

Chapter 12

INJURY CONTROL

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SUMMARY

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INTRODUCTION

Injuries remain the most underrecognized health problem of the US military. Whether we examine time lost from duty because of hospitalization,¹ permanent disability,² or premature death,³ injuries and their sequelae top the list in every category. Individuals under age 40 are at greatest risk for fatal and nonfatal injuries. Injury disproportionately affects young people because they tend to take greater risks and have more exposure to health hazards. In addition, young people have more potential years of life to lose. Therefore, an untimely death for a young person results in greater loss of productive life. If diseases of the elderly (eg, heart disease, stroke, and cancer) are eliminated from consideration, injury is the leading cause of morbidity and mortality in the United States. The armed forces consist of young adults engaged in many hazardous occupations. This chapter provides an overview of the effect of injuries in the US military and offers a framework that can be used to develop prevention and control strategies for militarily relevant hazards.

The military presents a unique occupational environment, particularly during times of war. The discipline of injury control, which has its roots in public health, has not been explicitly applied to the control of war-related injuries; thus, data on the burden of injuries in a deployed environment are sparse. Conflict situations yield injuries that are uncommon among any other occupational cohort, and they require triage and treatment under difficult conditions. Even peacetime military operations are hazardous in the extreme when compared with civilian occupational environments, because maintaining an effective fighting force requires active-duty soldiers to be in peak physical condition and to train continually. Soldiers, sailors, airmen, and marines must maintain a high state of preparedness, and their ongoing training often necessitates the use of potentially hazardous equipment or materials. Injury epidemiologic research has, however, produced a wealth of knowledge about causes, consequences, and effective intervention to prevent injury in nonbattle settings, and some of this knowledge may be applied with equal effectiveness in reducing war injuries. For that reason, in this chapter, we draw heavily on examples from the civilian medical literature; but, where possible, we provide examples of how these injury control strategies may be adapted for applicability in a deployed environment.

Among US military personnel, acute injury and musculoskeletal conditions account for more than 20% of outpatient clinic visits (830,000 visits in 1998),⁴ approximately 26% of hospitalizations (6,200 hospitalizations in 1998),⁴ almost 60% of permanent disabilities,⁵

and nearly 80% of active-duty deaths.⁶ The injury incidence pyramid in Figure 12-1 depicts the relative importance of various measures of injury morbidity and mortality in the US Army.

The effect of injuries is seen in many ways, including lost productivity, decreased mission effectiveness, human suffering, and the significant economic expenses associated with the care and rehabilitation of injured personnel. Because of the number of surgical procedures and the relatively long hospital stays required for the management of acute and chronic injuries, hospital expenses associated with the musculoskeletal system rank at the top of the scale (Table 12-1).⁷ In addition, the US government pays more than \$1 billion per month to individuals who have been disabled because of their service in the armed forces (Figure 12-2). Almost half of this amount is related to injury. Many of the costs associated with injury, however, are difficult to estimate, especially those associated with human suffering, lost opportunities, diminished capacity to lead a fully functional lifestyle, and indirect costs imposed on family members who must adjust their lifestyle or work to care for those who are injured or disabled.

Definition of Injury

Injuries will be defined in this chapter as the end result of a transfer of energy, usually sudden, above or below certain absorption limits of human tissue, causing physical damage to tissue or death.^{8,9} Table 12-2 lists some of the methods of energy transfer that may cause damage to human tissue and gives examples of some specific injuries that can result, as well as the events that may cause them.

Mechanical or kinetic energy, the energy of motion, is responsible for most common injuries.¹⁰ For example,

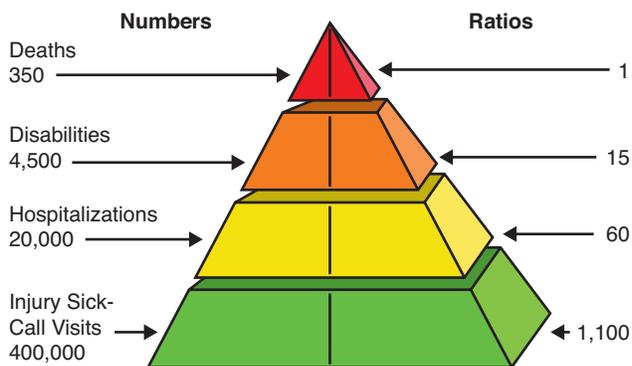


Fig. 12-1. Injury incidence in the Army.

TABLE 12-1
WORLDWIDE HOSPITALIZATION, US ARMY, 1995*

Principal Discharge Diagnosis by Major ICD-9-CM Group Code	1995 Total Cost (Millions)	Average Cost Per Hospitalization
Diseases of the Musculoskeletal System and Connective Tissue (710–739)	\$110.6	\$9,211
Injury and Poisoning (800–999)	\$68.6	\$9,378
Diseases of the Digestive System (520–579)	\$65.9	\$7,171
Mental Disorders (290–319)	\$45.9	\$7,565
Diseases of the Respiratory System (460–519)	\$40.2	\$6,823
Complications of Pregnancy, Childbirth, and the Puerperium (630–676)	\$35.7	\$4,840
Diseases of the Genitourinary System (580–629)	\$28.7	\$7,493
Infectious and Parasitic Diseases (001–139)	\$24.0	\$7,527
Symptoms, Signs, and Ill-defined Conditions (780–799)	\$22.1	\$7,389
Diseases of the Circulatory System (390–459)	\$21.8	\$10,422
Supplementary Classification (V01–V82)	\$20.0	\$6,623
Neoplasms (140–239)	\$19.6	\$10,507
Diseases of the Nervous System and Sense Organs (320–389)	\$17.3	\$8,652
Diseases of the Skin and Subcutaneous Tissue (680–709)	\$10.8	\$6,784
Congenital Anomalies (740–759)	\$5.0	\$10,947
Endocrine, Nutritional, Metabolic Diseases, and Immunity Disorders (240–279)	\$4.2	\$9,039
Diseases of the Blood and Blood-forming Organs (280–289)	\$2.5	\$11,301
Total	\$542.9	\$7,819

ICD-9-CM: International Classification of Diseases, 9th Revision, Clinical Modification

*Calendar year 1995, estimated based on national HCFA DRG codes.

Data source: Amoroso P, Swartz W, Hoin F, Yore M. *Total Army Injury and Health Outcomes Database [TAIHOD]*. Natick, Mass: USARIEM; February 21, 1997. Technical Note 97-2. The TAIHOD has been described in Amoroso PJ, Yore MM, Weyandt MB, Jones BH. Chapter 8: Total Army Injury and Health Outcomes Database: a model comprehensive research database. *Mil Med.* 1999;164(suppl 8):1–36.

moving objects and projectiles are common causes of injury, as are vehicle crashes, falls, and physical assault. Thermal energy, chemical energy, electrical energy, and ionizing radiation may also cause injuries. Recall that, from the definition given previously, injury may occur from the transfer of energy above or below human tolerance. Thus, application of thermal energy can cause burns, and the withdrawal of thermal energy can also cause injury (eg, frostbite or hypothermia). Chemical energy can lead to injuries such as poisonings (eg, mustard gas) (Figure 12-3). An absence of necessary chemical substrates, or interference of normal energy processes—such as oxygen exchange—may also lead to an injury (eg, drowning and suffocation). Electrical energy can result in electrocution or electrical burns. Ionizing radiation can result in various forms of injury. For instance, looking at the sun during a solar eclipse (nonionizing radiation) could cause retinal injury, and exposure to atomic weapons explosions (ionizing radiation) can result in radiation burns or instant death.

Sometimes energy transfers result in conditions that are more commonly thought of as illnesses rather than injuries. The etiological agents for injury and illness may therefore be identical.¹¹ Energy transfers that

culminate in injury are generally rapid or acute. As with most rules, however, there are exceptions. Chronic exposure to low levels of mechanical energy may result in repetitive motion injuries, such as carpal tunnel syndrome, back pain, or other overuse injuries.¹² In contrast, long exposure to low levels of ionizing radiation may result in leukemia—an illness (Figure 12-4). Thus, there is some ambiguity, even in differentiating between illness and injury.

Despite the enormous impact of injuries in the military, much remains to be done in terms of prevention and control. Perhaps one of the reasons injury prevention has not received adequate attention is the tendency to focus only on injuries resulting in death. Although the need to reduce injury fatality is indeed pressing, focusing on only the top of the pyramid diverts attention from the hundreds of thousands of other service members who suffer nonfatal, permanent, or partially disabling injuries each year.

Another reason that injuries may receive too little attention at the command level, and too little priority as a health problem, is the misleading association of injuries with the concept of accidents. For many people, the term accident suggests an event that is



Fig. 12-2. (a) World War II amputee receiving therapy. (b) CPT Lockett wears a modern prosthetic that exhibits the technology that is allowing seriously injured soldiers to return to combat duty.

Photographs: Reproduced from the Archival Research Catalog, the National Archives and Records Administration, ARC identifier 195903.



random and unpredictable, and therefore unpreventable. In fact, however, the events surrounding most injuries are scientifically understood and largely predictable. Although it is not possible to predict precisely which individual will be injured at a specific moment or in a specific situation, it is possible to identify high-risk groups of people. Once a specific population has been defined, it becomes possible to identify and rectify situations that have a high likelihood of causing injury, to tailor appropriate interventions, and to reduce ultimately the incidence of injuries in that population.

The concept of an accident, moreover, is understood to have behavioral connotations that place emphasis on individual behaviors that may contribute to an incident. As a result, preventive interventions may focus on the difficult and often unsuccessful task of trying to change behavior. The result is that these strategies may underplay or ignore the role of environmental or equipment-related interventions that could reduce the likelihood of injury regardless of individual actions or inactions. Injuries are not simply the result of random events but, like diseases, follow patterns that can be described and predicted.¹⁰ Perhaps most significantly, these patterns can be altered by various behavioral or

environmental intervention strategies. For example, ankle injuries among parachutists have been reduced by using ankle braces^{13,14} and by decreasing the porosity of parachutes (thereby increasing air resistance and reducing the speed and impact forces on landing).¹⁵ These are both approaches that might have been ignored if the preventive intervention had focused only on improper landing technique. For this reason, many injury control practitioners prefer a definition of injury that entirely avoids the word “accident.”

Classification of Injury

In addition to the challenges in defining injuries, there may also be uncertainty in the categorization and description of specific types of injuries. There are a number of schemes for classifying injuries. Several approaches to injury classification are in widespread use, including the following¹⁶:

- body part affected (eg, head or spinal cord);
- pathological mechanism (eg, fractures, burns, amputations);
- etiological mechanism (eg, blunt trauma, penetration by sharp object);

TABLE 12-2

**VARIOUS METHODS OF ENERGY TRANSFER
AND THE INJURIES THAT MAY RESULT FROM
THEM**

Energy	Injury	Event
Mechanical	Bullet wound Skull fracture Pneumothorax Ankle fracture	Enemy fire Jeep rollover Landmine explosion Basketball
Thermal	Burn Hypothermia	Air crash on flight deck Man overboard
Chemical	Asphyxiation Burns	Scud missile attack Mustard gas release
Electrical	Tissue destruction	Electric shock
Ionizing radiation	Cerebral edema Gastroenteritis	Nuclear power plant breach

- intent (eg, homicide, suicide, unintentional injury);
- severity (eg, Trauma Severity Score, Abbreviated Injury Scale, fatal);
- event (eg, car crash, earthquake);
- location (eg, workplace, ship, home, battlefield); and
- activity (eg, working, fighting, sports).

Individual researchers may use more than one scheme for classifying and evaluating injuries in a population.

Injury information, especially regarding hospital inpatients, is typically collected and coded based on the nature and cause of injury. Civilian hospital records are coded using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM).¹⁷ The nature of injury codes (previously referred to as N-codes) define the type of injury sustained (eg, fracture) and the body part affected (eg, femur). The range of codes from the ICD-9-CM



Fig. 12-3. Men and horses fitted with gas masks, circa 1917–1918.

Photograph: Reproduced from the Archival Research Catalog, the National Archives and Records Administration, ARC identifier 516483.



Fig. 12-4. Military personnel exposed to open air testing. Photograph: Reproduced from the Archival Research Catalog, the National Archives and Records Administration, ARC identifier 558591.

that are commonly considered injury-related fall between 800 and 900.¹⁸ External cause-of-injury codes (or E-codes) describe the cause of the injury and are also derived from the ICD-9-CM coding system (Exhibit 12-1).

US military medical databases do not use E-codes, but they do include ICD-9-CM N-codes (for type of injury and body part affected). Instead of E-codes, military hospitals in most nations that have signed the North Atlantic Treaty Organization Standardization Agreement (STANAG) 2050 use a set of codes that were developed to provide additional precision for military causes of injury. As an example, a 23-year summary (a period covered by the Total Army Injury and Health Outcomes Database) of these codes for all worldwide Army hospitalizations (1980–2002) is provided in Table 12-3.

Intentional Versus Unintentional Injuries

Determination of intent, although an integral component of injury cause-coding schemes, is rarely a simple matter. From a research and surveillance perspective, it is not the mechanism of injury that sets intentional injury apart from unintentional injury. Rather, it is the circumstances under which these injuries occur that are different. Thus, it is necessary to distinguish between unintentional injury (eg, homicide and assault) and intentional injury (eg, self-inflicted

EXHIBIT 12-1

INJURY RESEARCH USING HOSPITALIZATION FILES: CODING FOR HIGH-QUALITY RESEARCH

Researchers and practitioners should exercise caution when interpreting published accounts of injury hospitalization rates. Many such studies commonly include all ICD-9-CM-coded cases between 800 and 999 that also have an injury E-code. This approach may include some conditions that may not be of interest to injury epidemiologists and may miss some potentially important injury outcomes. Although the range of ICD-9-CM codes between 800 and 999 includes most injuries, it also includes codes for some conditions that are not necessarily of interest to injury researchers (eg, adverse reactions to medications or other iatrogenic “injuries”). It also omits codes for some chronic conditions that may have originally been injury-related (eg, internal derangement of the knee may be coded with other musculoskeletal conditions, even if it was the result of an older, acute injury to the anterior cruciate ligament).

The US military does not use E-codes, but instead uses cause of injury codes utilizing the STANAG system. Regardless of whatever coding system is used, however, codes must be applied accurately and consistently to ensure effective surveillance of causes of injuries and identification of risk factors. In the civilian world, there have been recent efforts to coordinate the coding and recording of external causes of injuries. Improved data collection efforts can be expected to improve injury surveillance, to enable the design and delivery of targeted interventions, and to facilitate international comparisons.

ICD-9-CM: *International Classification of Diseases, 9th Revision, Clinical Modification*
STANAG: Standardization Agreement

TABLE 12-3

DESCRIPTION OF STANAG CODES AND FREQUENCY (CAUSE OF HOSPITALIZED INJURY) FOR US ARMY: 23-YEAR SUMMARY (1980–2002)*

STANAG Code Group	Frequency		Total	
	Men	Women	Overall Frequency	Overall %
Falls (900–999)	74,028	7,669	81,697	26.97
Medical Complications (250–299)	44,708	9,941	54,649	18.03
Land Transport Accidents (100–149)	41,333	3,569	44,902	14.81
Athletics (200–249)	35,294	1,931	37,225	12.28
Machinery and Tools (600–699)	29,096	2,375	31,471	10.38
Poisons, Fire, Hot/Corrosive Substances (700–790)	20,639	5,715	26,354	8.69
Air Transport Accidents (000–059)	9,551	334	9,885	3.26
Environmental Injuries (800–899)	7,793	1,119	8,912	2.94
Guns, Explosives (500–599)	6,396	150	6,546	2.16
Enemy Instruments of War (300–479)	1,111	24	1,135	0.37
Water Transport Accidents (150–199)	216	11	227	0.07
Own Instruments of War (480–499)	94	3	97	0.03
Total	270,259	32,841	303,100	100

STANAG: Standardization Agreement

*Major groupings based on the North Atlantic Treaty Organization STANAG 2050 coding system.

Data source: Total Army Injury and Health Outcomes Database (TAIHOD). The TAIHOD has been described in Amoroso PJ, Yore MM, Weyandt MB, Jones BH. Chapter 8: Total Army Injury and Health Outcomes Database: a model comprehensive research database. *Mil Med.* 1999;164(suppl 8):1–36.

wounds and suicide), whenever possible, to develop better preventive approaches.

The STANAG injury coding system, unlike the ICD-9-CM, uses two components, or axes, to code in-

tent and mechanism of injury. It begins with a trauma code—a single-digit code with 10 possible values that distinguish among general classes of injury (Table 12-4). The trauma code conveys information on both

TABLE 12-4

NATO STANAG TRAUMA CODES

General Trauma Class	Code	Definition
Battle wound or injury	0	Direct result of action by or against an organized enemy
	1	Other battle casualties
Intentionally inflicted nonbattle injuries	2	Result of intervention of legal authority
	3	Assault, or intentionally inflicted by another person
	4	Intentionally self-inflicted
Accidental injury	5	Occurring while off-duty (includes leave, pass, AWOL, and other off duty)
	6	Schemes and exercises
	7	All other scheduled training (includes basic training, assault courses, etc)
	8	Occurring while on duty
	9	Unknown whether on or off duty

AWOL: absent without leave

NATO: North Atlantic Treaty Organization

STANAG: Standardization Agreement

Data source: North Atlantic Treaty Organization. *NATO STANAG 2050 Statistical Classification of Diseases, Injuries and Causes of Death*. Brussels, Belgium; 1989.

intent and work activity. This code distinguishes between battle-related, non-battle-related intentional, and non-battle-related unintentional injuries. It also provides information about whether the injury occurred while the person was on duty or off duty, and whether the on-duty activity was specific to certain training activities or exercises. The 10 possible codes are, however, not mutually exclusive, but rather are listed in order of priority, such that war-related injuries are given highest priority, followed by intentional injuries, and then unintentional injuries. An assault occurring on duty (eg, a military police officer as-

saulted by a prisoner) can therefore be coded only as a 3 (“assault”) and not as an 8 (“on duty”), because information regarding intent takes precedence over duty status. Similarly, an injury that occurs to an individual attempting to evade police arrest while on vacation would be coded as a 2 (“legal intervention”) and not as a 5 (“off duty”) (Table 12-4). Although the STANAG system performs well in coding militarily relevant injuries, the lack of mutually exclusive and exhaustive codes creates some difficulties, especially in coding injuries that commonly occur off duty or for intentional injuries.

TABLE 12-5
SEVERITY SCALES USED TO CLASSIFY GENERAL TRAUMA

System	Common Uses
AIS	Physiologically based classification system that describes individual injuries and rates them based on severity. Impractical for comparing patients with multiple injuries in different regions of the body. ⁽¹⁾
APACHE III	Physiologically based classification system for measuring severity of illness in critically ill patients (not necessarily injured). Comprises an APACHE III score (provides initial risk stratification for severely ill patients within patient group) and an APACHE III predictive equation (provides risk estimate of hospital mortality for individual intensive care unit patients). Scores range from 0 to 299, with ratings in 78 major medical and surgical categories. ⁽²⁾
CRAMS scale	Used to prioritize which patients require the services of a level I trauma center and which ones can be treated at local facilities. Simple, 10-point scale; scores less than or equal to 8 signify major trauma, requiring transport to level I trauma facility. ^(3,4)
GCS	Assesses three measures of neurological function in victims of head trauma: eye-opening, motor response, and verbal response. Scores range from 3 to 15, depending on extent of trauma. ⁽⁵⁾
ISS	Combines ratings of several injuries into a single score of severity; composite score based on the most severe AIS scores for the three most severely injured regions of the body. ⁽⁶⁾
IPCAR	Assesses trauma victims on the basis of five criteria: injury and pain, pulse, consciousness, appearance and bleeding, and respiration and airway. Each indicator is measured on a 4-point scale; total scores range from 15 for a healthy person to a low of 0. ⁽⁷⁾
RTS	Combines GCS scores with measures of cardiovascular and respiratory sufficiency. ⁽⁸⁾
TRISS	Predicts mortality based on severity of injury, patient’s age, and RTS (see above). ⁽⁹⁾
ICISS	Simplifies the ISS; is a better predictor of survival in trauma centers. ⁽¹⁰⁾

AIS: Abbreviated Injury Scale; APACHE III: Acute Physiology and Chronic Health Evaluation III; CRAMS: Circulation-Respiration-Abdomen-Motor-Speech (scale); GCS: Glasgow Coma Scale; ICD: *International Classification of Diseases*; ICISS: ICD-9-based Injury Severity Score; IPCAR: Injury, Pulse, Consciousness, Appearance, Respiration (score); ISS: Injury Severity Score; RTS: Revised Trauma Score; TRISS: Trauma and Injury Severity Score.

Data sources: (1) Brennehan FD, Boulanger BR, McLellan BA, Redelmeier DA. Measuring injury severity: time for a change? *J Trauma*. 1998;44:580–582. (2) Knaus WA, Wagner DP, Draper EA, et al. The APACHE III prognostic system. Risk prediction of hospital mortality of critically ill hospitalized adults. *Chest*. 1991;100:1619–1636. (3) Clemmer TP, Orme JF Jr, Thomas F, Brooks KA. Prospective evaluation of the CRAMS scale for triaging major trauma. *J Trauma*. 1985;25:188–191. (4) Gormican SP. CRAMS scale: field triage of trauma victims. *Ann Emerg Med*. 1982;11:132–135. (5) Becker DP. Injury to the head and spine. In: Wyndgarden JB, Smith LH, eds. *Cecil Textbook of Medicine*. Philadelphia, Pa: WB Saunders; 1988: 2239–2247. (6) National Committee for Injury Prevention and Control (US). *Injury Prevention: Meeting the Challenge*. New York, NY: Oxford University Press; 1989. (7) Buckingham RE Jr. The IPCAR score: a method for evaluation of the emergency patient. *J Indiana State Med Assoc*. 1974;67:21–25. (8) Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the trauma score. *J Trauma*. 1989;29:623–629. (9) Bonnie RJ, Fulco CE, Liverman CT, eds. *Reducing the Burden of Injury: Advancing Prevention and Treatment*. Washington, DC: National Academy Press; 1999. (10) Meredith JW, Evans G, Kilgo PD, et al. A comparison of the abilities of nine scoring algorithms in predicting mortality. *J Trauma*. 2002;53:621–628.

Determining Injury Severity

Severity scales are often used to describe injuries and to evaluate their relative severity or economic impact. There are a number of classification schemes used in the United States, many of which are disease-specific or patient-specific. Table 12-5 lists some of the more common systems in use to describe general trauma. Other indicators of severity include length of hospital stay, days lost from duty, or diagnostic-related groups. These diagnostic-related group codes are a means of classifying patients into similar groups based on their utilization of healthcare resources and length of stay. These codes capture information on a patient's diagnosis, procedures, complications, preexisting conditions, and discharge status. They are used by many institutions to evaluate quality of care and to plan for utilization of services.

There are several injury severity scales:

- Abbreviated Injury Scale (AIS),
- Maximum Abbreviated Injury Scale (MAIS),
- Injury Severity Score (ISS), and the
- ICD-9-based ISS.

The most commonly used anatomically based injury severity scale is the AIS, developed by the Association for the Advancement of Automotive Medicine.¹⁹ The AIS system rates each injury based on the body region and consensually derived assessment of damage to that region, ranging from 1 (minor) to 6 (not treatable with current medical technology). A related scale, the MAIS, is sometimes used instead of the AIS. The MAIS uses the single highest AIS scored injury for each individual. Another derivative of the AIS is the ISS. This score is the sum of the squares of the highest AIS scores for three different body regions.²⁰ The ISS is a better predictor of overall morbidity or survivability and length of hospital stay for individuals experiencing multiple traumas.^{21,22} A simplification of the ISS, the new ICD-9-CM-based ISS,²³ is an even better predictor of survival in trauma centers.²⁴ Even though the AIS does not provide an assessment of disability or impairment, it has proven useful in estimating injury costs.²⁵⁻²⁸ A computer program is available that links ICD-9-CM codes to an AIS score and makes the AIS system relatively easy to use, therefore avoiding the tedious task of reviewing each individual medical record.²⁹

INJURIES IN A MILITARY ENVIRONMENT

As noted previously, the military is a unique occupational environment that presents hazards not found in civilian occupational settings, both in garrison and on deployment. This section describes some of the common types and causes of injuries among military personnel during war and peacetime, and highlights some of the unique aspects of military life that contribute to the injury hazard (Exhibit 12-2).

Recent Conflicts and Wars

It has been estimated that since 1700 AD, more than 100 million people have died because of wars. Of these, more than 90 million people have been killed in the 20th century.³⁰ Although the prevention of intentional injuries and combat casualties remains the major focus of command during conflict situations, unintentional injuries—at least in recent history—also exact a substantial toll on the health of deployed forces. During Operation Desert Storm (1990–1991), unintentional injury deaths exceeded combat casualties (147 [or 39.5%] deaths were a result of combat during the war, whereas 194 [or 52.2%] resulted from injuries not incurred in battle).³¹ In addition to these fatalities, injuries were the leading cause of hospitalization among deployed forces, with more than

5,000 soldiers being hospitalized in theater during the conflict (25% of all hospitalizations).¹ The majority of injuries whose cause was known were unintentional, and most of the nonbattle fatalities were caused by transportation (motor vehicle accidents were most prevalent, followed by aircraft). Hospital admissions were also commonly related to motor vehicle crashes or falls, followed by athletic activities.⁵ More than 400 soldiers were hospitalized for athletic injuries during the war, suggesting that commanders of deployed units should expand their focus to include prevention of sports injuries to preserve military readiness and maintain critical capabilities.

War Injuries and Special Environmental Circumstances

Military environments are inherently hazardous because they combine service members and lethal weapons in terrains that are often hostile. Whether these environments are training areas, staging areas, or actual battlefields, a number of circumstances can contribute to injuries. This section will discuss the most prevalent of these circumstances: (a) weapons, (b) transportation systems, (c) environmental hazards, (d) stress, and (e) sports and athletic injuries.

EXHIBIT 12-2

PEACETIME INJURIES AND UNIT READINESS

In recent history, peacetime injuries have been more of a threat to unit readiness than wartime injuries. In training exercises and maneuvers and in fitness activities and physical conditioning, soldiers are exposed to myriad other hazards in the performance of their everyday duties in garrison. Soldiers who are injured hinder mission accomplishment and create a substantial drain on resources through additional medical care utilization and lost time from work. For these reasons, it is important to be aware of peacetime injury threats and to comply with regulations and programs designed to minimize risk of injuries at all times.

Training Exercises and Maneuvers

Training, although important to maintaining unit effectiveness, also has the potential to cause many injuries and could even lead to short- or long-term disability. Physical readiness training, whether addressing specific military skills or multiday unit maneuvers or field exercises, exposes soldiers to some or all of the hazards of the military environment described previously: weapons accidents; materiel handling; transportation and aviation accidents; sleep deprivation; and exposure to adverse weather conditions, such as extreme heat and cold.

Fitness Training

Even though the specific types of exercises and procedures for assessing physical fitness vary from service to service, all require individuals to maintain a certain level of fitness. This is usually achieved through a variety of calisthenics (eg, sit-ups, push-ups) and marching or running. Some training combines rudimentary military skills with elements from athletic or recreational sports training, such as some of the SEAL boat and log drills.

Environmental Hazards in an Occupational Environment

Other environmental hazards are as varied as the jobs that exist in each branch of the service. Aviators face risks ranging from air transport crash to hypoxia and altitude illness. Sailors face a host of risks ranging from falling overboard to injury from handling heavy equipment.⁽¹⁾ Workers may also be exposed to poisonous substances in the course of performing their duties.

Other Hazardous Exposures

Unintentional injuries related to motor vehicle use and to athletic activities are among the most common reasons for hospitalization, both in peacetime and in times of war. Thirty-five percent of the 12 most common injuries among hospitalized Air Force personnel during 1992 were either from athletic and sports activities or motor vehicle crashes.⁽²⁾ Intentional injuries, whether self-inflicted or an assault, are also a risk, as belligerent behavior resulting in physical injury was the 10th most common cause for hospitalization among Air Force and Army personnel in 1992.⁽²⁾

SEAL: Sea, Air, and Land (US Navy)

Data sources: (1) Krentz MJ, Li G, Baker SP. At work and play in a hazardous environment: Injuries aboard a deployed US Navy aircraft carrier. *Aviat Space Environ Med.* 1997;68:51-55. (2) US Army Center for Health Promotion and Preventive Medicine (USACHPPM). *Injuries in the Military: A Hidden Epidemic. Report for the Armed Forces Epidemiologic Board.* Aberdeen Proving Ground, Md: USACHPPM; November 1996. Report 29 HA 4844 97.

Weapons

Firearms, mines, grenades, missiles, biological and chemical agents, and related equipment are used during conflicts to support the war effort (ie, to fight). All of these hazards create the potential for intentional or unintentional injury. This chapter is not intended to serve as a tactical guide for strategies on how to avoid enemy fire, but rather to serve as an overview of the types of injuries that could occur, a review of the prevention options in general, and factors that may influence survivability and long-term sequelae.

Weapons may cause injury when discharged unintentionally, while being transported, or when a friendly

soldier is mistaken for the enemy. Intentional, nonbattle injury may also occur through self-inflicted wounds (approximately 4% of nonbattle deaths during Operation Desert Storm).⁵ Measures designed to prevent weapon-related injuries may also lead to unintentional injury. For example, pharmacological treatments taken for prophylaxis or as antidotes to chemical weapons attack may cause undesirable side effects or adverse reactions among service members. Full chemical protective gear can limit mobility, obscure vision, and interfere with safe performance of tasks. Transportation and use of hazardous substances, such as chemical and biological weapons, may result in unintentional exposure among friendly forces. Grenades, missiles, and mines are also potential

sources of unintentional injury among friendly forces. Long after conflicts have ended, landmines continue to pose a serious injury problem in a number of countries.^{32,33}

Transportation

Transportation of troops is an essential element of any war or peacekeeping mission. During World War II, US military personnel experienced more than 20,000 nonbattle aviation deaths,³⁴ presumably because of troop movement, supply transportation, and pilot training. Unfortunately, motor-vehicle crashes related to the movement of troops remain one of the leading causes of mortality in recent military deployments. Hazardous travel conditions, unfamiliar terrain, sleep deprivation, stress, and illness may all contribute to the injury morbidity and mortality associated with the use of motor vehicles, aircraft, and ships. Sometimes an assault or maneuver requires parachuting troops or landing small boats on enemy shores. The potential for enemy fire is ever present; but, during recent low-intensity conflicts, the greatest risk of injury has been posed by the maneuver itself. Often, troops must parachute onto unforgiving surfaces, such as a concrete airfield, or rapidly transfer from one moving transport vehicle to another (Figure 12-5). The resulting impact injuries are debilitating not only for the individual service member who is injured, but also for the one or two other members of the unit who may end up dividing their energy between the planned mission and the rescue of their injured companions.

Environmental Hazards

Environmental conditions and related factors also present hazards. Unfamiliar and dangerous flora and fauna may lead to injuries. Poisonous plants, animal bites, and insect bites and stings may cause acute injury and may serve as vectors for the transmission of diseases. Pesticides and insecticides, meant to provide protection, may also cause injury or illness. Exposure to cold or heat can also directly lead to injuries such as frostbite, heatstroke, or heat illness (see Chapter 8). Such exposure may also indirectly contribute to injuries by compromising a soldier's vigilance—the ability to respond to risks or make decisions. In the Persian Gulf War, oil-well fires caused poor visibility in some areas and may have contributed to poorer health and increased susceptibility to injury.³⁵

Stress

The stress soldiers experience in war environments may also contribute to their injury risk. War environments require extraordinary adaptation on the part

of the individuals involved. Often, a soldier leaves a spouse and children behind, crosses through several time zones, enters new climatic conditions, and faces the ever-present risk of being killed or seriously injured. Although the human body adapts well, coping mechanisms are better suited for short-term stress than to the chronic stress of a drawn-out conflict or even a long peacekeeping mission. During stressful situations, a number of physical and mental responses occur, including “arousal, alertness, vigilance, cognition...focused attention...aggression...[and] inhibition of pathways that subserve vegetative functions, such as feeding, [growth], and reproduction,” and changes in the body's immune and inflammatory responses.³⁶ Heart rate and respiration increase, blood pressure increases, and the body starts to produce glucose more rapidly to prepare itself for rapid response to the stressor. These mental and physiological responses to stressors associated with deployment and war conditions may influence a service member's ability to respond to a hazard or injury situation. “Chronic stress may result in melancholic depression, poor appetite and weight loss, hypogonadism, peptic ulcers, immunosuppression, memory loss, inability to concentrate and think clearly, anxiety, as well as severe chronic disease, panic disorder, obsessive-compulsive disorder, chronic active alcoholism, alcohol and narcotic withdrawal, chronic excessive exercise, hyperthyroidism [or] hypothyroidism, premenstrual tension syndrome, vulnerability to addiction, Cushing's syndrome, seasonal depression [and other] atypical depression, anorexia nervosa [or] obesity, PTSD [posttraumatic stress disorder], nicotine withdrawal, vulnerability to inflammatory disease.”³⁶

Stress may also increase risk for psychiatric conditions, such as depression and PTSD. High rates of clinical depression, PTSD, and other psychiatric conditions have also been documented among soldiers returning from deployment. Such conditions have been documented among US, British, and Danish veterans of Operation Desert Storm.³⁷⁻⁴⁹ A more recent survey of soldiers deployed to Iraq and Afghanistan in the winter and spring of 2003 found that major depression, generalized anxiety, and PTSD symptoms were more common in those deployed to Iraq (15%–17%) than in those deployed to Afghanistan (11%). Moreover, less than one half of soldiers who reported mental health symptoms reported having sought care, citing concerns about stigmatization and other barriers.⁵⁰

Civilian studies have shown that depression and PTSD are associated with subsequent risk for self-inflicted injury.⁵¹⁻⁶⁰ In the civilian world, suicide is an important cause of mortality among teenagers and young adults, and suicide rates appear to be increasing



Fig. 12-5. Two examples of high-risk military training. (a) COMPUTEX '98 (or Composite Training Unit Exercise, 1998). US Navy SEALs conduct a fast-rope exercise from the cargo door of an SH-60H-Seahawk assigned to the Helicopter Anti-Submarine Squadron Seven (HS-7 "Dusty Dogs") onto the hull of the fast-attack submarine USS *Hampton* (SSN 767). This photograph provides another example of the many hazardous activities military personnel are exposed to in the conduct of their duties. Photograph: Taken by PH2 Michael W. Pendergrass, US Navy. (b) During Kernel Blitz '99, a biannual amphibious training exercise designed to test and develop US Navy and Marine Corps forces to operate in littoral areas and project combat power ashore. CH-46 helicopters fast-roped and retrieved Marine Corps reconnaissance members during the exercise. One consideration to reduce the hazard is to carefully consider the weather conditions under which such training will be allowed to proceed. Photograph: Taken by PH3 Eric S. Logsdon, US Navy.

among adolescents, particularly young men.^{61,62} Although rates of suicide are generally lower among active-duty military personnel than among their civilian counterparts, significant variation in suicide rates exists across the services by gender and occupation. Certain subgroups seem to be at especially high risk, such as military security and law enforcement personnel.⁶³ Studies among military populations have shown that suicide risk and PTSD were greatest among Vietnam veterans who had been wounded during battle and/or had experienced psychological trauma while in Vietnam.⁶⁴⁻⁶⁶ These psychiatric conditions may also be indirectly associated with increased risk for unintentional injuries. Depression, for example, may slow response time and is associated with alcohol use.

In addition to affecting risk of injury, psychiatric conditions that are related to deployment have other consequences for military readiness and for the delivery of healthcare services both in military and civilian settings. Studies of mental health in the military population generally have found that personnel hospitalized with a mental health disorder as the primary diagnosis are more likely to separate from service within 6 months than those hospitalized for other reasons (45% and 11%, respectively). Early separation from service was also associated with misconduct, legal problems, unauthorized work absences, and failure to comply with alcohol treatment programs.⁶⁷ Combat-related stress may also contribute to increased use of healthcare services.⁶⁸

Sports and Athletic Injuries

Recreation may provide a means to help relieve wartime tensions and boredom. It is a normal aspect of human activity, and should be expected and planned for as part of deployment operations. This is especially true as an operation transitions from the maneuver phase to sustained operations in theater, and soldiers have more free time on their hands. Sports and athletics programs can be useful in staving off boredom and distraction, especially in contexts where soldiers are prohibited from leaving the area and mingling with local civilian populations. Recreation and more coordinated physical fitness training can also be important in enhancing and promoting physical fitness so that soldiers can maintain compliance with Army physical fitness standards, especially during an extended deployment.

There is, however, a tradeoff between recreation that is necessary for health, and well-being, and prevention of injuries. It is easy to take for granted the safety precautions and protective equipment available for sports and recreation activities in garrison. Battalion surgeons

should be involved in the planning and coordination of recreation activities. Among other things, playing fields should be screened for uneven playing surfaces or other hazards. Courses set for physical fitness runs should be designed with safety in mind. Basketball backboards and other stationary sports equipment should be securely mounted on sturdy structures that are free from sharp edges. Protective gear should be requisitioned and inspected for adequacy. Finally, battalion surgeons and other medical personnel should be prepared to treat a variety of sprains, strains, and other injuries that are likely to accompany sports and leisure activities.

During the Vietnam War, injuries related to recreation resulted in evacuation of many soldiers from theater. We do not always retain the lessons we learn from history, however, as evidenced by the relatively high number of soldiers evacuated during Operation Desert Storm for injuries incurred playing "combat football." Even for military personnel treated without evacuation, sports injuries can significantly impair a soldier's readiness for battle. Given the Army's recent transition to smaller and more streamlined operational units, even a small number of injuries to key personnel may have significant and negative impact on the unit's overall readiness. Commanders and medical personnel should be vigilant about the potential for recreational injuries, and should attempt to make sports and fitness activities that take place in theater safer—if not as safe as possible, then at least safe enough so that they do not compromise a mission's effectiveness.

Injury Risk After Redeployment

Over the past several decades, and especially since Operation Desert Storm, researchers have devoted considerable time and resources to studying the effect of deployment on long-term health.⁶⁹⁻⁷⁴ An often overlooked fact, however, is that the only significant difference in postdeployment mortality is with respect to injury: returning soldiers are at significantly greater risk of injury mortality than their nondeployed counterparts. This was true for both US and Australian soldiers deployed during the Vietnam War and for US soldiers deployed during Operation Desert Storm. US veterans of the Vietnam conflict experienced greater risk for injuries resulting from motor-vehicle crashes, poisonings, fires and burns, homicide, and suicide after returning home.^{64,65,75-80} An Australian study found that injury accounted for 74% of the postwar mortality among their soldiers who served in Vietnam.⁸¹ Nonbattle injury remains the only documented cause of increased postwar mortality among the soldiers who fought in Operation Desert Storm.^{35,82,83}

Several explanations for how deployment to a hostile environment may directly or indirectly increase risk of injury after redeployment have been proposed (Figure 12-6). First, higher rates of injury mortality may be a consequence of increases in clinical depression, PTSD, or other psychiatric conditions subsequent to deployment. As reviewed previously, such conditions may be associated directly with self-inflicted injuries and suicide or indirectly with unintentional injuries.

Second, the physical and psychological traumas experienced during war may result in the postwar adoption of potentially unhealthy “coping behaviors.” Several studies have documented an association between exposures to emotional or physical trauma and increased use of alcohol or other substances.^{84–88} Changes in behavior may occur independent of any diagnosed mental illness or condition, yet still be an indirect consequence of an experience occurring during deployment. For example, perceived near-death experiences have been shown to result in profound changes in values, beliefs, and behaviors as they relate to living and dying.^{89–91} Such changes might result in more reckless behavior and less regard for personal safety.

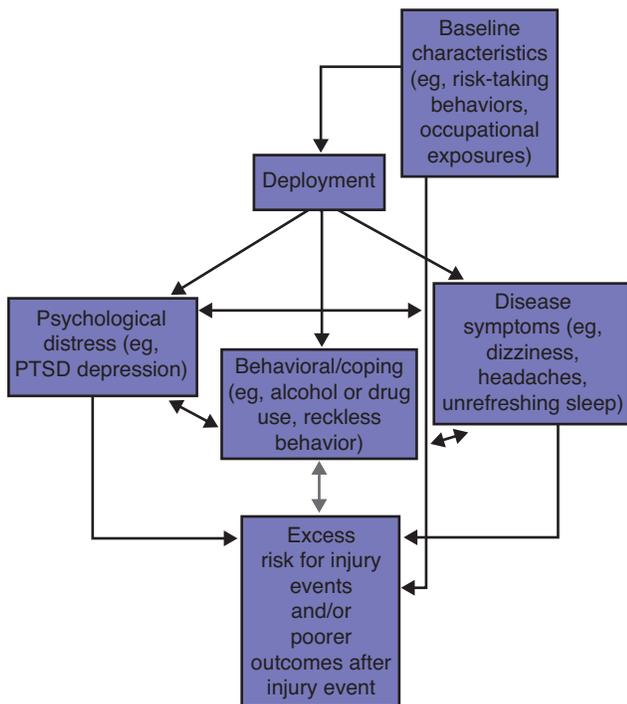


Fig. 12-6. Potential explanations for the association between deployment and increased risk of injury. PTSD: posttraumatic stress disorder.

Illustration: Reproduced with permission from Bell NS, Amoroso PJ, Wegman DH, Senier L. Why are people who return from war at increased risk of injury? *Injury Prev.* 2001;7:4–9.

Third, increased risk of injury may be the indirect consequence of the ill-defined diseases and symptoms reported by many veterans, including fibromyalgia, chronic fatigue syndrome, and symptoms such as dizziness, shakes or tremors, unrefreshing sleep, fatigue, muscle and joint pain, and confusion.^{92–101} Whether or not these conditions are a direct consequence of deployment-related service, they are frequently reported by soldiers returning from deployment. (They were especially common among soldiers who served in the 1990–1991 Persian Gulf conflict.) These conditions may result in reduced response time or an inability to safely negotiate out of a hazardous situation (eg, motor-vehicle collision avoidance). Alternatively or concurrently, soldiers suffering from these conditions might be more likely to make decisions that may increase exposures to hazardous circumstances. For example, they may be more inclined to enter a quarrel, which could escalate to interpersonal violence. Thus far, the documented association between deployment and increased injury mortality has not been evaluated to determine if certain subgroups (eg, those suffering from multisymptom illnesses) are responsible for the observed differences in injury risk.

Fourth, the observed increase in postwar injury mortality may be masking broader patterns of increased susceptibility to both injury mortality and morbidity. Without an understanding of the prevalence of nonfatal injury among deployed and nondeployed soldiers, it is impossible to ascertain whether or not deployers are at increased risk for injury events, or whether they are at increased risk for death (or poorer outcomes in general) once they experience a given type of injury (eg, motor-vehicle crash-related injury). Psychological distress, coping behavioral responses, and illness symptoms may act as modifiers of an injury event. A deployed soldier who incurs a postwar injury may be more likely to experience adverse sequelae than an injured veteran who was not deployed, because of the presence of war-related comorbidities.

Finally, findings of excess injury morbidity among deployed soldiers may reflect a bias in selecting individuals for deployment who are inherently at greater injury risk (self-selection). This increased injury risk may stem from a number of baseline personality or occupational characteristics, such as belonging to an occupational group with documented hazards (eg, vehicle drivers) or risk-taking (eg, speeding, smoking, alcohol consumption). These factors could elevate the risk of experiencing an injury event and /or result in a poorer outcome after the event.

There is little baseline information available that would allow exploration of pre- and postwar risk-taking habits and injury predisposition among

deployed and nondeployed soldiers. It is plausible, however, that the same factors that make a soldier a likely candidate for deployment may also be associated with a greater risk of injury independent of war. Soldiers who are sensation seekers or risk takers may be more inclined to self-select into or be assigned to occupational specialties with a higher likelihood of deployment (eg, Infantry, Airborne, Rangers, and Special Forces). A recent study demonstrated that soldiers who received hazardous duty pay for activities such as parachuting or exposure to enemy fire in the period

well before the start of Operation Desert Storm were the same ones most likely to be deployed to the Gulf during the 1990–1991 conflict, even after controlling for occupation.¹⁰²

Increased injury frequency or severity may stem from any one of these five proposed explanations, some combination of them, or some other yet undiscovered pathway. In any case, the relationship between deployment experiences and postdeployment injuries needs further study. This requires more support and attention from policymakers and researchers alike.

INJURY CONTROL IN THE MILITARY

The history of the armed forces provides numerous examples of injury control successes. Safety programs and injury prevention initiatives have resulted in the remarkable reduction of aircraft crashes, the near elimination of fires after crashes of helicopters, and the dramatic reductions of parachuting injuries over the past several decades. No single factor can be cited as the reason for these successes. Only through multidisciplinary approaches can injury reduction of this magnitude be accomplished. Cooperation and collaboration of medical, safety, command, legal, engineering, and behavioral scientists are necessary to obtain true success in injury control. Yet, fatalistic attitudes still prevail, embodied in the notion that there will always be some injuries we are powerless to prevent. A class A accident is one in which the total cost of property damage is \$1 million or more; an aircraft or missile is destroyed, missing, or abandoned; or an injury and/or occupational illness results in a fatality or permanent

total disability.¹⁰³ Although there will likely always be injury, class A aviation crashes did not appear any more preventable decades ago—when rates were greater than 100 per 100,000 flying hours—than now, when there are only 1.5 per 100,000 flying hours; and the rate is still dropping.¹⁰⁴ Figure 12-7 illustrates Navy aviation fatality rates, demonstrating the effect that injury prevention interventions have had on the trend line.

Understanding the Dynamics of Injury: The Epidemiological Triangle

Recall the definition of injury: the end result of a transfer of energy, usually sudden, above or below certain absorption limits of human tissue, causing physical damage to tissue or death.^{8,9} The key to injury control lies in modifying the injury-causing agent (energy), individual behavior, the environment, or the interaction of any of these factors. The goal is to interrupt

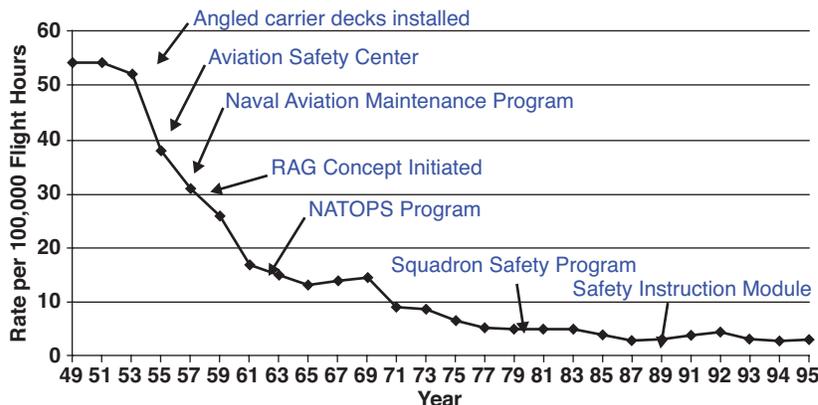


Fig. 12-7. Navy rates of aviation fatalities, 1949–1995. This graph demonstrates that class A aviation accidents have dropped precipitously over the past 50 years. The steepest declines have happened concurrently with the implementation of accident-prevention initiatives, beginning with the angling of carrier decks in the mid-1950s. NATOPS: Naval Air Training and Operating Procedures Standardization; RAG: Replacement Air Group (now Fleet Replacement squadron). Illustration: Courtesy of the Naval Safety Center, Norfolk, Virginia.

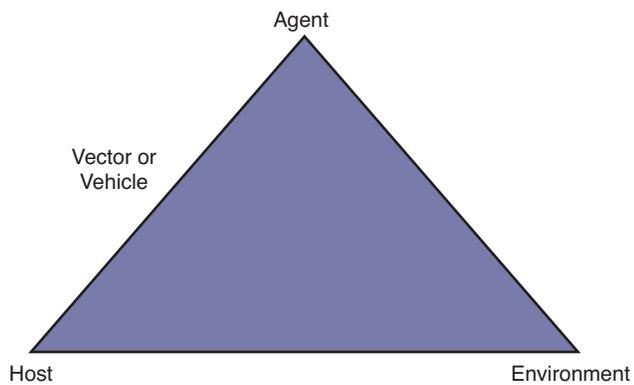


Fig. 12-8. The epidemiological triangle: a traditional epidemiological host–environment–agent model.

the normal injury-causing sequence of events. It is not always necessary to prevent the energy transfer entirely; sometimes, a change in the interaction of the person and the energy can bring the energy transfer within the limits of human tolerance. A traditional epidemiological host–environment–agent model is sometimes used to describe this process (Figure 12-8).

This model is often used when studying infectious diseases and identifying intervention opportunities. In the infectious disease model, these elements include the following:

- the agent (or disease pathogen),
- the host (the human suffering from or at risk from the infectious agent),
- the environment (taken broadly to include both the physical and sociocultural milieus that may contribute to the infection), and
- the vehicle or vector that carries the agent to the host.

If the infectious disease is malaria, for example, the agent is the parasite *Plasmodium falciparum*, and the host is the human. Malaria is transmitted by mosquitoes, which, because they are living creatures, are classified as the vectors. To prevent malarial infections, we should examine each element in this triangle and consider the intervention options we could apply to each. We may choose to address the agent itself. For example, a chemical could be developed and distributed (eg, aerial spraying) that would alter the *Plasmodium* in such a way as to disrupt its reproductive capabilities. Alternatively, or in addition, we could focus on the host and try to build up host resistance through inoculation (eg, in the past, people were given quinine as a prophylactic agent against malaria). We could also try to prevent host contamination by eliminating the

vectors. For example, we could introduce bats and mosquito fish (*Gambusia* sp.) to reduce the mosquito population. We could also make changes in the physical environment by eliminating stagnant water where mosquitoes tend to breed. Environmental changes should be viewed broadly to also include normative behavior changes, such as teaching people to not wash clothes or bathe in sluggish water where mosquitoes breed. Environmental changes can also include encouraging the use of mosquito netting, including pesticide-impregnated mosquito netting or repellents alone, or fostering an environment where it is socially acceptable, even macho, to practice self-protection.

The epidemiological triangle can also be used to identify strategies to prevent or reduce harm from injury. In injury control, it is the magnitude of the energy that is transferred to the potential victim that is the agent of concern, rather than a disease pathogen. Most commonly, kinetic energy is the culprit. The host is, again, the human. The environment, as with infectious disease interventions, includes both the physical and broader socioeconomic and cultural environments, including command-level influences. As with disease, in injury control we need to think about vehicles and vectors that transmit the unwanted energy to the host. Usually, in injury control, these are inanimate vehicles, such as electric power lines or motorcycles. However, in some cases, the energy carrier is a living creature—as in assaults by humans—and, in these cases, the energy carrier is correctly called a vector. Each of these elements is discussed herein in more detail.

Host Factors

Host factors are characteristics that predispose an individual either to experience an unintended transfer of energy or that cause the individual to be more susceptible to tissue damage given the occurrence of such an event. These intrinsic factors might include an individual's age; gender; race; anthropometric characteristics, such as height, weight, and muscle mass; and behavioral factors, such as the propensity to use or abuse alcohol or drugs, or engage in other high-risk activities. Some acquired individual factors that may place active-duty personnel at risk include sleep, diet, general nutrition, immunization status, and stress responses. Deploying to new environments often involves traversing several time zones, losing contact with friends and family, and coping with the uncertainty of survival in a war zone. All of these factors combine to create substantial stress that, in turn, may contribute to poorer cognitive functioning (and thus increased risk for exposure to injury) or poorer response and recovery from an injury. Certain host

behaviors (eg, risk-taking behaviors, alcohol use, smoking status) have been associated with an increased risk for experiencing an injury event,^{9,61,105-131} increased severity of injury, or ability to survive and recover from the injury event once it has occurred.^{20,132-141}

Environmental Factors

In thinking about environmental factors that contribute to injury risk, we should consider not only aspects of the physical or structural environment, but also how the sociocultural or socioeconomic milieu may contribute to injury. Certain environmental physical factors and structural conditions may encourage, or at least not inhibit, the unwanted transfer of energy. These may include driving on unfamiliar, hazardous terrain, or parachuting onto a hard surface.¹⁴²⁻¹⁴⁵ Sociocultural factors include attitudes about risk-taking and health, such as beliefs about wearing a safety belt and awareness of, or beliefs about, the risks of consuming alcohol before or while operating a motor vehicle. Sociocultural factors also include community and command-level attitudes and support of safety-related issues. The example set by senior noncommissioned officers, officers, and others in command sets a precedent for the behavior of subordinates. Law enforcement presence, cultural views of violence, and the presence of safety-related laws are also examples of environmental factors. For example, most bases require gun owners who live in the barracks, usually younger enlisted personnel, to register and lock up their weapons in a secure, centralized location, usually the unit arms room. Because this makes it difficult to obtain the weapon, the result could be a significant reduction in intentional and unintentional firearm injuries resulting from impulsive actions. The inconvenience of obtaining the weapon when it is needed, however, may give soldiers the incentive to find other places to store their weapons, such as in the glove compartment of their car or at a friend's house. These unintended consequences are discussed further in the section titled *Intervention Strategies: Different Approaches*.

Vehicles, Vectors, and Equipment

Design characteristics of vehicles and equipment have a great potential to either mitigate or cause injuries. Some of the greatest advances in injury prevention have been achieved through modification of vehicles or equipment. Indeed, of all of the advancements in motor-vehicle safety, the most substantial reductions in morbidity and mortality have been obtained through the reengineering of vehicles and roadways. For example, helicopters are now equipped with breakaway

or collapsible control sticks, thereby reducing the risk of impaling the pilot during a crash. Many helicopters now have airbags as well. As noted previously, Navy Safety Center data shows a 90% decrease in the rate of class A aviation accidents (see Figure 12-7), but we should note that the greatest gain in this reduction came in the mid-1950s, when aircraft carrier decks were angled (eg, the runways were laid out at an angle), thereby reducing the likelihood of a crash when a plane touched down (Exhibit 12-3).

Agents

Energy transfer, most commonly the transfer of kinetic energy, causes injuries. The development of intervention strategies should incorporate approaches to modify the energy transfer in such a way as to prevent the release of the energy or reduce the amount of energy that may be released. Safety mechanisms on firearms, for example, reduce the chance that the firearms will be unintentionally fired. Bulletproof vests and Kevlar helmets reduce the character of the energy transfer, and thus the morbidity and mortality that an individual may experience when hit by a bullet or fragments. Injuries among parachutists are influenced by drop zone terrain, obstacles, and environmental conditions, but are also a function of the vertical sink rate of the parachute and jumper. Low-porosity parachutes that reduce the kinetic energy at the moment of impact have been shown to significantly reduce the injury rate to parachutists, both in terms of overall injuries and for each of the three types of injuries examined: (1) fractures, (2) strains/sprains, and (3) contusions.¹⁵

Intervention Strategies: Different Approaches

There are two basic approaches to preventing or reducing injuries in the military: (1) active strategies are interventions that require an individual to make a conscious decision to behave in a certain way (eg, choosing to put on a seatbelt); whereas (2) passive strategies do not require a specific change in an individual's behavior to be effective (eg, an air bag). Although each approach has merit, each also has disadvantages. Most members of the injury control community agree on the virtues of both passive and active approaches to injury prevention, but there is often considerable debate over the specific implementation of various active and passive countermeasures. The basics of these two strategies will be described briefly; further discussion will follow later in the chapter.

Active strategies require an individual to make decisions regarding his or her health. Such approaches are usually less intrusive on personal liberties and are

EXHIBIT 12-3

PIONEERS IN INJURY EPIDEMIOLOGY

Epidemiology is the branch of medical science that examines the spread of disease in human populations. The application of these techniques to injury prevention and control is a fairly recent phenomenon, dating back to mid-20th century. One of the first pioneers was Hugh De Haven, a former World War I pilot who drew on his own experience as a crash survivor to argue that injury could be minimized by altering the structural environment.⁽¹⁾ His work applied biomechanical principles to injury prevention questions, measuring the body's ability to withstand changes in mechanical injury, and how measures such as seat belts, airbags, and other safety devices could protect a vehicle's occupant. Further developments in the field were made by John Gordon, who argued that injury could be studied with the tools and methods applied to infectious disease epidemiology, and that by examining epidemic episodes, seasonal variation, long-term trends, and demographic characteristics of injured parties, we could design appropriate and effectively targeted interventions.⁽¹⁾

But the greatest conceptual and theoretical developments in the field, by far, were advanced by William Haddon, Jr, an occupational physician with the New York State Health Department. Haddon pioneered two conceptual frameworks that are still widely used in injury epidemiology today: (1) the Haddon matrix and (2) 10 principles to reduce hazards of all kinds.⁽¹⁻³⁾

The contributions of De Haven, Gordon, and Haddon, and others who have followed them, have served to mitigate the attitude that accidents are random, unpredictable, or the result of unwise behavior on the part of careless individuals. By applying the tools and methods of epidemiologic inquiry, they demonstrated that it is possible to predict where and how injuries may occur, and, more importantly, by leveraging the expertise of biomechanical engineers, they showed it is possible to alter the structural environment in ways to reduce the burden of injury. Their early foundational contributions have spawned decades of scholarly work expanding our understanding of the causes and consequences injury has for our society. These insights have shifted the focus of injury prevention programs away from educational interventions aimed at changing individual behaviors; have led to the design of safer products and the institution of environmental modifications to reduce injuries in many different settings; and have become the basis of policy recommendations, programs, and legal mechanisms to make our society a safer place.

Data sources: (1) National Committee for Injury Prevention and Control. Injury prevention: meeting the challenge. The National Committee for Injury Prevention and Control. *Am J Prev Med.* 1989;5(suppl 3):1-303. (2) Haddon JW. The basic strategies for reducing damage from hazards of all kinds. *Hazard Prev.* 1980;Sept/Oct:8-12. (3) Haddon matrix: eliminating the mumbo jumbo. *IIHS Status Report.* 1986;21:8.

often, if successful, less expensive than engineering approaches, although the cost per success may be high. On the downside, some people will never change their behavior, and everyone is subject to momentary lapses in attention or judgment. Those who are at greatest risk of injury because of risk-taking habits are often among those least likely to alter their behavior.¹⁰ In addition, some fall victim to the behavioral transgressions of others—often the result of actions entirely beyond individual control. Behavior change requires maintenance and tends to erode over time as education campaigns end or lose their novelty. Moreover, active strategies require that a person possess a specific skill or level of cognitive functioning to be effective. Thus, individuals with a temporary cognitive deficit (eg, someone who is sleep deprived, is in an extremely fearful state, is injured, or who has used alcohol or medication) may be unable to perform the safety procedure effectively. Most importantly, active strategies ignore the poten-

tial for human error. No matter how many times a person rehearses a specific skill, there will always be the potential for a small mistake. The question, then, is should the penalty be death for a momentary lapse in judgment or a small slip-up?

Passive strategies have several distinct advantages over active strategies when it comes to accounting for human error potential. Passive strategies provide automatic protection and cover all members of a population, even those who take great risks or who are temporarily or permanently impaired. They do not erode over time and do not require any specific set of skills for an individual to be protected. Nor do passive strategies require an action each time someone is to be protected. Furthermore, they are generally the most effective. On the downside, some passive strategies may be viewed as intrusive on personal liberties and some are expensive. Distribution of the costs for these interventions may be a contentious issue as well.

There are strengths and limits to both active and passive approaches. A comprehensive injury control program capitalizes on the most effective measures (usually passive) while also incorporating strategies to change the behavior of individuals (ie, consumers, manufacturers, and legislators whose decisions ultimately affect the risk of injuries to others). Injury control in the military might be enhanced by procurement decisions and product assessments that include an evaluation of the potential utility of passive safety features.

Unintended Consequences and Risk Compensation

Injury interventionists must be concerned not only with the prevention of injury through appropriate intervention, but also with the potential for unintended consequences. Knowledge that a safety device is in place has the potential to change the behavior of an individual or an organization (economists refer to this idea as risk compensation). However, the idea of risk compensation is by no means universally accepted in injury control circles. In essence, risk compensation is said to occur when an individual takes additional risks that he or she may have been unwilling to take in the absence of the safety device or intervention. A good example from a civilian context may be found in differences among drivers of vehicles with and without airbags (ie, a person driving a car with an airbag may be less likely to fasten the seat belt). As a final example, boxing gloves allow boxers to exchange blows for longer periods of time and target the bonier face and head. Although each punch may seem to be less injurious (because of the padding afforded by the gloves), the cumulative effect of sustaining repeated blows to the head may still result in long-term neurological consequences or even death.

Risk compensation may also be used to the advantage of safety by increasing the perceived riskiness of an activity. For example, speed bumps in roadways actually *increase* risk of damage to the vehicle by mimicking the hazards of driving over a bad road. Driving quickly over a speed bump may cause damage to the vehicle or could cause the driver to lose control of the

car, leading to an injury-producing accident. It is also uncomfortable for vehicle occupants to drive quickly over a speed bump. The combination of these factors ensures that most drivers will slow down when approaching a speed bump. In parks, residential areas, and near schools, the net effect of this is to make the roads safer for all. Although this particular example may not relate to conditions common during deployment, the concept of risk compensation may be useful in thinking about how hazards present in theater may increase risk of injury and how risk compensation mechanisms may be useful as adjuncts to other types of injury prevention strategies.

In some cases, the trade-offs in terms of risks and benefits associated with an intervention are not easy to evaluate. The relative benefits of interventions to address specific and different types of problems can be even less clear. For example, a recent analysis of Army Safety Center data suggests that adding protective armor to "Humvees" (actually "HMMWV" [high-mobility multipurpose wheeled vehicle]) makes the vehicle more top heavy and thus more prone to rollover.¹⁴⁶ Approximately 70% of the soldiers killed in Humvee accidents in Iraq between March 2003 and November 2005 were killed when the vehicle rolled over. Decades of research in the civilian world have demonstrated that light trucks and sport utility vehicles are more prone to rollover than automobiles because of their height and high center of gravity.¹⁴⁷ Although other factors (eg, driver behavior and environment) have also been shown to increase rollover risk, such factors are difficult to predict and control, thus making modifying the vehicle to reduce rollover risk an appealing option. As this example shows, however, all proposed vehicle modifications should be made in joint consideration of the overall impact on risk of both intentional and unintentional injuries. Injury interventions should be evaluated not only for their efficacy in preventing the target injury, but also for unintended consequences. Proper evaluation research of newly proposed injury prevention programs is necessary to identify unintended consequences that may appear and to make plans to mitigate or eliminate them.

PLANNING INJURY PREVENTION PROGRAMS

Injury prevention has been considered an important component of the medical arts since the time of Hippocrates, but was not systematized until the mid-20th century through the efforts of several injury control pioneers. William Haddon, Jr, is credited with the most substantial methodological and theoretical advances in the field, having created two widely accepted tools related to the prevention and control of

injuries. The first of these tools is known as the Haddon matrix and provides a conceptual framework for considering approaches that target the host, agent, and environment at different temporal points during the injury-producing event. The second tool is a set of prevention strategies known in the injury control field simply as the "10 strategies." The 10 strategies provide a scientific approach to injury control; when coupled

with the Haddon matrix, they provide an extremely useful methodology for the control of injury hazards of all kinds.^{11,148}

The Haddon Matrix: Identifying Injury Intervention Opportunities

All elements of the injury epidemiological triangle are incorporated in a deceptively simple tool known as the Haddon matrix (Figure 12-9).¹⁴⁹ The matrix plots the elements of the epidemiological triangle against another dimension that is important in the development of injury prevention strategies—time.

The Haddon matrix is essentially a heuristic technique. It facilitates the careful evaluation of all options available to prevent or reduce harm resulting from a specific injury event. Haddon noted that there are three different stages to the injury process:

1. a preevent phase, in which the energy transfer has not yet occurred;
2. an event phase, or the actual point at which energy is transferred to the host; and
3. a postevent phase, after the incident has occurred.

There are different intervention strategies that can be applied in each of these phases. Each of these intervention strategies corresponds to each element of the injury epidemiological triangle. Haddon proposed that it is often necessary to implement several different interventions to control injuries effectively. As with attempts to control infectious agents, the goal should be to identify the weakest link and apply appropriate intervention strategies.⁸

The Haddon matrix, as it was initially developed, was intended for use as a tool to identify ways to

Phase	Factors		
	Human	Equipment	Environment
Preevent	 Virtual reality training	 HMMWV tire maintenance	 Training in realistic environments
Event	 Restraint system use	 MRAP survivability testing	 Convoy vehicle-spacing policies
Postevent	 Medical response	 BEAR evacuation robot for hazardous environments	 HMMWV fire suppression system

Fig. 12-9. The Haddon matrix illustrated with examples of the Army Safety Center and other Army proponent responsibilities. Haddon’s breakthrough concept was to parse accident events into modifiable elements involving timing (preevent, during, and postevent) and contributor (people or hosts, vehicle or vector, and environment). BEAR: Battlefield Extraction and Retrieval Robot (Vecna Technologies, Inc, Greenbelt, Md); HMMWV: high-mobility multipurpose wheeled vehicle; MRAP: mine-resistant ambush-protected (vehicles).

reduce injuries and their sequelae. Some researchers who have used the Haddon matrix have incorrectly related the individual rows directly to primary, secondary, and tertiary prevention approaches.¹⁵⁰ Dr Haddon, however, did not agree with this interpretation. In fact, he proposed the three-phase model because the primary/secondary/tertiary model did not fit injury well, inasmuch as primary prevention strategies could be applied in the event phase, the preevent phase and, to a limited degree, even in the postevent phase (W Haddon, oral communication with S Baker, 1970s).

The Haddon matrix can be used to identify options for preventing or reducing harm in each phase of the injury event and for each element of the injury epidemiological triangle. In each cell of the matrix, one could list the ideas for injury prevention strategies that apply to that stage. For example, the first row of the matrix could include strategies that attempt to prevent the injury event from occurring. Examples of interventions that might fit in this row could include combat survival training, pilot training and requalification, flight checklists, and military aircraft/vehicle maintenance programs.

In the second row of the matrix, one could list strategies that attempt to modify the individual, environmental, or protective equipment to reduce or eliminate energy transfer to prevent injury altogether, or to minimize the damage caused by the energy transfer. Examples of interventions in this row might include required use of safety belts, helmets, life jackets, flak vests, and parachute ankle braces. This type of intervention strategy would also mandate the installation of crashworthy fuel systems and breakaway sticks in helicopters. Note that none of these interventions would prevent the energy transfer event from occurring (ie, the plane or car would still crash), but they might prevent the individual from being hurt during that event.

Most injury control efforts tend to focus on the first and second rows because it is optimal to prevent or reduce the severity of the injury altogether, if possible. Irving Zola captured the essence and importance of prevention as follows,

[Y]ou know, sometimes it feels like this. There I am standing by the shore of a swiftly flowing river and I hear the cry of a drowning man. So I jump into the river, put my arm around him, pull him to shore and apply artificial respiration. Just when he begins to breathe, there is another cry for help. So I jump into the river, reach him, pull him to shore, apply artificial respiration, and then just as he begins to breathe, another cry for help. So back into the river again, reaching, pulling, applying, breathing and then another yell. Again and again, without end, goes the

sequence. You know, I am so busy jumping in, pulling them to shore, applying artificial respiration, that I have *no* time to see who . . . is upstream pushing them all in.¹⁵¹

One approach to solving the problem of injury morbidity and mortality is to stand on the riverbank and try to pull people out as they float by. A better approach may be to go upstream and see what can be done to stop them from jumping in or being thrown in the water in the first place. Because some people will inevitably end up in the river, however, it is worthwhile to consider interventions that could be placed in the third row of the Haddon matrix (those that influence the long-term sequelae of injuries once they have occurred and prevent reinjury or injuries that occur subsequent to the initial injury event). Strategies that fit in this row include field hospital readiness and access, secured runways for medical evacuation (MEDEVAC), and training all soldiers in basic first aid and cardiopulmonary resuscitation.

Columns of the Haddon matrix correspond to the elements of the injury epidemiological triangle. The first column includes all intervention strategies that relate directly to host behavior or susceptibility to injury and attempts to modify these factors. Such interventions might include improving physical fitness, training, and providing good reconnaissance information about terrain. The second column focuses on changes in the vehicle (which carries energy to the person) and protective equipment (eg, airbags, seatbelts, helmets, ankle braces, and so forth). The third column focuses on modifications to the physical and broader social environmental factors (eg, system support of MEDEVACs and disaster preparedness, norms and laws against driving while impaired, and enforcing safe behaviors).

The easiest way to understand and begin using the Haddon matrix is by example. Consider injuries occurring among airborne soldiers during tactical parachuting exercises and jump operations. To control these types of injuries, we will attempt to identify strategies within each cell of the matrix (Table 12-6). The first cell should inspire thoughts of interventions that may be implemented prior to jumping to improve human performance. Examples include prior training, proper nutrition, and physical conditioning. The event phase for human interventions would include using protective gear (eg, ankle braces) and being well-rested and in good condition. Postevent measures might also include training, because soldiers should know what to do if they are injured in a jump operation, including basic first-aid training.

Preevent interventions in the second column (vehicles and equipment) include the choice of low-porosity

TABLE 12-6

HADDON MATRIX OF INTERVENTIONS TO REDUCE WARTIME MOTOR-VEHICLE CRASHES

Phase	Factors		
	Human (Host)	Equipment (Vector or Vehicle)	Environment
Preevent	Degree of fatigue, familiarity with terrain and vehicle, driving experience, personality, speed, smoking, use of alcohol/drugs	Antilock brakes, vehicle in good condition (eg, lights, brakes), weight distribution to avoid rollover, good tire traction, speed capability	Terrain, weather, visibility, enemy position and disposition reconnaissance accuracy, command enforcement of training protocol and alcohol/drug prevention, speed limit
Event	Use of safety belt, speed	Air bags, helmets, collapsible steering column, structural integrity (roll bars, side bars)	Obstacle-free road, vehicle following distance
Postevent	Knowledge of first-aid, general health, age, smoking, alcohol or drug use, prior injury history	Fire-retardant interior and gas tank, first-aid gear on board, fire extinguisher	Open terrain for rapid evacuation, command support of MEDEVAC, planning for triage, distance to field hospital, training of field hospital staff

MEDEVAC: medical evacuation

parachutes if the situation warrants. Event-phase equipment strategies might include the presence of a reserve chute if the primary chute fails. Postevent interventions might include the availability and proximity of well-maintained first-aid equipment and phone or radio communication systems, if appropriate.

Preevent strategies in the third column should target social and physical environmental factors. Airborne soldiers need to be prepared to jump in a variety of drop-zone conditions, in varied weather conditions, and with prior consideration of enemy position and disposition. Modifications to these plans could be made to enhance the accuracy and support of a reconnaissance team. Event-phase strategies might include weather conditions, which could make drop-zone terrain or obstacles more hazardous or could make it more difficult for a jumper to maneuver out of a hazardous situation. Postevent strategies might include factors such as accessibility for a MEDEVAC crew, lighting for the crew, command support of a MEDEVAC program, knowledge of the distance to a field hospital, and training of the field hospital staff (Figure 12-5b).

Many of the interventions that appear in the first column (human factors) derive from models for changing individual behaviors, whereas most strategies listed in the second column, and some in the third column, involve engineering or structural changes that do not require specific actions by the host. Many interventions may also be appropriate in more than one cell. For example, training may both prepare a soldier

in proper jump techniques, but should also address first-aid and other emergency procedures if an injury should occur. Likewise, interventions aimed at increasing physical fitness generally or specific behavioral interventions around reducing tobacco and alcohol use may be relevant in many cells. Although alcohol use is prohibited in forward-deployed zones, habitual use of alcohol may impact physical conditioning and would be relevant in the preevent phase of injury prevention. Some research suggests that alcohol and tobacco impede tissue-repair processes and thus may prolong rehabilitation or contribute to adverse sequelae.¹⁰⁶

The Haddon matrix has been a useful tool in the design and implementation of injury interventions for more than 50 years, but some researchers have recently proposed adding a “third dimension” or a third axis to it.¹⁵² The third axis comprises factors that may impact the acceptability of the various proposed interventions (eg, cost, feasibility, and potential for stigmatization). Once all possible ideas for interventions have been collected and placed in the appropriate cells, it is useful to establish the guidelines by which the pros and cons of each suggestion can be assessed, and from those, make decisions about which interventions to develop and implement. The conceptual model of the matrix then becomes more cubelike, with the addition of these factors aligned along the edge of one of the sides of the cube. Each of the ideas recommended in each of the cells of the matrix is then weighed by these standards in deciding which intervention ideas get developed and implemented. For

example, in designing an intervention to reduce ankle fractures among airborne parachutists, commanders might weigh such factors as cost, efficacy, feasibility, soldier preferences, or effect on readiness. This expansion of the matrix formalizes the process of weighing the costs and benefits of the various ideas that have been suggested and conceptualizes the decision-making process within the tool to an even greater degree.

Haddon's 10 Strategies for Control of Hazards of All Types

The 10 strategies allow each aspect or component of an energy transfer to be analyzed separately¹⁵²:

1. prevent the creation of the hazard in the first place;
2. reduce the amount of the hazard brought into being;
3. prevent the inappropriate release of a hazard that already exists;
4. modify the rate or spatial distribution of the release of a hazard from its source;
5. separate, in time or space, the hazard and that which is to be protected;
6. separate the hazard and that which is to be protected by the interposition of a material barrier;
7. modify relevant basic qualities of the hazard;
8. make that which is to be protected more resistant to damage from the hazard;
9. begin to counter damage already done by the environmental hazard; and
10. stabilize, repair, and rehabilitate the object of the damage.

In essence, the 10 strategies are a multidimensional approach to discover the best or most practical intervention point or points. In some cases, a given strategy may suggest an intervention that is not practical, economical, or feasible. Nevertheless, by considering each strategy carefully, the probability of finding a viable intervention is greatly increased.

Strategy 1: Prevent the Creation of the Hazard in the First Place

Without the buildup of thermal, kinetic, or electrical energy, few high-energy hazards would exist. If we could avoid war, no one would be killed in battle. If nuclear weapons were never created, no detonation of nuclear weapons could take place. In some cases, international law bans certain weapons. Examples of this strategy include the following:

- banning chemical weapons; and
- banning rifle or pistol ammunition without full-metal jackets (eg, soft-point or hollow-point bullets that expand or fragment on entering the body).

In a more basic sense, the decision not to put a 2,359 kg HMMWV in motion also illustrates this first strategy. On one hand, as the first and perhaps most basic of the 10 strategies, it can also be the least practical from a sociopolitical standpoint. On the other hand, the military is an environment in which commanders have broad powers to dictate policy pertaining to individual and unit activities (Figure 12-10), as well as the choice of equipment and vehicles. With proper



Fig. 12-10. Weather watchers give parachute training the all clear. Two soldiers at the Fryar Drop Zone (Fort Benning, Ga) take measurements at a weather station. If weather conditions are hazardous, training jumps may be canceled. This illustrates Haddon's first strategy of hazard control: to prevent the creation of a hazardous situation in the first place.

command support, safety measures that may not be possible to implement in a civilian environment may be initiated with little debate in the military. Examples of this strategy include:

- banning personnel weapons and all munitions from barracks;
- banning alcohol consumption during deployment in Muslim countries; and
- declaring businesses such as massage and tattoo parlors off-limits to military personnel to control disease and physical assaults.

Strategy 2: Reduce the Amount of the Hazard Brought Into Being

The second strategy is similar to the first, except that it requires only a significant reduction of a hazard, not its complete elimination (Figure 12-11). This strategy is more viable because it represents a degree of compromise. Most people are used to

having limits placed on their activities and will accept reasonable constraints. Many successes have come from the employment of this second strategy, such as the reduction in motor-vehicle fatalities by lowering the speed limit. Examples of this strategy include the following:

- substituting nonalcoholic or low-alcohol beer for alcoholic beverages,
- instituting a speed limit based on terrain,
- reducing the speed capability of vehicles, and
- shortening the length of a training run during hot weather to avoid heatstroke.

Strategy 3: Prevent the Inappropriate Release of a Hazard That Already Exists

Sometimes it may not be feasible to eliminate or even reduce the amount of a hazard that is present. The next logical step, then, is to try to prevent a hazard from being released in an inappropriate or uninten-



Fig. 12-11. Destruction of antipersonnel mines. These Marines are stacking antitank and antipersonnel land mines for destruction at Guantanamo Bay, Cuba. During the Cold War, more than 50,000 land mines were buried in the buffer zone separating the Marine installation from mainland Cuba. They have been replaced with motion detectors and sound sensors. This is an example of Haddon's second strategy of hazard control: to reduce the amount of the hazard that exists, especially when it already exists or where it cannot be eliminated completely. The work these Marines do will protect future generations of Marines patrolling the periphery at Guantanamo Bay. They may be placing their own safety in jeopardy, however; although they are wearing some EOD (Explosive Ordnance Destruction) protective gear, they are working without helmets. Photograph: Reproduced from the Department of Defense. Taken by PO1 Ronald L. Heppner, US Navy.



Fig. 12-12. Crashworthy fuel systems. (a) This OH-58C helicopter crashed, but both soldiers on board survived the crash, in part because these aircraft are designed with a crashworthy fuel system. (b) The fuel bladder, which seals on impact, prevents fuel from spilling after the crash. Crashworthy fuel systems for helicopters have reduced postcrash fires from one of the most important causes of aviation-related deaths and injuries, and such fire-related deaths are now relatively rare events. This demonstrates Haddon's third strategy of hazard control: to prevent inappropriate release of a hazard that already exists.

tional manner. Although this can be accomplished by destroying a hazard that already exists (Figure 12-12), it can also be accomplished by stopping or controlling its release, or some combination of both. Examples of this strategy include the following:

- following deicing procedures on ship decks, aircraft carriers, and aircraft wings;
- eliminating delivery vehicles of biological weapons (eg, destroy Scud missiles);
- designing grenades with safety pins;
- installing and engaging safety mechanisms that prevent accidental discharge of weapons; and
- installing self-sealing fuel bladders and auto shut-off fuel valves on aircraft.

Strategy 4: Modify the Rate or Spatial Distribution of the Release of a Hazard From Its Source

Modifications that influence the rate at which the hazard is released are particularly useful in cases of mechanical (kinetic) energy transfers in which reducing the speed of the transfer is key in determining the degree of damage caused. Human tissue can often sustain transfers of large amounts of energy if the energy transfer occurs slowly enough. For example, low-porosity parachutes decrease the velocity of descent and thus reduce the energy of ground impact. Likewise, increasing the spatial distribution of release of energy also reduces injury risk. For example, the parachute landing fall allows the jumper to distribute the energy of landing across a wider area (Figure 12-13). Doing so dissipates the



Fig. 12-13. Parachute landing fall allows the jumper to distribute the energy across five separate body regions rather than one. Doing so dissipates the force of the impact over a larger area, thus lessening (and usually eliminating) trauma to the ankles and feet. The pack will hit the ground first, further minimizing the forces of ground impact.

force of the impact over a larger area, thereby lessening, and usually eliminating, trauma to the ankles and feet. Other examples of this strategy include the following:

- installing fire-, smoke-, or heat-activated sprinkler systems;
- providing diver-decompression tables;
- installing emergency shut-off valves;
- using low-porosity parachutes; and
- installing UH-60 Black Hawk helicopter G-force reducing seats.

Strategy 5: Separate, in Time or Space, the Hazard and That Which Is to Be Protected

This strategy seeks to keep the hazard and personnel from being present at the same place or time. This can be accomplished through a variety of methods, including physical and temporal phasing of transportation or work schedules. Examples of this strategy include the following:

- maintaining altitude spacing of aircraft (instrument flight rules),
- setting shipping lanes,
- evacuating civilians before political upheaval in foreign nations,
- applying insecticides before troops arrive,
- storing weapons and munitions in a secure

- facility on military installations, and
- installing aircraft ejection seats to remove pilot from aircraft before the crash.

Strategy 6: Separate the Hazard and That Which Is to Be Protected by the Interposition of a Material Barrier

This strategy, using protective gear (Figure 12-14), is perhaps the most straightforward of all of the strategies. It has been used successfully for centuries. Examples in a military context include the following:

- wearing Kevlar helmets;
- using safety glasses, earplugs, and sunglasses with ultraviolet protection;
- using torpedo nets;
- wearing Mission-Oriented Protective Posture (MOPP) gear;
- wearing surgical gloves;
- issuing Nomex flight suits to flight crews; and
- wearing flak vests.

Strategy 7: Modify Relevant Basic Qualities of the Hazard

Common sense applied to the manufacture and design of equipment, vehicles, and materials can go a long way toward injury prevention (Figure 12-15). Two simple attributes of objects, known since the



Fig. 12-14. This Air Force technician is outfitted in full protective gear as he checks the fins of a sidewinder missile. Haddon's sixth strategy for injury prevention recommends the separation of a person from hazardous substances by a material barrier. Although such protective equipment is important in shielding military personnel from chemical and biological hazards, it may carry with it unintended consequences. It may encumber the individual, limit dexterity to accomplish certain tasks, and cause a risk of heat exhaustion.

Photograph: Reproduced from the *Best of the US Air Force CD-ROM*, Defense Visual Information Center, image 88-08702.



Fig. 12-15. “Designed to crash,” the UH-60 Black Hawk helicopter was developed to the military’s specifications with consideration of the decades of crash data and to maximize survivability on impact. Its safety features include a self-sealing, crash-resistant fuel system; energy-absorbing landing gear and crew seats; and a collapsible control stick. Despite affectionately saying that the Black Hawk is “built to crash,” many a thankful aviator has walked away from a devastating crash with a greater appreciation for the meaning of the word “crashworthy.” Efforts to modify the hazardous elements of the vehicle and protect its occupants in the event of a crash render the Black Hawk a fine example of Haddon’s seventh strategy: to modify relevant basic qualities of the hazard.

Photograph: Reproduced from the *Defense Image Digest CD-ROM*, Defense Visual Information Center, image 329.

time of Hippocrates,¹⁵³ are that softness and a large radius of curvature make objects less likely to cause injury during collisions. The application of these basic engineering principles to the design of tools, vehicles, and equipment can improve safety with little or no additional cost. This seventh strategy thereby focuses on the hazard itself. A few examples of this strategy include the following:

- applying nonskid surfaces;
- using less lethal rubber bullets and fire hoses instead of night sticks and firearms for riot control;
- eliminating sharp or hard surfaces in aircraft cockpits;
- installing shock-absorbent surfaces on obstacle courses;
- designing collapsible control sticks in helicopters;
- placing sand- or water-filled barrels at road-blocks, control points, and cliff edges;
- using low-voltage lighting or electrical systems where possible; and
- constructing ships with double hulls.

Strategy 8: Make That Which Is to Be Protected More Resistant to Damage From the Hazard

In contrast to the seventh strategy, this strategy attempts to redesign or modify the victim of injury rather than modify the hazard (Figure 12-16). This strategy attempts to increase the strength, stamina, conditioning, or other inherent qualities of a person or his/her environment that will, in turn, make that person better able to withstand an injury-producing event. Some examples of this strategy include the following:

- applying sunscreen before sun exposure;
- maintaining psychological and physical conditioning of soldiers or athletes;
- ensuring that soldiers get adequate nutrition and rest;
- administering appropriate vaccines to counter the effect of biological agents;
- inducing pharmacological sleep on transcontinental flights; and
- ensuring gradual, staged ascent to altitude to ensure acclimatization or preconditioning in a hypobaric chamber before conducting training or operations at altitude.



Fig. 12-16. Physical training exercises. Military personnel routinely undergo physical conditioning to maintain their strength and stamina. Doing so may make them better able to withstand an injury-producing event.
Photograph: Reproduced from the *Best of the US Air Force CD-ROM*, Defense Visual Information Center, image 92-06073.



Fig. 12-17. After tragedy, relief in Oklahoma City. These Air Force members are distributing bottled water to search and rescue workers in the aftermath of the explosion of the Alfred P Murrah Federal Building. Secondary prevention measures such as this are an important example of Haddon's ninth strategy: to begin to counter damage already done by a hazard.
Photograph: Reproduced from the *Best of the US Air Force CD-ROM*, Defense Visual Information Center, image 96-00585.

Strategy 9: Begin to Counter Damage Already Done by the Environmental Hazard

Most of the methods suggested by this strategy are secondary rather than primary prevention efforts (Figure 12-17). The first step in this strategy is to detect damage that has already occurred or that is still occurring and to take steps to stop the damage from continuing. This stage also initiates the recovery process. Although it is generally preferable to prevent injury in the first place, rapid detection and prompt treatment of injuries can eliminate or greatly reduce their consequences. The ninth strategy may involve primary prevention in some cases, because it may prevent reinjury or development of a fatal condition among those already injured. A few examples of this strategy include the following:

- reconstructing or restoring bridges, hospitals, and key infrastructure sites;
- activating an emergency radio beacon on a downed aircraft;
- equipping water survival gear with a radio and water-soluble dye indicator to increase the likelihood of rescue;
- restoring damaged desalination plants;
- establishing telemetry with higher echelons

- of care/telemedicine links;
- airdropping food, water, and medicine to war-ravaged territory; and
- providing rapid first aid and evacuation for victims of injury.

Strategy 10: Stabilize, Repair, and Rehabilitate the Object of the Damage

Once damage has occurred, it is important to stabilize the victim to prevent further damage. The next step is to begin the process of treating the injury and facilitating rehabilitation to prevent reinjury or susceptibility to new injuries. The Air Force MEDEVAC program provides a good example of this strategy (Figure 12-18). Other examples include the following:

- detecting and responding to injuries on the battlefield—combat lifesaver training for all deployed soldiers,
- placing Forward Surgical Teams in the war zone,
- establishing trauma centers,
- establishing burn centers (eg, Brooke Army Medical Center was instrumental in treating military burn patients from the Vietnam War to the present),



Fig. 12-18. US Army UH-60 Medical Evacuation (MEDEVAC) helicopter lands on the USS *New Orleans* during a joint-service, mass-casualty exercise held in Somalia during Operation Restore Hope. Rescue is the first step in rehabilitation and convalescence, Haddon's tenth strategy (to stabilize, repair, and rehabilitate the object of damage).

Photograph: Reproduced from the *US Forces in Somalia CD-ROM*, Department of Defense Joint Combat Camera Center, image 364.

- creating the Military Advanced Training Center for Soldier Amputees at Walter Reed Army Medical Center, and
- providing rehabilitation services.

Passive Intervention Strategies

Over the past few decades, there has been increased emphasis on environmental and engineering-based injury prevention interventions and a reduced emphasis on interventions directed at changing individual behavior. Focusing on external solutions rather than on personal actions in injury prevention has had a twofold advantage. First, physicians and other health-care personnel who may have been discouraged in their attempts to influence the behavior of individuals have found other ways to address injury prevention in their practices. Second, researchers have discovered other opportunities for preventing injury, even when the injury-producing activity itself cannot be averted.

Passive strategies generally use engineering and biophysical modifications to vehicles, equipment, or the environment. They may also apply to clothing and other equipment, if the garments are treated to provide sun protection or to protect the wearer from hot surfaces, burns, and insects. The principal advantage to passive strategies is that they often prevent injury, regardless of human behavior, and they can be very cost effective. Because passive interventions are engineered into the environment, they usually provide their benefits without having to rely on the memory, training, skill, sobriety, or mental state of the individuals being protected. The problem of blaming the victim can also be avoided.

Active Intervention Strategies

Although all active strategies require an individual to consciously make a behavior choice, the approaches available to achieve this are varied and largely determined by the particular philosophical and methodological inclinations of the injury prevention specialist designing the intervention. Much research has been devoted to understanding and predicting health behavior choices. If one examines the behavior of individuals within large populations, one will observe substantial differences in the types of health behaviors in which those individuals engage. There are many reasons why these differences exist and, as a result, many different ways one might attempt studying these variations and, ultimately, modifying relevant behaviors. Some of these approaches to understanding differences in health behaviors focus on factors extrinsic to the individual, and some approaches focus on factors intrinsic

to the individual.¹⁵⁴

Extrinsic factors that affect health behaviors include environmental regulations and legal restrictions. In a military setting, examples may be found on individual military installations, where rewards are conferred on units with the highest fitness scores, completion of a year without an injury fatality, or in the provision of easy access to healthcare. Legal restrictions are laws and regulations that ban dangerous substances or punish individuals for engaging in undesirable behavior (eg, not using safety belts, not wearing helmets). Thus, power to leverage behavior change is generally in the form of social or economic sanctions and incentives. For example, although it may happen rarely, service members who allow themselves to get sunburned may be punished under Article 15 of the Uniform Code of Military Justice. Sailors ordered not to consume alcohol the night before deployment could be subjected to a Breathalyzer test and face punishment if found to be noncompliant.

As previously mentioned, there are certain features of the military environment that make passive intervention strategies easier to implement than they might be in civilian settings. The military command structure and nature of the military's top-down decision-making processes make it easier to adopt changes quickly and uniformly. Communication systems make it easy to disseminate information fairly rapidly to all units and personnel. Although it may seem that having these features in place may make it easier to implement an injury prevention program, it is important to remember that nothing can happen without command support and explicit agreements by individuals at all levels of the command structure to enforce standards and regulations once they are implemented. In light of this, proposed intervention strategies should be appropriate to the nature of military occupational setting and requirements, and must be acceptable to the military's unique social and cultural environment. Finally, it is important to remember that, in designing and promoting injury prevention programs, all parties at all levels of command need to be briefed on the need for and the rationale for the intervention. Getting all parties to buy into the intervention is important to make sure that it is fully and appropriately implemented.

Interventions that modify extrinsic factors arise primarily from deterrence theory. Deterrence theory suggests that these extrinsic factors may effectively deter one from engaging in unsafe behaviors (or as a corollary, encourage one to engage in safe behaviors) if the following holds true: (a) the individual believes that he/she has a high probability of getting caught if he/she fails to engage in the desired behavior; (b) the person will, once caught, have a high probability of being

convicted; (c) the time between being caught and being convicted is short; and (d) the punishment following conviction is severe. These elements are sometimes abbreviated as “swift, severe, and certain.”¹⁵⁵

Deterrence strategies essentially coerce behavior change through the leverage of power.¹⁵⁶ The strategies may be either proscriptive or prescriptive. Proscriptive approaches include rules, laws, regulations, and incentives designed to discourage the adoption of unsafe behaviors (eg, fines for speeding, docking of pay for unsafe behavior). For example, the military’s policy of performing routine urine screening for certain illicit drugs is widely credited for the decrease in drug abuse among service members since the early 1980s. Prescriptive strategies also leverage power; but, instead of discouraging unsafe behavior, these approaches encourage the adoption of safe behaviors. These strategies include safety belt regulations, helmet rules, and pilot safety checklists to be completed before takeoff.

There are some problems that may arise when using deterrence approaches to control injuries. First, deterrence strategies assume that individuals engage in a process of rationally weighing the costs and benefits of an action before proceeding. In reality, behavior choices are influenced by other factors as well, such as the psychological and social status of the individual. The use of alcohol or drugs may also affect decision-making ability. To be completely effective, this approach also requires that an individual be capable of performing the desired behavior 100% of the time. Overdeterrence may also be a problem. It is possible to create a great enough deterrence effect that the person overcompensates.¹⁵⁷ For example, it is wise for a soldier in a battle situation, or a pilot in flight, to proceed with great caution to avoid serious trouble. However, if these individuals are too cautious in using life-preserving efforts, vital missions may never be accomplished. Some element of risk-taking is necessary. Deterrence approaches are somewhat retrospective, in that for deterrence to work, an individual must first engage in the behavior; individuals are punished after the behavior has already hurt them. Finally, the ability to enforce policies consistently in a manner that is “swift, severe, and certain” is often hampered by limited resources and by the discretionary behavior of those called to the task of enforcement.^{158,159} Also, the development of laws and regulations occurs through a level of command that may be influenced as much by concerns over broad military objectives as by reductions in key risky behaviors.¹⁶⁰ The need to achieve military objectives may necessarily trump concerns about individual risk-taking and safety that might impact or impede pursuit of those objectives.

Intrinsic factors affecting behavior choices include

demographic characteristics (eg, gender, age, and race), personality traits, social support, social networks, and cognition. Behavioral theories have arisen out of each of these intrinsic factors. However, because most of these elements are intractable (ie, one cannot change a person’s gender or age), it seems most prudent to focus on cognition as a predictor and motivator of health behavior choices. In addition, cognition is important in predicting how an individual will react to extrinsic factors.

Cognition is the thought processes that occur between experiencing a stimulus and making a behavior choice in various situations.¹⁵⁴ It is how individuals make sense of the world in a specific situation and with the information they possess (including beliefs, attitudes, and knowledge the individual maintains about a particular health behavior).

Several models, all broadly described as social-cognitive, have been developed to assist in understanding and predicting health behavior choices. Each model holds certain assumptions about human nature. Intervention strategies are derived from the particular model believed to be valid or useful in predicting a particular health behavior decision. Like deterrence theory, social-cognitive models assume a person will engage in a process in which he/she rationally weighs costs and benefits of a behavior and then makes a choice. Instead of focusing on the nature of those costs and benefits, however (as with deterrence models), social-cognitive models focus on how people interpret costs and benefits, how they perceive their environment, and then use that information to make health-related behavior choices. Interventions are then derived from these models. Once a behavior is understood, efforts can be made to alter the perceived cost or benefit of an action to change behavior.

Although there are many social-cognitive models, a few of the more common models are particularly salient to this discussion and worth a quick review. These include the health belief model, health locus of control, social learning theory, the theory of reasoned action, stage models, and the social contagion model.

The Health Belief Model

This is one of the oldest of the social-cognitive models, and it has been moderately useful in predicting actual health behaviors. This model focuses on how perceptions of a threat to one’s well-being influence beliefs and behaviors that are associated with that threat. This model suggests that, to motivate an individual to change risky behavior, the person must first believe that engaging in a certain behavior makes it likely that he/she will experience an injury *and* that the

injury must be viewed as serious. Behavior alternatives are selected on the basis of the person's awareness of behavior options, beliefs about the efficacy of those alternative behaviors, and perceptions about the costs (or barriers) of engaging in the new behavior.¹⁶¹ Cues to action, such as education efforts that suggest new behavior choices, are also often included in this model.

Examples of injury prevention efforts that are derived from this model include programs designed to modify risk perceptions (eg, education about the importance of helmets while parachuting and posters that remind sailors of the risks involved in drinking before or during scuba diving). Such programs may also attempt to change perceptions about the benefits of adopting a new health behavior, reduce barriers to changing behaviors, and provide cues to action (eg, a pilot's preflight checklist). Thus, most efforts designed to provide military personnel with additional information (educational campaigns) come from the health belief model.

When healthcare practitioners endeavor to prevent or reduce injuries, it often seems that the first intervention plan they develop involves educating those at risk. Even though there are some situations in which education is useful in preventing injuries, there are some significant limitations to this approach. First, some key cognitive variables that have been found to be very useful in predicting health behavior decision-making are missing. Social and peer pressures are not taken into account (except as a modifier of perceived risk of injury). Peer groups may have an enormous influence on risk-taking, particularly in certain settings. Self-efficacy, or beliefs about how much control one has over a behavior, is not included in the health belief model or in general education campaigns. In injury prevention terms, this might mean that a person believes injuries are the result of random events and not something to be controlled or avoided. He or she may believe that seat belts are uncomfortable or that they even increase risk; thus, the person may be unwilling to buckle up. When the risky behavior in question includes use of alcohol or drugs, there may be a physical inability to control the behavior without some form of medical intervention.

Health Locus of Control

Related to self-efficacy is the concept of locus of control. Health locus of control is an important axiom in the entire health promotion field. In essence, it describes an individual's sense about how much the person controls or influences his/her own health and well-being. There are three possible beliefs that individuals can have about control over their own

health: (1) internal control, (2) external control with a belief in powerful others, and (3) external control with a belief in fate. Internal control means that individuals believe they are in control of their health and can affect their health status through their behavior choices. Those who subscribe to external control with a belief in powerful others believe they have little control over their health status, but believe that others (eg, their spouse, doctors, or nurses) can affect their health. External control with a belief in fate means that these individuals believe they have little control over their health status and that injuries and illnesses are a result of fate or acts of a deity.¹⁶² The association between individuals' sense of control over their health is strengthened when the relative value they place on their health is also included.¹⁶⁶ Interventions deriving from the health locus of control arena strive to increase perceptions individuals hold about their control over their health and well-being. For example, fitness programs may be enhanced when individuals are also counseled about the effectiveness of this effort in achieving overall good health. A program that documents improvement in health (eg, reduced blood pressure, lower weight, better lung capacity, less foot pain or low back pain) also may facilitate a sense of control over health and well-being. An individual with a belief in external powers may be encouraged to adopt safer behaviors if a respected person (eg, physician, commander) suggests it.

Social Learning Theory

Many commonly used social-cognitive models are based or draw on key components from Albert Bandura's social learning theory.¹⁶³ Social learning theory suggests that a person's perception of control (self-efficacy) and environmental controls and incentives interact to affect the adoption of health behaviors. A person is most likely to engage in safe behaviors if that person thinks choosing the safe behavior (over an unsafe action) will result in positive reinforcement (eg, better health, positive feedback from important others, such as friends and family) and if that reinforcement has value to the individual. The theory of reasoned action, which is discussed in the next section, is closely related to this model.

The Theory of Reasoned Action

This model focuses on an individual's attitudes about a particular safe (or unsafe) behavior, as well as the social context in which the individual engages in the behavior. Like the social learning theory, this model recognizes that peer and social groups are important

elements in making behavior choices. This model also focuses on intentions to behave in a given manner (ie, is the person motivated to adopt the safe behavior or does the person have a conscious plan in place to determine behavior?). Attitudes about safe behavior are also important (eg, does the individual enjoy exercising and maintaining physical fitness?) and affect the likelihood of actually performing the behavior, because these attitudes directly affect intention to behave. Attitudes are developed not just from thinking about the relative enjoyment (or costs) of a behavior, but also from subjective norms (eg, what will people think of me if I wear safety goggles and protective gear?) and how much one values the opinions of others.

Interventions that incorporate tenets from social learning theory and the theory of reasoned action focus on peer groups and norms. Examples in the civilian world include the “Friends Don’t Let Friends Drive Drunk” media campaign. The military environment is perhaps particularly well suited for development of these types of interventions because much emphasis is placed on teamwork, camaraderie, and caring for one another. Examples include having a buddy check camouflage before a maneuver, restricting privileges for an entire group if one member does not comply with a safety rule, or giving the entire unit a 4-day pass if there are no motor-vehicle-related injuries in a set period of time. Although no one in a unit would admit to valuing a 4-day pass more than life, awareness of motor vehicle safety is heightened as the end of the time period nears, and thus the likelihood of obtaining the award becomes a powerful motivator.

Stage Models

Stage models suggest that different cognitive stages or thought processes are important at different stages in the development of a health behavior. One of the best-known stage models, the transtheoretical model of change, was developed by Prochaska and DiClemente to understand and predict addictive behaviors.¹⁶⁴⁻¹⁶⁷ The model has now been widely applied to other health behaviors, including some injury-associated risk-taking behaviors (eg, alcohol use, smoking, and exercise). In this model, individuals are seen progressing through a series of stages on their way to adopting a new, desirable health-related behavior.

There are six stages of change in this model: (1) precontemplative stage, (2) contemplative stage, (3) preparation stage, (4) action stage, (5) maintenance stage, and (6) relapse stage. In the precontemplative stage, the individual is unaware that an existing behavior is risky. In the contemplative stage, the in-

dividual becomes aware of the risks related to his or her behavior. At the preparation stage, the individual begins preparing to change the risky behavior. The action stage is when the person begins putting intentions to change into action. In the maintenance stage, he/she establishes and supports the continuance of this new behavior. A relapse stage often occurs when a person reverts back to the old unsafe behavior and then must cycle through some or all of the stages again to reacquire the new safe behavior. Decisional balance is a key component of stage models. Intervention efforts, developed around an individual’s stage of readiness to change behavior, are designed to help tip the balance toward moving on to the next stage.

It is important to ascertain an individual’s or a community’s level of readiness to design an appropriate intervention. Individuals or communities in precontemplative stages require interventions that focus on making them aware of the risks of their current behaviors and supporting thoughts about the desirability and feasibility of a new, alternative healthy behavior. Individuals and communities that are moving toward the preparation and action phases do not need educational campaigns telling them of the dangers of their current behavior. Instead, they need assistance in developing a plan for changing their behavior. Those who have already adopted a new, safe behavior (in the action/maintenance phases) require intervention efforts that support their efforts and provide feedback on how well they are doing in achieving their expected goals (Exhibit 12-4).

The Social Contagion Model

This model is derived from the study of infectious diseases. It suggests that behaviors (eg, diseases) may be thought of as contagious if an individual is more likely to engage in that behavior when a significant other has already done so. In many ways, this model is similar to social learning theory. However, the model also postulates that contagion will cause an increase in the prevalence of a behavior as the size of the population that engages in that behavior increases. The model has been shown to have some use in predicting behaviors in teenagers and young adults, such as promiscuity, drug abuse, binge eating, suicide, and driver speeding. For example, a driver’s decision to speed is only partly predicted by his demographic background, attitudes toward speeding (theory of reasoned action), beliefs about the consequences of speeding (social learning theory and health belief model), and law enforcement efforts to enforce speed restrictions (deterrence theory). The remaining variation in speeding behavior may be dependent, at least in part, on the

EXHIBIT 12-4

LESSONS OF HISTORY

It is important to note that health promotion interventions must be periodically evaluated for them to remain effective. This applies to both passive and active interventions, because even passive interventions require active behavior change, especially insofar as they require the formulation, implementation, and periodic enforcement of regulations. A review and evaluation of a health behavior program may often need to cover the same cognitive ground that was traversed when the program was initially designed and put in place, whether the program involves active or passive intervention strategies. Failure to periodically review the rationale for injury prevention programs and to reaffirm their necessity and importance may lead to noncompliance with safety standards and practices, and could bring about resurgence in injury rates. As an example, consider use of the outside-the-boot ankle brace used to reduce ankle injuries among Airborne soldiers (described previously). Another example is the recurrence of cold injuries in military populations, especially trenchfoot and frostbite, despite a repeated history of outbreaks and subsequent medical and command interventions from World War I to Bosnia and Afghanistan.

The command at Fort Bragg was initially briefed about the high rate of ankle injuries associated with the Army Airborne operations. Reviewing this information made commanders aware of the scope of the injury problem associated with this particular type of injury. After reviewing the data, the commanders granted permission to a team of researchers to pilot-test an ankle brace designed to prevent ankle injuries. Data the researchers gathered demonstrated a significant reduction in ankle injuries when the ankle brace was used. This intervention has both an active component (command support; parachutists must put braces on) and a passive component (once donned, the braces offer protection independent of any action by the jumper). Ankle braces became routine equipment for students in the Army Airborne School at Fort Benning and were made available to all Airborne soldiers in the Army. Several years after the program was implemented, however, the Army Airborne community began to question the necessity of the continued costs of the program, and also to question the efficacy of the brace, as they began to receive anecdotal reports of proximal injuries that may have been related to use of the brace. A new evaluation study was commissioned to reevaluate efficacy of the ankle brace as a means of preventing ankle injuries during airborne training and operations. These data resulted in renewed support and reimplementing of this intervention.⁽¹⁾

The effects of health promotion interventions may atrophy over time; this may be especially true in the Army, because there is a fairly steady rate of turnover among commanders and key decision-making personnel (eg, medical officers, senior noncommissioned officers). Although this may seem dispiriting, because it may feel like relearning the lessons of history the hard way, it is important to recognize and be open to new opportunities to identify injury hazards and to look for creative ways (some new, others less so) to mitigate them.

Source: (1) Schmidt MD, Sulsky SI, Amoroso PJ. Effectiveness of an outside-boot ankle brace in reducing parachuting related ankle injuries. *Inj Prev*. 2005;11:163-168.

behaviors of drivers around the individual at a given point in time (eg, "Yes, officer, but I was just driving fast enough to keep up with the rest of the traffic.").¹⁶⁸

Models of health behavior have some utility in predicting the choices that individuals make about their own safety. However, they are all limited, in that they require an individual to be capable of engaging in a particular behavior (ie, they require rational thought and the physical and mental abilities to make behavior changes). They do not take into account that some injuries are caused by other individuals, nor do

these models acknowledge that humans are simply not capable of operating at 100% effectiveness 100% of the time (people sometimes make mistakes or are in situations that limit behavior choices). Moreover, because of tactical conditions, enemy action, and unit discipline and practices, soldiers may have limited choices to pursue safer behaviors. Human behavior is motivated by a multitude of factors, some of which are not amenable to change through intervention, or at least they are not easily changed (ie, behavior is influenced by culture, peers, income, education, etc).

MANAGEMENT OF INJURIES IN THE FIELD AND ACCESS TO CARE

In this section, we provide a new approach to the organization of wartime, battle-related injury prevention. The proposed model incorporates some of the unique characteristics of war environments in the

development of injury control approaches.

Comprehensive injury prevention programs attempt not only to prevent or reduce the severity of injuries, but also to provide a plan for management of

injuries when they do occur (Figure 12-19). Access to care may pose a major barrier to the effective management of injuries in the field. Although the purpose of this chapter is not to provide great detail on combat casualty care, injury control covers the full spectrum of care from prevention to rehabilitation.

The principal goals of injury management in the field should be to stabilize the individual, take steps to minimize long-term consequences of the injury, and facilitate the rapid return of the individual to as normal a level of functioning as possible. Three distinct phases in the management of field injuries may be identified: (1) short-range or immediate needs, (2) medium-range care, and (3) long-range care and rehabilitation. Access to care is important at all levels or phases of injury management.

Short-Range Management of Injury

Short-range management refers to what happens in the time interval immediately after the injury has occurred. During this time, the victim must be stabilized and transported to treatment, if necessary. The following three components of access to care must be considered in planning for short-range field management of injury: (1) availability, (2) accessibility, and (3) accommodation.

Availability

Does the service exist (eg, are MEDEVACs or trained medical technicians in the area)? Does it exist in quantities sufficient to meet the demand (eg, are there enough UH-60 Black Hawk helicopters to pick up all those who are seriously injured in a particular area)? Injury mortality and injury morbidity are related to the types of injuries incurred on the battlefield, and the proximity and sophistication of available medical care. Experience in past conflicts, for example, has shown that putting surgeons and surgical facilities at or near the front lines helps reduce injury deaths.¹⁶⁹ The widespread deployment of Forward Surgical Teams during Operation Iraqi Freedom is evidence of this.

Accessibility

Can the injured person be readily picked up or can the injured person easily reach the treatment center? What sort of assistance will he or she require to get to the facility? Factors that affect accessibility include the terrain or vegetation where the injured person is located, the number of noninjured soldiers available to assist in evacuation, the presence of enemy fire and backup friendly fire, distance to the MEDEVAC crew, and distance to the hospital or treatment center.

Accommodation

Are the resources available for the injured person sufficient to meet his or her needs? Factors that influence accommodation include the severity of the injury and the presence of co-morbidities or other factors that might reduce the ability to stabilize the victim for transport. Training factors include training the MEDEVAC crews in how to stabilize the injury, and training other soldiers in the unit to assist with treatment of the individual. Finally, medical resources must be available to stabilize and treat the injured person (eg, the MEDEVAC helicopter must be adequately equipped).



Fig. 12-19. South Vietnam—medical evacuation patients on the deck of the amphibious assault ship USS *Tripoli* (LPH-10) await transfer to the 22nd Casualty Station in Danang from which they will be sent to the States. Wounded Marines who cannot be returned to duty, or who will require more than 6 days of hospitalization, are removed from the USS *Tripoli* and returned to the States.

Photograph: Reproduced from the Archival Research Catalog, the National Archives and Records Administration, ARC identifier 58511.

Medium-Range Management of Injury

Medium-range management of injuries involves medical treatment and short-term rehabilitative efforts to save the injured person's life, reduce adverse sequelae, and improve functioning. The following components of access must be considered: availability, accessibility, and accommodation.

Availability

Is there an adequate treatment facility available for the injured person, and is it near enough to the site of the injury event? Administrators must accurately estimate the number of field hospitals needed in a particular area and must have alternate plans in place to accommodate overflow at other installations. The field hospital must have enough beds, surgical rooms, and emergency supplies and services.

Accessibility

Can injured personnel reach the care facility quickly? Of prime importance are the proximity of the field or shipboard hospital to the battle area, as well as the availability of MEDEVAC resources, presence of helicopter landing pads or ambulance-accessible roadways, and availability and ability of staff to transport and triage patients. The care facility must be located so that it is safe from enemy fire and strategically located away from flood plains and other potential hazards. Injured personnel must ultimately be evacuated from the theater.

Accommodation

Are services sufficient to meet the patients' needs? It is essential for the medical treatment staff to be adequately trained and experienced to handle the specific level (ie, severity) of injuries they will encounter, and there must be enough staff at the site. The staff must have the ability to link up with other facilities and experts. The severity of injuries encountered by soldiers in the field influences accommodation, as well as the general state of individuals on arrival. Their state on arrival depends not only on the severity and type of injury they have sustained, but also on their physical fitness and health habits (smoking, alcohol use, illness history, sleep, and nutritional status) and how well they were stabilized and managed in the field and during transport.

Long-Range Management of Injury

Long-range management of injury is related to the ability to manage and support the longer rehabilitation necessary for treating some types of injuries, and to facilitate recovery of function and independence. Several elements affect this ability, including adequate facilities (staffing and resources) to provide for the physical and mental recovery and rehabilitation of military personnel. A comprehensive program will also include counseling and training for the development of new life skills or occupational skills to facilitate return to work in some capacity.

As the nature of modern warfare changes, soldiers are finding themselves deployed to a variety of set-

EXHIBIT 12-5

LONG-TERM CARE NEEDS

Planning and management of long-term care of war-related injuries will depend, in large part, on whether the injured soldier is returned to active duty or separated from service. For soldiers who remain in the military, changes may need to be made to their duty assignment so that they can continue to succeed in their military career. Soldiers who are separating from service may need different kinds of support, depending on whether they suffer a temporary or permanent disability as a result of their injury. Medical advocates need to assist injured military personnel in understanding benefits and options available to them, including navigating the administrative complexities of the military and the Department of Veterans Affairs healthcare systems. Follow-up is needed to continue monitoring the recovery process and document the progress of reintegration. Latent development of physical or mental problems related to injury must also be monitored. Some soldiers may require the assistance of a social worker or other counseling services to facilitate their reintegration into a job in the civilian sector. Finally, long-range planning should include incentive programs for disabled members of the armed forces to adopt a healthy lifestyle, such as programs to promote smoking cessation and to prevent and treat substance abuse. Efforts should be made to encourage the maintenance of physical fitness, as well as appropriate nutrition, rest, and mental health.

tings and in a variety of contexts, from extended combat situations to short-term humanitarian or peacekeeping assignments. An expanded research agenda is urgently needed to examine the effects of deployment in these different contexts on soldier health, to plan for services that can deliver appropriate care to manage the short- and long-term health

needs of those injured in action, and to design and develop appropriate interventions to minimize the burden of injury. The achievements and sacrifices of individual injured military personnel must never be overlooked, and we must continue searching for ways to restore their health and protect the health of all future deployed forces (Exhibit 12-5).

SUMMARY

Injuries are a preventable military health problem. Prevention strategies are best developed when the full spectrum of injury events (preevent, event, and postevent) is considered and when each element of the epidemiological triangle is considered (agent, host, environment, and vehicle). Using the Haddon matrix and Haddon's 10 strategies will help ensure that a comprehensive list of intervention alternatives is developed. Although medical officers are in a unique position to prevent injury on an individual,

case-by-case basis through the provision of care and education of patients, and through the training of clinic personnel, they may have even greater influence on injury prevention through their influence on those in command. Medical officers can accomplish this by acquiring knowledge of injury patterns, problems, and costs, and by applying common sense and the injury prevention principles outlined herein. Success depends on presentation of viable options at the appropriate command level.

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