Principles of Public Health Practice 2nd Ed 3752
Scutchfield, FD, Keck CW) Eds.

CHAPTER 27

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Injury Control

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Seguí-Gómez M, Baker S. Injury Control. In: Scutchfield, Keck (eds.), Principles of Public Health Practice. 3rd edition, Delmar Learning. Clifton Park, NY, 2008. ISBN 978-141-806-7250.

LEARNING OBJECTIVES

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

1. Define the term *injury.*
2. Communicate the dimension and magnitude of the problem and its relationship with other public health problems.
3. Justify the application of the public health model to injuries.
4. Describe William Haddon's framework and proposed countermeasures.
5. Describe other conceptual frameworks for injury prevention.
6. Be aware of the axioms guiding injury prevention.
7. Defend the role of individual and institutional public health practitioners to prevent injuries.

KEY TERMS

Accident
Energy
Event
"Iceberg" or "Pyramid"
Injuries
Injury Prevention
Vehicles (or Vectors)

ACKNOWLEDGEMENTS: We thank Dr. Sleet and Dr. Rosenberg for their contribution in the first edition of this book. Partial support for the writing of this chapter was provided by a CDC grant to the Johns Hopkins Center for Injury Research and Policy (R49/CCR302486) and structural funds from the European Center for Injury Prevention at the University of Navarra (MSG).

We normally think of health problems or diseases as those conditions associated with exposure to infectious agents (e.g., HIV, malaria), 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 of a time period, therefore resulting in injuries. This is a 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 control. Unfortunately, this has not always been the case.

Injuries and their prevention 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 retarded 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 control was characterized by misunderstanding, lack of progress, and scarcity of relevantly trained scientists.

Fortunately, current public health thinking embraces injury prevention, and all 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. 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 its prevention. Emphasis is placed on the preventability of these injuries, and wherever possible, we have provided examples of 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 first 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. The chapter does not address psychological damage as a result of, for example, violence or motor vehicle crashes. 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). 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.

Table 27.1. Examples of Energy, Vehicle, Injury Types and Their Proportion of Injury Deaths in the United States, 2004, Fatally Injured Population (N = 167,184)

Etiology of Injury	Vehicle (vector)	Type of Injuries	Percentage of Deaths
Kinetic energy	Motor vehicle, train, other vehicles, guns, knives, machinery	Abrasions, contusions, sprains, strains, dislocations, fractures, concussion, blunt, open wounds (cuts, piercing), crushing	58.2
Chemical energy	Drugs, cleaning products, poisonous animals	Poisonings, chemical burns	16.3
Absence of oxygen	Water, foreign objects	Strangulation, suffocation, drowning	10.7
Potential energy*	Falling person	Same as kinetic	11.8
Thermal energy	Fire, heat	Burns, heat stroke	2.3
Electrical energy	Wires, appliances	Electrocution	<1
Absence of heat		Frostbite	<1
Ionizing radiation	Radioactive materials	Burns	<1

SOURCE: CDC NCHS, Compressed mortality file 1999–2004. CDC WONDER On-line Database, compiled from Compressed Mortality file 1999–2004 Series 20 No. 2J, 2007. Query date: June 11, 2007. Available at: http://wonder.cdc.gov.

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

DIMENSIONS AND MAGNITUDE OF THE PROBLEM

In the United States in 2004, 167,184 people died because of injuries, amounting to a rate of 5.7 per 100.000. Injuries are among the five leading causes of death in our population, right behind cancer, heart, cerebrovascular, and respiratory diseases (Table 27.2). 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 fourth leading causes of death for ages 1 to 54. Therefore, injuries become the most important cause of Years of Potential Life Lost (YPLL), almost 80 and 100 percent higher than the YPLLs (before age 65) associated with cancer and cardiovascular diseases, respectively (Figure 27.1).[10]

In addition to deaths, injuries result in some 2 million hospital admissions (95% Confidence Interval 1,594,930–2,354,046), which implies a rate of 672 per 100,000 and 48 million emergency department contacts every year.[11] The relationship between mortality and morbidity (or different degrees of severity) is referred to as the "**iceberg**" **or** "**pyramid**" of injury (Figure 27.2), and the actual ratio between each of 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. In the table, drowning/near drowning has a death:hospitalization ratio of 1:0.6, whereas homicide/legal interventions have a ratio of 1:6, and fall-related injuries have a ratio of 1:36.

Injuries are also a leading source of short- and long-term disability. It is estimated that some 7 percent of individuals who are injured sustain some degree of disability, which means some 4 million new cases per year.[12]

Table 27.2. Five Most Common Causes of Death by Age Category, United States 2004. All Races, Both Sexes

Rank	Age Groups <1	1–4	5–9	10–14	15–24	25–34	35–44	45–54	55–64	65+	Total
1	Congenital Anomalies 5,622	Unint. Injuries 1,641	Unint. Injuries 1,126	Unint. Injuries 1,540	Unint. Injuries 15,449	Unint. Injuries 13,032	Unint. Injuries 16,471	Malignant Neoplasms 49,520	Malignant Neoplasms 96,956	Heart Disease 533,302	Heart Disease 652,486
2	Short Gestation 4,642	Congenital Anomalies 569	Malignant Neoplasms 526	Malignant Neoplasms 493	Homicide 5,085	Suicide 5,074	Malignant Neoplasms 14,723	Heart Disease 37,556	Heart Disease 63,613	Malignant Neoplasms 385,847	Malignant Neoplasms 553,888
3	SIDS 2,246	Malignant Neoplasms 399	Congenital Anomalies 205	Suicide 283	Suicide 4,316	Homicide 4,495	Heart Disease 12,925	Unint. Injuries 16,942	Chronic L. Resp. Disease 11,754	Cerebro-vascular 130,538	Cerebro-vascular 150,074
4	Maternal Complications 1,715	Homicide 377	Homicide 122	Homicide 207	Malignant Neoplasms 1,709	Malignant Neoplasms 3,633	Suicide 6,633	Liver Disease 7,496	Diabetes Mellitus 10,780	Chronic L. Resp. Disease 105,197	Chronic L. Resp. Disease 121,987
5	Unint. Injuries 1,052	Heart Disease 187	Heart Disease 83	Congenital Anomalies 184	Heart Disease 1,038	Heart Disease 3,163	HIV 4,826	Suicide 6,906	Cerebro-vascular 9,966	Alzheimer's Disease 65,313	Unint. Injury 112,012

SOURCE: CDC NCHS. Office of Statistics and Programming. National Vital Statistics Systems. WISQARS™. Available at: http://www.cdc.gov/ncipc/wisqars/. Accessed June 11, 2007.

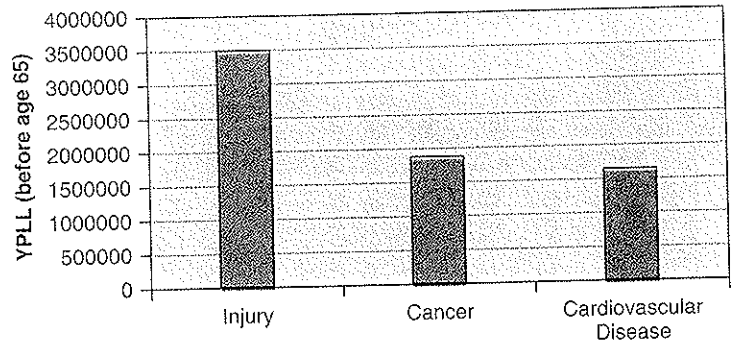

Figure 27.1. Years or Potential Life Lost* by Cause of Death Before Age 65. Adapted from the CDC NCIPC National Center for Health Statistics Vital Statistics System. U.S., all genders, both sexes, 2004.

*Years of Potential Life Lost calculated up to age 65.

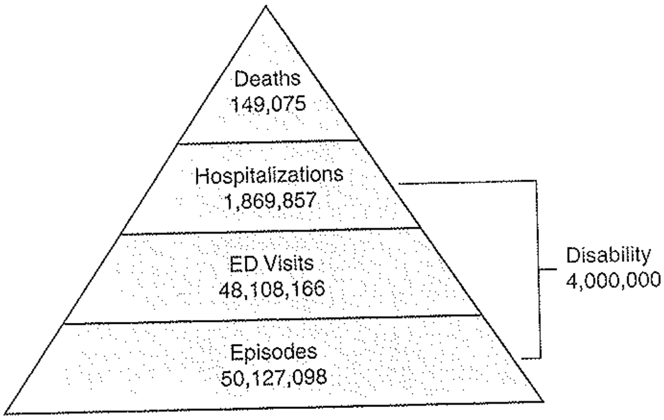

Figure 27.2. The Pyramid of Injury U.S. 2000

SOURCE: 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.

When one combines mortality, morbidity, and disability in a metric such as the Disability Adjusted Life Years (DALYs), injuries are responsible for approximately *15 percent* of all DALYs lost in the world. As of 2002, injuries due to motor vehicle crashes, interpersonal violence, or suicide are the 8th, 15th, and 17th leading causes of DALYs lost worldwide, respectively. Worse yet, it is estimated that by the year 2030, their burden will increase to make them causes number 4, 13, and 14 of lost DALYs.[13]

The economic impact of injuries is significant also. It is estimated that the aggregate lifetime costs of all injuries produced in 2000 will amount to $326 billion dollars; $80 billion of which will relate to costs of health care, and the remaining will be associated with lost productivity resulting from premature death and disability.[14]

Last, 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 is peppered with 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 27.3. Crude Rates of Deaths and Hospitalizations Due to Injury per 100,000 Population. United States 2004. All Ages, Both Sexes

	Deaths	Hospitalizations	Ratio death:hospitalizations
Motor Vehicle	15.4	121.7	1:7.9
Falls	6.7	242.8	1:36.2
Drowning/near drowning	1.4	0.9	1:0.6
Fires/flames	1.3	6.0	1:4.6
Poisonings	10.3	118.4	1:11.5
Homicide/legal intervention	6.0	35.1	1:5.9
Suicide/self-harm	11.5	97.8	1:8.5
Total	56.9	672.4	1:11.8

SOURCE: Office of Statistics and Programming. National Vital Statistics Systems. WISQARS™. Available at: http://www.cdc.gov/ncipc/wisqars/. Accessed June 11, 2007.

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).

During 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 socio-cultural environment where the interaction occurs. (*Vehicles* are the inanimate objects that transmit the energy [e.g., cars, matches, guns], 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[2] and in several of the specific competencies outlined in the first domain (Analytic Assessment Skills) of the Core Competencies for Public Health

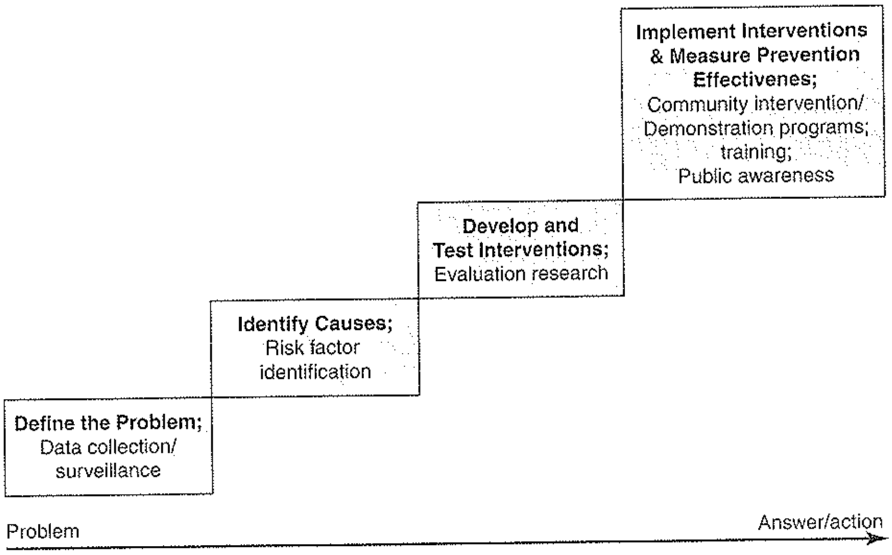

Figure 27.3. Public Health Model of a Scientific Approach to Prevention

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

Professionals,[3] see Appendix C 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 guide 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 toward the injuries (i.e., the medical aspects) or toward the events (i.e., the incidents or "accident" aspects), and rarely include enough detailed information for both. Several United States 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 at all (i.e., preventing the interaction) or from 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 30 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 undergoing an event that may lead to

Table 27.4. Selected Surveillance Systems Used in Injury Control

Data System	Acronym	Federal Agency	Web Address
Census of Fatal Occupational Injuries	CFOI	Bureau of Labor Statistics	http://www.bls.gov
Survey of Occupational Injuries and Illnesses	SOII	Bureau of Labor Statistics	http://www.bls.gov
Survey of Workplace Violence Prevention	—	Bureau of Labor Statistics	http://www.bls.gov
National Crime Victimization Survey	NCVS	Bureau of Justice Statistics	http://www.ojp.usdoj.gov
National Ambulatory Medical Care Survey	AMCS	Centers for Disease Control and Prevention	http://www.cdc.gov/nchswww
National Hospital Ambulatory Medical Care Survey	NHAMCS	Centers for Disease Control and Prevention	http://www.cdc.gov/nchswww
National Hospital Discharge Survey	NHDS	Centers for Disease Control and Prevention	http://www.cdc.gov/nchswww
National Health Interview Survey	NHIS	Centers for Disease Control and Prevention	http://www.cdc.gov/nchswww
National Vital Statistics Systems—Current Mortality Sample	NVSSS	Centers for Disease Control and Prevention	http://www.cdc.gov/nchswww
National Vital Statistics Systems—Final Mortality Data	NVSSF	Centers for Disease Control and Prevention	http://www.cdc.gov/nchswww
Behavioral Risk Factor Surveillance System	BRFSS	Centers for Disease Control and Prevention	http://www.cdc.gov/brfss/
Youth Risk Behavioral Surveillance System	YRBSS	Centers for Disease Control and Prevention	http://www.cdc.gov/nccdphp/dash/yrbs
National Traumatic Occupational Fatality Surveillance System	NTOF	Centers for Disease Control and Prevention	http://www.cdc.gov
National Electronic Injury Surveillance System	NEISS	Consumer Product Safety Commission	http://www.cpsc.gov
Law Enforcement Officers Killed and Assaulted	LEOKA	Federal Bureau of Investigation	http://www.fbi.gov
National Incident Based Reporting System	NIBRS	Federal Bureau of Investigation	http://www.icpsr.umich.edu/NACJD/NIBRS
Uniform Crime Reporting System—Supplemental Homicide Report	UCRSHR	Federal Bureau of Investigation	http://www.fbi.gov

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Table 27.4. (*continued*)

Data System	Acronym	Federal Agency	Web Address
Nationwide Personal Transportation System	NPTS	Federal Highway Administration	http://www.bts.gov/ntda/npts
Healthcare Cost and Utilization Project	HCUP	Agency for Health Care Policy and Research	http://www.ahcpr.gov/data
Healthcare Finance Administration	CMS	US Dept. Health & Human Services	http://www.cms.hhs.gov
Indian Health Service—Ambulatory Care System	IHSACS	Indian Health Service	http://www.ihs.gov
Indian Health Service—Inpatient Care System	IHSICS	Indian Health Service	http://www.ihs.gov
National Data Archive On Child Abuse and Neglect	NDACAN	National Center for Child Abuse and Neglect	http://www.ndacan.cornell.edu
Fatal Accident Reporting System	FARS	National Highway Traffic Safety Administration	http://www-fars.nhtsa.dot.gov
National Accident Sampling System—Crashworthiness Data System	NASS CDS	National Highway Traffic Safety Administration	http://www-nrd.nhtsa.dot.gov/Pubs/NASS94.PDF
National Accident Sampling System—General Estimates System	NASS GES	National Highway Traffic Safety Administration	http://www-nrd.nhtsa.dot.gov
National Occupant Protection Use Survey	NOPUS	National Highway Traffic Safety Administration	http://www-nrd.nhtsa.dot.gov
Monitoring the Future Study	MTFS	National Institute of Drug Abuse	http://monitoringthefuture.org
Drug Abuse Warning Network	DAWN	Substance Abuse and Mental Health Services Administration	http://dawninfo.samhsa.gov/
Census of Agriculture—	BCCOA	Bureau of the Census	http://www.nass.usda.gov/Census_of_Agriculture/index.asp
National Fire Incident Reporting System	NFIRS	Fire Administration	http://www.nfirs.fema.gov
Web Based Injury Statistics Query and Reporting System*	WISQARS	CDC National Center for Injury Prevention and Control	http://www.cdc.gov/ncipc/wisqars/

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

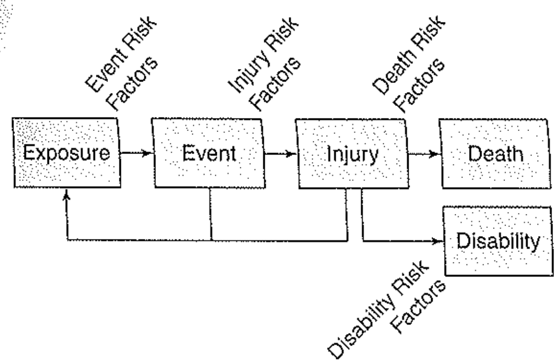

Figure 27.4. Sequence of Injury Incidence and Outcomes

SOURCE: Delmar Cengage Learning.

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 has been labeled as the Domino Model[17] because of the linear relationship between the different components of this model. **Injury prevention** 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 an energy-absorbing flooring underneath the swing. Finally, we could have minimized the consequences of the injury by providing quick care at a pediatric facility 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 carrying the energy, and the *environment* in which the interaction occurs with the sequence of events associated with the injury.[18]

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 post-event (i.e., minimizing the adverse results after the event has occurred). For example, interventions aimed at eliminating motor vehicle crashes or falls from windows, 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. Post-event interventions can be directed to two goals: reducing any further damage or restoring the health of the individual who sustained injuries.

In Table 27.5, we have listed potential interventions to prevent motor vehicle-related injuries using the Haddon Matrix.

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 (in parentheses):

1. Prevent the initial marshaling of the agent. (Do not produce lead paint.)
2. Reduce the amount of the agent marshaled. (Package medicine in small quantities.)
3. Prevent release of the agent. (Use childproof caps on bottles of medicine.)
4. Modify rate or spatial distribution of release of agent from its source. (Devise containers that release poison at limited rates.)

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
PRE-CRASH	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	
POST-CRASH	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

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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 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.)

Obviously, there are some commonalities between these 10 countermeasures and the matrix described in the previous section. Several of these countermeasures relate to the host (strategies 5, 6 and 8), some to the vehicle or vector (strategies 1 through 4, and 7), and some to the environment (strategies 5, 6, 9, and 10). They could also be classified as pre-event, event, or post-event. Actually, countermeasures 1 through 3 could be described as pre-event interventions, 4 through 8 as event interventions, and 9 and 10 as post-event interventions, although Haddon himself disagreed with such categorization because each strategy is broadly relevant. For example, countermeasure 1 could also be an event intervention, and countermeasure 5 could also be considered a pre-event intervention.

Human Performance and Environmental Demands Model

Another system-oriented model was described in the ergonomics literature by Blumenthal.[19] His model is centered 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

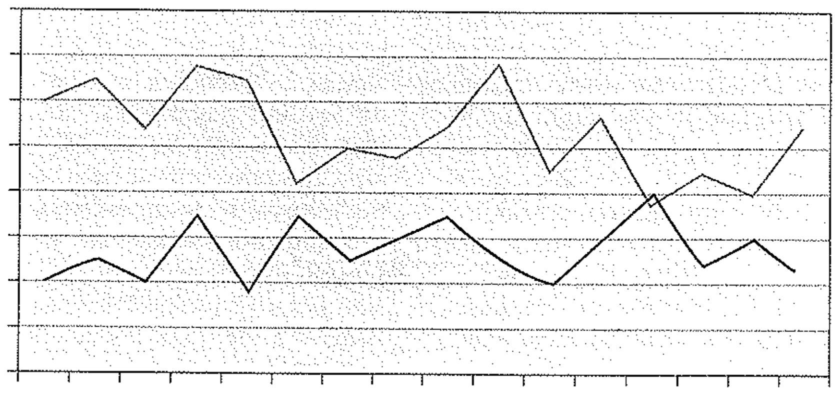

Figure 27.5. Hypothetical Localized System Failure
SOURCE: Adapted from Blumenthal 1968.

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.

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 exact 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 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 has been the rationale for countless programs, from "defensive driving" training to holiday death counts. Safety programs not only may lack effectiveness, but under certain circumstances, they could even increase the number or severity of injuries, as in the case of driver education programs that enable teenagers to drive at an earlier age than they otherwise would.[20]

Numerous safety measures have been adopted without proof of their effectiveness or without being evaluated. 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[2] 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 *Injury Prevention*.[21]

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.[22]

Table 27.6. Examples of Injury Prevention Strategies of Known Effectiveness

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
Fires/burns	Manufacture of fire-safe cigarettes
	Smoke detectors
	Automatic sprinklers
	Fire-resistant pajamas 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
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)
Shootings	Having no firearms in the home
All injuries	Minimum drinking age of 21
	Increase in excise tax for alcohol
	911 response systems

Choices must be made, by default if not consciously, 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, tap water temperature of less than 120 degrees Fahrenheit 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 elderly and 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 weakest or most adaptable link in the chain of causation can reduce injuries. Unsanctioned swimming in a home swimming pool is more easily reduced by placing an isolation fence or barrier between the child and the pool than by supervising the child's behavior all the time. During sanctioned swimming, supervision is the most important strategy. Changing the environment, the laws, the person, or the product can each lead to reductions in injuries.

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, 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. 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 efficient 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]

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 Essential Services[2] 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 belt use, 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 enacted again 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. 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.

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.

Education

It is essential to educate not only individuals in the community but also, and even more important, 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 always to 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.

Influencing Legislation and Regulation

Public health practitioners are particularly well positioned to assist (or initiate) local policy discussions and assist in evaluating the appropriateness 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.

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 should 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 advance of the injury field.

National public health agencies must 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. As of 2007, all states except New Hampshire have some form of safety belt law for motor vehicle occupants. 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 (i.e., 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.

Emergency Systems

When primary prevention strategies fail, secondary and tertiary strategies become imperative. Municipal, state, and federal agencies are taking an increasing interest in emergency care and transport. 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 patients 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 we have said before 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.[29] 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 post-event. 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.

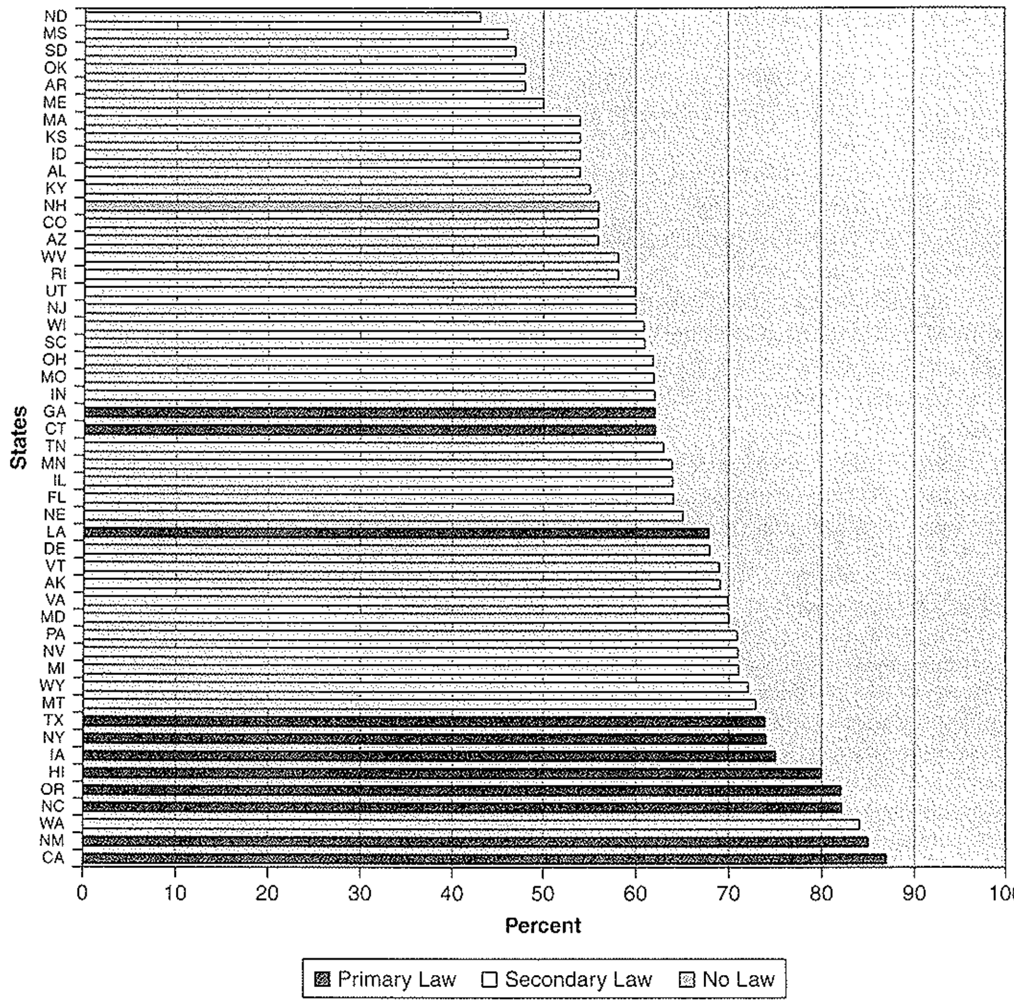

Figure 27.6. State Safety Belt Use Rates by Law Type. United States, 2006

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.

SUMMARY

Injury is a public health problem that can be controlled with the application of public health tools such as epidemiology, program design and implementation, and evaluation. Major achievements over the past 30 years or so 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 of automobile passengers.
5. True or False: Seat belts are an example of automatic ("passive") protection of automobile passengers.
6. True or False: Primary enforcement of a seat belt law means that not wearing a seat belt is sufficient reason to arrest someone.

REFERENCES

1. Baker SP. Injury control. In: Sartwell PE, ed. *Preventive Medicine and Public Health*. 10th ed. New York: Appleton Century-Crofts; 1973.
2. Public Health in America. Available at: http://www.health.gov/phfunctions/public.htm.
3. Council on Linkages Between Academia and Public Health Practice. *Core Competencies for Public Health Practice*. Washington, DC: Council on Linkages Between Academia and Public Health Practice; 2001. Available at: http://www.phf.org/link/corecompetencies.htm.
4. Baker SP, O'Neill B, Li G, Ginsberg M. *The Injury Fact Book*. 2nd ed. New York: Oxford University Press; 1992.
5. Laflamme L, Svanstrom L, Schelp L, eds. Safety Promotion Research: *A Public Health Approach to Accident and Injury Prevention*. Stockholm, Sweden: Karolinska Institutet; 1999.
6. Gielen AC, Sleet DA, DiClemente RJ. *Injury and Violence Prevention: Behavioural Science Theories, Methods and Applications*. San Francisco: John Wiley & Sons; 2006.
7. Christoffel T, Scavo Gallagher S. *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, supp l):297.
9. Bonnie RJ, Fulco CE, Liverman CT, eds. In: IOM report *Reducing the Burden of Injury: Advancing Prevention and Treatment*. Washington, DC: National Academy Press; 1999.
10. CDC NCHS, Office of Statistics and Programming. Vital statistics system for numbers of deaths. WISQARS. Available at: http://www.cdc.gov/ncipc/wisqars/. Accessed June 11, 2007.
11. CDC NCHS, Office of Statistics and Programming. Vital statistics system for numbers of deaths. WISQARS. Available at: http://www.cdc.gov/ncipc/wisqars/. Accessed June 11, 2007.
12. Warner M, Barnes PM, Fingerhut LA. Injury and poisoning episodes and conditions; National Health Interview Survey. *Vital Health Stat*. 2000; 10(202).
13. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. *PLOS medicine*. 2006;3;2011–2029.
14. 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.
15. Segui-Gomez M. *Literature Search for Psychological and Psychosocial Consequences of Injury*. 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;84:664–670.
17. Heinrich HW. *Industrial Accident Prevention. A Scientific Approach*. 4th ed. New York: McGraw-Hill; 1980.
18. Haddon W Jr. A logical framework for categorizing highway safety phenomena and activities. *J Trauma*. 1972;12:193–207.
19. Blumenthal M. Dimensions of the traffic safety problem. *Traffic Safety Res Rev*. 1968;12:7.
20. Vernick JS, Li G, Ogaitis S, MacKenzie E, et al. Effectiveness of high school driver education on motor vehicle crashes, violations, and licensure. *Am J Prev Med*. 1999;1S:40–46.
21. Dannenberg AL, Fowler CJ. Evaluation of interventions to prevent injuries: An overview. *Inj Prev*. 1998;4:141–147.
22. Graham JD. *Preventing Automobile Injury: New Findings from Evaluation Research*. Dover, MA: Auburn House Publishing Co; 1988.