Epidemiology of Injuries: Current Trends and Future Challenges

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In the United States, over 400 people continue to die of injuries every day; at least 57 of these deaths occur among children. In 1997 alone, 146,400 US residents died as a result of an injury, which translates into an overall rate of 56 injury deaths per 100,000 population (1). Unintentional injuries accounted for 63 percent of these deaths, with suicide and homicide accounting for 21 percent and 13 percent, respectively. Despite some success in reducing the age-adjusted injury death rate by 21 percent between 1980 and 1997, injury from intentional and unintentional causes remains the leading cause of death for children, adolescents, and young adults between the ages of 1 and 44 years and the fourth leading cause of death over all age groups (2). Taken together, unintentional and intentional injuries account for more years of potential life lost before age 75 per 100,000 population than either cancer, heart disease, or human immunodeficiency virus infection (figure 1) (3).

While still unacceptably high in number, deaths due to injury represent only the tip of the injury iceberg. Although much less is known about the incidence and patterns of nonfatal injuries, it is estimated that for every injury death, there are 18 hospital discharges with a first listed diagnosis of injury and 250 injury-related visits to hospital emergency departments (2, 4). Almost one in four people in the United States sustains an injury during a given year. Injuries account for an estimated 8 percent of all hospital discharges (2.6 million annually) and 37 percent of all emergency department visits (37 million annually) (2). Although many nonfatal injuries are minor in severity and result in only 1 or 2 days of restricted activity, a large proportion result in fractures, brain injuries, major burns, or other significant insults to the body that often have far-reaching consequences for the individual, his or her family, the health care system, and society at large (2, 4, 5). Total lifetime costs associated with both fatal and nonfatal injuries occurring in a single year have been estimated to exceed $260 billion (in 1995 dollars) (4, 6).

In this paper, current patterns of injury are briefly described, and trends in these patterns over time are summarized. These trends suggest important directions for future epidemiologic investigations.

CURRENT PATTERNS OF INJURY

In its 1999 report "Reducing the Burden of Injury," the Institute of Medicine recognized the tremendous strides that have been made over the past three decades in defining the epidemiology of injury (6). A better understanding of the patterns of injury distribution and causation has led to the development of successful strategies for reducing both the occurrence of injuries and the severity and impact of those that occur. Clearly, however, our successes have not been equal across all types of injuries and population subgroups.

Injuries result from acute exposure to physical agents such as mechanical energy, heat, electricity, chemicals, and ionizing radiation in amounts or at rates beyond the threshold of human tolerance (7). However, it is now well recognized that both an exposure and its consequences are greatly influenced by a variety of factors both within and beyond our control (8, 9). Our understanding of how these multiple factors interact to influence the occurrence and severity of injury has been significantly advanced as a result of the pioneering work of William Haddon, who proposed a matrix approach to the study of injury and its consequences (7). His model builds on the classic epidemiologic triad of host, agent, and environment but adds a second axis of time sequence to emphasize that the event leading to the injury is separate from the injury itself. This time sequence is divided into three phases: the pre-event, event, and post-event phases. Factors in the pre-event phase contribute to the likelihood of the potentially injurious event's occurring (e.g., a motor vehicle crash or fall); factors in the event phase contribute to the likelihood that an injury will actually occur as a result of the event (and its severity); and factors in the post-event phase influence the consequences of the injury once it occurs. The introduction of this matrix approach for delineating the factors influencing the incidence and severity of injury laid the foundation for the science of injury control, and it
continues to guide epidemiologic investigation and the development of new strategies for preventing injuries and ameliorating their consequences.

The leading mechanisms of injury death (i.e., the external agent or particular activities that precipitate the injury) are motor vehicles and firearms, accounting for 29 percent and 22 percent of the total number of injury deaths, respectively (1, 2). Poisoning is the third leading mechanism (12 percent of deaths), followed by falling (8 percent), suffocation (7 percent), drowning (3 percent), and fires/burns (3 percent). In contrast to fatal injury, the leading cause of nonfatal injury is falls, accounting for 33 percent of all injury-related hospitalizations and 24 percent of injury-related emergency department visits (2, 10). Motor vehicles are also an important mechanism of nonfatal injury and account for 22 percent and 12 percent of injury-related hospitalizations and emergency department visits, respectively. On the other hand, firearm injuries account for less than 1 percent of all nonfatal injuries. Other common causes of nonfatal injury include being hit by an object or person and being injured by a cutting or piercing instrument (including stablings).

Approximately one third (34 percent) of all injury deaths are intentional (1). Of these, 61 percent are the result of suicide and 39 percent are the result of homicide. Firearms are involved in the majority of intentional injury deaths (68 percent of all homicides and 57 percent of all suicides). The distribution of nonfatal injuries by intent is not as well understood, largely because intent is not uniformly and reliably defined and recorded in medical records. Based on the available data, rough estimates are that a minimum of 5–15 percent of injury-related hospitalizations and emergency department visits are related to intentional injuries (4, 10, 11).

Patterns of mechanism and intent of injury vary significantly by age, race, and gender. For example, firearm injury deaths disproportionately affect males and young people. In 1997, firearm injuries among males aged 15–24 years actually outnumbered motor vehicle-related injuries as the leading cause of death (1). A total of 7,312 young adult males (aged 15–24) died of a firearm injury in 1997; nearly two thirds (63 percent) of these deaths were homicides. The magnitude of the firearm injury problem among young males is further illustrated by a comparison of firearm and motor vehicle injury death rates across several industrialized countries (2). The rate of firearm-related deaths among males aged 15–24 years in the United States is 4.5 times to >50 times higher than rates reported in other developed countries (figure 2).

Any discussion of patterns of injury, however brief, would not be complete if mention were not made of the important role of alcohol. It is estimated that more than one third of all trauma deaths directly involve alcohol; over one half of all traffic fatalities among persons aged 15–34 years are alcohol-related (i.e., they involve a driver, occupant, or nonoccupant with a blood alcohol concentration of 0.01 g/dl or greater) (8, 12). Despite the importance of alcohol as a modifiable risk factor for injury and injury death, research aimed at understanding the complex relations between alcohol use, drinking behavior, and risk of injury and its

**FIGURE 1.** Years of potential life lost before age 75 (YPLL-75) per 100,000 population aged <75, by cause of death, United States, 1985 and 1995. □, 1985; ■, 1995. HIV, human immunodeficiency virus. Source: Fingerhut and Warner (2).
FIGURE 2. Firearm injury death rates among males aged 15–24 years for selected countries and selected years, 1992–1995. Data were provided by members of the International Collaborative Effort on Injury Statistics (National Center for Health Statistics, Hyattsville, Maryland).

consequences is limited. Further work is needed to better inform the establishment of effective policies and programs.

TRENDS IN INJURY RATES

As figure 3 shows, there has been a substantial decline over the past century in the overall rate of death due to injury (8). Most of this decline is attributable to a decrease in rates of non-motor-vehicle-related unintentional injuries. In more recent years we have seen further declines, although trends clearly differ by mechanism and intent (table 1). Rates of death due to motor vehicle traffic injuries, for instance, decreased from 18.4 per 100,000 population in 1985 to 15.5 per 100,000 in 1997 (1, 2). However, this overall decline in rates is the product of a substantial decrease of 15 percent between 1985 and 1993, followed by a 2 percent increase between 1993 and 1995 and another 2 percent decrease between 1995 and 1997. While this more recent increase in motor vehicle injury deaths is

FIGURE 3. Rates of death (per 100,000 population) from unintentional injury, suicide, and homicide, by year, United States, 1910–1990. —, unintentional injury not due to motor vehicles; ●, unintentional injury due to motor vehicles; ••, suicide; —, homicide. Source: Baker et al. (8).
relatively small in absolute terms (and is attenuated when adjusted for miles driven), it represents over 1,000 deaths.

In stark contrast to what has happened with motor vehicle-related deaths, age-adjusted rates of death due to firearms increased by 22 percent between 1985 and 1993 but then declined by 22 percent between 1993 and 1997 (1, 2). These trends were largely driven by changes in rates of firearm homicide among adolescents and young adults aged 15–34 years. Nearly 50 percent of all firearm-related deaths occur in this age group. Recent declines in firearm injury death rates between 1993 and 1997 were observed for both firearm homicides and suicides, although rates of decline were higher for homicides. The rate of unintentional firearm death remained relatively constant at 1 per 100,000 until 1995, when it fell slightly to 0.8 per 100,000, a trend that continued until 1997.

OPPORTUNITIES FOR FURTHER PROGRESS

In many instances, we know how to reduce the incidence and severity of injuries; the greatest challenge for the field of injury control is to translate this knowledge into effective programs and policies that are economically, socially, and politically acceptable and sustainable (6). Implementation research that examines issues of adoption, diffusion, and sustainability of polices and programs is essential for maximizing the potential impact of efficacious interventions. As we implement new strategies, however, we must continue to monitor their impact through effective surveillance at the national and local levels. In many other instances, significant strides in reducing the impact of injury will depend on new data and rigorous epidemiologic investigations. The challenges in developing this new knowledge are many, and a detailed discussion of these challenges is beyond the scope of this article. Three are briefly mentioned here as an illustration of the breadth and complexity of these challenges.

As described above, motor vehicles and firearms constitute the two leading causes of injury death in the United States, resulting in 42,473 and 32,436 deaths, respectively, in 1997 (1). Although we have made significant progress in reducing the overall incidence of motor vehicle-related deaths and injuries, we have not had comparable success in abating the problem of firearm-related injuries. The explanations for this difference in trends are complex and multifaceted (6). However, in examining the public and private response to these two health crises, it becomes evident that in contrast to the comprehensive, multidisciplinary approach that has been successful in reducing traffic injury rates, the approach to firearm injury reduction has been fragmented at best, with little science emerging to serve as the basis of sound public policy. The Institute of Medicine’s Committee on Injury Prevention and Control concluded that what is needed is “…the implementation of a comprehensive approach for preventing and reducing firearm injuries that includes firearm surveillance, firearm safety regulation, multi-disciplinary research, enforcement of existing restrictions on access by minors and other unlawful purchasers, prevention programs at the state and local levels, and mobilization of public support” (6, p. 131).

Fundamental to a comprehensive approach to firearm injury reduction is better surveillance of firearm injuries and more rigorous investigations on the risk factors associated with both intentional and unintentional firearm injuries. Given the particularly high rates of firearm homicide among adolescents and young adults in the United States, studies focusing on access to, use of, and misuse of guns in this age group should be given high priority. There currently exists no ongoing federally sponsored system of surveillance for firearm-related injuries (6, 14, 15). The Uniform Crime Reporting System, maintained by the Federal Bureau of Investigation, provides some information on homicides; however, specific information on the types of guns involved is lacking, and because it is a voluntary reporting system, it tends to underestimate the actual incidence of homicide. Moreover, firearm suicides, which outnumber homicides, as well as unintentional firearm injury deaths, are not included in the database. The National Crime Victimization Survey of the Bureau of Justice Statistics (US Department of Justice) provides estimates of and information on victimization of persons aged 12 years or older. However, the estimates are based on self-reports, which may lead to serious underestimation, especially of injuries resulting from interpersonal violence. Like the Uniform Crime Reporting System, the National Crime Victimization Survey does not include self-inflicted injuries and unintentional injuries. Thus, although some data exist that are useful for monitoring the incidence and patterns of gun-related injuries, they are not coordinated or comprehensive in their scope of coverage or content. There is an urgent need for the establishment of a firearm injury data collection system similar to that developed by the National Highway Traffic Safety Administration for motor vehicle crashes. Such a database would tap into multiple sources of information from police, medical examiners, and the health care system and would require collaboration among multiple agencies at the federal, state, and local levels. It has been suggested that at a minimum, this database provide information on all
firearm injury deaths and include data on: the time and place of the event and death; the characteristics of the injury and its severity; the characteristics of both the victim and the perpetrator (where relevant); the circumstances surrounding the event (including motivation and the possible involvement of alcohol and drugs); and detailed characteristics of the firearm and ammunition involved (6, 15).

Although effective surveillance is clearly an important element of a comprehensive program of firearm injury control, solving this major public health problem will require a multipronged approach that includes not only good research and programmatic efforts but also regulatory action and broad public support (6). Although guns are present in approximately 40 percent of all US households (16) and are carried by one in 12 US students (17), they remain a virtually unregulated consumer product. The Consumer Product Safety Commission, which is charged with protecting the public from unreasonable risks of injury from consumer products, is specifically prohibited from regulating firearms or ammunition; yet studies have shown that people who live in homes with guns are more likely to die from homicide and suicide in the home than are people who live in homes without guns (18, 19). In addition, familial and intimate partner assaults involving firearms are 12 times more likely to result in death than assaults not related to firearms (20). Americans generally support government regulation of guns as consumer products, especially with regard to their safety of design (21).

A second overarching challenge for the field of injury control is the development of better information on the epidemiology of nonfatal injuries and their consequences. Until recently, the scope of the injury problem has been measured primarily in terms of numbers and rates of death and years of potential life lost due to premature death. Similarly, the success of strategies for controlling injuries has been measured largely in terms of numbers of lives saved. However, it has become increasingly apparent over the last decade that while death rates and years of potential life lost are powerful indicators of the relative magnitude of the injury problem, they do not adequately measure the full burden of injuries in society. As was noted above, while the number of injury deaths remains unacceptably high, they represent less than 1 percent of all injuries. For this reason, we must find better ways to measure and monitor the impact of nonfatal injuries. Substantial progress has been made towards this end. In the last 10 years, we have developed more refined estimates of the numbers of nonfatal injuries by cause and nature of the injury (2, 4, 22), and the economic costs associated with injury have been estimated, albeit using sparse and fragmented data (4, 5, 23, 24). New and exciting work is now being pursued to develop measures of the noneconomic or human costs of injury in terms of quality of life or disability-adjusted life years (6, 25). Perhaps most important, critical steps have been undertaken to improve existing sources of data on injury, and we are developing ongoing surveillance systems that will enable us to monitor trends and patterns of injury and its outcome on an ongoing basis and at the local level (26-30). Although these advances are encouraging, there remain significant gaps in our understanding of the incidence and impact of injury on society.

In particular, more studies are needed to elucidate the risk factors associated with impairments, functional limitations, and disability following injury. Several frameworks have been suggested for guiding these investigations (31, 32), but they have not been broadly applied. More specifically, while several studies have documented the important role of injury severity, age, and comorbidity on outcome, few have examined a broader set of predictors that include characteristics of both the individual (e.g., level of education, motivation, health behaviors) and his or her physical, social, and economic environment (33). Only by understanding the nature of specific outcomes and the factors that influence the relation across different levels of human functioning postinjury can we know how and when to intervene to improve quality of life and reduce the overall impact of injuries on society.

Finally, as in other areas of health, the aging of the population introduces significant challenges to the injury field. Although children and young adults account for the majority of injuries, elderly people aged 65 years or more are actually at highest risk of both fatal injuries and injuries resulting in hospitalization. Persons aged 75 years or more, in particular, sustain serious injuries at a rate that is nearly three times higher than the rate for all age groups combined. Although they comprise only 5 percent of the US population, persons aged 75 years or more account for nearly 15 percent of all injury deaths and hospitalizations. As the proportion of the population aged 75 years or more increases from 5 percent to a projected 9 percent over the next 30 years, we can expect that elders will eventually account for over one quarter of all deaths and hospitalizations due to injury (34, 35). They will also account for an equal, if not higher, share of acute hospital costs for trauma (35).

The principal mechanism of injury among the elderly is a fall or trip on a level plane, most often resulting in a hip fracture. Although epidemiologic research has contributed to our understanding of the multiple factors that influence the incidence of falls
summaries and reports were identified in the literature but a recently published systematic review of 10 different establishment of programs and policies. These evaluations of new interventions to better inform the strategies for preventing motor vehicle injuries, 54,708 are well known. However, major new advances in the field of injury epidemiology to move from the largely descriptive studies that have predominated in the literature to the application of more rigorous analytical methods for defining the underlying casual principles of injury mechanics and the physical and physiologic responses of the human body to the impact of injury is fundamental to the study of injury causation (6). While significant advances have been made in this regard, more work needs to be done. The biomechanics of head injury are still not well understood, yet head injuries account for nearly 50 percent of all injury deaths and remain the leading cause of both injury death and disability among children and young adults. Animal and human cadaver research combined with rapidly evolving techniques of computerized modeling will continue to play a critical role in increasing our understanding of injury mechanisms. At the same time, the development of effective interventions is dependent on a better understanding of the role of behavior in injury causation and prevention (45). We know, for example, that the use of personal protective devices such as seat belts, car seats, and bicycle helmets reduces injury risk and that these behaviors can be influenced through educational, behavioral, and legislative strategies (46-49). Interventions addressing individuals at risk can be enhanced by additional research into risk perception, risk-taking, and behavioral responses to safety improvements. However, behavioral strategies may also be used effectively with key decision-makers who design and manufacture products and who pass and implement laws that affect the injury risk of entire populations; more research is needed to understand and influence the process of behavior change in these groups (50).

The importance of injury as a major public health problem worldwide was highlighted in the seminal report “The Global Burden of Disease” (25). Worldwide, injuries account for approximately one in eight deaths among males and one in 14 deaths among females (51). Motor vehicle injuries alone constitute the ninth leading cause of disease burden as measured by the number of associated disability-adjusted life years (25). By the year 2020, motor vehicle injuries are projected to increase in rank to third. The importance of violence as a cause of disease burden is also projected to increase, moving from its current rank of 19
to 12. These estimates and projections underscore the need for increased attention to the study of injury and its causes and consequences. We must continue to: 1) improve our methods of surveillance to better define and monitor the magnitude of the problem, especially for intentional injuries and nonfatal injuries; 2) expand our work in defining the epidemiology of injuries and their outcomes, focusing on the identification of causal patterns and risk factors; 3) foster the development and application of rigorous methods for evaluation of both preventive and health services interventions; and, perhaps most importantly, 4) develop a better understanding of how we can change perceived legal, ethical, and behavioral barriers to injury control into opportunities to reduce the burden of injury worldwide.

REFERENCES