The burden of traumatic injury to the world's health is staggering, and this burden is disproportionately born by children. Road traffic crashes, drowning, fires, interpersonal violence, poisoning, and suicide are all among the leading causes of children worldwide. Injury prevention efforts are an important societal investment. Injury prevention is best accomplished through an integrated and comprehensive approach that involves multiple partners. Pediatricians are a very important stakeholder in the prevention of injuries among children.

Descriptors: TRAUMATIC INJURY, PEDIATRIC, PREVENTION, EPIDEMIOLOGY

SCOPE OF TRAUMATIC INJURIES WORLDWIDE

The burden of traumatic injury to the world's health is staggering, and this burden is disproportionately born by children. Injuries cause nearly six million deaths each year, and nearly a quarter of these deaths occur among children younger than 15 (1). For children aged five through 14, seven of the 15 leading causes of death are types of traumatic injuries. These include road traffic injuries, drowning, war injuries, fire, interpersonal violence, poisoning, and self-inflicted injuries. Between the ages of 15 and 29, seven of the 10 leading causes of death are injuries.

The World Health Organization anticipates that, if current trends continue, road traffic injuries, interpersonal violence, war, and self-inflicted injuries will all be among the leading 15 causes of death by 2020. Road traffic crashes, which in 2000 ranked as the ninth leading cause of disability adjusted life years lost, is predicted to reach the rank of three in 2020 (1). Operations of war will rise from the rank of 16 in 1990 to eight by 2020, and interpersonal violence will rise from 19th to 12th. Deaths are just a small part of the overall injury burden. For every injury death in the United States, for example, there are an estimated 3200 reported injuries of which 550 require emergency medical care (2). These injuries cause significant physical harm and a high probability of temporary physical impairment or even life-long disability. In addition, these injuries can lead to emotional trauma, time away from school, and considerable monetary expense.

The public is largely unaware of the preventable nature of many injuries. The most common reference to injurious events, "accidents", evokes a feeling of chance, misfortune, and helplessness. Injuries, however, occur in predictable patterns that can be altered to prevent an injury from occurring or to reduce the severity of an injury.

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Pediatricians have several critical roles in injury prevention. One primary role of the pediatrician is to provide anticipatory guidance to parents so that parents are aware of their child's injury risk as different life stages and create safe environments. Pediatricians also play an important role as social advocates. Physicians can educate stakeholders about the important health threats to young children and encourage these stakeholders to take action. For example, the American Academy of Pediatrics issues many policy statements supporting injury prevention measures, ranging from safe playgrounds to the execution of juvenile prisoners.

Pediatricians have a strong and respected voice in the community and can therefore focus public attention on issues that can lead to greater public good. The goal of this manuscript is to define injury risks for different developmental age groups and to present a theoretical approach to the prevention of injuries.

INJURY RISKS BY DEVELOPMENTAL AGE

Birth through 6 months

Injuries to very young children are usually a combination of environmental influences and lack of appropriate supervision. In the very worst cases, these injuries are intentionally inflicted by a caregiver. Children at this age are characterized by the most rapid rates of growth found throughout the life cycle, and have disproportionately large heads with open skull sutures and calcifying long bones. Although children this age
are not self-mobile, they crave environmental interactions and constantly take in information on their surroundings.

Worldwide, injury risks at this age include falls, burns and scalds, and choking. Falls are best prevented by reducing exposure to surfaces with differential heights and supervision to reduce falls from surfaces such as beds, changing tables, and from strollers. Physicians should always rule out abusive trauma when a severe injury to a young child, especially to the head, is attributed to a fall (4). In developed countries, very young children spend an increasingly time as passengers in cars. Infant car seats have been very effective in reducing motor vehicle occupant injuries to children. Car seats used correctly and placed in the proper seating position decrease fatality and serious injury by approximately 71 and 67 per cent, respectively (3). However, effective use of car seats must involve parental education, policy initiatives to require their use, and adequate resources to make safety seats available.

Six to 12 months

Most children become self mobile through crawling or walking at this stage, and this opens many new possibilities for environmental exploration and injury risk. They become increasingly aware of their social environments, developing a potential fear of strangers. Children in this age should be able to actively explore their environments, and thus their homes and play areas need to be designed to be free of severe injury hazards. Injuries during this period are characteristi-cally falls, burns and scalds, drowning, poisoning and choking. At about nine months, their pincer grasp matures, enabling them to put very small objects into their mouths. Parents need to be educated about choking hazards from food and small objects, and to remove these from the child's reach. Policy efforts, such as those that require child-resistant caps on medicine bottles, can be effective in reducing choking and poisoning from medications (5).

Pre-School (Ages one through five)

The toddler years are characterized by increased mobility with poor coordination. Toddlers have pre-operational thinking which is illogic, and although they can follow directions they often do not understand them. Toddlers imitate the behaviors of those around them and seek feedback about these behaviors. They will formulate future behavior based on these imitative/feedback experiences.

The main injuries to toddlers include falls, burns, drowning, pedestrian and bicycle injuries. Pedestrian injuries are of increasing concern because children must interact with increasingly complex and busy roadways. The combination of increased mobility with a lack of understanding of the traffic environment (e.g. inability to judge the speed of oncoming cars) makes them very vulnerable to injury. While children can understand the basic skills of road crossing, they are usually unable to apply these skills when

### Table 1
Leading causes of death for children, World Health Organization, 2000

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Rank</th>
<th>0-4 years</th>
<th>5-14 years</th>
<th>15-29 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lower respiratory infections</td>
<td>2</td>
<td>134 248</td>
<td>Childhood cluster diseases</td>
</tr>
<tr>
<td>2</td>
<td>Diarrhoeal diseases</td>
<td>1</td>
<td>315 412</td>
<td>Childhood cluster diseases</td>
</tr>
<tr>
<td>3</td>
<td>Childhood cluster diseases</td>
<td>1</td>
<td>108 666</td>
<td>Diarrhoeal diseases</td>
</tr>
<tr>
<td>4</td>
<td>Low birth weight</td>
<td>1</td>
<td>025 488</td>
<td>Lower respiratory infections</td>
</tr>
<tr>
<td>5</td>
<td>Malaria 905 838</td>
<td></td>
<td></td>
<td>Diarrhoeal diseases</td>
</tr>
<tr>
<td>6</td>
<td>Birth asphyxia and birth trauma</td>
<td>787 179</td>
<td>Malaria 76 257</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>HIV/AIDS 419 480</td>
<td></td>
<td></td>
<td>HIV/AIDS 46 022</td>
</tr>
<tr>
<td>8</td>
<td>Congenital heart anomalies</td>
<td>281 751</td>
<td>War injuries 43 671</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Protein-energy malnutrition</td>
<td>172 530</td>
<td>Tuberculosis 36 362</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>STD's excluding HIV 142 176</td>
<td></td>
<td>Tropical cluster diseases 31 845</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Drowning 115 922</td>
<td></td>
<td>Fires 30 599</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Anencephaly 85 247</td>
<td></td>
<td>Interpersonal violence 24 668</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Meningitis 76 870</td>
<td></td>
<td>Leukaemia 23 808</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Road traffic injuries 75 710</td>
<td></td>
<td>Poisoning 23 293</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Tuberculosis 67 372</td>
<td></td>
<td>Self-inflicted injury 21 967</td>
<td></td>
</tr>
</tbody>
</table>

they are engaged in play. Thus, many of young children's pedestrian injuries occur when the child runs into the street while playing or not paying attention (6). Because of their small stature, cars cannot see children in the road and may not successfully avoid hitting them. Spleen and liver injuries are particularly common among children hit by cars because at this age these organs are differentially large within the abdominal cavity and have less bony protection from the ribs than the adult body.

Primary School (Ages six through ten)

During the early school years, children establish good coordination of large and small muscle groups and must engage in vigorous physical activity for optimal development. Children will begin to have differential rates of growth, so children of the same age will vary in their height and weight. They begin to develop concrete operational thought and have increased capacity to make simple decisions. Children begin to shift their imitative behavior from adults to peers, and some begin taking risks to seek peer approval. Road traffic injuries, falls, injuries during sports and recreation, and drowning are the most common injuries during this age range. In politically unstable countries, children can experience war and weapon-related injuries, as well.

Adolescence (ages 11-17)

Adolescents have the difficult cognitive tasks of developing an identity psychologically independent from friends and peers, developing a sexual identity, and beginning to define their place in the world. Physical and cognitive changes that accompany puberty lead to a tumultuous period of ups and downs, sporadic asynchronous physical growth, constant hunger, changes in hormonal balances, and sleep patterns. Adolescents reasoning process are inductive and highly influenced by peers. Adolescents have decreasing adult supervision. Adolescence is marked by a sharp increase in interpersonal violence and self-inflicted injury, in addition to ongoing risks for road traffic injuries, drowning, fires, and poisoning. Unlike younger children, drowning and road traffic crashes are much more likely to involve the use of alcohol or drugs. In many countries, war injuries and occupational injuries are also common. In many countries, adolescents can be licensed to drive, and this is marked with a sharp increase in motor vehicle occupant injuries.

Adolescent suicide is an important public health and medical issue, yet little work on prevention has been done in this area. Although some level of suicidal thought is normal in adolescence development, concrete thoughts of attempting suicide, symptoms of depression, or rapid changes in behavior should all be considered a warning of potential suicide risk. Accidental or purposeful drug overdoses also contribute significantly to self-inflicted deaths among adolescents. The risks and causes of injury among children are diverse, and efforts to address all of the diverse risks for injury may seem daunting. Yet, comprehensive approaches to the prevention of injuries have proven effective many times over. The key is to identify an organized and systematic approach.

THEORETICAL APPROACHES TO INJURY CONTROL

The main objectives of injury research are to prevent the occurrence of injuries and to reduce their level of severity. Limiting injury prevention strategies to any single aspect of the many causes of injuries is an ineffective and narrow approach; successful strategies will incorporate many countermeasures and involve many different professionals (7). Within the framework of the public health model, the primary focus of injury control is to identify sources of energy forces which cause injury, define mechanisms of human exposure, and to identify precisely where interventions (countermeasures) may be introduced.

Public health defines three levels of prevention. *Primary prevention* aims to prevent the event which causes injury by eliminating the mechanisms of energy transfer or exposure. Traffic safety laws which prevent automobile crashes, fences around swimming pools which prevent submersion and drowning, locking devices on guns and safety caps on poisonous substances are all examples of primary prevention which reduce or eliminate the chance of exposure.

The goal of *secondary prevention* is to eliminate injuries or reduce injury severity once a potential injury-producing exposure has occurred. Motorcycle and bicycle helmets, seat belts, life vests, and bullet proof vests are examples of secondary prevention. It is important to note that some of the most effective secondary prevention strategies do not eliminate all injuries. For example, the motorcycle helmet is very effective in reducing head trauma in motorcycle crashes, but is not effective in preventing trauma to other body regions. Seat belts do not prevent all injuries in vehicle crashes; cuts, contusions, and extremity fractures are common among belted vehicle occupants because belts do not restrain the limbs (8). The crucial role of seat belts is to reduce severe injury to critical anatomic regions such as the head or chest, and for this purpose they are enormously effective.

Tertiary prevention acknowledges that an injury has occurred, and aims to reduce the consequences of the injury. These efforts can include emergency response, trauma care, social work, and physical, occupational, and speech therapy. Some of the most important advances in injury prevention have occurred with the development of organized trauma care systems in the last decades (9). However, less attention has been focused on the emotional and psychological consequences, and subsequent recovery, from a severe injury.

One framework for conceptualizing the many approaches to injury prevention is termed the "4 E's", which consist of *Education*, *Environmental modification*, *Enforcement*, and *Engineering*. Education refers to efforts using educational messages to increase safe behavior among the intended audience. Of the four approaches, education is perhaps the most difficult to implement. Successful educational messages must be clear, appropriate for the audience, and must be periodically repeated to maintain behavior change. Many educational strategies
have been implemented to teach young children about safety. These include programs such as RiskWatch (http://www.riskwatch.org/) and Think First (http://www.thinkfirst.org/). These programs have demonstrated success in improving children's knowledge, attitude and safety behaviors, but their larger impact on reducing injury rates is difficult to enumerate (12).

The effectiveness of environmental modification has been demonstrated through reduction in motor vehicle crashes following changes in the driving environment (11). Examples include skid-free road surfaces, cross slopes on curved roadways in areas with heavy rainfall, separation barriers on freeways and two-way roads. Other examples of successful environmental modification include the introduction of pool fencing barriers, window guards, reducing the temperature on hot water heaters, and installing stair guards. Enforcement refers to legislative regulations and the enforcement of these activities.

One important component of a successful legislative effort involves identifying the audience. For example, educating legislators regarding effective safety legislation may be more beneficial than broad community-based education. One example was the implementation of the Poison Prevention Packaging Act, which also established state Poison Control Ho-

tines. These legislative approaches were only possible due to the availability of data to educate legislators about the risks for childhood poisonings, which were dramatically decreased following the legislation (10).

Engineering advancements have been highly successful in reducing injuries. The most notable examples are the seat belt and airbag, which have been attributed with decreasing injuries in frontal collisions by over 50% (13). Although engineering measures tend to be very effective, they must be followed to determine if the engineering strategy introduces new injury risks. An example of this phenomenon involves the airbag, which has caused several fatalities among infants in car seats placed in the front passenger seat.

The Haddon Matrix

One of the most successful theoretical approaches to injury prevention is the Haddon Matrix, developed by Dr. William Haddon in the 1970's. The Haddon Matrix identifies three phases in an injury event, and links approaches to prevent or reduce injury in each phase. This matrix was developed for application to countermeasures for highway safety but continues to be a useful theoretical framework for many types of injuries (14, 15).

The Haddon Matrix divides the timing of the injury event into three phases: pre-event, event, and post-event. In the pre-event phase, as in primary prevention, the goal is primary prevention to eliminate any energy transfer to the host. Additional examples include fences around swimming pools which prevent submersion, trigger locks on guns, and safety caps on poisonous substances are all examples of countermeasures that reduce the chance of exposure to energy. In the event phase, which represents secondary prevention, the goal is to eliminate or reduce the amount of energy absorbed by the host once an energy transfer has occurred. Post-event interventions, also called tertiary prevention, reduce the consequences of the injury once an injury-producing energy transfer has occurred.

The Haddon Matrix categorizes interventions in each injury phase into those that affect the host, the vehicles or vectors in the causal pathway, and the environment. The environment is often separated into physical and socioeconomic components. While the Haddon Matrix is an important tool to recognize the many opportunities for prevention, it is not a useful tool in deciding which intervention approach to implement. Table 2 presents an example of the Haddon matrix for childhood falls.

### Table 2

*The Haddon Matrix for the Prevention of Childhood Burn and Scald Injuries*

<table>
<thead>
<tr>
<th>Human Factors</th>
<th>Vehicle or Vector of Injury</th>
<th>Physical Environment</th>
<th>Socioeconomic Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preinjury Teaches children not to play with matches</td>
<td>Fire safe cigarettes</td>
<td>Use safe heating sources in homes</td>
<td>Implement policies to reduce cigarette smoking (a major cause of home fires)</td>
</tr>
<tr>
<td>Injury Fire escape plans</td>
<td>Use fabrics in children's sleepwear, sofas, and curtains that are flame-resistant</td>
<td>Reduce temperature of the water heater</td>
<td>Implement policies to require smoke alarms in all homes</td>
</tr>
<tr>
<td>Postinjury Teaches the general public about first aid</td>
<td>Include non-toxic building materials, such as exclusion of lead and asbestos in homes</td>
<td>Access to trained firefighters and EMS personnel</td>
<td>Training medical professionals in burn treatment and management</td>
</tr>
</tbody>
</table>
CONCLUSION

Prevention strategies are not only possible, they are imperative. Protecting children from injuries has important consequences for the children, but will also benefit families, communities, schools, and the medical community. Investment in injury prevention pays off quickly, particularly when primary prevention efforts are undertaken. Pediatricians are a critical partner in injury prevention efforts through their contact with patients and families, as well as their potential role as safety advocates.

Acknowledgements

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LITERATURE


