CHAPTER 27

Injury Prevention and Control

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LEARNING OBJECTIVES

Upon completion of this chapter, the reader will be able to:

1. Describe the term *injury* and the importance of energy.
2. Summarize the dimension and magnitude of injury as a public health problem, and its relationship with other public health problems.
3. Explain the application of the public health model to injuries.
4. Describe William Haddon's framework and proposed countermeasures.
5. Outline other conceptual frameworks for injury prevention.
6. Recognize the axioms guiding injury prevention.
7. Explain the role of individual public health practitioners and agencies in preventing injuries.

KEY TERMS

accidents
countermeasures
energy
event
injuries
injury prevention
vehicles (or vectors)

INTRODUCTION

We normally think of health problems or diseases as those conditions associated with exposure to infectious agents (e.g., HIV), environmental agents (e.g., tobacco, lead), chronic degenerative processes, or those due to genetic disorders. Yet the leading cause of years of potential life lost, one of the top five causes of death, and a major source of disability in the United States population and worldwide, has nothing to do with those conditions. These deaths and morbid and disabling conditions relate to exposure to some form of **energy** (kinetic, potential, electrical, or other) in amounts that exceed the individual's tolerance threshold or in amounts released in too short a time period, therefore resulting in injuries. Injuries are a major health problem as old as humankind.

Given the magnitude of this problem, it seems natural, then, that as public health practitioners we should turn our attention to injuries and their prevention and control. Unfortunately, this has not always been the case. **Injuries**, and their prevention and control, have not traditionally been embraced as a public health issue. One obstacle has been the belief that injuries are the result of **accidents**, which has caused them to be considered by many as unpredictable and therefore unpreventable. In the instances in which they were "investigated," the conclusion was often that they were primarily due to some irresponsible behavior on the part of the injured individual or someone else. As a result, injury control has been stymied by the "accident" folklore, including the notion of reckless, selfish, careless, and intoxicated people as primarily responsible for injuries.[1] Thus, until the last quarter of the twentieth century, the field of injury prevention and control was characterized by misunderstanding, lack of progress, and scarcity of relevantly trained scientists.

Fortunately, current public health thinking embraces injury prevention and control. In fact, all of the 10 Essential Public Health Services and the Core Competencies for Public Health Professionals are applicable to this major public health problem.[2,3] In this chapter, we will provide a brief overview of the injury problem and some solutions. The chapter is designed to provide a general orientation, rather than an exhaustive discussion. The goal is to facilitate a clearer understanding of the role of the public health practitioner and public health agencies in the reduction of the burden related to injuries. To achieve that goal, we will present useful definitions and conceptual frameworks, a summary of the magnitude of the problem, and examples of the use of public health tools in injury prevention. Emphasis is placed on the preventability of these injuries, and wherever possible, we have provided examples of evidence-supported prevention efforts. It is not our intent to provide a detailed account of the epidemiology of injuries, nor the effectiveness or efficiency (or lack thereof) of all interventions tested to date. Many other references are available to the reader interested in those matters.[4–7]

DEFINITION OF INJURY

We will use the term *injury* to describe any damage to the body due to acute exposure to amounts of thermal, mechanical (kinetic or potential), electrical, or chemical energy that exceed the individual's tolerance for such energy, or to the absence of such essentials as heat or oxygen. We have, therefore, adopted the broad definition described in *Injury Prevention*[8] and endorsed by the Institute of Medicine (IOM),[9] which includes intentional injuries (e.g., homicide, suicide) as well as unintentional injuries (e.g., falls, burns). This chapter also encompasses injuries regardless of where they occur (e.g., outdoors, at home, or at school), the activity that was taking place when the injurious event happened (e.g., occupational, recreational, sports-related), and the object that was involved in the energy transfer (e.g., motor vehicle, gun). The chapter does not address psychological damage as a result of, for example, violence or motor vehicle crashes.

Table 27-1 lists energy types, their frequency as the source of fatal injuries in the United States population, the **vehicles (or vectors)** that most frequently transfer the energy, and the most common types of resulting injuries.

DIMENSIONS AND MAGNITUDE OF THE PROBLEM

In the United States in 2010, 180,811 people died because of injuries, amounting to a rate of 58.6 per 100,000. Injuries are among the five leading causes of death in our population, right behind heart, cancer, respiratory diseases, and cerebrovascular disease. As seen in Table 27-2, unintentional injuries are the fifth leading cause of death for individuals of all ages combined, and the leading cause of death for individuals ages 1 through 44. Intentional injuries (whether suicide or homicide) are the second to fifth leading causes of death for ages 1 to 54. Therefore, injuries are the leading cause of years of potential life lost (YPLL, see Chapter 12) amounting to 35.2 percent of YPLL before aged 65—a proportion twice that of

TABLE 27-1 Examples of Energy, Vehicle, Injury Types, and Their Proportion of Injury Deaths in the United States, 2010, Fatally Injured Population (N = 180,811)

Etiology of Injury	Vehicle (vector)	Type of Injuries	Percentage of Deaths
Kinetic energy	Motor vehicle, train, other vehicles, bullets, knives, machinery	Abrasions, contusions, sprains, strains, dislocations, fractures, concussion, blunt, open wounds (cuts, piercing), crushing	40.0%
Chemical energy	Drugs, cleaning products, poisonous animals	Poisonings, chemical burns	23.7%
Absence of oxygen	Water, foreign objects	Drowning, strangulation, suffocation	11.5%
Potential energy*	Falling person	Same as kinetic	15.4%
Thermal energy	Fire, heat	Burns, heat stroke	1.7%
Other (electrical, absence of heat, ionizing radiation)	Wire, radioactive materials	Electrocution, frostbite, burns	7.6%

*It has been argued, however, that potential energy causes injury only when transformed into kinetic energy.

SOURCE: CDC NCHS, Underlying Cause of Death File, 1999–2010. CDC WONDER On-line Database. Available at: http://wonder.cdc.gov.

YPLL to malignant neoplasms, the next most common condition (see Figure 27-1).[10]

In addition to deaths, injuries result in some 2 million hospital admissions and 29 million emergency-department-only visits every year.[10] The relationship between mortality and morbidity (or different degrees of severity) is referred to as the "iceberg" or "pyramid" of injury (Figure 27-2); the actual ratio between the levels of that pyramid varies depending on the specific injury or the specific injury mechanism because some injuries are more lethal than others. Table 27-3 further illustrates this point by presenting the crude death and hospitalization rates per 100,000 population by several mechanisms of injury. As shown in the table, drowning/near drowning has a death:hospitalization ratio of 1:0.5, whereas the ratio for homicide/legal interventions is 1:7.5, and fall-related injuries, 1:35.7. All injuries combined have an average death:hospitalization ratio of 1:12.8.

Injuries are also a leading source of short- and long-term disability.[11] Globally, estimates are that up to 25 percent of disabilities may result from injuries and violence. In the United States alone, approximately 5 million people suffer from chronic, injury-related disabilities.[12]

When one combines mortality, morbidity, and disability in a metric such as Disability Adjusted Life Years (DALYs; see Chapter 12), injuries are responsible for approximately 11 percent of all DALYs lost in the world.[13] According to 2010 data documenting the 30 leading conditions contributing the most to DALYs lost in the United States, injuries due to motor vehicle crashes, suicide, falls, and interpersonal violence ranked 9th, 14th, 15th, and 22nd, respectively.[11] Poisoning from prescription overdose, an emerging injury issue, was not in the top 30, but its contribution to DALYs increased by more than 30 percent in the past two decades.[13] If this trend continues, it is likely that prescription drug overdose will join the list of other pressing injury issues contributing the most to DALYs lost in the United States.

The economic impact of injuries is also significant. It is estimated that the aggregate lifetime cost of all fatal and nonfatal injuries produced in 2005 amounted to $404 billion dollars; $80 billion of which resulted from health care, and the remainder from lost productivity resulting from premature death and disability.[14] In the last Global Burden of Disease publication, injuries rank among the highest as death and disability-inducing conditions when compared to any other health problem.[13]

Finally, a summary of the impact of injuries cannot be complete without reference to the largely unmeasured but immense burden that they impose on families and communities. The literature in this field provides evidence of higher divorce rates among parents of injury victims, higher school dropout rates among siblings of victims, and higher alcohol and drug involvement among relatives and others.[15]

TABLE 27-2 Five Most Common Causes of Death by Age Group, United States 2010, All Races, Both Sexes

	Age Groups										
Rank	**<1**	**1–4**	**5–9**	**10–14**	**15–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65+**	**Total**
1	Congenital Anomalies 5,107*	Unint. Injuries 1,394	Unint. Injuries 759	Unint. Injuries 885	Unint. Injuries 12,341	Unint. Injuries 14,513	Unint. Injuries 14,792	Malignant Neoplasms 50,211	Malignant Neoplasms 109,501	Heart Disease 477,338	Heart Disease 597,689
2	Short Gestation 4,148	Congenital Anomalies 507	Malignant Neoplasms 439	Malignant Neoplasms 477	Homicide 4,678	Suicide 5,735	Malignant Neoplasms 11,809	Heart Disease 36,729	Heart Disease 68,077	Malignant Neoplasms 396,670	Malignant Neoplasms 574,743
3	SIDS 2,063	Homicide 385	Congenital Anomalies 163	Suicide 267	Suicide 4,600	Homicide 4,258	Heart Disease 10,594	Unint. Injuries 19,667	Chronic L. Resp. Disease 14,242	Chronic L. Resp. Disease 118,031	Chronic L. Resp. Disease 138,080
4	Maternal Pregnancy Comp. 1,561	Malignant Neoplasms 346	Homicide 111	Homicide 150	Malignant Neoplasms 1,604	Malignant Neoplasms 3,619	Suicide 6,571	Suicide 8,799	Unint. Injury 14,023	Cerebro-vascular 109,990	Cerebro-vascular 129,476
5	Unint. Injuries 1,110	Heart Disease 159	Heart Disease 68	Congenital Anomalies 135	Heart Disease 1,028	Heart Disease 3,222	Homicide 2,473	Liver Disease 8,651	Diabetes Mellitus 11,677	Alzheimer's Disease 82,616	Unint. Injury 120,859

*Numbers indicate counts of deaths.

SOURCE: CDC NCHS, Office of Statistics and Programming. National Vital Statistics Systems. WISQARS™. Available at: http://www.cdc.gov/ncipc/wisqars/

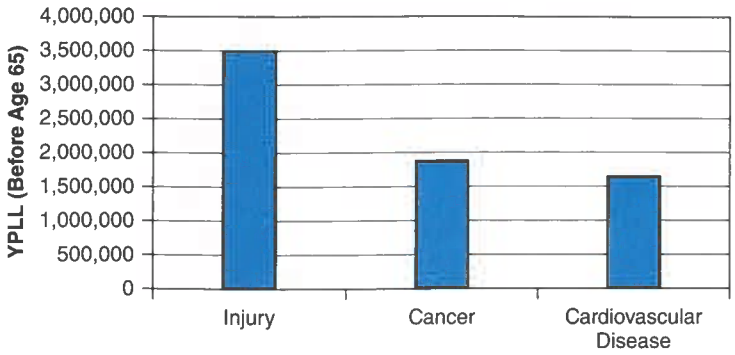

FIGURE 27-1 Years of Potential Life Lost by Cause of Death Before Age 65

Adapted from the CDC NCIPC National Center for Health Statistics Vital Statistics System, U.S., all genders, both sexes, 2004.

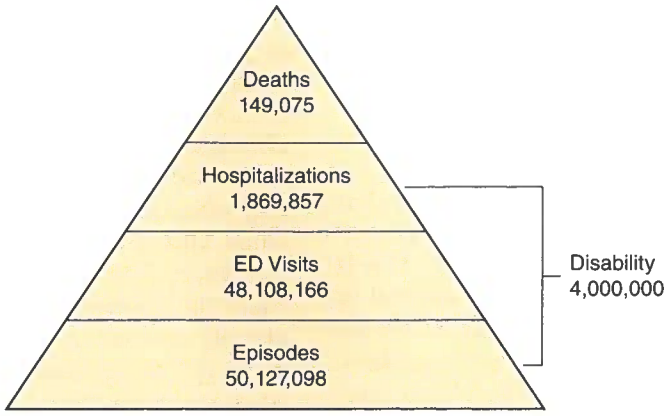

FIGURE 27-2 The Pyramid of Injury, U.S. 2000

Adapted from Finkelstein EA, Corso PA, Miller TR, et al. *The Incidence and Economic Burden of Injuries in the United States*. New York: Oxford University Press; 2006.

TABLE 27-3 Crude Rates of Deaths and Hospitalizations Due to Injury per 100,000 Population, United States 2010, All Ages, Both Sexes

	Deaths per 100,000	Hospitalizations per 100,000	Ratio of Death : Hospitalizations
Motor vehicle	11.5	102.8	1:8.9
Falls	8.7	310.7	1:35.7
Drowning/near drowning	1.5	0.7	1:0.5
Fires/flames	1.0	3.8	1:3.8
Poisonings	13.9	122.7	1:8.8
Homicide/legal intervention	5.4	40.3	1:7.5
Suicide/self-harm	12.4	69.5	1:5.6
Total	58.6	747.8	1:12.8

SOURCE: Office of Statistics and Programming. National Vital Statistics Systems. WISQARS™. Available at: http://www.cdc.gov/ncipc/wisqars/

THE ROLE OF PUBLIC HEALTH

As with any other population health problem, we can apply the public health model of a scientific approach to prevention (Figure 27-3).

For the remainder of this chapter we will follow this model. Under "Epidemiological Framework," we will discuss issues related to the definition of the problem: data collection and surveillance, the identification of causes and risk factors, and the development of interventions. Under "Choice and Evaluation of Countermeasures," we will present issues related to the testing and selection of interventions. Issues that relate to the last step of the public health model will be presented in the "Axioms to Guide Injury Prevention" section and in our discussion of the roles of public health practitioners and public health agencies.

Epidemiological Framework

Injury epidemiology allows for investigation of the interaction among the host (or individual injured), the etiological agent (energy), the vehicle or vector that transmits the energy, and the physical and sociocultural environment where the interaction occurs. This is the same *epidemiologic triad* that is usually applied to infectious or communicable diseases. (*Vehicles* are the inanimate objects that transmit the energy [e.g., cars, flames, bullets], whereas *vectors* are the plants, animals, or persons that transmit the energy [e.g., biting animals, poisonous snakes, human fists].) The use of epidemiology has helped demonstrate that injuries, like diseases, display long-term trends and demographic, geographic, socioeconomic, and seasonal patterns. However, it was not until 1949 that Dr. John Gordon first acknowledged that injury occurrence and severity, much like any other health condition, could be measured and related to different characteristics of individuals, the sources of injuries, and their environments. It was only in 1961 that Dr. James Gibson separated the role of the vehicles or vectors from that of the energy they transmit, thus enabling the application of the analytical framework of epidemiology to the study of injuries. (Readers interested in a more extensive review of the history of injury control are referred to the work of J. A. Waller.[16])

Data Collection and Surveillance

As identified in the essential public health services[17] and in several of the specific competencies outlined in the first domain (Analytic Assessment Skills) of the Core Competencies for Public Health Professionals,[18] effective control of injury (or any other disease, for that matter) requires collection of appropriate detailed data (e.g., frequency, location) related to the injury under study and the events or circumstances surrounding that injury. The analysis of such data helps us to understand the epidemiological patterns of these problems, identify risk factors, suggest causal factors, and guides us in the development of preventive interventions. At times, researchers develop unique data collection efforts to better address the issues under investigation. Most commonly, however, existing datasets are used, despite the fact that most of these datasets are administrative in nature and tend to be oriented either

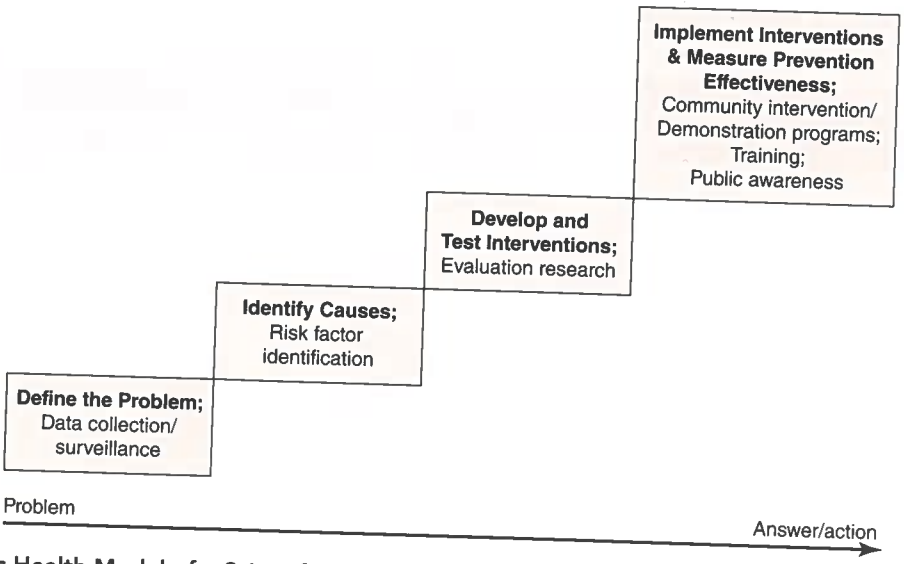

FIGURE 27-3 **Public Health Model of a Scientific Approach to Prevention**

Adapted from the National Center for Injury Prevention and Control, Centers for Disease Control and Prevention

toward the injuries (i.e., the medical aspects) or toward the events (i.e., the circumstances), and rarely include enough detailed information for both. Several U.S. government and private agencies maintain data systems that collect injury data on a continuous basis as part of their public health practice. Table 27-4 lists some of the most commonly used data systems, as well as their website addresses.

Identification of Causes and Development of Interventions

We have indicated, thus far, that injuries involve an unfavorable interaction between etiologic agents and the individual. Therefore, the essence of injury prevention involves keeping the etiologic agent from reaching the potential host (i.e., preventing the interaction) or from

TABLE 27-4 Selected Surveillance Systems Used in Injury Control

Federal Agency	Data System	Acronym	Web Address
National Institute of Drug Abuse	Monitoring the Future Study	MTFS	http://monitoringthefuture.org
Substance Abuse and Mental Health Services Administration	Drug Abuse Warning Network	DAWN	http://samhsa.gov/ (Search "DAWN")
Bureau of the Census	Census of Agriculture	BCCOA	http://www.agcensus.usda.gov/
Agency for Health Care Policy and Research	Healthcare Cost and Utilization Project	HCUP	http://www.ahrq.gov/data/hcup
Bureau of Justice Statistics	National Crime Victimization Survey	NCVS	http://www.bjs.gov
Bureau of Labor Statistics	Census of Fatal Occupational Injuries	CFOI	http://www.bls.gov
	Survey of Occupational Injuries and Illnesses	SOII	http://www.bls.gov
	Survey of Workplace Violence Prevention	—	http://www.bls.gov
Centers for Disease Control and Prevention	Behavioral Risk Factor Surveillance System	BRFSS	http://www.cdc.gov/brfss
	Youth Risk Behavioral Surveillance System	YRBSS	http://www.cdc.gov/yrbs
	Web Based Injury Statistics Query and Reporting System*	WISQARS	http://www.cdc.gov/injury (Search "WISQARS")
	National Ambulatory Medical Care Survey	AMCS	http://www.cdc.gov/nchs
	National Health Interview Survey	NHIS	http://www.cdc.gov/nchs
	National Hospital Ambulatory Medical Care Survey	NHAMCS	http://www.cdc.gov/nchs
	National Hospital Discharge Survey	NHDS	http://www.cdc.gov/nchs
	National Vital Statistics Systems—Current Mortality Sample	NVSSS	http://www.cdc.gov/nchs
	National Vital Statistics Systems—Final Mortality Data	NVSSF	http://www.cdc.gov/nchs/deaths.htm

(*Continued*)

TABLE 27-4 (Continued)

Federal Agency	Data System	Acronym	Web Address
	National Traumatic Occupational Fatality Surveillance System	NTOF	http://www.cdc.gov/niosh/
Consumer Product Safety Commission	National Electronic Injury Surveillance System	NEISS	http://www.cpsc.gov/
Federal Bureau of Investigation	Uniform Crime Reporting System—Supplemental Homicide Report	UCRSHR	http://www.fbi.gov
	Law Enforcement Officers Killed and Assaulted	LEOKA	http://www.fbi.gov/
	National Incident Based Reporting System	NIBRS	http://www.fbi.gov/
National Center for Child Abuse and Neglect	National Data Archive On Child Abuse and Neglect	NDACAN	http://www.ndacan.cornell.edu
Fire Administration	National Fire Incident Reporting System	NFIRS	http://www.nfirs.fema.gov
National Highway Traffic Safety Administration	Fatality Analysis Reporting System	FARS	http://www.nhtsa.gov/FARS
	National Automotive Sampling System—Crashworthiness Data System	NASS CDS	http://www.nhtsa.gov/NASS
	National Automotive Sampling System—General Estimates System	NASS GES	http://www-nrd.nhtsa.dot.gov
	National Occupant Protection Use Survey	NOPUS	http://www-nrd.nhtsa.dot.gov (Search "NOPUS")
Federal Highway Administration	National Household Travel Survey	NHTS	http://www.rita.dot.gov (Search "NHTS")

*It contains multiple data sources identified in this table and provides user-friendly access to its data.

reaching it at rates and in amounts that would produce damage (i.e., minimizing the consequences). Under some circumstances, prevention is aimed at modifying the agents; under others, at reducing exposure to the agent or the susceptibility of individuals. Several conceptual models have been developed over the past 40 years to facilitate the understanding of injury-producing events and possible **countermeasures**. Before we present these models, let us revisit the sequence of injury events.

We live in a particular environment. In this environment, we conduct our lives: we walk, drive, exercise, prepare meals, and do countless other things. On each occasion, we are exposing ourselves to the possibility of experiencing an event that may lead to an injury. This is what could be referred to as the *exposure* component of the chain of events. For example, consider every minute a child spends enjoying a playground. Every so often, a potentially injurious **event** may happen. Following our example, the child falls from the swing; but only a fraction of such falls lead to any *injury*. Some of these injuries, however, may be severe enough to cause death or disability. This chain of events is depicted in Figure 27-4. This sequence of events is very similar to what is known as the Domino Model[19] because of the temporal relationship between the different components of this model. **Injury prevention** and control consists of intervention(s) aimed at blocking the progression of the events. In our example, we could have prevented the event from happening by eliminating the swings from the playground area or by designing them in such a manner that prevents ejection of the child. We could have minimized the impact of the fall by using energy-absorbing flooring underneath the swing. Finally, we could have minimized the consequences of

the injury by providing timely care at a pediatric trauma center with expertise in head injury.

The Haddon Matrix

Dr. William Haddon, Jr., a pioneer in the field of injury prevention, proposed a framework that integrates the role of the individual, the vehicle or vector conveying the energy, and the environment in the sequence of events associated with the injury.[20]

Individuals, vehicles (or vectors), and environments play different roles at different times. The sequence of events over time is divided into three phases: *pre-event* (i.e., preventing the event or incident from occurring), *event* (i.e., preventing injury while the event is happening), and *postevent* (i.e., minimizing the adverse results after the event has occurred). For example, interventions aimed at preventing motor vehicle crashes or falls, suicide attempts, or shootings are pre-event interventions. Event-phase interventions are aimed at either preventing the injury or at reducing the resulting injury by minimizing its severity. Examples of interventions at this stage include bicycle helmets, bullet-proof vests, or pills with smaller medication doses so that they are not as toxic if ingested. The variety and effectiveness of countermeasures at this event stage highlight the point that even if the event (e.g., crash) is not prevented, damage to passengers and occupants can be reduced or eliminated. Postevent interventions can be directed to two goals: reducing any further damage or restoring the health of the individual who sustained injury.

In Table 27-5, we have listed potential interventions to reduce motor vehicle-related injuries using the Haddon Matrix.

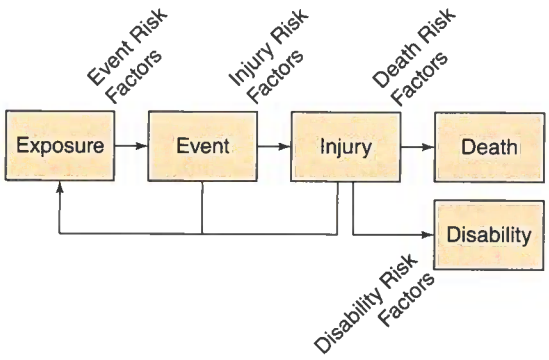

FIGURE 27-4 Sequence of Injury Incidence and Outcomes

Haddon's 10 Basic Strategies

In addition to developing the matrix, Haddon described 10 basic strategies for injury control, presented here with examples relating to injury produced by chemicals:

1. Prevent the initial production of the agent. (Do not produce lead paint.)
2. Reduce the amount of the agent produced. (Package medicine in small quantities.)
3. Prevent release of the agent. (Use childproof caps on bottles of medicine.)

TABLE 27-5 Haddon Matrix with Selected Examples of Motor Vehicle Occupant Injury Prevention Interventions

	Host (Child and Adult Occupants)	Vehicle (Car)	Environment Physical (Road)	Socioeconomic
Precrash	Avoid distracting technology and behaviors Driver's drug or alcohol use, and fatigue	Antilock brakes Speed control Daytime running lights	Improve traffic patterns Increase visibility of hazards	Children in rear seats Legislation regarding child restraint Speed limits Licensing laws
Crash	Use adequate child restraint Use safety belts, airbags	Seating position Built-in child car seats Vehicle speed, size, and mass Interior surfaces	Separation from other lanes Energy-absorbing roadside fixtures	
Postcrash	Exercise and other health enhancement to reduce comorbidity	Crash detection systems that notify EMS (and indicate type of occupants on board) Designs to facilitate extrication Improve location of fuel tank	Designated lanes for emergency vehicles Reduce distance from EMS	Trauma system EMS system prepared to handle children Societal acceptance of residual disabilities

4. Modify the rate or spatial distribution of release of agent from its source. (Devise containers that release poison at limited rates.)
5. Separate, in space or time, the agent from the susceptible person. (Keep children out of orchards while spraying.)
6. Separate the agent from the susceptible person with a material barrier. (Use personal protective equipment such as gas masks.)
7. Modify the contact surface, subsurface, or basic characteristics of the agent. (Reformulate detergents to make them less caustic.)
8. Strengthen the resistance of the person who might otherwise be damaged. (Immunize susceptible people against insect stings.)
9. Counter the continuation and extension of the damage. (Provide and make use of first-aid treatment and poison control centers.)
10. Repair and rehabilitate. (Institute intermediate and long-term therapy.)

Human Performance and Environmental Demands Model

Another system-oriented model was described in the ergonomics literature by Blumenthal.[21] His model focuses on the dynamic interaction between the subject and the environment (Figure 27-5). The lower line represents the variable demands of a particular task, for example, driving a car, and includes the limitations and deficiencies in the vehicle and the environment (including other drivers). The upper line represents the performance of the subject of interest. The injurious event occurs when the system demands increase or the subject performance decreases simultaneously to levels at which they overlap. At times, it is the individual's behavior that fails dramatically, such as in the situation of a driver who suffers a myocardial infarction or stroke. At other times, it is the system that becomes overwhelming, as in the case where another vehicle on the road has a tire blowout. The third, and most common situation, involves neither cataclysmic human failure nor overwhelming demands but rather a simultaneous decrease in performance and increase in task demand. Such would be the situation where an intoxicated driver (who may be able to drive in a straight line) fails to negotiate an unexpected curve, or a teenager who is distracted by a passenger.

Historically, efforts in injury prevention have focused on the individual's performance. It is only recently that attention has been focused on reducing demands of the task—for example, by using automated lighting systems that do not require drivers to remember to turn on their vehicle lights at dawn or dusk.

Regardless of which specific model of injury causation one prefers, data from the data systems described in the previous section (and others) can and should be rigorously examined using public health science methods such as those listed under the sixth domain (Basic Public Health Sciences Skills) of the Core Competencies,[3] for example, social sciences, biostatistics, and epidemiology, to better characterize the contribution of each possible factor involved in the occurrence of an injury.

Choice and Evaluation of Countermeasures

The role of epidemiology in identifying modifiable risk factors is closely related to the identification of countermeasures. Modifiable risk factors become the basis for intervention design. Note that factors playing an important role in minor injuries are not necessarily the same as factors that are important in severe or fatal injuries. Consequently, the choice of countermeasures may

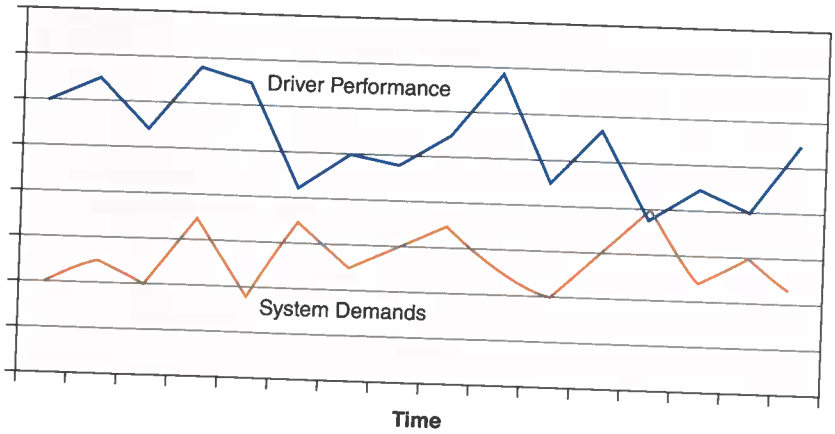

FIGURE 27-5 Hypothetical Localized System Failure
Adapted from Blumenthal 1968.

change as the severity of injuries changes. Also, countermeasures should not be determined by the relative importance of causal or contributing factors or by their earliness in the sequence of events. Rather, priority and emphasis should be given to measures that will most effectively and efficiently reduce injury losses. For example, although psychological factors may be important in the initiation of motor vehicle crashes, it does not follow that psychological screening of drivers would be fruitful.

It is also important to discuss the assumption that anything that sounds reasonable will be effective; this assumption has been the rationale for countless programs, from "defensive driving" training to holiday death counts. Safety programs may not only lack effectiveness, but also may even increase the number or severity of injuries under certain circumstances. One example of this is the case of driver education programs that enable teenagers to drive at an earlier age than they otherwise would.[22]

Numerous safety measures have been adopted without proof of their real-world effectiveness. In many such cases there was only efficacy or laboratory-tested effectiveness data, which turned out to be insufficient when actually applied—for example, Antilock Brake Systems in motor vehicles when first adopted. In other cases, not even efficacy data were available at the time of implementation. The resulting entrenchment of untested measures makes improvement difficult and comparison with alternatives impossible. Millions of dollars can be wasted in unsuccessful safety campaigns, and without adequate preplanned evaluation, no one will ever know whether a campaign was effective and guidance for the future will be lost. The importance of effectiveness evaluation across all public health problems is emphasized both in the Essential Services[17] and as "monitoring program performance" under the seventh domain of the Core Competencies.[3]

In contrast, many other interventions have been evaluated. Table 27-6 lists selected injury control interventions that have been proven effective. For a review of the issues involved in evaluating more detailed prevention interventions, refer to Dannenberg and Fowler's article in the journal *Injury Prevention*.[23]

Another issue to keep in mind when selecting countermeasures is that, very frequently, a "mixed strategy" should be employed, incorporating countermeasures that address complementary aspects. Here the challenge will be in choosing the right type, intensity, and order of interventions to make the "combined" countermeasures most efficient. For example, whether airbags should be designed to protect even unbelted occupants in a frontal collision or as a supplement to safety belts became the issue of a long and intense dispute among motor vehicle safety specialists in the early 1980s. After it was decided that they should be supplemental restraints, the issue of which crashes were severe enough to warrant airbag deployment in a belted occupant became the new topic of debate.[24] Fortunately, current thorough reviews of countermeasure effectiveness are available to public health practitioners, particularly in the area of motor vehicle safety.[25]

Choices must be made, consciously or by default, on such matters as these or on the question of how many dollars to spend in preventing a given number of lost days or injury hospitalizations or deaths. More complicated still are decisions as to how many hundreds of drivers a state will attempt to take off the road in an effort to prevent one of them from killing himself or herself or someone else. This conscious weighing of alternatives is often lacking in the safety field.

AXIOMS TO GUIDE INJURY PREVENTION

Over the years, enough experience has been gathered to establish several axioms that can help guide efforts in controlling injuries.

Injury Results from Interactions between People and the Environment

The agent of injury will cause little damage if the amount of energy reaching tissues is below human tolerance levels. For example, limited exposure to tap water temperature of less than 49°C (120°F) is not likely to acutely damage human tissue, although higher temperatures or lengthy immersion may. The importance of this interaction is reflected in approaches that control the environment by reducing hot water temperatures at the tap and that simultaneously target the parents of small children for education about hot water scald risk.

Injury-Producing Interactions Can Be Modified through Changing Behavior, Products, or Environments

Modifying the immediate or most adaptable link in the chain of causation can reduce injuries. For example, placing an isolation fence or barrier between a child and a residential pool more easily reduces unsanctioned swimming than by supervising the child's behavior all the time. During sanctioned swimming, supervision is the most important strategy. Changing the environment, policies, the person, or the product can each lead to reductions in injuries.

TABLE 27-6 Examples of Injury Prevention Strategies of Known Effectiveness

Type of Injury	Effective Prevention Strategies
Motor vehicle	Child passenger restraint
	Child passenger restraint laws
	Safety belts
	Safety belt laws
	Sobriety check points
	Laceration protective windshields
	Nighttime curfews for teenage drivers
	Pedestrian-friendly front end of automobiles
	Minimum drinking age laws
	Breakaway utility poles
Firearm	Absence of handguns in homes
	Police efforts to target persons illegally carrying guns in high-risk places
	Programs integrating mentoring of at-risk youth, violence interruption, workers and community mobilization
	Restricting gun access with child access protection laws and universal background check laws
Fires/burns	Manufacture of fire-safe cigarettes
	Smoke detectors
	Automatic sprinklers
	Fire-resistant clothing for children
	Legislation regulating flammability of children's clothing
	Fire exits and fire drills
Recreational	Four-sided barriers around swimming pools
	Bicycle helmet use
	Promoting bicycle helmet use (e.g., laws)
	Breakaway bases for softball
Sports injuries	Mouthguards
	Protective equipment (e.g., knee and elbow pads, wrist pads for inline skating)
Falls	Window guards in high-rise buildings
	Weight-bearing exercise among elderly
	Fall-cushioning materials underneath playground equipment
	Protective hip pads for elderly
	Prevention or treatment of osteoporosis in women
Poisonings	Packaging of children's aspirin in sublethal doses; Implement Prescription Dug Monitoring Programs (for prescription drug misuse/overdose)
Farm	Rollover protective structures on farm tractors
Choking and suffocation	Legislation and product design changes (e.g., safe refrigerator disposal, warning labels on thin plastic bags)
All injuries	Minimum drinking age of 21
	Increase in excise tax for alcohol
	911 response systems

Environmental Changes Have the Potential to Protect the Greatest Number of People

Changes to the environment that automatically provide protection to every person have the potential to prevent the most injuries. Automatic protection includes, for example, bullet-proof windows in liquor stores, automatic sprinkler systems in buildings or homes, energy-absorbing steering wheel columns in vehicles, fuses in homes, and child-resistant packaging of consumer products.

Effective Injury Prevention Requires a Mixture of Strategies and Methods

The primary strategies—behavior change (whether by education or by legislation) and technology/engineering are widely recognized as potentially effective in preventing injuries. Strategies such as individual behavior change, product engineering, public education, legal requirements, law enforcement, and changes in the physical and social environment work together to reduce injuries. The challenge in intervention planning is to select the most effective

combination of strategies to produce the desired results. Identifying target populations and deciding on the proper combination of strategies are not exclusive to injury prevention but are part of the fundamental competencies of a public health professional, as outlined in several of their second domain (policy development/program planning) skills.[3]

Further supporting a need for interventions that involve multiple strategies is the concept of the "Three E's" of injury prevention: education, enforcement, and environment.[26] Modifying the design of products and the environment, enforcing laws, educating the public about risk factors and policies—all of these strategies together can be effective. Fully as important is the "Fourth E"—evaluation—without which we cannot move forward with proven preventive measures.

Public Participation Is Essential for Community Action

Effective public policy requires the support and participation of community members. This is, again, reflected both in the 10 Essential Public Health Services[17] and under the fifth domain (Community Dimensions of Practice Skills) of the Core Competencies.[3] Local conditions and resource availability often determine the direction of injury prevention programs. Injury prevention is most successful when there is public participation, support for, and understanding of injury prevention methods. Without public support, laws that are designed to protect the public, such as laws requiring the use of bicycle or motorcycle helmets or safety belts, may be ignored or repealed. This was clearly seen in the Massachusetts legislature regarding mandatory safety belt use; the law was repealed by popular vote in 1986, 11 months after the legislation had been enacted, and then reenacted in 1994.

Cross-Sector Collaboration Is Necessary

Injury prevention requires coordinated action by many groups. Participation by community leaders, in addition to health officials, is necessary in planning and implementing injury prevention programs. Behavior and environmental modification to large numbers of people and sustained through time, together with coordinated postevent responses, require the participation of all. If, as suggested by James Reason´s Human Error Model,[27] injury prevention is about ensuring that no holes are permitted through the always imperfect slices of life´s whereabouts, everybody needs to be doing their part.

There are a number of ways that other community members can contribute to a program's success, ranging from identifying problems to mobilizing community action and evaluating intervention effectiveness.

THE ROLE OF THE PUBLIC HEALTH PRACTITIONER

Public health professionals can play a vital role in injury prevention from a variety of positions. One of the earliest examples of the role that public health practitioners may have in reducing injuries is the 1980s development and establishment of the Massachusetts Statewide Injury Prevention Program, where public health-trained professionals in government-related public servant roles set up a surveillance system from which they derived information as to what risks were larger to the pediatric population in the state, developed an intervention to address them, and evaluated and disseminated their findings.[28]

Research

Public health practitioners are particularly well positioned to collect and analyze local data to identify injury patterns, trends, and risk factors. They are also well positioned to introduce scientific methods to injury control by insisting that new countermeasures be evaluated and that, where relevant, they first be subjected to testing in the field.

Service

Public health practitioners can assist community organizations in analyzing data and choosing countermeasures that are known to be effective. They can also help conduct surveillance of important injury problems.

Education

It is essential to educate not only individuals in the community but also the public and private decision makers (e.g., legislators, designers, executives, builders) whose decisions affect the risk of injury for large numbers of individuals. Every day, these decision makers are confronted with issues such as whether to delay implementation of vehicle standards; whether to make an appliance safer or depend upon users to always follow directions; or whether to promote products on the basis of their potential for reducing injury, as opposed to assuming that "you can't sell safety." Public health practitioners can be of great assistance in these processes. It is also particularly important to educate the members of the media who, in their reporting of injury stories, inform public opinion and shape our understanding of health issues.[29]

Influencing Legislation and Regulation

Public health practitioners are particularly well-positioned to assist (or initiate) local policy discussions and assist in evaluating the validity or quality of the facts presented by the different parties involved in policy discussions. For a public health practitioner to be successful in all these areas,

he or she must also be aware of the barriers to the implementation of injury prevention activities, including funding limitations, organizational difficulties, and turf battles.[7]

THE ROLE OF PUBLIC HEALTH AGENCIES

The growing awareness that injuries can be reduced through the application of public health principles to populations has expanded expectations for national, state, and local public health agencies to increase their activities in injury control.

National Leadership

A good example of national leadership is the 1986 enactment by the U.S. Congress of legislation creating the Division of Injury Control within the CDC's Center for Environmental Health; in 1992, the Division became the National Center for Injury Prevention and Control (NCIPC). The NCIPC supports both extramural and intramural research that is essential to advancing the science and prevention strategies for violence and injury.[30] Research has been supported through several mechanisms, including funding for Injury Control Research Centers (ICRCs). ICRCs are centers for excellence in injury research and they not only study prevention, acute care, and rehabilitation, but also train the next generation of injury prevention specialists. NCIPC's support has also guided the field through landmark documents including the Injury Research Agenda.[31]

Information Collection

Effective injury control depends on adequate information systems. National agencies play a major role in the response to injury-related issues, but the quality of their basic data is determined, predominantly, at the local level. Health departments can stimulate uniform reporting and prompt analysis of injury data and make appropriate use of injury data in administration. Numerous issues that are related to injury definition, coding, case inclusion criteria, event definition and coding and its standardization, remain unresolved and prevent further advancement of the injury field.

National public health agencies can also reinforce these activities by ensuring that information developed from local data eventually gets back to the local level.

Regulation and Legislation

Safety standards have long been applied to many kinds of products and operations. Standards may be descriptive in nature, specifying such things as materials, design, and process, or they may be performance standards, indicating what a product should do (and what it should never do) no matter how it is made. For safety purposes, performance standards are generally preferable, although both types sometimes contribute little except a false sense of security. Most commonly, standards are voluntary and industry-wide. Yet voluntary standards are often insufficient. When public attention is drawn to an industry's failure to keep its products from being unreasonably hazardous, the government may consider issuing regulatory standards.

In addition to product and environmental standards, laws regulating human behavior are also intended to reduce injuries. As with other regulations, whether they succeed depends upon whether they are enforced, whether the penalties are effective, and whether the basic assumptions underlying the regulations and their enforcement are valid. State-level safety belt laws provide a wonderful example of this point. By 2007, all states except New Hampshire had established some form of safety belt law for motor vehicle occupants. (As of 2015, New Hampshire remained the only state without a primary or a secondary seat belt law for adults, although it does have a primary child passenger safety law that covers all drivers and passengers under 18.) The degree of coverage, details, and enforcement of these laws varies widely from state to state; however, one of the most distinguishing factors of these laws' effectiveness is whether they are primary (e.g., not wearing safety belts is reason enough for arrest and punishment) or secondary (i.e., some other offense is needed for the safety belt regulation to be enforced). Figure 27-6 shows safety belt use as reported from observational surveys by state. States with secondary safety belt laws have significantly lower safety belt use.

The ability to regulate is one key characteristic of government structures, and these structures are critical for injury prevention. For instance, the United Nations Decade of Action for Road Safety, an effort to stabilize and reduce global road traffic fatalities by 2020, underscores the importance of government structures. This initiative's activities revolve around five strategies, one of which, Road Safety Management, emphasizes stronger institutions to prevent injury.[32] Specifically: "Designation of national lead agencies with the capacity to develop and lead the delivery of national road safety strategies, plans, and targets, underpinned by the data collection and evidential research to assess countermeasure design and monitor implementation and effectiveness."

Emergency Systems

When primary prevention strategies fail to accomplish needed injury reduction, secondary and tertiary strategies become imperative. These emergency systems are governed by agencies at the local, state, and

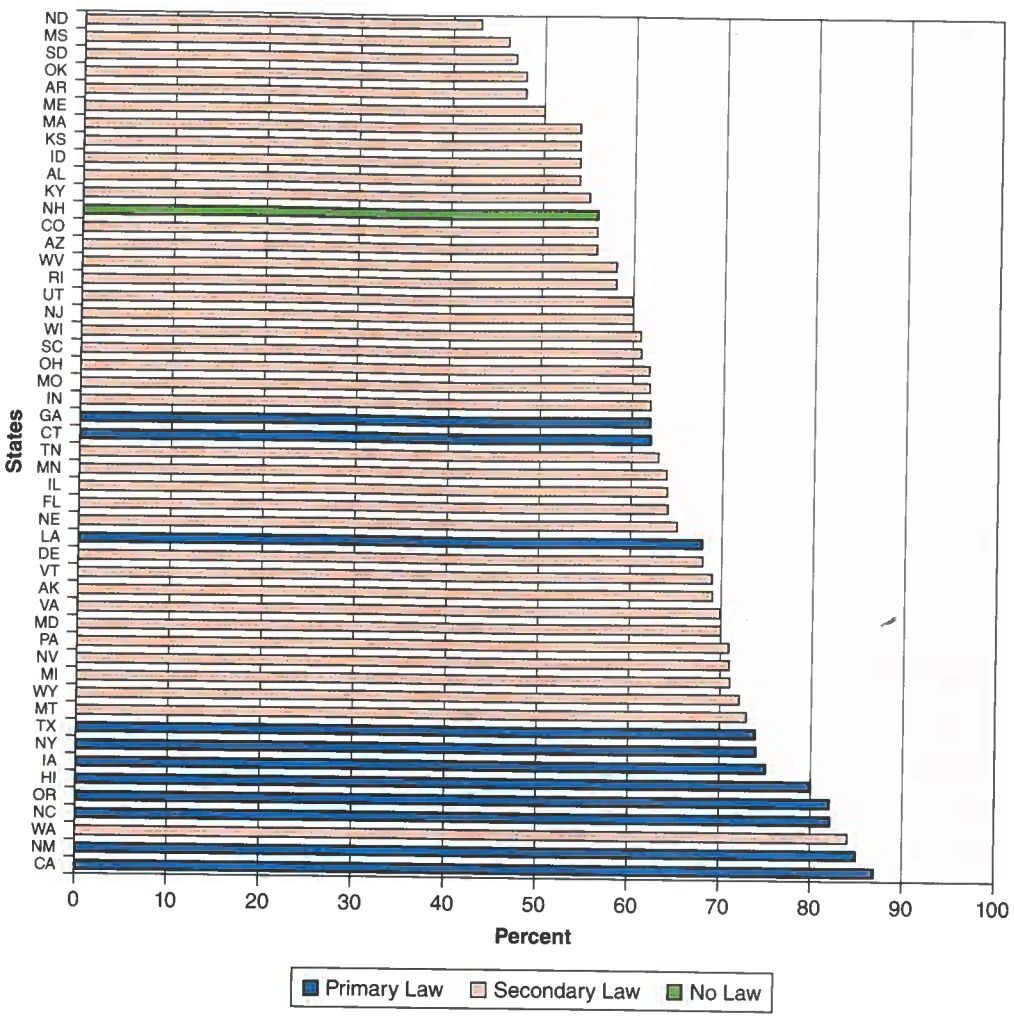

FIGURE 27-6 State Safety Belt Use Rates by Law Type. United States, 2006

SOURCE: National Highway Traffic Safety Administration. Traffic Safety Facts: Safety Belt Use in 2006–Use Rates in the States and Territories. DOT HS 810690. Washington, DC; 2007.

federal levels. Local and regional planning is required for successful organization of emergency communication systems, transportation, trauma units, poison control centers, and specialized units such as those for burns. Public health agencies have a role in organizing such systems, for example, by categorizing emergency facilities on the basis of what kind of injury cases they are equipped and staffed to treat, so that seriously injured persons can have the optimum chance of receiving adequate care. Lately, this role has expanded into development of triage criteria and establishment of regionalized trauma systems where not only the emergency facilities are categorized, but hospitals are too.

Education

Even though it has been earlier stated that priority in injury prevention should be given to measures that require little or no human action or cooperation, education must supplement some forms of injury control.[33] Public health agencies must devise and implement educational efforts directed to the general public that address all three phases of the injury sequence: pre-event, event, and postevent. Another very important function of education is to convince the public as well as private and public organizations that the hazards of their environment can be controlled, reduced, or eliminated. Public support is often needed before a preventive measure can be introduced; for example, people must be persuaded of the benefits of a motorcycle helmet law before they support it. Finally, individuals (e.g., legislators, regulators, administrators) whose decisions can determine the likelihood of injury to thousands of people need to be educated to take advantage of their role in injury prevention.

SUMMARY

Injury is a public health problem that can be controlled with the application of public health tools such as epidemiology, program design, policy change, implementation, and evaluation. Major achievements of the field over the past 30 years reinforce this point. Further reductions in both unintentional and intentional injuries and their associated medical, psychological, and economic burden will require continued efforts by the public health community in surveillance and research, in building partnerships with public and private organizations, and in the development of state and local health department injury control programs. Those public health practitioners who understand the issues and scientific concepts involved in injury occurrence can contribute effectively to substantially reducing this huge problem.

REVIEW QUESTIONS

1. If the bumper of a car strikes a pedestrian, fracturing the femur, what is the etiologic agent?
2. Name the three phases of the injury sequence.
3. What is the most important criterion when choosing among possible countermeasures to reduce an injury problem?
4. Give an example of automatic ("passive") protection from electrical injuries.
5. Seat belts are an example of what type of protection of automobile passengers?
6. What is the difference between a primary and secondary seat belt law?

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REFERENCES

1. Baker SP. Injury control. In: Rosenau MJ, Maxcy KF, Sartwell PE, eds. *Preventive Medicine and Public Health.* 10th ed. New York: Appleton Century-Crofts; 1973.
2. Public Health Functions Steering Committee. Public Health in America. 1995; http://www.health.gov/phfunctions/public.htm.
3. Council on Linkages Between Academia and Public Health Practice. Core Competencies for Public Health Practice. Vol Available at: http://www.phf.org/link/corecompetencies.htm. Washington, DC; 2001.
4. Baker SP, O'Neill B, Li G, Ginsberg M. *The Injury Fact Book.* 2nd ed. New York: Oxford University Press; 1992.
5. Gielen AC, Sleet DA, DiClemente RJ. *Injury and Violence Prevention: Behavioural Science Theories, Methods and Applications.* San Francisco: John Wiley & Sons; 2006.
6. Laflamme L, Svanstrom L, Schelp L, eds. *Safety Promotion Research: A Public Health Approach to Accident and Injury Prevention.* Stockholm, Sweden: Karolinska Institute; 1999.
7. Christoffel T, Gallagher SS. *Injury Prevention and Public Health: Practical Knowledge, Skills and Strategies.* 2nd ed. Gaithersburg, MD: Aspen Publishers; 2006.
8. National Committee for Injury Prevention and Control. Injury prevention: meeting the challenge. *Am J Prev Med.* 1989;5 (3, Supplement):1–303.
9. Bonnie RJ, Fulco CE, Liverman CT. *Reducing the Burden of Injury: Advancing Prevention and Treatment.* Washington, DC: Institute of Medicine, National Academy Press;1999.
10. Centers for Disease Control and Prevention/ National Center for Health Statistics Office of Statistics and Programming. Vital statistics system for numbers of deaths. http://www.cdc.gov/ncipc/wisqars/. Accessed June 10, 2014.
11. U.S. Burden of Disease Collaborators. The state of US health, 1990–2010: burden of diseases, injuries, and risk factors. *JAMA.* 2013;310(6):591–608. DOI: 510.1001/jama.2013.13805.
12. National Center for Injury Prevention and Control. CDC Injury Research Agenda, 2009–2018. Atlanta, GA: Centers for Disease Control and Prevention, US Department of Health and Human Services; 2009:Available at: http://www.cdc.gov/ncipc.
13. Murray CJ, Vos T, Lozano R, et al. Disability -adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet.* December 15, 2012;380(9859): 2197–2223.

14. Centers for Disease Control and Prevention/ National Center for Health Statistics Office of Statistics and Programming. Cost of Injury Reports. http://www.cdc.gov/ncipc/wisqars/. Accessed June 10, 2014.
15. Segui-Gomez M. *Literature Search for Psychological and Psychosocial Consequences of Injury (Report # NHTSA DOT HS 808 527).* National Highway Traffic Safety Administration, US Dept of Transportation;1996.
16. Waller JA. Public health then and now: reflections on a half century of injury control. *Am J Public Health.* 1994;84:665–670.
17. CDC National Public Health Performance Standards (NPHPS). The Public Health System and the 10 Essential Public Health Services. Updated May 29, 2014; http://www.cdc.gov/nphpsp/essentialservices.html.
18. Calhoun JG, Ramiah K, Weist EM, Shortell SM. Development of a core competency model for the master of public health degree. *Am J Public Health.* September 2008;98(9):1598–1607.
19. Heinrich HW. *Industrial Accident Prevention. A Scientific Approach.* 4th ed. New York: McGraw-Hill; 1980.
20. Haddon W. A logical framework for categorizing highway safety phenomena and activities. *J Trauma.* 1972;12:193–207.
21. Blumenthal M. Dimensions of the traffic safety problem. *Traffic Safety Research Review.* 1968;12: 7–12.
22. Vernick JS, Li G, Ogaitis S, MacKenzie E, Baker SP, Gielen AC. Effectiveness of high school driver education on motor vehicle crashes, violations, and licensure. *Am J Prev Med.* 1999;16 (1 Suppl):40–46.
23. Dannenberg AL, Fowler CJ. Evaluation of interventions to prevent injuries: an overview. *Inj Prev.* June 1998;4(2):141–147.
24. Graham JD. *Preventing Automobile Injury: New Findings from Evaluation Research.* Dover, MA: Auburn House Publishing Co; 1988.
25. Elvik R, Hoye A, Vaa T, Sorensen M. *The Handbook of Road Safety Measures,* 2nd ed. Wagonlane, Bingley, U.K. : Emerald Group Publishing Limited; 2009.
26. Standfast SJ. Prevention of motor vehicle injuries in state and local health departments: the New York model. *Bull NY Acad Med.* 1988;64(7):846–856.
27. Reason J. Human error: models and management. *BMJ.* 2000;320(7237):768–770.
28. Guyer B, Gallagher SS, Chang B-H, Azzara CV, Cupples LA, Colton T. Prevention of childhood injuries: evaluation of the Statewide Childhood Injury Prevention Program (SCIPP). *Am J Public Health.* 1989;79(11): 1521–1527.
29. Smith KC, Girasek DC, Baker SP, et al. It was a freak accident': an analysis of the labelling of injury events in the US press. *Injury Prevention.* 2012;18(1):38–43. DOI: 10.1136/ip.2011.031609.
30. Gielen A, Runyan C, Pollack K, Mickalide A, Baker S. Reflections on NCIPC's 20 Years of Injury Control..... Then..... Now..... Imagine. *Journal of Safety Research.* 2012;43(4):319–321.
31. National Center for Injury Prevention and Control. *CDC Injury Research Agenda, 2009–2018.* Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention;2009.
32. World Health Organization. Global Plan for the Decade of Action Road Safety. 2011–2020. 2014; http://www.who.int/roadsafety/decade_of_action/.
33. Sleet DA, Gielen AC. Behavioral interventions for injury and violence prevention. In: Doll LS, Bonzo SE, Mercy JA, Sleet DA, eds. *Handbook of Injury and Violence Prevention.* New York: Springer; 2007.