

Injury Prevention and Other International Public Health Initiatives

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The word injury originates from the Latin *in-juris*, which literally means "not right." In cellular terms, injury is physical damage caused by the excessive transfer of energy (whether mechanical, electrical, chemical, thermal, or radiation) or the lack of essential factors for energy production, such as oxygen or heat (eg, suffocation, drowning, or frostbite).

Traditionally, public health officials ignored injuries because they were assumed to be random, unavoidable "accidents." We now know that many injuries, like diseases, affect identifiable high-risk groups, follow a predictable chain of events, and are therefore preventable. Even when prevention fails, the severity of an injury may be reduced. The likelihood of death or long-term disability can be reduced by prompt provision of acute care and rehabilitation. The combination of these three strategies—prevention, acute care, and rehabilitation—is termed "injury control."

General concepts of injury epidemiology

Global burden of injuries

Injuries rank among the 10 leading causes of death worldwide [1]. An estimated 5 million people worldwide died from injuries in 2000, accounting for 9% of world's deaths and 12% of the world's burden of disease. More than 90% of these injuries occurred in low-income countries (LICs) or middle-income countries (MICs) [2]. Even in high-income countries (HICs)

such as the United States, injuries produce about one fourth of all emergency department visits [3].

Injuries disproportionately affect children, adolescents, young adults, and parents of young children. In the United States, injuries are the number one cause of death among persons 1 to 44 years of age and account for more years of potential life lost before age 65 than all causes of cancer and all causes of heart disease combined. According to the World Health Organization, injury ranks as a leading causes of death and disability among all age groups except people 60 years of age or older [2].

In contrast to the progress that has been made in the control of many infectious diseases, little has been done to stem the tide of injuries around the world. The World Bank predicts that the global burden of injuries, especially those caused by interpersonal violence, war, self-inflicted injuries, and road traffic injuries, will increase dramatically by the year 2020 [4]. Road traffic injuries are expected to rise from the ninth leading cause of disability-adjusted life years lost worldwide to the third by 2020 (Table 1).

Injury typology

There are various ways to classify injuries. The most widely used approach divides injuries by intent. "Intentional" injuries are subdivided into those caused by self-directed harm (eg, attempted or completed suicide, parasuicide) and those caused by interpersonal violence. The latter subcategory is further subdivided into individual violence (eg, assault, homicide), group violence (eg, gang violence), and collective violence (eg, religious or ethnic violence, war). "Unintentional" injuries are often subdivided by mechanism—road traffic injuries, falls, burns, poisoning, drowning, etc. Injuries may also be classified according to the environment or circumstances in which they occur (eg, home, recreation/leisure, workplace, and road traffic injuries).

Major causes of injury fatalities

Worldwide, the most common causes of injury-related deaths are road traffic injuries and suicide. The 10 leading causes of injury death for persons

Table 1
World ranking of injury-related mortality and burden of disease (DALYs lost), 1990 and 2020

Injuries	Number of deaths		DALYs lost	
	1990	2020	1990	2020
Road traffic injuries	9	6	9	3
Self-inflicted injuries	12	10	17	14
Interpersonal violence	16	14	19	12
War	20	15	16	8

Abbreviation: DALYs, disability-adjusted life years.

15 to 29 years of age include road traffic injuries, self-inflicted injuries, interpersonal violence, war injuries, drowning, poisoning, and injuries resulting from exposure from fire.

Impoverished people in LICs and in HICs tend to carry the highest burden of injuries. The LICs and MICs of Europe have the highest injury mortality rates, but Southeast Asia and Western Pacific Regions account for the highest number of injury deaths worldwide.

Young people between 15 and 44 years of age account for nearly half of the world's injury-related mortality. Male mortality from road traffic injuries and interpersonal violence is almost three times higher than female mortality. Globally, injury mortality among men is twice that of women. In some regions, however, mortality rates for suicide and burn fatalities among females are as high as or even higher than that of males. Because of their vulnerability and close proximity to water and fire, children under 5 years of age account for approximately 25% of drowning deaths and a little over 15% of fire-related deaths worldwide.

Concept of the "injury pyramid"

The injury mortality figures provided above represent a small fraction of the total injury burden. For every injured victim who dies, there are typically many more who sustain serious but nonfatal injuries. Many of these victims suffer long-lasting or permanent disabilities. Some describe the ratio of injury deaths, hospitalizations, and outpatient emergency department or office visits as an "injury pyramid" because nonfatal events typically outnumber fatalities to a large degree. A recent population-based, descriptive study of fatal and nonfatal injuries in two states in the United States identified 13,052 injury-related deaths. During the same period, the researchers counted 131,210 injury admissions and 1.9 million injury visits to the emergency departments [5].

It is likely that similar if not larger ratios of fatal to nonfatal injuries prevail in LICs and MICs. However, the data systems necessary to routinely collect and tabulate these counts are lacking in many parts of the United States (less in LICs and MICs). When this is true, mortality data are often the only information available to quantify the public health impact of injuries.

General concepts of injury prevention

Haddon matrix

William Haddon, a physician, established the field of injury control by applying the core principles of public health to the prevention and mitigation of injuries. Using the time-tested concept of the "epidemiological triangle"—the idea that many diseases are the result of harmful interactions between the host, the disease vector, and the environment, Haddon showed

how these same three factors interact to cause many injuries. To facilitate the identification of opportunities for prevention and control, Haddon divided injury-causing events into three temporal phases: (1) pre-event, (2) the injury-producing event itself, and (3) the post-event phase. Doing this produced a "phase-factor" matrix of nine discrete cells [6]. Examining each cell can suggest various strategies to prevent or control injuries. Since its introduction in 1972, this phase-factor matrix, more commonly called the "Haddon matrix," has proven to be an invaluable tool for injury prevention and control (Fig. 1).

Haddon later outlined 10 generic injury-control strategies that can be used to break the chain of injury causation (Table 2) [7]. Examining this list to identify the most promising approaches is known as "options analysis." The best strategy is not always the most obvious one or the one most proximate to the injury. Often, a combination of strategies is superior to any single one.

Haddon's ideas were first applied to the prevention and control of motor vehicle crashes. They produced dramatic results. According to the Centers for Disease Control (CDC), between 1925 and 1999 six times as many people drove automobiles, the number of motor vehicles increased 11-fold, and the number of miles traveled in motor vehicles increased 10-fold. Despite this dramatic increase in automobile use, the death rate per 100 million vehicle miles traveled plummeted from 18 in 1925 to only 1.7 in 1997—a 90% decrease [8]. On the strength of this accomplishment, the CDC acclaimed the reduction in road and road traffic fatalities as one of the top 10 public health achievements of the 20th century. Other developed countries, such as Sweden and the United Kingdom, have achieved equally if not more impressive improvements in road traffic safety [9].

The "public health approach" to injury prevention

Injury control draws on the expertise of many disciplines, including epidemiology, disease prevention, health promotion, biomechanics, acute

	Host	Agent	Environment
Pre-event	Alcohol Speed	Tires Brakes	Signs, Signals, Surface
Event	Belt Use Helmet Use	Seat Belt Airbags	Side Slope Guardrails
Post-event	Health Age	Fuel System Materials	EMS Response Road Shoulders

Fig. 1. Haddon's matrix.

Table 2
Options analysis

Options	Examples
1. Prevent creation of hazard	Ban production and sale of assault weapons to civilians
2. Reduce the amount of hazard	Limit water heater temperature to 125 °F (47.25 °C)
3. Prevent the release of a hazard that already exists	Put dangerous medications in "child-proof" containers
4. Modify the rate of distribution of release of the hazard from its source	Require fire-safe cigarettes that cannot easily ignite furniture or bedding
5. Separate, by time or space, the hazard from host	Construct overpasses or underpasses to eliminate crossing streams of traffic
6. Physically separate, by barriers, the hazard from host	Equip cabs with bullet- and knife-proof partitions
7. Modify surfaces and basic structures to minimize injury	Equip all new cars with driver- and passenger-side air bags
8. Make that which is to be protected more resistant to damage	Issue bulletproof vests to law enforcement officers and security guards
9. Begin to counter damage already done	Promote citizen training in first aid and CPR
10. Stabilize, repair, and rehabilitate the injured person	Implement trauma care

care, rehabilitation, law, and public administration. It follows the traditional public health approach, which involves four generic steps: (1) Define the health problem, (2) identify causes and risk factors, (3) develop and test interventions, and (4) implement successful interventions and evaluate their impact.

Step 1: define the problem

Population-based data are essential to describe the scope of an injury problem, monitor patterns and trends, and evaluate the impact of countermeasures. Several sources of information may be used for this purpose. Vital records or death certificates can be used to document overall rates of mortality, but they do not provide information about nonfatal injuries. Hospital records [10] and trauma registries, emergency department data, EMS reports [11], and police reports, or a combination of these [12] can be used to provide essential information about cases of major trauma, depending upon local resources and the nature of information being sought.

Step 2: identify causes and risk factors

Descriptive epidemiologic studies determine who is injured; what kinds of injuries are involved; and where, when, and why particular injuries occur. These data can generate hypotheses for further investigation with analytical studies.

In some cases, the link between a risk factor and injury is so strong that no additional research is needed. For example, early studies of road traffic

injury in the United States revealed that half of fatal crashes and 60% of fatal single-vehicle crashes involved alcohol [13]. In other cases, to quantify the impact of particular risk factors, it is necessary to compare the rate of injury among those with the risk factors of interest to similar individuals who lack these risk factors.

Step 3: develop and test interventions

Once a problem and its associated risk factors are identified, several countermeasures may be considered for implementation. Careful attention must be given to the characteristics of the target population, the feasibility of the candidate countermeasures, their acceptability to the target population, and the cost of their implementation. Pilot programs are often helpful to test various strategies. The most promising can be selected for widespread implementation.

Step 4: implement successful interventions and evaluate their impact

Many prevention programs are evaluated by determining their impact on morbidity or mortality in the target population. It is not always feasible to do this, particularly when the program is a small-scale demonstration project. In some instances, surrogate measures may be used to assess program impact. For example, pre- and postintervention rates of smoke detector use in a target neighborhood can be compared to evaluate the impact of a program to promote their distribution. Telephone surveys can be used to evaluate the impact of educational campaigns on knowledge, attitudes, and self-reported behavior.

Injury countermeasure

Active versus passive interventions

Most injury-prevention strategies can be classified as "active" or "passive." Active countermeasures require the conscious cooperation of the individual to be effective. Examples include use of manual safety belts, motorcycle helmets, child safety seats, and protective eyewear in the workplace. Passive countermeasures require little or no cooperation by the person being protected. Examples include air bags in cars, sprinkler systems in public buildings, floatation hulls on watercraft, and shields that prevent workers from becoming ensnared in hazardous equipment.

The three "Es" of injury control

Most injury-control countermeasures, whether active or passive in nature, use one of three generic strategies: (1) Education (to encourage the public to voluntarily adopt safe behavior or practices), (2) Enforcement of safety regulations (eg, add the force of law to compel the desired behavior

or practices), or (3) Engineering (eg, designing safer products or environments). Each approach offers certain advantages and disadvantages.

Education. Education is often the first approach taken to promote safe behavior. Implicit in this approach is the belief that once people know what to do to reduce their risk of injury, they change their behavior. Examples include driver's education, child pedestrian training [14], education of parents and caregivers to reduce playground injuries among children [15], posters and videos that promote safe behavior in the workplace [16], and various training materials to promote burn prevention [17,18]. Public education campaigns are popular because they are voluntary in nature. They do not consistently produce sustained behavior change.

The impact of public education is often blunted by attenuation of effect. No matter how powerful, pervasive, and repetitive a safety message may be, some people never encounter it. Among those who do, some actively reject the message. Some who agree with the message are insufficiently motivated to change their behavior. Among those who change their behavior, some relapse over time. Others fail to consistently follow the message. Finally, not everyone who adopts a protective strategy escapes injury.

Enforcement. When voluntary acceptance of a countermeasure is poor, adding the force of law may increase compliance. Appropriate regulations coupled with effective enforcement can promote safe behaviors, products, and environment. The impact of "mandatory use" laws, such as those that compel the wearing of safety belts and motorcycle or bicycle helmets, can be impressive. In the United States, an educational campaign to promote bicycle helmets increased its use by only 1%, which increased to 26% after the state enacted a mandatory helmet law [19]. Similarly, the use of safety belts increased by 15% after law enforcement agencies began issuing traffic citations and levying fines [20]. In Brazil, a 20% reduction in road traffic fatalities was seen after implementation of speed limits [21].

Combining the strategies of education and enforcement usually works better than relying on either strategy alone. In Elmira, New York, a publicity campaign combined with high-visibility enforcement of the state's safety belt law boosted rates of seat belt use from 49% to 77%. Four months after the effort ceased, safety belt use sagged to 66% but rebounded to 80% during a reminder campaign [22]. In Bogota and Cali, Colombia, a widely publicized and visibly enforced ban on the carrying of firearms during elections and "high-risk" holidays was associated with a significant decrease in the rate of homicides compared with comparable times when the ban was not in effect [23].

Mandatory use laws are often effective, but they are difficult to enact. Opponents of such laws argue that they are an infringement of personal freedom and that individuals have the right to choose hazardous behavior if the risk is acceptable to them. Enforcement of regulations can be difficult in

many low-income countries (LIC) due to limited resources [LIC defined by World Bank as countries with Gross National Income (GNI) per capita of less than US \$768/y]. In Ghana, for example, the total number of vehicles available to the police for the whole country of 18 million people is 145 [24].

In workplace settings, rules to promote safe behavior by employees may be easily introduced, but they are unlikely to be effective unless they are visibly and consistently enforced. Examples include requiring the wearing of hardhats in construction zones, requiring the use of safety goggles, requiring that employees use safety straps when working in high places, and enforcing a strict "no smoking" policy around flammable materials.

Engineering. Many injuries can be prevented by building safety into products or local environments. The up-front costs of engineering are often greater than education or enforcement campaigns, but the downstream effects are often greater as well. Engineering is usually more effective than behavior change because it does not require cooperation of users to exert its protective effects.

Consider the following examples. In contrast to unsuccessful efforts to "fix the nut behind the wheel," the adoption of federal standards for passenger restraint systems, safety glass, fuel system integrity, and the use of nonflammable interior fabric saved 37,000 lives between 1975 and 1978. The subsequent introduction of airbags further cut the annual toll of crash-related deaths and injuries.

Seatbelts in cars are a good example of successful engineering for injury prevention. They reduce motor vehicle fatality by about 50% and serious injury by 55%. They are affordable and feasible in many LICs.

Unlike in HICs (HIC - GNI per capita > US \$9386, World Bank 2003), drivers of vehicles make up a small portion of road traffic deaths in LICs. Pedestrians, passengers of large vehicles, and drivers of two-wheelers (bicycle and motorcycles) are most at risk [11]. Promising engineering interventions for pedestrians include sidewalks, roadway barriers, pedestrian crossing signs, one-way street networks, school zone measures, adequate roadway lightening, and pedestrian indicator lights [25]. Many of these interventions can be used in LICs [24]. For two-wheelers, helmets are an excellent intervention. Properly designed and worn helmets reduce head injuries by more than 60% [26]. The implementation of a helmet program in Taiwan reduced mortality by 14% [27].

In South Asia, high burn death rates among females result from the use of portable stoves on uneven surfaces where they can explode or overturn or on the floor where long skirts can catch fire and where refueling and maintenance are difficult [28,29]. Simple intervention in stove designs that keep heat and flames away from clothing and out of reach of children could prevent burns. This has been proven to work in Nepal and in parts of Africa [30]. Loose, flammable clothing is another important risk factor for burns among children and women in some LICs. Proven interventions from HICs

[31], such as decreased flammability of fabrics, flammability standards for children's sleepwear, and change from loose, frilly dresses to more close fitting clothes, can be applied in LIC settings with significant advantage.

Because engineering solutions usually increase the cost of a product, they are unpopular with manufacturers. For this reason, many advocates of injury prevention support consumer product safety laws to compel manufacturers to act. Manufacturers typically oppose these laws because they fear it will raise the price of their products, potentially discourage sales, and reduce their ability to compete with nonregulated manufacturers. If and when efforts to regulate a hazardous product fail, product liability lawsuits may be the only way to force a needed change in product design.

Emergency medicine and injury prevention

Emergency physicians, trauma surgeons, and other acute care clinicians are ideally placed to be effective advocates for injury prevention and control. This is because they see first hand what happens when prevention fails. The practice of emergency medicine combines elements of patient care, public health, and public safety. From our vantage points in hospital emergency department and the prehospital care system, we can promote public awareness through bedside safety education, the screening for injury risk factors (such as alcohol abuse and domestic violence), and referral of patients for aftercare services. On the societal level, we can be effective advocates for sound legislation and public policy.

The value of injury prevention cannot be over emphasized. According to an Institute of Medicine report on EMS for children, injury prevention efforts have "the potential to be the most effective EMS intervention" [32]. A report by National Highway Traffic Safety Administration, expanding on the notion of an "EMS agenda for the future," identified injury prevention as a priority area for future EMS education [33]. Emergency care providers, including EMS professionals, can contribute to injury prevention in three ways: (1) risk assessment and intervention at the individual level, (2) data collection to support problem identification at the population level, and (3) public education and advocacy at the policy level. Efforts like these need not be limited to wealthy nations. Examples of injury-related data collection from developing countries exist [34,35]. Likewise, much good can be done in LICs and MICs by developing simple, sustainable emergency care systems linked to a nation's existing health infrastructure [36].

Global public health response to injuries and other emergencies

Growing recognition of the global burden of injury has led to a modest but growing interest in injury prevention and control among a variety of governmental and nongovernmental organizations (NGOs). Some of the

most noteworthy programs and organizations are outlined below. The descriptions that follow represent only a fraction of what each organization is doing on a global scale. Readers are referred to the web sites for more information about each organization (Box 1).

World Health Organization

In fulfilling its global mission to promote public health, the World Health Organization (WHO) has multiple divisions working on a diverse set of global public health initiatives. Three projects are mentioned in the context of this article.

WHO Department of Injuries and Violence Prevention

The Department of Injuries and Violence Prevention (VIP) at the WHO focuses its resources on the public health burden presented by injuries and violence and "acts as a facilitating authority for international science-based efforts to promote safety and prevent violence and unintentional injuries and mitigate their consequences as major threats to public health and human development" [37]. The VIP, like other departments at the WHO, maintains a network of collaborating centers. These centers consist of institutions, organizations, and departments that assist and support the WHO in fulfilling its global health care objectives with regard to specific programs or activities. VIP has approximately 22 collaborating centers, including the London School of Hygiene and Tropical Medicine, Karolinska Institute, Emory University, and, more recently, the Injury Control Centre of Uganda (ICCU), located in Kampala, Uganda. The ICCU was established in 1998 as a NGO to address the growing problem of injury in Uganda. The center's mission is to "to reduce the incidence and impact of injury through research, advocacy, design and evaluation of interventions, and implementation of injury management programs" [38]. The ICCU is involved in training, surveillance, and international research studies and has published data on injuries in Uganda [39,40].

Box 1. Selected organization Web sites

World Health Organization: www.who.int
Centers for Disease Control and Prevention: www.cdc.gov
The World Bank Group: www.worldbank.org
United States Agency for International Development:
www.usaid.gov
International Federation of Red Cross and Red Crescent
Societies: www.ifrc.org
Injury Control Center Uganda: www.iccu.or.ug

World Health Day—2004

Each year, on April 7, the WHO focuses on a particular global public health concern in an effort "to raise global awareness of a specific health theme to highlight a priority area of concern for the World Health Organization (WHO). The day serves as a launch for a long-term advocacy program for which activities will be undertaken and resources provided well beyond 7 April" [41]. Recent World Health Day (WHD) themes have included emerging infectious diseases, maternal health, and mental health. The focus of WHD 2004 was on road safety, using the motto, "Road Safety is no Accident." WHD 2004 seeks to raise global awareness regarding road traffic crashes, encourage preventative efforts, and emphasize existing technology and strategies to reduce morbidity and mortality secondary to road traffic crashes [42]. In conjunction with WHD 2004, the WHO and the World Bank released the "World Report on Road Traffic Injury Prevention" [43]. This report, created with input from trauma and injury prevention experts around the world, is available in multiple languages.

Prehospital injury care guidelines

The VIP Division at WHO is finalizing a document regarding guidelines for prehospital injury care, which is targeted at government and ministry of health officials, to assist countries with improving injury care through the design and implementation of basic prehospital systems that are locally relevant and use available resources.

The World Bank Group

The World Bank Group provides technical, financial, educational, and policy development assistance to LICs in an effort to combat poverty and describes its mission as one "to fight poverty and improve the living standards of people in the developing world" [44].

The Global Road Safety Partnership is a World Bank-supported project aimed at improving road safety in LICs and MICs. In addition to this initiative, the Transportation Sector within the World Bank Group has incorporated emergency medical services (EMS) as a key component in its road safety endeavors, stating that, "Timely and proper treatment of road casualties is essential for reducing the severity of injury to crash victims. Driver education on first aid procedures and correct transportation of crash victims is important. A single emergency telephone number (for example, "911" is used in USA) can facilitate the simultaneous alerting of police, ambulance and other rescue services and help to reduce response times (depending on the availability of road-side telephones)" [33].

World Bank acceptance of EMS as an important component of transportation safety emphasizes the fact that emergency physicians must consider broad-based approaches, identify partners, and work collaboratively to leverage resources from multiple fields.

Centers for Disease Control and Prevention

The CDC supports the National Center for Injury Prevention and Control, a program devoted to promoting a wide range of injury prevention and control strategies. The NCIPC funds targeted capacity-building grants to state health departments, supports a small but energetic intramural research program, and devotes significant resources to extramural research through its network on comprehensive injury control research centers and targeted grants. Recently, the CDC developed a new program emphasis on mass trauma events. Resources listed on its web site can benefit acute care providers and public health professionals [45].

United States Agency for International Development

The Bureau for Global Health at the United States Aid for International Development "focuses on global leadership, technical support to the field, and research and evaluation" [46] and in the recent past has been involved in novel approaches to improving emergency and urgent care in Central Asia [47].

Summary

Injuries, whether caused by unintentional or intentional events, are a significant public health problem. The burden of injury is greatest in low- and middle-income countries and among individuals of low socioeconomic status living in high-income countries. Most of these injuries are preventable. Emergency physicians can play an important role in reducing the global burden of injuries by providing expert care and by identifying, implementing, and evaluating population-based countermeasures to prevent and control injuries. The strategy used in a particular country depends in large part on the nature of the local problem, the concerns of the population, the availability of resources, and competing demands. Even simple countermeasures may have a big impact in reducing the global burden of death and disability due to injury.

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