The History of Injury Control and the Epidemiology of Child and Adolescent Injuries

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Abstract

Unintentional injuries claim the lives of more children each year than any other cause of death. A substantial proportion of child hospitalizations and emergency department visits also are attributable to unintentional injuries. The conceptualization of unintentional injuries as a public health problem that is preventable has gained credibility over the past few decades, as effective solutions to reduce the burden of injuries—such as child safety seats, bicycle helmets, and smoke detectors—have been identified. Successful implementation of these strategies requires a clear understanding of the circumstances surrounding injuries and the risk and protective factors that influence the likelihood that a child will be injured. Although adequate data on these factors is available for some causes of injury, such as motor vehicle crashes, it is almost nonexistent for others, such as unintentional firearm injuries.

Overall, unintentional injury rates are highest among adolescents ages 15 to 19, males, children from impoverished families, and minorities. Also, some injuries occur more often in rural areas. Although these demographic risk factors cannot be modified, environmental and behavioral risks, such as unsafe roads, alcohol intoxication, unfenced swimming pools, and the absence of a smoke detector in the home, can be modified successfully with appropriate strategies.

Motor vehicle occupant, drowning, and pedestrian injuries were the most common unintentional injuries causing death among children ages 0 to 19 in 1996. Together, these mechanisms accounted for more than half of all unintentional injury deaths among children and adolescents, although rates varied considerably by age. Child injury death rates across most age categories and mechanisms of injury have declined during the past 20 years, yet the reasons for these declines are poorly understood. Additional research about risk and protective factors, and efforts to implement successful injury prevention strategies among populations at highest risk for injuries, are necessary to further reduce the toll on children's lives.

Unintentional injuries are the leading cause of death to children over age one in the United States. In 1996, more than 13,000 children and adolescents under age 20 died from unintentional injuries nationwide. These deaths include many causes of injury (see Table 1), such as
motor vehicle crashes, falls, and burns, but specifically exclude suicide and homicide. (Suicide and homicide, including child abuse, are classified as intentional injuries and are treated separately in many discussions of injury prevention.) The number of unintentional injury deaths of children in the United States is greater than the next nine causes of death combined, which occur at only a fraction of the rate of deaths attributed to unintentional injury. With the sharp decline in childhood deaths related to infectious diseases over the past 50 years, prevention of unintentional injuries among children and adolescents has emerged as one of the top public health priorities.

Death is the most dramatic outcome of injury, but it is not the most common. Nonfatal injuries occur with much greater frequency than deaths for most categories of unintentional injuries. It is estimated that approximately 18 hospitalizations and 233 emergency department visits occur for every injury death. An estimated 21.2 million nonfatal injuries occurred annually among youths 21 years of age and younger between 1987 and 1994, involving almost one-quarter of all youths each year. Males represented 61% of these injuries, while 86% of injuries occurred to whites and 75% occurred in metropolitan areas (see Table 2).

After pneumonia, unintentional injuries are the second leading cause of hospitalization among youths under 15 years of age, accounting for 241,000 hospital admissions in 1995. The most common types of injuries leading to hospitalization among children result from falls, motor vehicle crashes, and poisoning (see Table 3).

Children 15 years of age and younger in the United States made an estimated 8.7 million emergency department (ED) visits for injuries during 1992, accounting for 39% of all ED visits in this age group. Approximately 93% of these visits were for unintentional injuries. The most common reasons for an injury-related ED visit included falls, being struck against a person or an object, motor vehicle crashes, and lacerations.

Children suffer directly and indirectly from unintentional injuries. In addition to dying or becoming disabled from injuries, children may also lose a parent to injuries, since unintentional injuries are the leading cause of death among adults under age 35, often their parents' age group. The psychological trauma associated with injury-related disability among adults also affects children in the family and can result in long-term problems caused by the injured adult's pain or inability to work.

Rates of unintentional injury deaths among children for most mechanisms have gradually declined over the past several decades (see Figure 1). Between 1979 and 1996, deaths from all unintentional injuries declined by 43%, or an annual total of 9,679 deaths, among children and adolescents 19 years of age and under. Substantial rate decreases occurred for almost every cause of injury. The largest decrease occurred among poisoning deaths, while the smallest occurred among fire- and burn-related deaths. Although great reductions in injury mortality have been observed, almost one-third of injury deaths among children are preventable using known strategies.
The reduction in childhood unintentional injury rates in the United States during the past 25 years is not a coincidence. These changes have occurred in the context of concerted efforts by many people shaping injury prevention as a public health discipline in the areas of surveillance, intervention, and evaluation. This article will explore the epidemiology of childhood unintentional injuries by examining the distribution of injuries by major causes and age groups over time. Risk and protective factors for particular causes of injuries will be examined, and knowledge gaps identified. Potential interventions for each cause of injury will be discussed briefly within the context of existing knowledge of risk and protective factors. Other articles in this journal issue examine in greater detail the effectiveness of specific injury prevention interventions at the individual, community, state, and national levels. To provide a backdrop for understanding the reduction in certain types of injuries, this article begins with a discussion of the development of injury control as a public health discipline and a major public policy priority in the United States.

The History of Injury Control

The Semantic Debate

The importance of injuries as a leading killer of children has been recognized for centuries. Until recently, injuries were commonly referred to as "accidents." As advocates struggled to bring injury control into the public health domain, however, the word "accident" was recognized as a barrier. The dictionary defines "accident" as "a happening that is not expected, foreseen, or intended; a chance or fortune." These meanings imply randomness and lack of predictability, and they defy a specific causal model. In fact, as early advocates of injury control concluded, the opposite is true of injuries.

The more accurate term of "injury" is defined as the transfer of kinetic, thermal, radiation, or chemical energy to the human body, leading to tissue damage and destruction at a cellular level. The definition has been expanded to include drowning and choking/asphyxiation, although the transfer of energy causes neither of these mechanisms. Injury occurs when the amount of energy transferred to the body exceeds the maximum tolerance for affected tissue. The severity of an injury should be predictable, following the principles of biology and physics, and not random. Similarly, science has helped to further dispel the myth of "randomness" of injuries by identifying specific factors, known as risk or protective factors, that elevate or reduce the likelihood of sustaining an injury. The identification of risk and protective factors is a crucial prelude to any credible intervention to reduce the incidence or severity of injuries.

The paradigmatic shift of redefining "accidents" as "injuries" was based on refuting the concept of "accident proneness" among children as an explanatory model for childhood injury. A dominant theory of childhood injury in the first half of the twentieth century, accident proneness framed the risk of injury as an individual trait. This theory conflicted sharply with traditional public health approaches to disease and prevention, which focused on children's interactions with their environment. As the modern concept of injury control took hold, its multidisciplinary nature began to emerge. Injury control efforts became defined as both the prevention of injury by a diverse group of professionals, such as engineers, city planners, and behavioral scientists, and the mitigation of injury effects by health care professionals working in acute care and rehabilitation settings. Although these efforts found a natural home within the framework of biomedicine, injury prevention seemed naturally suited for the public health profession as well.

The Campaign for Public Health Solutions

The emergence of injury prevention as a public health discipline guided by science was grounded in these basic semantic shifts. For public health practitioners to make
progress, they would have to convince the public and policymakers that injuries were as amenable to control as were diseases. Public policy efforts to reduce motor vehicle injuries became early models of the current injury prevention paradigm.9

Motor Vehicle Safety

During the 1960s, groups of doctors and engineers were beginning to address widespread concern regarding occupant injuries from motor vehicle crashes. The postwar economic boom that made automobiles widely available to the U.S. public also led to a steady rise in fatalities and injuries resulting from crashes. The prevailing view—that drivers were largely responsible for these injuries and that injury countermeasures should focus on improving driver behavior—was challenged by a small number of skeptical physicians and engineers.10,11 Using observations from airline safety strategies, these advocates began to focus on automobile design as an important component of occupant safety. They argued that, if crashes could not be prevented, designing more crashworthy cars and promoting the use of seat belts could still reduce injuries.

The publication of Ralph Nader’s book about the Corvair, Unsafe at Any Speed: The Designed-in Dangers of the American Automobile, led to intense scrutiny of car safety by politicians and consumer advocates.12 This investigation resulted in the National Traffic and Motor Vehicle Safety Act and the Highway Safety Act, signed by President Lyndon Johnson in September 1966. These acts, and the people charged with carrying out their intent, largely redefined injury control as a public health issue during the remainder of the century.

The first large-scale involvement by the federal government in civilian injury prevention came when the National Highway Safety Bureau was created in 1966 under the National Traffic and Motor Vehicle Safety Act.12 William Haddon, a physician who strongly advocated the public health approach to injury prevention, was appointed as the first director of the bureau. Under Dr. Haddon’s leadership, injury prevention efforts shifted from changing individual behavior toward changing the agent (for example, the motor vehicle) and the environment (for example, highway design).

Table 1

<table>
<thead>
<tr>
<th>Injury Mechanism</th>
<th>Age Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 to 4</td>
</tr>
<tr>
<td></td>
<td>Deaths</td>
</tr>
<tr>
<td>Overall Injury Mortality</td>
<td>3,759</td>
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<tr>
<td>Unintentional Injury Mortality</td>
<td>2,895</td>
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<tr>
<td>Selected Mechanisms of Unintentional Injury Mortality</td>
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<tr>
<td>Motor vehicle occupant, traffic-related</td>
<td>514</td>
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<tr>
<td>Pedestrian, traffic-related</td>
<td>225</td>
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<tr>
<td>Bicyclist, traffic-related</td>
<td>4</td>
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<tr>
<td>Drowning and submersion</td>
<td>533</td>
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<tr>
<td>Residential fire and flames</td>
<td>451</td>
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<td>Fall</td>
<td>55</td>
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<tr>
<td>Firearm</td>
<td>17</td>
</tr>
<tr>
<td>Suffocation and choking</td>
<td>532</td>
</tr>
<tr>
<td>Poisoning</td>
<td>57</td>
</tr>
</tbody>
</table>

\(^a\) Per 100,000 people.

Source: Compressed Mortality files, National Center for Health Statistics, Centers for Disease Control and Prevention.
Haddon developed a conceptual matrix model of motor vehicle injury prevention that focused on the host (for example, driver), the agent, and the environment at three different temporal phases of the crash: before, during, and after (see Table 4). Although Haddon’s matrix was conceptualized as an approach to motor vehicle occupant injury, it has become a model for the prevention of many types of injuries among children and adults. Using pedestrian injury as an example, factors addressed in a matrix could include human factors (pedestrian intoxication), agent characteristics (high-profile car grille), environmental factors (absence of sidewalks), and sociological factors (auto advertisements that promote vehicle speed). Opportunities to prevent morbidity and mortality due to crashes...
could be present at one or more of three different time intervals: before, during, and following the crash.

Most safety activities at the time focused on decreasing the risk of a crash by focusing on driver behavior. Too little attention had been paid to improving cars to make crashes more survivable or to changing highway design to lessen the chance of a crash. Haddon’s focus on potential vehicle improvements led to the creation of federal standards for motor vehicle design and safety equipment—including stronger vehicle occupant cages, collapsible steering columns, shatterproof glass, padded interiors, and safety belts—aimed at decreasing the risk of injury when crashes occur. The postcrash phase of injury control focused mainly on acute care of injuries and stimulated federal involvement in the creation and support of emergency medical response and trauma systems. Importantly, Haddon’s model embraced a multidisciplinary approach to injury prevention by integrating the work of behavioral scientists (to address driver behavior and societal norms), engineers (to address changes to vehicle and highway design), and physicians (to address the acute care and rehabilitation of injured patients).

### The Expansion of Product Regulation

Federal involvement in automotive safety signaled a novel interest on the part of the government in broader product safety issues. Before product liability represented a serious concern for manufacturers, medical and public health experts began to apply the same analytic strategies and preventive approaches to other major causes of childhood injuries related to consumer products, such as the ignition of children’s sleepwear (see the article by Schieber, Gilchrist, and Sleet in this journal issue). An independent federal regulatory agency, the U.S. Consumer Product Safety Commission (CPSC), was created by Congress in 1972 to “protect the public against unreasonable risks of injuries and deaths associated with consumer products.” The CPSC today has jurisdiction over about 15,000 types of consumer products, from automatic-drip coffeemakers to toys to lawn mowers. With the creation of the CPSC, childhood injury prevention had clearly moved toward improving children’s environments. Advocates had learned that

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### Table 3

<table>
<thead>
<tr>
<th>Injury Mechanism</th>
<th>Age Group 0 to 4</th>
<th>Age Group 5 to 9</th>
<th>Age Group 10 to 14</th>
<th>Age Group 15 to 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle occupant</td>
<td>13.2</td>
<td>14.7</td>
<td>19.5</td>
<td>132.6</td>
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<tr>
<td>Motor vehicle-pedestrian</td>
<td>12.2</td>
<td>21.4</td>
<td>16.7</td>
<td>15.0</td>
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<td>Motor vehicle-pedal cyclist</td>
<td>0.48</td>
<td>6.4</td>
<td>9.5</td>
<td>5.3</td>
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<td>Motor vehicle-motorcycle</td>
<td>0.26</td>
<td>0.89</td>
<td>3.6</td>
<td>17.4</td>
</tr>
<tr>
<td>Other pedestrian</td>
<td>3.0</td>
<td>16.4</td>
<td>22.7</td>
<td>9.8</td>
</tr>
<tr>
<td>Drowning and submersion</td>
<td>5.9</td>
<td>1.6</td>
<td>1.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Fire Flame</td>
<td>4.2</td>
<td>2.8</td>
<td>2.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Hot object scalding</td>
<td>32.6</td>
<td>5.0</td>
<td>2.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Fall</td>
<td>95.5</td>
<td>91.0</td>
<td>83.9</td>
<td>88.4</td>
</tr>
<tr>
<td>Firearm</td>
<td>0.54</td>
<td>0.92</td>
<td>4.0</td>
<td>17.4</td>
</tr>
<tr>
<td>Suffocation and choking</td>
<td>9.4</td>
<td>1.06</td>
<td>0.84</td>
<td>0.72</td>
</tr>
<tr>
<td>Poisoning</td>
<td>55.3</td>
<td>7.8</td>
<td>9.7</td>
<td>28.9</td>
</tr>
<tr>
<td>Other</td>
<td>37.5</td>
<td>45.3</td>
<td>59.9</td>
<td>85.7</td>
</tr>
<tr>
<td><strong>All Causes</strong></td>
<td><strong>270.0</strong></td>
<td><strong>215.3</strong></td>
<td><strong>236.7</strong></td>
<td><strong>409.8</strong></td>
</tr>
</tbody>
</table>

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*Table 3: Hospitalization Rates for Unintentional Injuries among Children and Adolescents by Mechanism and Age Group*

**Notes:**
- All Causes: 270.0 215.3 236.7 409.8
- Per 100,000 population. Includes injuries of undetermined intent.
influencing legislation and administrative agencies provided a powerful and necessary tool to effect change.

**Capacity to Monitor Childhood Injuries**

The cornerstone of a strong public health system is the capacity to conduct ongoing surveillance of targeted conditions in the population. Surveillance provides data to prioritize health problems, evaluate interventions and programs, and recognize new epidemics. Until recently, scientific advancements in injury prevention programs were stymied by a lack of high-quality surveillance data. Anatomic descriptions of injuries (for example, arm fracture or liver laceration) have always been available in mortality and hospitalization data, but the paucity of injury mechanism data has prevented researchers from gaining a richer understanding of possible causes. The rise of injury control, however, led to wider adoption of the “external cause of injury” code system for the International Classification of Diseases (ICD). These codes attribute injuries to one or more specific mechanisms (for example, pedestrian in traffic), and they are used in hospital and emergency department records and on death certificates to describe cause of injury.

Where they are used, external cause of injury codes have provided enormous insight into the leading causes of injury mortality. The U.S. National Center for Health Statistics (NCHS) requires death certificates that document an injury-related death to include the external cause code. The need for nonfatal injury data is paramount, however, since for every injury death it is estimated that an additional 15 to 20 hospitalizations and 200 to 250 emergency department visits occur. Unfortunately, external cause of injury codes are not used universally by hospitals for coding discharge data. As of 1997, some 23 of the 36 states that routinely collect some level of external cause of injury codes (63.9%) have mandated this coding in their statewide hospital discharge data system.
As progress is made toward reducing preventable injury deaths, the focus of public health efforts will shift to reducing and mitigating severe nonfatal injuries. Unfortunately, there are few population-based data available for monitoring injury mechanisms that lead to emergency department visits. External cause of injury codes are often unavailable from emergency records and are infrequently coded on billing data. Only 11 states have developed the capacity to provide external cause of injury coding data on statewide emergency department data systems.19

Aside from death certificates and hospital and emergency department data, other large surveillance systems also exist to provide sound data on the epidemiology of childhood injury in the United States and other parts of the world (though a detailed description of each of these surveillance systems is beyond the scope of this review).

In summary, problems remain with regard to access to injury prevention surveillance data. The first problem is the lack of adequate data regarding nonfatal injuries. The second barrier is obtaining access to community-specific data. Significant geographic variations in injury rates occur, and national statistics are not always useful to policymakers in states and communities. Although Internet technologies (such as the Centers for Disease Control and Prevention’s WONDER project, an interactive Web site that provides county-specific injury mortality data20) have made access to local data easier, further strides should be made to improve access. Finally, the inconsistency of content and quality among injury surveillance databases makes comparisons of impact and outcomes difficult. For example, there are excellent national data systems for surveillance of and research on motor vehicle injury, but firearm surveillance systems are at a more primitive stage.21

### The Epidemiology of Childhood Injuries

The causes of childhood injuries are diverse, and their incidence varies considerably between different groups of children. Injury epidemiology is the study of variations in the incidence of injuries between populations and the study of specific factors that place individuals at higher (risk factors) or lower risk (protective factors) of injury. Epidemiological research depends on the availability of sound data systems that provide information on the occurrence of new injury events, as well as characteristics of individuals and environments that might be associated with higher risk for injury. This section outlines the relative importance of different injury mechanisms among children and adolescents, as well as risk and protective factors that can affect prevention efforts.

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http://www.futureofchildren.org
Risk Factors for Childhood Unintentional Injuries

There is considerable variation in injury rates among children, depending on their age group, location of residence, gender, family income, race/ethnicity, and other factors. For example, motor vehicle crashes are more common in rural counties. Also, males have higher rates of injuries compared to females, though this gender gap is narrow in early childhood and steadily widens throughout later childhood and adolescence. Some demographic characteristics, such as race, may be a marker for other underlying related factors, such as poverty or education. Among racial and ethnic groups in the United States, for instance, American Indians and Alaska Natives suffer from the highest rates of unintentional injury mortality followed by African Americans and Hispanics.\(^2\)\(^2\) The apparent racial disparities associated with childhood injury mortality and morbidity may be mostly due to the confounding effects of socioeconomic status, however, and have little to do with race.

Quantifying the Risk of Unintentional Injury

Identifying independent risk and protective factors for childhood injuries is necessary for the development of successful prevention strategies. The overall societal importance of a risk or protective factor is a function of both the magnitude of the risk imposed by the factor and the prevalence of the risk factor in the population. The magnitude of a risk is usually expressed as the relative risk of a specific factor for certain individuals, compared with those without the risk factor, for the injury of concern. For example, children living in a trailer home are at twice the risk of dying by fire than children living in other types of housing.\(^2\)\(^3\) Thus, the relative risk of living in a trailer home is 2.0. Relative risks also can be less than 1.0 if the factor is protective. Wearing a bicycle helmet, for example, is associated with a relative risk of brain injury of 0.15, meaning that bicycle riders using helmets can expect an 85% reduction in the likelihood of brain injury compared with riders without helmets.\(^2\)\(^4\)

The decision to target a risk factor for a community intervention should be based both on the magnitude of a relative risk as well as on data regarding the prevalence of the risk factor in the community. A risk factor with a high relative risk (for example, 10.0) but present in only 0.1% of the population, may be lower in priority than a risk factor that has a smaller relative risk (for example, 3.0), but is present in 50% of the population. Unfortunately, the relative risk and prevalence of risk factors for injuries are not always known. The elucidation and quantification of risk and protective factors for different causes of injury continue to be a high priority for injury epidemiologists. (Some factors that are known for different causes are discussed in the subsequent sections.)

Risk and Protective Factors for Childhood Unintentional Injuries

Motor Vehicle–Related Injuries

Injuries related to motor vehicle crashes result in the largest loss of life to children and
adolescents, accounting for 41% of all injury deaths in the United States. Overall, 8,350 children and adolescents were killed in motor vehicle-related incidents in 1996; more than 60% of those who died were teens ranging from ages 15 to 19.1 Young children have relatively low rates of motor vehicle injuries compared with adults, but adolescents 15 to 19 years of age have one of the highest rates of motor vehicle death of any age group. Common subcategories of motor vehicle injuries include occupant (drivers and passengers), bicycle-related, motorcycle, and pedestrian injuries. Since risk and protective factors for these vary, each of these mechanisms is examined separately.

Motor Vehicle Occupant Injuries. Roughly half of all motor vehicle–related deaths in the United States occur to occupants of motor vehicles during a crash. In 1996, some 4,970 children and adolescents died from occupant injuries; 71% of these deaths occurred to teens ages 15 to 19, the age group with the highest fatality rate from this mechanism.1 Despite the lower absolute number of deaths among children compared with teenagers, occupant injuries are the leading cause of injury death among children ages 5 to 14 and the third leading cause of death among children under 5 years of age (see Table 1).

Trends in motor vehicle occupant death rates (expressed as deaths per 100,000 population) have been relatively stable during the past 20 years (see Figure 2). However, little is known about changes over time in exposure (that is, the amount of time children spend riding in motor vehicles). The most valid denominator for occupant death rates is based on the number of deaths as a function of miles driven (that is, the number of deaths per 100 million vehicle miles traveled) and accounts for changes in driving patterns of the population. Improvement in death rates could still be inferred if the number of deaths remained constant over time, but each year children were found to be spending more hours per day in cars. Unfortunately, specific estimates of vehicle miles driven are unavailable for children, although they are available for the population as a whole.25 If the denominator for deaths takes into account the driving habits of the U.S. population, the fatality rate has dropped from 2.4 deaths per 100 million vehicle miles traveled in 1987 to 1.6 deaths per 100 million vehicle miles traveled in 1997, a substantial decrease.25 It is unknown whether changes in children’s rates are similar, using this denominator, to the overall population.

Injuries related to motor vehicle crashes result in the largest loss of life to children and adolescents, accounting for 41% of all injury deaths in the United States.

Motor vehicle crashes also lead to substantial numbers of nonfatal injuries. The National Highway Traffic Safety Administration (NHTSA) estimates that there were 906,000 injuries to occupants under age 21 involved in crashes during 1997.25 An estimated 14% of these injuries resulted in hospitalizations and 69% resulted in treatment in emergency departments only. The remainder were treated and released at the scene of the crash.26

Factors associated with the likelihood of a crash are usually a result of an interaction among driver behavior, the car, and the highway environment. Factors associated with the incidence of injury when a crash occurs are often associated with structural features of the car and the availability and use of safety equipment by the occupant. Modifiable risk factors are usually related to one of the first three columns of Haddon’s matrix. Although demographic factors such as gender, race, geography, and income are strongly associated with most unintentional injuries, these factors are not modifiable and, therefore, not usually subject to direct intervention. However, demographic factors can help policymakers target specific populations and regions for interventions.

Several demographic factors are known to place occupants at higher risk of motor vehicle injury and death. Gender is a strong risk factor after age 15, when adolescents begin to drive. Male deaths then greatly outnumber female deaths (4:1), and the incidence of severe injury among males is higher.22 Rural children are also at higher risk of motor vehicle occupant deaths, compared with urban and suburban children.22 This may result from a combination of factors, including
Factors Associated with the Risk of a Crash. Adolescents between 15 and 19 years of age constitute only 8.4% of the population, but they account for 14.4% of all occupant deaths from motor vehicle crashes in the United States. Because adolescents are disproportionately represented in motor vehicle fatalities, the identification and mitigation of risk factors that lead to crashes among teenagers is critical to reducing deaths from this cause. The most important risk factors associated with an increased likelihood of a crash involving teenage drivers include driver inexperience and alcohol use. Teenage drivers are at particularly high risk for crashes because of their lack of experience with challenging driving conditions, such as nighttime driving, inclement weather, and high-volume traffic. This inexperience, combined with the use of alcohol, often is deadly. In 1996, some 21% of all fatally injured young drivers were intoxicated at a level of greater than 0.10 grams per deciliter, the former threshold for blood alcohol concentration (BAC) in states with a legal limit of 0.10 BAC. Lower rates of seat belt use, higher rates of alcohol-related crashes, and rural residence also are associated with increased speed, hazardous road conditions, and less access to timely trauma care.

Higher rates of crash death are also associated with residence in poor areas. This finding may be related to an association between poverty and rural residence, older and poorly maintained vehicles, and lower rates of seat belt use. Racial differences in occupant death rates are present, although they also are likely related to the association between socioeconomic factors and crashes. Rates of crash death (per 100,000 population) among African-American children are about 50% higher than among white children under age 5, similar among children ages 5 to 14, and about one-third lower than among whites between ages 15 and 20. American Indians have the highest rates of occupant mortality and morbidity, though much of this disparity appears to be related to factors such as low seat belt use rates, high rates of alcohol-associated crashes, and rural residence.
for legal intoxication in many states (now 0.08 g/dl in many states). Male occupants were much more likely to be involved in an alcohol-related traffic death than were females (25% versus 12% of traffic deaths). Despite the strong association between teenage crashes and alcohol, there has been a significant downward trend in these types of crashes among teenagers since the mid-1980s. Strategies such as raising the legal drinking age from 18 to 21, graduated licensing, and zero tolerance laws (discussed in the article by Schieber, Gilchrist, and Sleet in this journal issue) have influenced this trend.

Factors Associated with the Risk of a Crash-Related Injury. The risk of injury and death to occupants during the occurrence of a crash is a function of the protection afforded by the integrity of the motor vehicle structure and its safety restraint equipment. The incidence of death and severity of injuries from frontal impact collisions has been reduced by the introduction of safety improvements in cars (for example, safety glass, collapsible steering columns, padded interiors, and frame design) backed by standards and testing. Although improvements have been directed mostly at frontal impact collisions, side impact collisions represent an increasing proportion of fatalities and severe injuries among all ages. Vehicle occupants are afforded far less protection from side impact collisions because of the narrow “crush zone” in the door panels and the decreased efficacy of shoulder belts in these types of collisions.

A recent government standard designed to provide greater structural support to the lateral aspect of vehicles led to the placement of steel beams inside the doors of most vehicles built in 1997 and later. The success of this new standard has not yet been evaluated with regard to side-impact injuries.

Another concern is the increasing chance of height and weight mismatch between vehicles, such as in collisions involving sport utility vehicles (SUVs) or certain pickup trucks. One recent study estimated that for every fatality in the SUV, an additional four would occur to passengers in a car sustaining a frontal impact, and 27 would occur to passengers in a car sustaining a lateral impact. Because of the low height of many children, the higher riding impact of SUVs may have a greater effect on their chests and heads than among adult passengers.

The other main protective factor against occupant injury is the use of a child restraint device or seat belt when driving. Infant car seats reduce the likelihood of serious injury or fatality among infants by an estimated 70%. Safety seats for toddlers are estimated to be 47% effective, based on field experience. The NHTSA estimates that approximately 3,894 lives have been saved since 1975 as a result of infant and toddler car seat use. Although infant car seats are mandatory for occupants under age one in all 50 states in the United States and in Canada, a significant proportion (80% to 90%) of young children remain inadequately restrained. About half of the infants and toddlers who died in car crashes during 1996 were not in a car seat at the time of the crash. It is estimated that, overall, restraints are used for 85% of infants and 60% of toddlers in the United States, although correct restraint use is much lower. In addition, although adult shoulder-lap belts are not recommended for children under eight years of age, many children start using these belts too early. This results in a poor fit of the shoulder portion of the belt—because the lap belt rides up on the abdomen rather than low on the thighs—and decreases the effectiveness of the restraint overall. Children under eight years of age and between 40 and 80 pounds should use a belt-positioning booster seat to avoid injuries that can occur with inappropriate belt use.

Frontal air bags, now present in almost 60% of U.S. automobiles, are another safety feature designed to supplement the use of shoulder-lap belts among adult occupants. In frontal collisions, frontal air bags reduce the likelihood of death or serious injury to a belted occupant by an additional 9%, and 20% to an unbelted occupant. The benefit of frontal air bags, however, has been observed only for adult and adolescent occupants. For infants and children, passenger air
bags are not protective, and they even appear to pose harm, especially when children are unrestrained.\textsuperscript{42} One study of fatal crashes found that child front-seat passengers under 10 years of age in cars with dual air bags had a 34\% increased risk of dying, compared with children without an air bag present.\textsuperscript{43} As discussed in the article by Schieber, Gilchrist, and Sleet in this journal issue, interventions aimed at reducing harm to children from air bag deployment have been developed, but they are not widespread. Placing infants and children under age 12 in the rear seat remains the best protective action against air bag injury.

Compared to most causes of unintentional injuries, the body of knowledge regarding risk factors for occupant injuries is substantial. Much is already known about factors that place car occupants at higher risk of a crash, but more should be learned about factors that place children at higher risk during crashes. Little is known about child occupant kinematics, the biomechanical tolerance of children’s bodies and organs to crash forces. The protective effects of air bags and seat belts need further study, particularly with regard to the effects of age, height, and weight. For teenage drivers, much more needs to be known about the association between inexperience and the risk of crash. A better understanding of these concepts will translate into improved interventions to prevent crash injuries.

Pedestrian injuries. Pedestrian injuries (that is, motor vehicle collisions with a person) account for almost one-quarter of traffic fatalities among children and are the second leading cause of injury death among children older than five years of age.\textsuperscript{1} Mortality rates for pedestrian injuries are slightly higher among adolescents than younger children. In 1996, some 1,002 pedestrian deaths of children and adolescents ages 0 to 19 (see Table 1) accounted for 18.5\% of all pedestrian deaths in the United States.\textsuperscript{1}

An estimated 39,000 children and teenagers sustained nonfatal injuries in 1996 as a result of pedestrian collisions.\textsuperscript{25} Based on data from six states (see Table 3), pedestrian injury was the second most common cause of injury hospitalization among five- to nine-year-olds. Because of the substantial forces associated with motor vehicle collisions, pedestrian injuries tend to be severe and frequently result in traumatic brain injury, abdominal injuries, and fractures.

Pedestrian deaths and nonfatal injuries among children and adolescents have steadily decreased during the past decades, with declines most pronounced among children ages 5 to 9 and among adolescents ages 15 to 19 (see Figure 3).\textsuperscript{1} This trend may be a result of decreased walking and traffic exposure among children, however, rather than advances in prevention.\textsuperscript{44}
A considerable body of knowledge has accumulated defining individuals and environments at risk for pedestrian injury. Children living in poor neighborhoods, for example, are at higher risk, primarily because of environmental risk factors, such as high traffic volume and lack of defined play areas. Poverty also explains a strong association between this type of injury and nonwhite race. Alcohol intoxication of the pedestrian plays an important role in later adolescence. Toddlers between ages one and two are more likely to be injured in nontraffic conditions, usually in a driveway and when a vehicle is backing up, especially if there is no physical separation between the driveway and play space. Most injuries involving preschool and school-age children occur as a child darts out midblock between parked cars. Many of these injuries occur during a time when children are improperly supervised. One reason contributing to poor supervision may be inappropriate parental expectations regarding a child's developmental capability to negotiate a traffic crossing. Children also are at risk when they come in contact with drivers who are at high risk of colliding with pedestrians. These are drivers who have been shown to be more likely to have had prior citations and license suspensions and revocations compared with other drivers.

Future interventions will suffer unless there is better ongoing information about children's exposure to traffic. Without this information, it will be difficult to determine if the trend of decreased mortality is related to interventions or just decreased pedestrian activity by children. More precise information on distinguishing features of high- and low-risk road environments also could prove useful to traffic engineers and others involved in pedestrian improvements.

Bicycle Injuries. Approximately 95% of the 262 bicycle-related deaths in 1996 were associated with collisions with motor vehicles. The death rate for this type of injury
peaks among youths ages 10 to 14, with relatively high rates also among children ages 5 to 9 and 15 to 19 (see Table 1). Reasons for these age-specific differences are unclear. Some age groups may have higher rates of bicycle-related deaths and injuries because they have higher exposure to bicycle riding. Rates of bicycle-related deaths have declined substantially over time, although the reasons for this decline are unknown (see Figure 4).1 Younger children (ages 5 to 9) are more likely to have head injuries than are older children (ages 10 to 14).56 Almost two-thirds of bicycle deaths occur between May and September.57 The peak incidence of these injuries is from 3:00 P.M. to 8:00 P.M., and there is evidence that poor visibility of bicyclists contributes to collisions with motor vehicles. There is also some evidence that alcohol intoxication may be a risk factor for older teenage bicyclists.58

Bicycle crashes result in many nonfatal injuries treated in emergency departments and physician offices, and they usually occur from falls or collisions with objects other than motor vehicles. One study estimated the rates of emergency department–treated injuries were 671 per 100,000 for 5- to 9-year-olds and 809 per 100,000 for 10- to 14-year-olds.56 Head injuries are a relatively common outcome of bicycle crashes, accounting for about one-third of emergency department visits, two-thirds of hospital admissions, and three-fourths of deaths involving bicycle crashes.56

The separation of bicycles from motor vehicle traffic through dedicated bicycle paths may reduce the risk of injury from collisions, although strong evidence for this is lacking. In the absence of environmental strategies, bicycle helmet use is the most important protective factor reducing one's risk of serious injury or death from a bicycle
collision. Helmets are estimated to be about 70% effective in reducing any type of head injury even in collisions with motor vehicles. The incidence of certain types of facial injuries can also be reduced by up to two-thirds by wearing a helmet.

Substantial progress has been made in understanding the risk and protective factors for fatal and serious bicycle injuries among children. Helmets, for instance, have been proven to be a potent protective factor in the prevention of brain and face injuries when a crash occurs. However, less research has been done in the area of minimizing collisions with motor vehicles and other objects, although there has been substantial interest in defining the potential protective effects of environmental strategies, such as separating bicycle traffic from cars. There is also very little research available on risk factors for bicycle collisions with pedestrians and other bicycles. With improved helmet protection and subsequent decreases in fatal injury rates, more research will be needed to define the epidemiology of nonfatal injuries.

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Drowning is the most common type of injury death among children under five years of age and the second most common for adolescents in the United States, accounting for about 1,369 child and adolescent deaths in 1996 (see Table 1). Children under age five also have the highest drowning rate of any age group, including adults. For every 10 children who drown, an estimated 36 are hospitalized and 140 are treated in emergency departments. Some nonfatal injuries result in extreme disability from brain damage secondary to prolonged lack of oxygen. Fortunately, drowning mortality rates have declined substantially over the past 20 years, although the reasons for this are unclear. As shown in Figure 5, rates have fallen faster for adolescents and older children than for children under five years of age. The risk of drowning is twofold to fourfold higher among low-income families, both for boat- and nonboat-related incidents. Drowning rates are highest among rural populations, particularly among American Indians. Swimming pools are more prevalent in high-income areas and are a major mechanism in urban areas.

Drownings represent a heterogeneous array of circumstances. Infants often drown in bathtubs, usually as a result of poor supervision or neglect. The circumstances of drownings among toddlers and young children usually involve falling into a body of water such as a pool, lake, or river, usually while unsupervised. The majority of adolescent drownings, mostly among males, occurs in open water. Alcohol is estimated to be implicated in up to 25% of drownings among adolescents. The risk of drowning while boating increases almost 300-fold if alcohol is consumed.

Fencing that restricts access to pools by young children has been shown to protect against drowning in some studies. One study estimated that a four-sided fence can reduce drownings of children under 13 years of age by about 75%, compared with no fencing or a three-sided fence with the pool accessible to the house. Personal flotation devices (life jackets) are presumed to be protective against drowning in open water. Although case studies suggest that drowning while wearing a life jacket is uncommon, the effectiveness of this prevention strategy has not been adequately defined.

More needs to be learned about the changes in exposure over time to environments that put children at risk of drowning, including the amount of time children and adolescents spend around open water, in boats, and near swimming pools. More information also is needed about protective factors for drowning. The only protective factor for which efficacy data exists is pool fencing. For open water drowning, it would be very valuable to ascertain the magnitude of risk reduction associated with the use of flotation devices. Swimming lessons may also be a
protective factor, especially for young children, but no methodologically rigorous studies have been performed to determine if they prevent drowning. Finally, interventions to prevent alcohol-associated drowning need to be rigorously evaluated.

**Fires and Burns**

Unintentional fire-related injuries killed 810 children and adolescents under 20 years of age in the United States during 1996. All but about 50 of these fire-related deaths occurred by conflagration of a private dwelling. The rest occurred in other types of buildings or involved clothing fires. Rates of fire-related deaths drop steeply with age, since younger children are less able to escape from residential fires. Rates among young children under four years of age are six times higher than those among adolescents (see Table 1). Overall, residential fire-related deaths have dropped by almost 50% during the past 20 years (see Figure 6). This trend may be attributable to both prevention efforts and marked improvements in burn care and burn survival during the past two decades.

About 75% of house fire deaths are caused by a victim’s inhalation of smoke and subsequent lack of oxygen, not as a result of extensive burns. When burns do occur, the injuries can be severe, leading to prolonged hospitalizations, profound scarring and disfigurement, and the need for extensive plastic surgery and rehabilitation.

Poverty is strongly associated with risk of death in a house fire, perhaps due to poorly maintained housing and heating units, and a possible higher prevalence of smoking and drinking in poorer households. Two populations at particularly high risk of fire death are American Indians and African Americans. Poverty explains part of the increased risk, but there may be additional risk posed by being a rural resident, including the response time of fire-fighting and rescue units. The greatest proportion of

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fire-related deaths occur during the winter months, varying as much as threefold between summer and winter months.\textsuperscript{22}

Risk factors for residential fire deaths are stratified into two groups. The first group includes factors associated with the risk of ignition of a fire. The second group is risk factors associated with death or injury in a house fire. Faulty heating systems and cigarette smokers in the household are major risk factors for igniting a house fire.\textsuperscript{72} Smoking is attributed as a causal factor in 28\% of fire deaths.\textsuperscript{73} Smokers who are intoxicated with alcohol are at particularly high risk, since they may fall asleep while smoking, which can lead to ignition of the furniture or mattress. Their impaired sensorium prevents them from recognizing the fire at an early stage.\textsuperscript{74} Only about 10\% of residential fires are associated with children playing with matches.\textsuperscript{22}

When a residential fire ignites, the chief risk factors for death are related to the presence of occupants who use alcohol, occupant age, and the type of housing.\textsuperscript{23} The presence of an intoxicated person in the home increases the risk of a fire-related death by 7.5 times, compared to a home with sober occupants.\textsuperscript{23} The risk of death for household occupants is 1.7 times higher when a child under age five is present. This risk may be related to the child’s decreased ability to escape or an adult’s rescue actions. Finally, fire deaths are almost twice as likely to occur in trailer homes, homes older than 20 years, and homes with two or fewer exits, compared with other types of housing.\textsuperscript{23}

The presence of a functional smoke detector in the household is a major protective factor for residential fire injury and death, leading to a 50\% to 70\% reduction in death.\textsuperscript{23} Flame burns also occur to children when their clothing ignites from a combustible source, such as a stove top or fireplace.\textsuperscript{81} Although this type of burn has decreased since federal regulations mandated the use of flame-resistant sleepwear, these burns still occur, particularly since manufacturers continue to sell 100\% cotton sleepwear (see the article by Schieber, Gilchrist, and Sleet in this journal issue).\textsuperscript{82} The chief risk factors for rapid ignition of clothing are the material content and clothing style.\textsuperscript{83} Clothing made from cotton (pure or blended) will burn even after the source of ignition is removed. Polyester clothing, as well as clothing impregnated with retardants, will not burn after the ignition source is removed. Loose, flowing clothes also are at higher risk for ignition, compared to tight-fitting clothing, and this explains why sleepwear has been a significantly high-risk garment for children, particularly for girls wearing nightgowns.

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Most nonfatal burn injuries are from scalding water and other liquids.\textsuperscript{84} Scalds are the leading cause of burn hospitalizations among children under five years of age, followed by contact burns.\textsuperscript{73} Because
prolonged wound care and grafting are often necessary, the care of nonfatal burns is associated with longer hospitalizations than for most other injuries. Although children's scald burns, in the past, were commonly associated with tap water, this type of burn is now less common, probably as a result of widespread safety legislation by some states mandating that hot-water heaters be sold with a preset temperature of about 120°F or lower.85 Today, most scald burns are caused by hot beverages or liquids spilled while cooking.3 Preventing children from gaining access to containers of hot liquids, such as coffee cups and stove pots, should reduce the risk of scalds, but very few successful intervention studies have been conducted in this area.

Effective technology exists for preventing house fires, but problems continue to exist with the diffusion and long-term maintenance of this technology. Future research will need to address these issues as well as the implementation of recently introduced technology, such as the fire-safe cigarette.86 Further epidemiological research is also needed to define the potential benefit of residential sprinkler systems in preventing fire-related injuries.87 In addition, nonfatal scald burns from the spill of hot liquids continue to be a large problem because no passive solutions have proved effective. Continued research is necessary to determine effective risk and protective factors for this type of burn injury.

Falls

Unintentional falls accounted for 200 deaths among children and adolescents in the United States during 1996. About half of these deaths occurred to teenagers 15 to 19 years of age (see Table 1). For unclear reasons, rates of fall deaths have dropped by almost 50% over the past 20 years (see Figure 7).1 Most fall deaths among children occur when a child falls from a height of two or more stories, often from upper-level

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windows. Although falls are not a leading cause of injury deaths, they do, however, represent one-third of all injury visits to emergency departments among U.S. children under five years of age and are the leading cause of injury hospitalizations for children (see Table 3).88

Few studies have been done of risk factors for falls among children and adolescents. Fatal falls are usually from significant heights, often from windows of tall buildings.89,90 A recent study from New Zealand that used sophisticated injury surveillance data to study falls found that the circumstances of falls vary considerably with a child’s age and developmental status.91 The most common mechanism of falls (53%) leading to hospitalization of infants was falls from furniture and infant equipment. In contrast, half of fall injuries among children ages 5 to 9 were from physical activity or play equipment, and 43% of falls among 10- to 14-year-olds were associated with sports activities. Almost half of the New Zealand hospitalizations for falls resulted in upper-extremity fractures, and 10% resulted in brain injury. A population-based study of hospitalizations for falls among children in the state of Washington found that falls from heights accounted for up to 40% of fall-related admissions.92 Other recent reports also have highlighted the danger associated with falls from shopping carts and baby walkers.93,94

The severity of a fall-related injury is a function of the height, the characteristics of the impact surface, and the weight of the victim. One study of the rate of playground falls by impact surface found that falls onto asphalt led to a sixfold higher rate of injury compared with falls onto sand.95 Another study of playground injuries found that falls from heights greater than 1.5 meters led to a 4.1-fold increased rate of injury compared with falls from under this height.96 Simple physics dictates that the mass of a subject will also determine the force associated with the fall (force = mass × acceleration). Other

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possible risk factors for injury depend on the child’s age and, perhaps, the point of impact on the child’s body.

Falls among children and adolescents are an important area for further epidemiological research, particularly since they are the most common cause of injury hospitalization. Further studies need to identify risk factors for injury when a fall occurs, particularly for falls from heights. This will lead to more sophisticated approaches to the prevention of these injuries. Continued efforts are also needed to identify new and emerging hazard-specific situations, such as falls associated with baby walkers.

**Firearms**

Firearm injuries are the second leading cause of death among teenagers, but most of these deaths are associated with suicide and homicide. Only 8.1% of all firearm injuries to children under 19 years of age are unintentional, accounting for 376 deaths in this age group in 1996 (see Table 1). It is also estimated that up to five nonfatal unintentional injuries occur for every unintentional fatality recorded. There has been a recent downward trend associated with this type of firearm injury, but the reasons for this are unclear (see Figure 8). It is unknown whether handguns or rifles play a more important role in these types of injuries. Furthermore, little is known about the association of socioeconomic status and other demographic factors on the incidence of these types of injuries, since few large population-based studies of unintentional nonfatal firearm injuries have looked specifically at children and adolescents.

One important risk factor for unintentional firearm injuries to children may include access to an unlocked and/or loaded weapon in the victim’s or another person’s home. The circumstances of injury often involve play with loaded guns, leading to a child shooting himself or another person. A number of uncontrolled studies also have demonstrated the danger posed by loaded firearms to young children in the household. One study of unintentional shootings of children under 14 years of age in California concluded that 93% of these shootings occurred in the home, 58% involved handguns, and that almost all of these deaths involved play with a loaded weapon. Among adolescents, hunting may also be an important activity associated with these injuries.

Guns are more likely to be loaded and unlocked if they were acquired for household protection. A national telephone survey of gun owners reported that 30% of families with children store their guns loaded, and that an association exists between keeping a loaded gun and storing it in an unlocked location. Several other studies of households with children have reported that 10% to 20% of handguns in the home are stored both unlocked and loaded.

Few analytical epidemiological studies of risk factors for unintentional firearm injuries have been done. Compared to firearm suicides and homicides, much less is known about these injuries. Because the number of deaths is relatively low, more effort should be concentrated on the study of nonfatal events. More information is also
needed regarding the relative protective value of keeping guns locked and unloaded, or of removing guns from the home. Further studies should also be conducted on risks associated with specific classes of handguns and the potential protective value of manufacturing handguns with childproof designs.

**Suffocation and Choking**

Suffocations are often classified as injuries, although no transfer of energy is associated with the event. This mechanism of injury results from oxygen starvation, leading to organ injury and death. There were 733 child and adolescent unintentional deaths in the United States from suffocation and asphyxia during 1996 (see Table 1). Of these deaths, 358 (49%) were among infants under one year of age, and rates among males are 30% to 40% higher than among females. About half (n=151) of suffocation deaths among infants occurred while in a bed or cradle. Some of these deaths may represent misclassified episodes of sudden infant death. The extent of possible misclassification is unknown. Some of these deaths were due to entrapment of the head and neck in cribs, but external cause of injury codes are not sufficiently specific to clarify the extent of this exact mechanism. Another relatively common mechanism among infants (n=73) is choking on food or an object, leading to obstruction of the respiratory tract. Choking on food or an object was also implicated as the cause of death in slightly more than half of the 174 suffocation deaths among toddlers and preschoolers between ages one and four. The 5- to 10-year-old age group represented 18% of suffocation deaths. About half of the deaths in this age group were related to accidental hangings; the circumstances of these episodes are unknown.

Unintentional suffocation and choking episodes are the sixth leading cause of hospitalization for injury among children under age five. After this age, hospitalization rates are much lower (see Table 3). During the past decade, the death rate for unintentional suffocation and choking episodes decreased 30% from 0.98 (per 100,000) in 1989 to 0.68 (per 100,000) in 1996.

![Figure 8](http://www.futureofchildren.org)
two decades, deaths from suffocation and asphyxia have declined nearly 50% for children over one year of age. Some of this decline may be related to regulatory efforts focused on choking hazards associated with toys and other products. For infants, however, the decline has been much lower (23%). Only among children ages five to nine has there been no decline in suffocation death counts over the past 25 years (see Figure 9). The reasons for these trend differences by age group are unknown.

The CPSC issues standards for toy manufacturers that specify a minimum part size for toys intended for small children and warning labels identifying potential choking hazards on toys for older children. The CPSC also recently linked infant suffocation in bed to the placement of infants prone in beanbag cushions, leading to the recall of these cushions and warnings to parents. Subsequent warnings have been issued about all soft bedding for infants.

Future refinement of external cause of injury codes may provide an opportunity to better understand the circumstances and mechanisms involved. In addition, product injury surveillance for fatal and nonfatal injuries, such as the CPSC National Electronic Injury Surveillance System, will continue to play a vital role in detecting emerging hazards.

**Poisoning**

Unintentional poisoning deaths among children and adolescents have been a long-standing concern for health care providers, since many emergency department visits and hospital admissions are related to this mechanism. Unintentional poisonings are a prominent reason for childhood hospitalizations and they are the second most common cause of injury hospitalization among children under four years of age (see Table 3). However, poisonings are currently one of the least common causes of injury deaths among children, accounting for only about

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**Figure 9**

*Trends in Unintentional Suffocation Deaths by Age Group, 1979 to 1996*

![Graph showing trends in unintentional suffocation deaths by age group from 1979 to 1996.](http://www.futureofchildren.org)
2% (299) of these deaths in 1996 (see Table 1). For every poisoning death among children under six years of age, an estimated 40,000 additional ingestions are reported to poison control centers. Only about 2% to 5% of ingestions are thought to lead to moderate or severe effects.

Rates of unintentional poisoning deaths among children and adolescents are a fraction of the rates among adults. Children are far less exposed to drug therapy and drugs of abuse than adults, and some unintentional poisonings among adults and older teenagers may be misclassified suicide attempts. Over the past 20 years, death rates from unintentional poisonings have declined markedly among children and adolescents (see Figure 10).

The two major categories of unintentional poisoning deaths are accidental ingestion of medications and ingestion or inhalation of commercial products or gases. Among children under age 10, deaths are about evenly divided between these categories. The overall top five substances ingested by children under six years of age are cosmetics, cleaning substances, analgesics, plants, and cold/cough preparations. For older children and adolescents, ingestion patterns differ. Among 10- to 14-year-olds, for example, about 80% of unintentional poisoning deaths are from substances other than medication. However, among teenagers 15 to 19 years of age, more than half (58%) of the 190 deaths are from medications. The most lethal substances for children of all ages (expressed by the number of deaths per reported ingestions) are stimulants and street drugs, cardiovascular drugs, and antidepressants. An important protective factor for medication-related poisonings is the storage of medication in a childproof container. This finding led to the adoption of the Poison Prevention Packaging Act (1970), which specified that certain medications and dangerous substances must be stored in child-resistant containers (see the article by http://www.futureofchildren.org).
The proliferation of new drugs and non-medicinal products makes surveillance for poisoning an ongoing concern. Success in maintaining low rates of injury will need to focus on preventing access to potentially harmful substances by children. Further research is also needed on other factors that protect children after the ingestion, but before absorption has occurred. These include further research on charcoal and other substances to retard or eliminate absorption. Further research also is needed on the potential benefits of prehospital interventions to reduce absorption of poisons.

Summary

The past 25 years have led to substantial progress in defining the epidemiology of childhood injury. Despite impressive reductions in unintentional childhood injury deaths, injury remains the most important cause of death and disability for children and adolescents today. Successful intervention strategies have been developed, evaluated, and disseminated, but up to 31% of childhood deaths could be prevented using existing technology and strategies. In addition, challenges remain in improving the understanding of important risk and protective factors. High-quality research efforts related to childhood injury epidemiology will depend on improved surveillance systems, particularly for nonfatal injuries. As mortality continues to trend downward, nonfatal injuries and residual disability will emerge as increasingly important outcomes.

Surveillance systems are also important for the detection of new mechanisms of injury among children, such as the newly described injuries related to personal watercraft or passenger air bags.

Epidemiological surveillance also depends on good measures of risk exposure to children and the increased use of sophisticated analytical research tools from well-designed, adequately controlled studies. It needs to be determined if rates of some injuries (for example, pedestrian injury) are decreasing because of specific interventions or because children are less exposed to the activity that places them at risk. In addition, the availability of sophisticated research tools, such as case-control and cohort studies, to better define risk and protective factors is a positive development for the discipline. Finally, consistent results from multiple studies strengthen confidence and understanding of who is at risk and what environmental factors place children at risk.

It is unlikely that continued rapid progress in reducing injuries will prove easy. Risk and protective factors are not evenly distributed in the population; certain populations remain at high risk despite active programs to diffuse successful strategies and programs. Ensuring that the last 20% of the population uses motor vehicle restraints and bicycle helmets, and installs smoke detectors will prove much more difficult than achieving those aims for the first 80%. To maximize success, future studies of risk and protective factors may need to concentrate primarily on subjects at highest risk of injury.


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