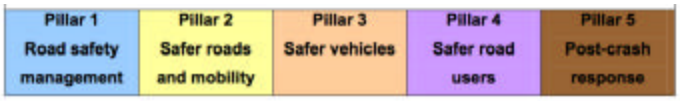

Figure 3: WHO Pillars for the Decade of Action

To leverage this attention on road traffic injuries and facilitate a focus on children, an international workshop entitled, "Setting the Future Agenda for Child Occupant Protection" was held in September 2011 in Prato, Italy bringing together international leaders in the fields of child occupant protection, biomechanics, and auto safety to:

1) Critically review the state-of-knowledge in the field;
2) Translate the Decade of Action framework to child-specific priorities; and
3) Identify high-priority research topics and strategize toward their implementation

Fitting to the model that the UN Road Safety Collaboration has provided will ensure a globally unified approach to traffic safety, and the pediatric-specific content will allow for targeted recognition of this important population with specific needs. The following describes the pediatric specific recommendations that emanated from the meeting.

PROCESS

A two day workshop was held in which the first day was composed of presentations on relevant topics. The focus of these presentations was on new research in the last two years with the goal of stimulating discussion and collaboration among active researchers in the field who are able to catalyze the needed advancements. The second day was a guided discussion focused on identification of high-priority research topics and policies and regulations and strategies for their implementation.

This effort included 20 individuals from a diverse set of key stakeholders including:

- Behavioral safety scientists
- Biomechanists
- Child restraint manufacturers
- Epidemiologists
- Government researchers
- Physicians (pediatrics, pediatric emergency medicine)
- Safety researchers
- System suppliers
- Vehicle manufacturers

A list of specific attendees is contained in the Appendix.

Presentations were given on the following topics:

- UN Decade of Action priorities
- Recent United States epidemiological data on child occupant protection
- Long term health outcomes for children
- Pediatric trunk and whole body biomechanics
- Pediatric head injury biomechanics
- Child anthropometry and relationship to anthropomorphic test devices (ATD)
- Naturalistic observation of child occupants
- Far side occupant protection for children
- Update on the European Union Child Advanced Safety Project for European Roads (CASPER)

The discussion was focused around the following topics and questions within the Decade of Action structure:

Pillar 1 - Road safety management (Data Collection, Strategic Planning, Infrastructure Development)	***Pillar 3 - Safer vehicles (Crash avoidance, Crashworthiness and Biomechanics)***	***Pillar 4 - Safer road users (Behavioral Science, Outreach and Advocacy)***
• National/global strategy • Priority setting • Realistic short-term and long-term targets • Data systems • Innovative funding mechanisms • Who should be leaders? • What partnerships are needed?	• Harmonize standards, consumer information • Needed tools (ATD/test procedures) • Injuries to target • Universal deployment of safety technologies • Accelerate uptake of technologies • Integrated child restraints	• Behaviors in need of change • Data from naturalistic studies • Influence attitudes and opinions • New laws or policies

KEY PRIORITIES IDENTIFIED

Before beginning to strategize research and policy priorities, consensus must be reached on the key targets or outcomes. For global road traffic injuries for the young, the panel placed a deliberate emphasis on not only reducing fatalities but also reducing injuries – with a particular focus on disabling injuries, short term and long term morbidity and, recognizing the impact of a child's health on their family, mitigation of familial burden.

The priorities discussed can be organized around a *Research to Action to Impact* model in which the steps are:

- Surveillance
- Identify Issues
- In-Depth Study
- Disseminate/Publish
- Implement interventions
- Measure impact

Surveillance

Effective surveillance is based on high quality data systems. The panel acknowledged that these data systems must: 1) contain child specific data, 2) be contemporary, and 3) provide the country specific data needed for change. Such data systems should characterize the degree to which occupant protection (versus other road user types) play a role in a country's child safety problem. Not every country needs a detailed surveillance system mimicked after the United States National Automotive Sampling System, Volvo's Accident Database in Sweden, or the German In-Depth Accident Study (GIDAS). The details of the data collected and on whom should be informed by the desired targets and interventions of the region/country/locale of focus. There should be, however, a set of recommendations directed that defines

the minimum data fields and best practice methods for collecting that data. The Model Minimum Uniform Crash Criteria Guideline in the United States and the Common Accident Data Set in Europe are two examples of such country/region-specific efforts. (MMUCC, 2011; Yannis et al, 2009) Effort should be made, however, to define aspects of child-specific data that must be collected in these surveillance systems worldwide.

Another aspect of surveillance that was highlighted is the need to know country specific occupant seating patterns in order to understand the landscape of the rear seat – i.e, who is seated where, in what seat positions, by what restraints (if any). This knowledge will lead to the identification of appropriate interventions – technological, regulatory, legislative or behavioral. In sum, surveillance should define the geographic variation of the traffic safety problem to solve – with enough breadth to be representative and with enough depth to move to the next step of the *Research to Action to Impact* paradigm – identification of issues.

Identify Issues

The identification of issues in need of further study is often achieved through rigorous epidemiological analyses that quantify the distribution and the determinants of injury. These analyses are tightly coupled with the surveillance activities described above. A particular area of focus that was highlighted by the panel was the need to more clearly define the epidemiology of disabling motor vehicle injuries for children. There are a few commonly used measurements of functional disability and long-term outcomes in children including the Functional Independence Measure (FIM) and the Pediatric Quality of Life (PedsQL). In addition to collecting data on large numbers of injured children in order to understand their long-term outcomes following injury, it will also be necessary to continue methodological research that compares these various measurements to each other and existing scales of injury severity. The most commonly used and accepted measure of injury severity, the Abbreviated Injury Scale, unfortunately has limitations in children. As an example, lung contusions which are rated as an AIS 4 on 1-6 scale (with 6 being the highest rating, likely high lethality of the injury) often heal without clinical intervention in children and as a result, are not associated with the same severity as these injuries in adults. The need to develop a pediatric component to AIS was underscored.

Consensus was reached around the importance of head and traumatic brain injuries. Head injuries account for about one third of all fatalities of children involved in motor vehicle crashes (MVCs) (Scheidler et al., 2000) and are the most common serious injuries sustained by children in MVCs regardless of crash direction (Arbogast et al., 2002, Durbin et al., 2003, Arbogast et al., 2005; Howard et al., 2004). These injuries are of critical importance with regard to long-term disability. Determination of the prevalence and nature of these injuries, the circumstances under which they occur and the importance of head contact in the causation scenario needs further study.

In-Depth Study

Once issues are identified, the appropriate discipline must be utilized to study the topic in-depth. Relevant disciplines in traffic safety include Behavioral Science, Biomechanics, Crashworthiness, Public Health, and Epidemiology. The table below summarizes several research priorities in each discipline as highlighted by the panel.

Discipline	Research Priority
Behavioral Science	• Determine children's postures and positions in rear seat and relate those to restraint system positioning and subsequent risk of injury • Improve ability for parents to consistently make age-appropriate restraint choices for their children • Determine country-specific barriers to adult restraint use (i.e., recognizing that adult restraint use leads to increased child restraint use) • Determine influence of child presence on driver behavior or distraction
Biomechanics	• Determine age-based brain injury tolerance • Develop novel methods for defining biomechanics across the development spectrum (from infant to young adult) – move beyond traditional methods of scaling • Define the ideal restraint protection for those children outside of harness-based child restraints • Define relative role of physical ATD and FE ATD in the engineering process – identify needed improvements in each • Catalogue and ensure global availability of pediatric-specific simulation tools
Crashworthiness	• Understand safety in far side crashes for children including the kinematics of the child seat and interaction with other occupants • Define the characteristics of the most basic restraint that provides adequate protection in order to develop low-cost restraints for emerging markets • Develop strategies to increase the use of LATCH/ISOFIX or develop new technology that attaches the child restraint to the vehicle with something other than the seat belt • Determine the relative balance of add-on child restraints and vehicle built-in systems adapted for the child
Public Health	• Educate key stakeholders (e.g., governments, health care providers, parents) about the importance of child motor vehicle safety • Evaluate viability of child restraint rental schemes to improve accessibility of restraints • Define and overcome country-specific cultural barriers to implementation of child safety regulations and policy
Epidemiology	• Measure effectiveness of new vehicle safety technologies • Continue to re-evaluate best practice recommendations as technology changes

The panel had a particular focus on recent advances in the field of naturalistic observation of child occupant postures and seating behavior during riding. This is an exciting new area of research that crosses many disciplines and may provide valuable data that will allow a paradigm shift from protection of an ideally in-position occupant to protection of child occupants in the positions they actually assume in the vehicle.

Furthermore, recent research conducted by panel members has shown that there is still confusion amongst parents regarding CRS use, especially in regards to the appropriate thresholds for transition from a booster seat to an adult seatbelt and the use of the front seat. This confusion may extend to the safety principles

behind the use of CRS and therefore it is vitally important to educate parents about both legislation for appropriate CRS, booster and adult seatbelt use, and the safety principles driving these recommendations.

Disseminate/Publish/Exchange information

In order to affect change, it is critical that information, data and research results are shared among all key stakeholders. These may include researchers, governments, industry, community leaders, and the lay public. This interaction should occur early in the research process, establishing a dialogue that defines the need for data, the breadth and depth of that need, mechanisms for data sharing, and plans of action once data are received. Through this exchange, one can determine whether successful interventions can be easily adapted from one country or region to another or whether the solution must lie in the development of novel interventions specific to a given region.

Often, however, coherent coordinated dissemination pathways are lacking to facilitate this interaction. While it is typical that academic research centers publish their findings in peer-reviewed literature that is read by other researchers, there is a gap between the scientific literature that contains the latest knowledge and awareness of that knowledge by those who are in a position to act on it (national and international policy makers, governing bodies, parents, etc). Information must be shared in a usable form to decision makers who must be motivated to receive it and educated as to how to use it. The research community must:

1) Embrace and become skilled in the use of alternative research dissemination tools, such as web pages and social media that can be targeted to non-academic stakeholders.

2) Understand marketing and other methods for changing behavior and use those tools to effect policy and behaviors based on the latest research.

3) Link into available child health, medical, and transportation safety stakeholder networks at the national and international level to ensure the child road traffic safety story is being heard.

As an example, in May 2011, the WHO adopted its first ever resolution on child injury prevention urging the development of science-based policies to prevent child injury as well as support of relevant research, capacity building and resource mobilization. (WHO, 2011) This resolution elevated the issue of child injury by recognizing it as a "major threat to child survival and health". The research community must now leverage this attention to promote child road traffic safety. To do so requires novel approaches outside the traditional tactics of peer-reviewed manuscripts and scientific conferences.

Implement Interventions

Interventions can take many forms – educational tools, improved product design, or improved legislative and regulatory policy in order to achieve measurable impact in the form of injuries avoided and lives saved. The panel identified several key policies, regulations and interventions that are urgent to improve traffic safety for the young. These include:

- Modify pediatric ATD to incorporate known biomechanical data – include ability to position the ATD in relevant postures
- Efficiently incorporate the most advanced pediatric ATD into current regulations worldwide
- Develop a dynamic restraint performance requirement for the pediatric and adolescent occupants in the rear seat of actual vehicles in frontal crashes – can be regulatory or consumer information tests

- Implement static seat belt fit assessments for the rear seat of vehicles for both adolescent and adult occupants
- Make child seat regulatory testing more vehicle like (e.g. include a floor, provide potential for interaction with front seat)
- Extend head impact protection regulations to components of vehicle interior with which child occupants interact
- Evaluate the potential unintended consequences (size and shape of child seat) of currently proposed side impact child seat regulations. Consider a regulation that encourages shared responsibility between the child seat manufacturer and the vehicle manufacturer.
- Strive to develop in-vehicle restraint products that are fully adjustable and provide optimal protection for a range of occupants from a child that has exceeded the weight limit of their harness based child restraint to an adult
- Develop improved strategies for enforcement as well as implement current enforcement strategies
- Initiate the development of a range of CRS accessible to emerging markets
- Develop strategies tofit three "correctly" restrained children in the rear seat in the smaller vehicles of the future

Measure Impact

The last component in the *Research to Action to Impact* cycle is to measure the impact of the intervention. This relies on the surveillance systems discussed at the beginning being in place. As the traffic safety landscape is constantly changing, no one intervention is introduced in isolation from other activities in the field. This shifting environment in combination with potential differences between the effectiveness (real-world) and efficacy (laboratory or experimentally controlled) of interventions make this last step crucial. Appropriate assessment of the impact relies on the quality of information systems in place. As a result, the information to be collected to those systems is critical to the whole process and needs to be updated at the same time that new technologies/standards/interventions are in place.

CONCLUSIONS

Motor vehicle crashes remain the leading cause of death and disability for children and young adults and represent close to half of all unintentional injury deaths to children and adolescents. Prevention of the fatalities and disabling injuries associated with MVCs is thus a priority not only for the traffic safety community but also for ensuring our children's overall health. The introduction of the Decade of Action for Road Traffic Injury has shown a spotlight on this issue.

The panel of experts convened for the Prato Workshop envisioned two key aspects to the future agenda of child occupant protection:

- *Advancing the fundamental science of child occupant protection in several key disciplines.*
  Even with the substantial increases in age-appropriate restraint use and rear seating for children realized in developed countries over the past two decades, the protection of children in motor vehicles can be further optimized. Achieving optimal protection will require knowledge of the unique biomechanical needs of children and youth, an understanding of their and their drivers' behavior in the vehicle, further development of pediatric-specific tools available to vehicle and restraint designers, and a holistic view of injury mitigation systems that combines child restraints and vehicles safety systems to achieve optimal safety.

- *Leveraging current knowledge to accelerate child occupant protection in countries where traffic safety is in its infancy*

  There is no justification for allowing emerging markets to progress at the same pace through the stages of child occupant protection that countries/regions such as the US, Europe and Australia have gone through over the last 50 years– from unrestrained children in the laps of caregivers to lap only seat belts worn by toddlers to advanced child restraints with dedicated attachment systems in the rear seats of vehicles. Mechanisms must be created that allow for the sharing of child traffic safety knowledge – in the context of the country specific needs – with countries/regions such as India, China and Latin America that are adding vehicles at a rapid rate daily. The focus of child road traffic injury prevention must expand to include other vulnerable road users in these emerging markets.

Further advances in child road traffic injury protection will require rigorous collaborative research by multiple disciplines and global organizations that consider the unique needs of children. This research must start with a comprehensive description of the problem that includes the context, actual use and behavior and assess outcomes that go beyond fatality. Evidence resulting from this research will provide an intellectually sound underpinning to the eventual introduction of appropriate public policies, improvements in vehicle and restraint design, and adaptation of consumer attitudes and behavior that further increase the protection of children.

Lastly, the entire field must work together to ensure that child road traffic safety is prioritized in funding decisions in both the traffic safety arena as well as child health. The Decade of Action is an important step – a moment in time where the issue of road traffic injury has gotten the world's attention. It will however, be only a footnote in history unless it is used as a platform for ensuring that child road traffic safety in on the worldwide child safety agenda with an appropriate level of funding.

WORKSHOP ATTENDEES

Specific attendees of the workshop are listed below. All contributed greatly to the discussion at the workshop and the formation of the concepts described in this manuscript.

- Marianne Andersson, MS – Saab Automobile AB, Chalmers University of Technology, SAFER
- Kristy Arbogast, PhD – Children's Hospital of Philadelphia, University of Pennsylvania
- Farid Benjellal - Britax Group, Ulm, Germany
- Katarina Bohman, MS – Autoliv Research, Karolinska Insitutet, SAFER
- Ola Bostrom, PhD – Autoliv Research, Chalmers University of Technology, SAFER
- Dennis Durbin, MD, MSCE – Children's Hospital of Philadelphia, University of Pennsylvania
- Brian Fildes, PhD - Monash University Accident Research Centre
- Jason Forman, PhD – University of Navarra
- Lotta Jakobsson, PhD – Volvo Car Corporation, Chalmers University of Technology, SAFER
- Richard Kent, PhD – University of Virginia
- Sjann Koppel, PhD - Monash University Accident Research Centre
- Philippe Lesire, PhD– Laboratory of Accidentology and Biomechanic PSA Peugeot -Citroen/Renault
- Francisco Lopez-Valdes – University of Virginia
- Matthew Maltese, MS - Children's Hospital of Philadelphia, University of Pennsylvania
- Matthew Reed, PhD– University of Michigan
- Isabelle Stockman, MS – Chalmers University of Technology, SAFER

- Mats Svensson, PhD– Chalmers University of Technology, SAFER
- Suzanne Tylko, BSN - Transport Canada
- Flaura Winston, MD, PhD - Children's Hospital of Philadelphia, University of Pennsylvania
- Mark Zonfrillo, MD, MSCE - Children's Hospital of Philadelphia, University of Pennsylvania

ACKNOWLEDGEMENTS

The authors would like to acknowledge SAFER, Vehicle and Traffic Safety Centre at Chalmers, and Monash University Accident Research Centre (Europe) for providing financial support for the conduct of the workshop.

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