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Surveillance, Research, and Prevention

Guest Editors

Bruce H. Jones, MD, MPH, and
Paul J. Amoroso, MD, MPH

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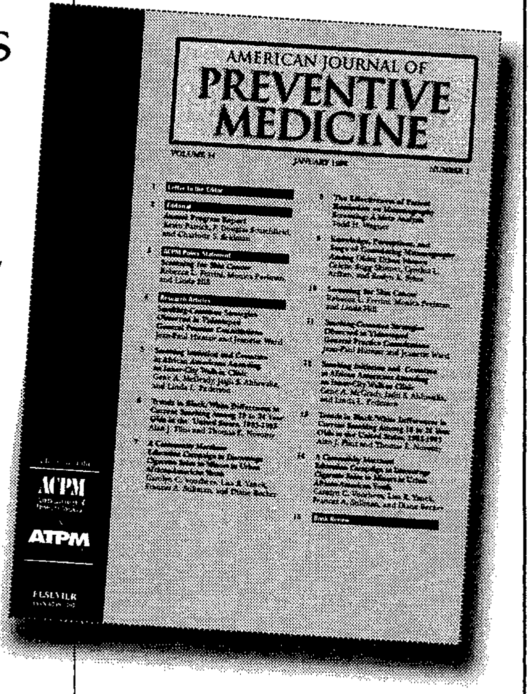

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This document contains a series of articles and commentaries as published in the American of Preventive Medicine, April 2000 (Volume 18, Issue 3S). The series begins with articles providing a general overview of deaths, disabilities, hospitalizations, and outpatient visits due to injury in the military. The series continues with original research on specific injury topics. Specific topics include motor vehicle injury/hospitalization risk factors, smoking and injury risk, occupational and sports issues concerning the use of military cause-of-injury coding. The document represents the culmination of years of collaborative work by subject matter experts in the field of injury prevention, including the military research and preventive medicine communities in all Services, members of the Armed Forces Epidemiology Board, and civilian experts.

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This journal supplement, *Injuries in the United States Armed Forces: Surveillance, Research, and Prevention,* gives tribute to the vision and expertise of many individuals and organizations. The guest editors, Dr. Bruce H. Jones and LTC Paul J. Amoroso, wish to thank the authors, commentators, and reviewers for their invaluable contributions.

The guest editors also extend their deep appreciation to Dr. Lewis H. Kuller, Past President of the Armed Forces Epidemiological Board (AFEB), and the AFEB members (1995) for their enduring interest in the problem of injuries in the military and their strong encouragement and support to have the AFEB report on injuries published.

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An endeavor of this magnitude requires dedication and teamwork. As the guest editors, we are grateful to all those who made this publication possible. Thank you.

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About the Guest Editors:

Dr. Bruce Jones currently heads the motor vehicle injury prevention program at the National Center for Injury Prevention and Control at the Centers for Disease Control and Prevention in Atlanta, Georgia. LTC Paul Amoroso conducts injury research at the U.S. Army Research Institute of Environmental Medicine in Natick, Massachusetts. Dr. Jones and LTC Amoroso have worked closely together on injury research and program development for 10 years. Dr. Jones is the former chairman of the Department of Defense Injury Surveillance and Prevention Work Group that LTC Amoroso now chairs.

Military Injuries and Public Health

An Introduction

David A. Sleet, PhD, FAAHB, Bruce H. Jones, MD, MPH, Paul J. Amoroso, MD, MPH

The series of papers reported in this issue of the *American Journal of Preventive Medicine* is a landmark for the field of injury prevention and control. The articles in this report provide a detailed picture of the biggest health threat confronting the U.S. Armed Forces. For the first time, military data on injuries and their magnitude, severity, and causes are carefully described and, where appropriate, are linked with potential prevention strategies. In his commentary, General Peake[1] speculates on why it has taken so long to focus on injuries in the military, given the historical advances of the military in fighting infectious and communicable diseases. These papers show why attention should be directed now to injuries. The papers also document how military health and readiness depend on an intensive effort to control injuries, in a way similar to the need for control of infectious and communicable diseases in the past.

The Centers for Disease Control and Prevention (CDC), the nation's prevention agency, has been in the forefront of disease control for over 50 years. The CDC grew out of the activity for Malaria Control in War Areas (MCWA) in the 1940s. The mission of the MCWA was to protect U.S. Armed Forces and civilians from malaria in World War II.[2] Since then, the CDC has expanded its focus to include infectious disease, occupational and environmental health, injury, and other threats to human health at home and around the world. More recently, the current director of the CDC, Dr. Jeffrey Koplan, took part in The Army Surgeon General's workshop on training-related injuries in 1985. The National Center for Injury Prevention and Control (NCIPC), one of the newest center at the CDC,[3] would welcome the opportunity to continue such collaborations and to contribute to a solution to this newly recognized epidemic of injury in the military, just as it has worked to prevent the problem in civilian communities.

The NCIPC has conceptualized how a public health approach to disease prevention can be used to prevent injuries.[4] This process includes defining the problem with surveillance data, identifying risk and protective factors through research, designing and implementing intervention strategies, disseminating the information, and evaluating program effectiveness. Scientific evidence must be collected and applied at every step and used for effective decision making.

As this series of articles shows, military populations are little different from civilian communities when it comes to identifying a public health problem and intervening with effective solutions. Because of the sheer numbers of men and women on active duty in the military, their standardized training regimes, and uniform access to preventive services, medical care, and rehabilitation services, studying injuries in the military can provide a unique opportunity for new understanding of injury causes and consequences that is not readily available in the civilian world.

To be successful using public health and preventive medicine, we must draw from the expertise within the military and from public health. As with the control of infectious disease, injury prevention practitioners and injury epidemiologists can work side by side with military medicine to explore ways to strengthen data capabilities, identify risk factors, apply and test interventions, and conduct evaluations of promising injury-prevention strategies to our mutual benefit. As Dr. Rosenberg[5] suggests in his commentary in this supplement, collaboration between civilian public health and research organizations and the military services may assist efforts to prevent not only unintentional injuries in the military and civilian communities, but also intentional injuries. The recent stunning success of the U.S. Air Force in preventing suicides provides such an example.[6]

We have learned that there are no single or easy solutions to injury prevention. It requires complementary strategies targeting multiple populations in various settings. It will require new partnerships among the military, other branches of the federal and state governments, businesses, schools, law enforcement, judges, and community agencies that serve military personnel and their families, and even churches. Injury preven-

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From the Centers for Disease Control and Prevention, National Center for Injury Prevention and Control (Sleet, Jones), Atlanta, Georgia; and U.S. Army Research Institute of Environmental Medicine (Amoroso), Natick, Massachusetts

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tion needs to take place on and off the base, in training, during active duty and leisure, with military families, in schools and communities, during deployment, and in the theater of combat. An injury to a soldier, whether obtained in training, at home, or on the highway, reduces combat readiness and compromises national military strength. In contrast to illnesses, injuries frequently put a soldier, sailor, or airman out of duty for longer periods and require longer rehabilitation times.

We think this set of articles is an important first step in taking an empirically-based public health approach to identifying the causes and consequences of injuries, and suggesting effective interventions to reduce injuries in the military.

Background

The articles in this series should be of interest to public health, preventive medicine, sports medicine, injury control, and military readers. They grew out of a collaboration between civilian and military researchers, military preventive medicine specialists and public health practitioners. The supplement evolved from a report from an injury prevention and control work group formed by the Armed Forces Epidemiological Board (AFEB) at the request of The Army Surgeon General's Office in 1994.

Contents

The series of articles is organized in two parts. The first describes the AFEB Injury Prevention and Control Work Group and the military databases and data sources of value for injury surveillance and research. These include data on deaths, disabilities, hospitalizations, training-related injuries, and military deployment-related injury data (e.g., Gulf War, Somalia, Haiti). The first part ends with a summary article reviewing the databases in the context of the five-step public health approach to injury prevention and control.[7]

The second part illustrates the types of research that can be conducted using military data, with original research examples from collaborative efforts between civilian university-based epidemiologists and military preventive medicine researchers. Topics used to illustrate the richness of military databases for research and surveillance include motor vehicle injury/hospitalization risk factors, smoking and injury risks, occupational and sports injuries, training/exercise-related injuries, and injuries among women. For those interested in methodologic issues and discussions of data quality, the last two papers discuss these issues using hospitalization data and the military (NATO) external cause-of-injury coding system.

Significance

These papers are an important contribution to the growing literature in injury prevention, and can positively lead the growth of injury prevention and control activities in the military. They can (1) help define injury problems that are unique to military personnel, (2) assess current and future injury data and surveillance needs, (3) help the Department of Defense (DoD) and its partners clearly define research directions and set injury prevention priorities, (4) identify promising interventions to evaluate in military settings and among tri-service populations, and (5) plan for the development and delivery of injury prevention programs to affect the widest cross-section of military personnel and their families. Many federal agencies can play an important role in assisting in these efforts, including the Departments of Transportation, Justice, Labor, Veteran Affairs, Education, and Health and Human Services (CDC, NIH, and others).

For civilians, preventive medicine specialists, and those in community public health, the information presented here is important for several reasons:

- The articles describe for the first time the epidemiology of injury in military populations. These are useful for prevention planning and as baseline data for comparative purposes.
- The articles enumerate the strength of military injury data and the importance of accurate and consistent injury surveillance systems. Surveillance of fatal and nonfatal injuries in the military can provide important clues for conducting surveillance of civilian injuries and for improving nonfatal hospitalization and emergency care data systems.
- The articles describe creative interventions and the potential role that health promotion and preventive medicine can play in maintaining force readiness through injury prevention and control.
- The articles describe various methods for analyzing injury data and underscore the importance of using science as a basis for applying injury-control strategies.
- The articles suggest how nonmilitary agencies and community injury prevention and health promotion professionals can team up with military medicine to begin collaborative efforts.
- Finally, the articles are a testament to the value of the AFEB and its Injury Prevention and Control Work Group, who reviewed data on injuries and made recommendations on injury surveillance, prevention, and control to the AFEB, which quickly became the foundation for recommendations to the surgeons general of various branches of the U.S. Armed Forces. This may well be an important model that can be emulated in communities and states to bring about widespread changes in how we view and respond to injuries as a public health problem.

Although the conclusions and recommendations emanating from these papers are those of the individual authors, they also speak more broadly to what is needed to improve our efforts to prevent and control injuries in both military and civilian populations.

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Reflections on Injuries in the Military

The Hidden Epidemic

MAJ GEN James B. Peake, U.S. Army

Projecting a healthy and medically protected force is one of the three fundamental accountabilities for which the Army leadership turns to the Army Medical Department. Preventive medicine has historically been a hallmark of Army medicine with medical officers associated with epidemic disease brought under control. Examples are officers like Walter Reed and yellow fever control in Panama; Alf Alving and malaria prophylaxis in Korea; and, more recently, Colonels Bill Bancroft and Bruce Innis and hepatitis A vaccine development.

High disease rates, which once stopped entire armies in their tracks, have been replaced by disease and nonbattle injury rates that ranged from 152/1000 soldiers/year in Operations Desert Shield and Storm (the Persian Gulf War) to 64/1000 in Bosnia. These must be compared to 669/1000 in World War II or 774/1000 in the Korean conflict.[1] This improvement is due to better general health of the soldier, immunization programs, appropriate chemo-prophylaxis, and, importantly, the command emphasis given to hygiene and to other prophylactic personal and public health measures.

It is ironic that the epidemic of injury has taken so long to become a front burner issue. Perhaps that is related to our large standing Army of the cold war era, the draft during the decade of the Vietnam conflict, and the major downsizing of the last decade. All contributed to a mindset that considered focusing on injuries to be expendable. Now, however, in our smaller Army of 480,000 men and women, an Army with an operational tempo that is up 300% from the cold war era, and with a recruiting shortfall of 6,000 last year, each and every soldier must count. We certainly cannot afford an Army plagued with injury. These series of articles finally provides a scientific basis to pursue the hidden epidemic of injury with the same scientific vigor and with the same line command involvement that it took to defeat yellow fever. It is the same rigor and command attention that it will take to effect the changes to minimize lost duty time and lost careers of service due to injury.

Many factors interact to cause injuries among soldiers.[2,3] Low levels of fitness beget injury. We see elevated rates of injury related to female gender, heavier body weight, prior history of injury, and tobacco use. These are things our sergeants could tell us, but they have not been sufficiently educated or empowered to effect change. Just as there are many injury risk factors, there are also many stakeholders inside and outside the military. Within the military the stakeholders are: those who set policies that determine time to train, levels of activity, and rate of physical training progression; the medical personnel who assess the initial injury; the safety community; and the trainers who promulgate the training doctrine. High school and junior high schools whose physical education program managers and antismoking campaigns touch our young people before they come to the military are stakeholders outside the military. All must come together to ensure that research, resources, and policy are consonant with the objectives of a fit and healthy force.

The papers in this supplement do not give us all the answers, but they start to frame the questions. We must identify and understand the processes that lead to injury. We must attack vigorously the points in the process that we can influence. Vehicle safety, seat belts, and antidrinking and driving programs have measurable impact on the deaths and disabilities due to injury. A more basic approach is required to recognize the categories of soldiers with variable vulnerabilities to biomechanical injury from repetitive trauma, for example, and to guarantee the policies that dictate their activities produce in each category the highest yield of fit and healthy soldiers at the end of the process. This is not to understate the scientific challenge in identifying and modifying the causal factors. For instance, which causal factors account for the significant increase in stress reaction/fractures in women in basic combat training? The road march (weight carried or miles marched)? Shoes? Bone density of women versus men? Timing of road march to running? The combination of all of these factors? Which intervention or combination of interventions makes a clinically significant difference in injury? Answers to these questions can only come from accurate data collection and large population trials with active command sponsorship.

Evidence is presented here that prior injury is a significant predictor of future injury. Do we know the

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additional attrition of soldiers with basic combat training acquired stress reaction/fracture once they move on to the advanced individual training environment? The cost of prevention measures may be more clearly balanced as the extended consequent costs of the injury are realized. We need the answers to these questions. The Army soldier will never function in a risk-free environment, but in the training arena reduction of that risk is, first, our obligation and, second, can contribute measurably to our overall ability to accomplish the mission. People aren't in the Army, people *are* the Army (Gen. Creighton Abrams)!

The power of this two-part series of information and analysis is that it assembles, in one place, compelling evidence of a problem of such magnitude that it dare not be ignored. It is a problem that still begs for even better and more refined data, but it is a problem that can be scientifically attacked. The evidence collected here must compel the attention and action of the scientific community, the Army, and the Department of Defense leadership.

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There's Safety in Numbers

Mark L. Rosenberg, MD, MPP

The articles in this series and the unique report, *Injuries in the Military: A Hidden Epidemic*[1] that generated them, not only make the problem of injuries visible but give it dimension for an entire population, the U.S. military. Part I of this series of articles illustrates the value of data in determining the existence of a public health problem and defining its magnitude, the first step of the public health approach to prevention.[2,3] Part II shows how research can further identify populations at risk and modifiable causes and risk factors for the problem, which are necessary for prevention, the second step of the approach. The articles demonstrate some of the great successes of the military services in preventing injuries, the third and fourth steps of the public health approach. The series also provides clear direction for improving surveillance, research, and prevention activities that should be of interest not just to military commanders, policymakers, and service members, but to all of us who are interested in preventing injuries.

Various articles in this series highlight not only some of the differences between military and civilian populations but also commonalities. Off-duty military personnel do the same things that lead to injuries as other young Americans. They drive cars, ride motorcycles, play football and basketball, and do household chores and maintenance. On duty, many have jobs similar to civilian workers—jobs such as truck drivers, clerks, physicians, nurses, and wheeled-vehicle mechanics. The underlying causes and risk factors for most injuries must be the same for military personnel and civilians; so as this series of articles illustrates, much can be learned from the rich data sources and research of the military services.

What the first sequence of articles does that is unusual is to provide a context for seeing how truly large the problem of injuries is for the military services measured against other causes of morbidity and mortality. It has been recognized for some time that injuries occur frequently among military personnel, but most commonly past reports have looked at a single data source to define the problem (e.g., fatalities, hospitalizations, or outpatient visits). Frequently, such reports examine only injuries, and therefore do not convey an appreciation of the relative size of the injury problem compared to diseases or health conditions. Part I of the series systematically examines the importance of injuries across the spectrum of health starting with the most serious injuries, those resulting in deaths.[4] Then it successively looks at the less serious but more common injuries resulting in disabilities,[5] hospitalization,[6] and outpatient treatment.[7] Each sequential piece of the puzzle shows that for this young military population, injuries are the most important health problem relative to others.[3] What emerges when all the pieces are fit together at the end of the first sequence of articles is a picture of an injury problem that is much bigger than previously realized from examination of single data sources, such as deaths.

In addition to revealing the true size of the problem of injuries for the military, Part I of this series also shows that, as with other young populations, much of the injury problem for the military stems from motor vehicle crashes, falls, and sports. Interestingly, these were the leading causes of morbidity and mortality for the Army in the Persian Gulf War (Operation Desert Shield/Desert Storm) and other deployments in the 1990s.[3,8] The civilian experts who made up the work group that produced the first series of articles evaluated each database not only to determine the important causes of injuries in the military, but more importantly, to determine how the available information sources could best be utilized for injury prevention in the future. The major recommendations from the panel of experts were (1) that a comprehensive military medical surveillance system be established, and (2) that the data from that system be used to prioritize prevention and research activities.[1]

The research articles in Part II of this series should be of equal interest to those concerned with preventing injuries in military and civilian populations. Papers in the second series investigate causes, risk factors, and populations at risk with general relevance to public health and safety. Some of the topics explored include:

- The association of seat belt use, alcohol use, and age on the likelihood of hospitalization.[9]
- The association of smoking cigarettes with higher risks of training-related injuries in Army trainees.[10]
- The risks of disabling occupational knee injuries among different demographic groups[11] and the early impact of prior knee injuries on disability and discharge from the military.[12]

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- Hospitalizations resulting from sports participation and physical training (i.e., exercise).[13]
- The relative importance of injuries as a cause of morbidity among Air Force recruits.[14]
- The primary importance of low levels of physical fitness as a risk factor for injuries associated with vigorous physical training among both female and male Army trainees.[15]
- The effect of prolonged rest on the risks of stress fractures and other training injuries among male trainees.[16]
- The increased risk of future injury imposed by past injuries among airborne soldiers.[17]

Military research has tested and shown a number of strategies that actually work to prevent injuries. Navy research on Marine recruits has demonstrated that reducing the amount of running and gradually increasing weight-bearing training significantly reduce injuries while maintaining desired physical fitness levels.[7] Another intervention, an "off-the-shelf," outside-the-boot ankle brace, reduced the incidence of parachute-related ankle sprains during airborne training by 85%.[7]

Furthermore, as with civilian prevention efforts, great success has been achieved by military programs, such as aviation and motor vehicle safety, that have received emphasis from leadership and for which good surveillance data have been available to monitor and evaluate outcomes.[3] The drastic reductions in aviation fatalities for the military services shows what can be accomplished when desire and tracking capabilities focus on the prevention of a specific cause of injuries. Reductions in motor vehicle crash–related deaths and hospitalizations in service members provide another illustration of the type of success that can be expected when energies are concentrated on the prevention of an injury problem.

Relevance to civilian prevention efforts can be seen in virtually all of the papers in this supplement. Even the two of the series of articles in Part II that explore methodologic issues are relevant to military and civilian scientists and public health officials interested in using the rich health databases available from the Armed Services.[18,19] The examples of research provided in the second series of articles indicate their great potential for application to prevention that should be of interest to the military and civilian communities alike. Furthermore, if prevention programs are evaluated as information from military surveillance and research are applied, then important public health approaches and concepts can be validated. While the articles in this supplement deal largely with unintentional injuries, the data showing low rates of homicide deaths in the military services suggest that a great deal of value relevant to the prevention of violence might be learned from military populations and research as well.

An aspect of this series of articles that should not be overlooked is the lesson it conveys about the power of scientific information to shape policy and influence the public health agenda.[1] Shortly after the report, *Injuries in the Military: A Hidden Epidemic*, was forwarded by the Armed Forces Epidemiological Board to the Assistant Secretary of Defense for Health Affairs, the first recommendations were implemented. A comprehensive medical surveillance system integrating tri-service data on deaths, hospitalizations, and outpatient visits with population data was implemented. More recently, injuries have been recognized as one of the top three prevention priorities of the Department of Defense and an advisory committee chartered. It will be interesting to observe how the military services use their rich health information resources to prioritize and prevent the problem of injuries. There is safety in these numbers. There may be lessons there for all of us.

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The Use of Existing Military Administrative and Health Databases for Injury Surveillance and Research

Andrew E. Lincoln, MS, ScD, Gordon S. Smith, MB, ChB, MPH, Susan P. Baker, MPH

Introduction

This issue of the *American Journal of Preventive Medicine* presents a comprehensive look at the major health problem of the nation's military population—injuries. Injuries are an important health concern both in the United States and globally.[1,2] The 1.5 million members of the services, predominantly young adults, are subject to many of the same hazards that cause injuries to the civilian population in the course of work, travel, and recreation, and are of special pertinence to the study of occupational injuries. The military comprises many occupational specialties that are similar to civilian workforce specialties such as maintenance, transportation, clerical, medical, and others. This issue is particularly timely as the nation seeks to implement the recently developed National Occupational Research Agenda (NORA).[3]

The NORA Trauma Injury Team Report sought to identify priority areas for investigation, recognize deficiencies in data quality and the methodologies that enable injuries to be prevented, implement efforts and models to permit researchers to address problems, and increase the utility of occupational injury research.[4] As the mechanism to identify worker groups with high frequency and risk of injury, surveillance is considered to be the driving force of research and prevention efforts. Without proper attention to surveillance, priority areas based on the magnitude of the problem, risk of injury, and amenability to prevention will go unserved; limited research resources will be directed according to political considerations rather than informed strategy; and the ability to evaluate these efforts will be lost.

Population-based administrative databases useful for epidemiologic and outcome studies have typically included national surveys, federal health care programs, large insurance programs or health care delivery systems, statewide hospital discharge databases, and workers' compensation databases.[4,5] However, some of the richest sources of data, those of the Armed Services, have until recently been left untouched.

The publication of the *Atlas of Injuries in the U.S. Armed Forces* by the Department of Defense (DoD) Injury Surveillance and Prevention Work Group[6] is an important first step in recognizing the importance of injuries to the Armed Forces. This report and an earlier report to the Armed Forces Epidemiological Board (AFEB)[7] clearly identify the value of medical surveillance databases in the military. The creation of a relational database with the ability to link personnel records of the total active duty Army population with various outcome measures (e.g., hospitalization, lost-time injury, physical disability, fatality)[8] is an example of how more effective use can be made of available data for injury prevention. The number of articles in this supplement that use this database demonstrates the utility of these efforts. The more recent availability of online DoD-wide medical surveillance data for both inpatients and outpatients[9] represents another major step forward in the maturation of the field of occupational injury epidemiology and coincides with the presentation of needs for effective research. This commentary describes how many of the research needs pertaining to surveillance systems have already been addressed by existing military administrative databases and suggests that these sources be better used to systematically investigate and devise prevention strategies for important occupational hazards.

Injury Research Objectives Addressed by Military Data

Surveillance is "the ongoing collection, analysis, and interpretation of health data in the process of describing and monitoring a health [injury] event."[10] For the military as well as the civilian population, mortality data have been the most utilized because of their importance and availability. Injuries accounted for 81% of all deaths in the military during FY 1996.[11] Casualty data for all branches are available from the Directorate for Information Operations and Reports (DIOR) based on DoD Form 1300. Additional information on deaths can

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Table 1. Military injury mortality by intent and service, FY 1980 and FY 1996

	Deaths per 100,000		
Intent and service	**FY 1980**	**FY 1996**	**% change**
Unintentional			
Army	73.6	40.1	−46
Navy	90.5	29.5	−67
Air Force	57.7	21.6	−63
Marines	109.3	63.5	−42
Suicide			
Army	11.1	15.1	+36
Navy	11.6	10.1	−13[a]
Air Force	10.9	14.7	+35
Marines	14.9	17.7	+19
Homicide			
Army	8.4	4.3	−49
Navy	8.2	5.0	−39
Air Force	3.9	2.8	−28
Marines	16.4	6.3	−62
Total			
Army	93.1	59.5	−36
Navy	110.3	44.6	−60
Air Force	72.5	39.1	−46
Marines	140.6	87.5	−38

[a] The Navy had the highest rate of deaths of undetermined intent (3.9/100,000 for the period 1990–1996), a category that typically includes possible suicides.

Source: DIOR 1997.[29]

FY, fiscal year.

be obtained from the hardcopy records in casualty offices of the various services. However, a major limitation of current official mortality data is that computerized DIOR records specify only five major cause groups: accidents, illness, self-inflicted (suicide), homicides, and hostile actions.[11] Data comparable to the civilian multiple-cause-of-death data coded on the death certificate is not available in military mortality data except those occurring in military hospitals. This is a major deficiency in otherwise good quality data available in the military.

Special studies such as that by Helmkamp[12,13] have been conducted and form the basis of the cause-specific data in the article in this issue by Powell et al.[11] However, these studies require laborious manual review of hardcopy casualty records. There is an urgent need to establish a DoD-wide mortality data system that collects, as a minimum, the same level of detail as that available for civilians. One example of how this could be done is the Air Force's Ranch Hand study that, since 1991, has been coding death certificate and autopsy data on all deaths of Air Force personnel.[14] Although this was set up to monitor deaths from Agent Orange, an important by-product of this work is that good data on injury deaths are now available.

Despite the lack of specificity, DIOR data can provide important surveillance data on trends. Injury rates from DIOR, classified by intent and service (see Table 1), reveal important differences among the services in the magnitude of the problem as well as in time trends. Overall injury death rates are highest for the Marines and lowest for the Air Force, with a twofold difference between these two services that may reflect their different missions, the hazards to which personnel are exposed, and differences in off-duty activities.

Between FY 1980 and FY 1996, the generally declining trends in injury death rates for the military have been far more dramatic than for young adult civilians. Especially noteworthy are decreases of about two thirds in unintentional death rates in the Navy and Air Force and in homicide rates in the Marines. However, the increases in suicide rates, especially in the Army and Air Force, have surpassed increases in the civilian world. The ability to identify such trends is an important value of good surveillance data. In fact, earlier dramatic increases in suicide mortality in the Air Force led to a large-scale effort to prevent suicides; a recent article demonstrated the effectiveness of these efforts.[15]

NORA implementation teams have identified specific capabilities required of health surveillance systems, and suggestions from their report[4] will be used to demonstrate the utility of using military data for injury surveillance, research, and prevention. We will use examples largely taken from the Total Army Injury Health Outcomes Database (TAIHOD) as representative of how research databases can be developed using administrative data.

Improve National-Level Surveillance of Nonfatal Injuries

With the inclusion of over 3 million hospitalization records of all Army active duty personnel between 1971 and 1999 across the nation and around the world, TAIHOD represents an opportunity to track morbidity trends over an extended length of time. Admissions include fatal as well as nonfatal injuries, and the quality of the data in terms of completeness and standardization is unusually high. The breadth of hospitalization data available (e.g., demographics, diagnoses and procedures, diagnosis related group [DRG] costs, injury type [IDC-9-CM codes] and military-specific cause [STANAG codes]),[16,17] and lost duty time (i.e., bed days) enables a range of investigations not often available to injury researchers. The TAIHOD integrates hospital, disability, outpatient, and other nonfatal injury data sources with Army personnel, while the Defense Medical Surveillance System (DMSS) integrates deaths, hospitalizations, and outpatient records with personnel data for all four services.

Collect Detailed Information on the Circumstances of Traumatic Occupational Injury

For events involving lost time from work, loss of life, or extensive property damage, the Army Safety Management Information System (ASMIS) provides detailed cause and activity data on 130,000 ground and aviation fatal and nonfatal injuries involving equipment, weapons systems, and vehicles for a 20-year period (1980–1999). Event-specific information includes descriptions of the activity (narrative), training relatedness, type and cause of injury, personal protective equipment used, drug use, environmental conditions, actions taken to eliminate the injury (narrative), and cost estimates.[6] However, more work is needed to determine the completeness of reporting by safety center data. Preliminary analyses by our group using medical surveillance data suggest considerable underreporting for some injuries. For instance, safety center data could be made more useful by routine linkage with medical surveillance data, and more extensive use of the rich text from this database—one of its particular strengths and a recent addition to the TAIHOD. In addition, more work needs to be done to develop qualitative and quantitative methods for analyzing free text from safety data as well as hospital and casualty sources. Preliminary investigation of the utility of free text from hospital records is described in this supplement.[17]

Use Exposure Data to Calculate Injury Risks Based on Actual Exposure Time or Exposure to Risk Factors

The Defense Manpower Data Center (DMDC) provides an historic archive of personnel files on all active duty military personnel and permits the calculation of midyear, end-of-year, and person-time denominators from 1971 to 1999. Of particular interest are variables on demographics, hazardous duty, occupation, departure from service, and Persian Gulf War deployment. These data can provide important means of examining injury rates for specific job tasks or military occupational specialties. One such effort is a study to examine hospitalized eye injuries by controlling for occupational exposure.[18]

Collect Information that Permits Linkage to Other Relevant Data Systems

Using encrypted social security numbers as case identifiers, TAIHOD data are already being used to link individual data from nine major data sources: personnel, hospitalization, outpatient, safety, disability, casualty (death), occupational toxin exposures, and health risk appraisal (HRA) (and its replacement, the Health Evaluation Assessment Review [HEAR]). In particular, the HRA/HEAR offers the opportunity to address behavioral aspects that are rarely available in injury epidemiology by including self-reported health habits (e.g., diet, exercise, tobacco and alcohol use, stress, risk-taking behavior). Use of the HRA is exemplified by two studies: self-reported risk-taking behaviors and risk of hospitalization for motor vehicle injuries[19] and the relationship between tobacco and suicide.[20]

Include Work-Relatedness, Occupation, and Industry

A major limitation of civilian hospital data is that it has no information on work-relatedness.[4] An important advantage of hospitalized injury coding in the military is that it uses NATO Standardization Agreement 2050 (STANAG) codes rather than ICD E-codes to describe injury cause.[16] The trauma code is part of this coding system and it describes the circumstances or duty status of the injury (e.g., battle, assault, training, off duty). An advantage of military data is that it includes all hospitalizations, regardless of whether or not they were associated with a job task or occurred while on duty, and whether or not the individual is hospitalized in a military hospital. This practice can provide invaluable data on the work-relatedness of an injury. However, at present, many injuries have unspecified duty status despite having sufficient data in the record to determine this.[17] Efforts should be made to improve the reporting of this variable in all military data, including its addition to the newly available outpatient data.[9] Similarly, it would be helpful to include the trauma code for hospitalized musculoskeletal disorders in order to investigate undetermined etiologies and exposures. Information regarding specific occupations, including task description and physical demands, are available for linkage as well and should add value to future studies.

Focus Surveillance Efforts on How to Capture Data as Health Care Changes

The recording of outpatient surgeries (length of stay = 0 days) in the hospitalization data has permitted the inclusion of many conditions that are available only for civilian data by ambulatory records. However, the increasing role of outpatient services and outside contracting of services requires additional surveillance measures to capture these data. In addition, by maintaining TAIHOD with recent updates so that they are never more than 6 months behind calendar time, research questions that investigate current trends in injury, disease, and health care can be addressed.[8] The expansion of the Defense Medical Epidemiology Database (DMED), an on-line service of the DMSS, to include outpatient data has greatly improved an already useful tool.[9]

Collaborate on Surveillance Efforts to Meet Multiple Needs and Decrease Per-Agency Costs

TAIHOD is a good example of adding value to already collected data as it uses only existing databases and, therefore, does not add the expense of developing a new data-collection mechanism. Instead, funding can be used to obtain, maintain, update, and query the data for specific research questions. Validation and subsequent feedback to the data-collection agencies can also be expected to result in improvements in data quality over time. Similar efforts will be needed as managed care and new health systems are developed to ensure that valuable medical surveillance data are not lost.

Application of Findings

The military represents a largely young, healthy, and active population relative to the general public. Therefore, when injury interventions are found to be effective in military personnel, the effectiveness should be equivalent to or even more dramatic in the general population. The military services offer a unique environment to investigate the effectiveness/efficiency of interventions because they are a "captive" population. By its nature, research involving military personnel permits more comprehensive evaluation than an equivalent civilian or occupational group because of the richness and completeness of health, demographic, and occupational data for every military population, as the first series of articles in this supplement shows. Examples of interventions that have been shown to be feasible among military personnel and hold promise for civilians include decreased amounts of exercise during basic training to reduce the risk of injury without an associated decrement in fitness[21] and over-the-boot braces to prevent ankle injuries during parachute landings.[22]

Another application of military surveillance data involved the use of hospitalization data to determine that women have a 3.9-fold greater risk of injury resulting in hospitalization than men, given the exposures associated with Army cadet basic training.[23] This information is used to focus prevention efforts on high-risk groups. Hospitalization data can also be used to demonstrate how injury patterns differ between men and women in the same sport. Although exposures to most sports differ greatly for men and women, the ability to look at all of the injuries incurred in a particular sport and ask the question, "Given a hospitalized injury in this sport, what is it likely to be?" reveals interesting gender differences. For example, analysis of 1989–1994 Army hospitalizations indicates that, of the injuries incurred in basketball and softball, women have a greater proportion of anterior cruciate ligament injuries (18% and 11%, respectively) than men (11% and 7%, respectively).[24] In physical training, a greater proportion of men's injuries are ankle sprains—11%, compared with 4% of women's injuries. Women engaged in parachuting appear to be at significantly greater risk of lower extremity injury than men.[25] These gender differences can provide insights into injury specifics that would be pertinent to civilians engaged in similar sports. In addition, Lauder et al.,[24] found that ankle fracture, an injury potentially preventable with breakaway bases, represents a major proportion of injuries for both men and women while playing softball.

Limitations

Some might argue that studies of military populations may be of limited generalizability to the civilian population. Demographic, occupational, environmental, and behavioral characteristics are likely to be distributed differently, but this is usually true of any occupational group.[5] In particular, differences in population ages, participation in hazardous tasks, activity level, and overall health status are likely to result in a different profile of injuries than might be expected for civilians. However, particularly in peacetime, many of the injuries occur in the same circumstances as those in civilians. In particular, one would expect leisure-time injuries to be similar. Information gained from the military is thus pertinent to civilians of similar ages and occupational exposures.

Direct comparability of overall injury rates to occupational groups in civilian populations is complicated by the fact that, in contrast to a company's data for job-related injuries of its workers, medical data in the military include all injuries from falls, assault, motor vehicles, whether job-related or not. Thus, crude injury rates are likely to be much higher than civilian work-related injury rates. Although members of the military are technically considered to be "on duty" except when on leave or away without leave, the STANAG trauma code was designed to designate an injury occurring during a work shift.[16] Injuries that occur while driving a private vehicle or playing basketball, for example, may be assigned a code indicating that duty status is unknown when, in fact, the status could have been determined by the activity or intent at the time of the incident.

Duty status, moreover, is not a separate variable in Army hospitalization data. It is combined with the "intent" of injury to produce a "trauma code" that includes codes for accidental injury (off duty, exercises, other scheduled training, on duty, and unknown whether on or off duty). However, the same variable includes codes for nonbattle assaults and self-inflicted injury without mention of whether on or off duty. Ideally, there should be separate codes for intent and duty status.

Data from the military safety centers are not representative of all injuries since cases chosen for investigation may underrepresent injuries that occur off base and overrepresent injuries that are serious and/or of special interest to the investigators. Fatalities are well reported, but nonfatal injuries are not. Moreover, since injuries are an undesirable occurrence, unit leaders—like civilian managers—may have a disincentive to report them. Validation studies of reporting and linkage with medical surveillance data should be a high priority for future work. Safety center data are useful, however, because of the availability of details on how the injury occurred. Data are very complete on deaths and serious injuries. Researchers can capitalize on this detailed information through the use of case–control studies or other designs that do not require information on all injured personnel or those that link to other data sources.

Recommendations

In their landmark 1996 report to the AFEB, *Injuries in the Military: A Hidden Epidemic,* the authors make a number of recommendations.[7] One of the most important unmet needs identified is for an automated, DoD-wide outpatient data system with a minimum data set that includes age, race/ethnicity, gender, diagnosis, cause, and circumstances of injury. This has been accomplished in part by the recent addition of outpatient data to DMSS and DMED. However, no data on outpatient injury causes and circumstances are currently available. Cause-of-injury codes should be included in all hospitalization records, including admissions classified within the ICD subgroup of musculoskeletal conditions, none of which presently receive cause codes unless there is an acute injury diagnosis in a secondary field. Data on at-work injuries should be included in this and be a required data field such that, if the trauma code indicates unknown duty status, follow-back inquiries are made. A major strength of the military information system is that it provides for information on injuries both on and off the job, all of which have a major impact on cost, lost readiness for deployment, and pain and suffering. We also recommend that these rich military data sources be used to better understand and prevent injury problems shared with the civilian community, for example, motor vehicle–related injuries and sports and exercise-related injuries, among others.

Given the burden that injuries place on the military, there is a need to develop a concerted DoD-wide initiative to address the problem of injuries. Many of the injury problems are not unique to the military. Even in recent combat deployments, unintentional injuries accounted for 81% of the deaths and 25% of hospital admissions.[26] Much can be learned from the experience of injury prevention in civilian populations. The establishment of Centers of Excellence in Injury Prevention and Control, including a central focus at the Centers for Disease Control and Prevention, has been the major reason that injury prevention science has progressed so rapidly in the civilian world in the United States.[27,28] Active collaboration between military and civilian researchers would benefit military and civilian populations. The success of this program has been emulated in several other countries. We recommend that similar dedicated injury programs be developed to study and prevent injuries in the military. Only through the establishment of a central multiservice effort can the best uses be made of available resources. Such efforts are needed to ensure that we will have a fit and healthy defense force in the future.

If the means by which the dramatic decreases in unintentional injury deaths among military personnel were better documented, not only would the military benefit more, but the civilian community would benefit as well. The process and effectiveness of strategies to prevent not just deaths but nonfatal injuries must be systematically and scientifically documented to achieve optimal benefit.

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An Armed Forces Epidemiological Board Evaluation of Injuries in the Military

Bruce H. Jones, MD, MPH, Barbara C. Hansen, PhD

Introduction

In the early 1990s, there was a growing awareness that injuries were becoming a major cause of morbidity and mortality in the military services. In January 1994, the Armed Forces Epidemiological Board (AFEB) formed the Injury Prevention and Control Work Group in response to a request from the Office of The Army Surgeon General for guidance and recommendations on surveillance, prevention, and control of injuries in military populations. The board selected a panel of civilian physicians, epidemiologists, and other scientists to:

- Gather information on injuries in the military.
- Make recommendations for future surveillance and prevention based on the data reviewed.
- Issue a report of its findings.

Active duty military liaison members were also selected to assist the civilian scientists in the work group. Production of the injury report required team work, not only between the civilian panel members and military liaisons, but also among the military services and the Department of Defense (DoD) Injury Surveillance and Prevention Work Group.

The AFEB Injury Prevention and Control Work Group presented its preliminary report to the board in October 1995. Subsequently, the board reviewed the report and added its own conclusions and recommendations. In November 1996, the AFEB published the work group's final report, *Injuries in the Military: A Hidden Epidemic*,[1] which was sent to the Assistant Secretary of Defense (ASD) for Health Affairs. In January 1997, the ASD for Health Affairs sent the report to The Surgeons General of the three military medical departments for implementation.

This article summarizes the process and methods used to generate the AFEB report[1] and five articles in this supplement.[2–6] It describes the following:

- The mission and membership of the AFEB and the Injury Prevention and Control Work Group.
- Goals and objectives of the work group.
- The process and methods used to gather and assess data on injuries in the military.
- Key conclusions and recommendations of the work group.
- DoD's progress toward implementing the recommendations since completion of the AFEB report.

Historical Overview

The Armed Forces Epidemiological Board

Before discussing the Injury Prevention and Control Work Group established by the AFEB, a brief history of the board itself will clarify its mission.[7] The AFEB is a civilian advisory group to the ASD for Health Affairs and The Surgeons General of the Army, Navy, and Air Force. At their request, the board evaluates public health and preventive medicine problems and provides recommendations for the prevention and control of diseases and injuries. The board is composed of 20 to 25 civilian physicians, epidemiologists, public health officials, and other scientists. The AFEB, formed in 1953, was an outgrowth of the Army Board for the Investigation of Influenza and Other Epidemic Diseases. Since its inception, the AFEB has been most recognized for its work on infectious diseases. However, the AFEB has demonstrated a history of interest in injuries going back to its first years in the 1950s when one of its commissions produced a report on accidental trauma in the Armed Services.[8]

When it was first established, the board consisted of 12 commissions or subgroups, one of which focused on accidental trauma.[7] In the early 1990s, however, there was only one multidisciplinary board with relatively little expertise in injury epidemiology and prevention. When the board decided to undertake The Army Surgeon General's January 1994 request to provide guidance on surveillance and prevention of injuries, it had to form a work group specially selected to address the issue. In February 1994, the board requested and received briefings on injuries from representatives of each military medical department. One month later,

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the AFEB commissioned the formation of a special work group to evaluate the problem of injuries.

The Injury Prevention and Control Work Group

The work group, selected by the AFEB, consisted of 11 civilian experts and 6 military liaison members (see Appendix 1 for the professions and affiliations of work group members). Most of the civilian work group members had backgrounds in injury epidemiology, medicine, or both. The military liaisons came primarily from research or preventive medicine backgrounds. Two AFEB board members participated on the injury work group. The work group was co-chaired by the authors, a civilian scientist, and an Army medical corps officer.

The work group's mission was to review data on injuries and make objective recommendations to the AFEB for injury surveillance, prevention, and control. The work group's recommendations were the foundation for the AFEB's recommendations to the ASD for Health Affairs and the military services' Surgeons General.

The AFEB work group is greatly indebted to the DoD Injury Surveillance and Prevention Work Group, chartered under the auspices of the Assistant Deputy Undersecretary of Defense for Safety and Occupational Health. Unlike the AFEB work group, the DoD work group was composed of all DoD personnel. Most members were either DoD civilian safety experts or military medical officers (see Appendix 2 for the professions and affiliations of the DoD work group members). The DoD work group provided the AFEB work group with comprehensive data on deaths, disabilities, and hospitalizations from administrative databases maintained by each service. All data were acquired from the primary source in each branch of the military services.

Goal and Objectives

The primary goal of the work group was to produce a written report summarizing the data they reviewed and provide conclusions and recommendations derived from that review. The work group's main objectives were to:

- Determine the magnitude of the injury problem across the military services.
- Identify sources of information, causes, risk factors, and prevention strategies for injuries.
- Assess the value of existing medical databases for surveillance and prevention.
- Make recommendations for database enhancement and use.
- Make recommendations for research and prevention.

Process and Methods

The work group met three times to accomplish its objectives. Agendas for these meetings are in Appendix 3.

First Meeting

In December 1994, the work group conducted strategic planning and outlined its goals and objectives. Members of the work group also conducted a preliminary review of injury data and established the format for data presentation, both oral and written, at the group meetings. At the first and subsequent meetings, the work group received data largely from two sources: (1) information from administrative data sources (e.g., medical records, disability evaluations, personnel records) maintained for reasons other than medical surveillance, and (2) research conducted specifically to address the problem of injuries.

Second Meeting

In February 1995, the AFEB work group examined data from the databases reviewed at the first meeting. These databases included:

- Deaths from the casualty offices in the military personnel departments of each branch.
- Disabilities from the physical disability agencies, again housed in each branch's military personnel departments.
- Hospital admissions from the military medical departments.
- Outpatient records from the military medical departments.
- Special research databases from the Army and Navy research commands.
- Accident reports from the U.S. Army Safety Center.

In addition to reviewing administrative databases with surveillance potential, the work group also received briefings on research by the Army and the Navy into the causes and risk factors for military training-related injuries.

The group also refined its goals and objectives during this meeting. They decided to focus on the databases that depend on medical input (i.e., deaths and disabilities) and those databases maintained by the military medical departments (i.e., hospitalizations and outpatient care) that the medical departments can most influence. At the second meeting, the group also decided to restrict its detailed evaluations to active duty military personnel for two key reasons. First, the primary mission of the military medical departments is to sustain the health and combat readiness of U.S. fighting forces. Second, the most complete and best quality medical, population, and demographic data exist for active duty service members. The AFEB work group elected to review data from five primary sources: casualty offices, disability agencies, hospital inpatient records systems, medical research studies of outpatient visits, and deployment/combat surveillance records. Three or four work group members were assigned to

Table 1. Five steps of the public health approach to injury prevention and control

1. Determine the existence and size of the problem.
2. Identify causes of the problem.
3. Determine what strategies and interventions work to prevent the problem.
4. Implement prevention strategies and programs.
5. Continue surveillance and monitor/evaluate effectiveness of prevention efforts.

Adapted from Robertson,[11] Mercy et al.,[9] and Jones and Knapik.[10]

review data and write chapters for the report for each of the primary data sources chosen for review. The work group assessed each data source under review for its ability to answer key questions associated with the five steps of the public health process of injury prevention and control[9–11] (see Table 1):

- From the perspective of each database, how big is the problem of injuries relative to other causes of morbidity or mortality?
- What are the most important types of injuries (e.g., internal derangements of the knee, fractures, sprains, etc.)?
- What are the most important causes of injuries (e.g., motor vehicle crashes, sports, falls, physical training, etc.)?
- What strategies work to prevent injuries as shown by credible research?
- What are the strengths and weaknesses of each database?
- What recommendations can be made to improve the database for surveillance, research, and prevention of injuries?

The questions asked were designed to obtain answers that would better define the roles and responsibilities of the military medical departments in the process of injury prevention (Table 1). The work group acknowledged that, while the medical community plays an important role in prevention, responsibility for the actual implementation of programs and prevention of injuries resides with other authorites such as unit commanders, worksite supervisors, DoD policymakers, and others.

Third Meeting

In July 1995, the work group was briefed on a concept for integrating the medical surveillance, research, and prevention program elements into a more effective whole. They also received presentations on the results of combat and deployment surveillance initiatives. A presentation on workers' compensation for civilian Air Force personnel was given to provide a context for better understanding the uniqueness of active duty military data. Conclusions and recommendations were developed and prioritized. Chapters of the report were developed to correspond to the primary databases, with sections addressing the questions listed above. Table 2 displays the outline of chapters for the report and the generic sections within each chapter.

Table 2. AFEB report outline

Report Contents	Section Contents Chapters 1–5
Introduction	Introduction
Chapter 1. Deaths Due to Injury	Magnitude of the Problem • Incidence/Frequency • Relative Morbidity
Chapter 2. Disabilities Due to Injury	Types of Injuries
Chapter 3. Hospitalizations Due to Injury	Causes of Injuries
Chapter 4. Military Training and Injuries Treated in Outpatient Clinics: A Research Perspective	Prevention of Injury Conclusions Recommendations • Surveillance
Chapter 5. Injury Casualties During Combat and Other Deployments	• Research • Prevention • Evaluation
Conclusions/Discussion	
Recommendations	

Key Conclusions and Recommendations

The data supporting the AFEB work group's conclusions and recommendations are given in their technical report[1] and in a series of articles found in this supplement.[2–6] Appendix 4 provides the overall conclusions and recommendations from the executive summary of the work group's report, followed by the more specific chapter-by-chapter recommendations. The most important conclusions of the work group were as follows:

- Injuries impose a greater ongoing negative impact on the health and readiness of U.S. Armed Forces than any other category of medical complaint during peacetime and combat.
- Training-related injuries treated on an outpatient basis cause a large amount of morbidity in military populations.
- Injury-related disabilities result in significant compensation costs.
- Databases reviewed are capable of identifying important types and causes of injuries.
- Valuable automated, linkable, military medical, and personnel databases already exist, but are not optimally used for medical or injury surveillance.

The work group made a variety of recommendations for improvements in surveillance, research, and prevention programs (Appendix 4). The most important recommendations are summarized below:

Table 3. Minimum basic dataset required for unintentional and intentional injuries

Unintentional injuries[12]	Intentional injuries[13]
Intent	Intent
Age of victim	Age of victim and perpetrator
Sex of victim	Sex of victim and perpetrator
Race of victim	Race of victim and perpetrator
Residence of victim	Time and date of injury event
Date of injury event	Type of injury/body location
Place of occurrence (home, work, school, etc.)	Place of occurrence (home, work, school, etc.)
Address of place of occurrence	Address of place of occurrence
Activity when injury occurred (work, education, sports, etc.)	Circumstances or motive surrounding injury event
Mechanism of accident/ event	Drugs or alcohol involved (yes/ no)
Type of injury/body location	Weapon(s) involved
Outcome measurements appropriate for source (days in hospital, cost of care, degree of disability, etc.)	Relationship of victim to perpetrator
	Outcome measurements appropriate for source (days in hospital, cost of care, degree of disability, etc.)
	Source of data

- Establish a comprehensive, military medical surveillance system by integrating medical outcomes, personnel files, and other databases.
- Use the existing surveillance capability to prioritize and target injury and disease prevention and research activities.
- Convene a meeting of key prevention partners, recognizing that medical and safety personnel play primarily a supporting role to military commanders, supervisors, and other decision makers.

In addition to the above, the work group made a number of recommendations for improving the completeness and quality of surveillance (Appendix 4) including:

- Standardize data collection and coding methods across services and databases.
- Acquire better data on causes of injuries.
- Provide better documentation concerning the "on" or "off" duty job/work status of those injured.
- Collect the minimum basic data set recommended by the International Collaborative Effort on Injury Statistics (Table 3).[12,13]

Impact

Significant progress has been made since November 1996 when the AFEB report was published.

- In January 1997, the ASD for Health Affairs forwarded the AFEB report to The Surgeons General of the military departments for implementation.
- The AFEB and the ASD for Health Affairs strongly endorsed the formation of a comprehensive military medical surveillance system. The process of building that system had already been launched prior to the work group formation, and became a reality in August 1997 when Health Affairs established the Defense Medical Surveillance System on the foundation built by the Army Medical Surveillance Activity.
- In June 1998, a workshop was convened by the Undersecretary of Defense for Personnel and Readiness to begin planning strategies for the prevention of the three top preventive medicine problems of the DoD: injuries, alcohol abuse, and tobacco use.
- In December 1998, the DoD Injury Surveillance and Prevention Work Group completed its final report for the Assistant Deputy Undersecretary of Defense for Safety and Occupational Health Policy. Their comprehensive report, *Atlas of Injuries in the U.S. Armed Forces*,[14] provided the military services with an extensive review of data from administrative databases on deaths, disabilities, hospitalizations, and outpatient visits. All data in the atlas were acquired from the primary sources in each branch of the military services.

Discussion

Recognition that injuries are the leading health problem of the military services represents the single greatest accomplishment of the AFEB work group. The first step of the injury and disease control process (see Table 1) is identification of public health problems.[9–11,15–18] The work group titled its report *Injuries in the Military: A Hidden Epidemic*, not so much because injuries were obscure, but because the magnitude of the problem was not fully appreciated before these investigations were complete. A comprehensive view of the impact of injuries across the entire spectrum of health—from injuries requiring only outpatient care to those resulting in deaths—was necessary to discern the true magnitude of the problem.

The next step of the prevention process is to target modifiable causes of injury for prevention or further research. To do this in a dependable, systematic, efficient, and prioritized manner, medical surveillance is required.[15–19] The work group's report added impetus to the development of a comprehensive medical surveillance system. The rapid progress made toward developing a comprehensive system may be attributed to a "paradigm shift" resulting from evolving concepts of military medical support and from technological advances in computer hardware and software. Factors contributing to an environment favorable to preventive medicine and surveillance include the end of the Cold

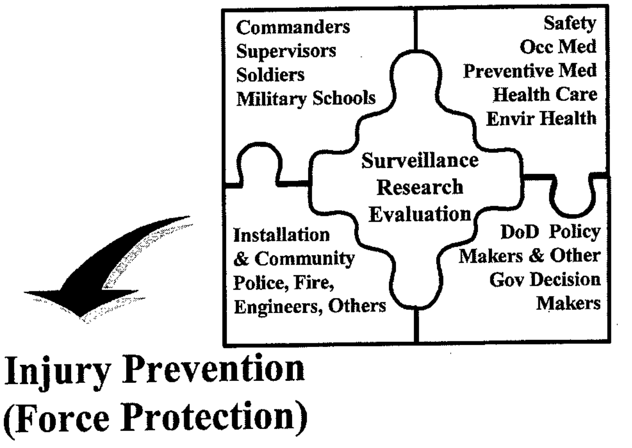

Figure 1. Key military injury prevention partners

War, concerns about Gulf War illnesses, and the availability of existing relevant databases.[20]

The future success of injury prevention will depend not only on medical surveillance, but also on providing surveillance and research data to those who can act to prevent injuries. Consistent with the civilian community's recognition that injury prevention requires the commitment of multiple partners,[21] Figure 1 identifies the military's key prevention partners. Recognition that medical and safety professionals play an important but primarily supportive role in the prevention of injuries is essential for program success. The services' safety centers already provide risk management training for commanders and service members. The steps of risk management—hazard identification, assessment, risk control, implementation, and evaluation—mirror the steps of the public health process of injury and disease control. Thus, military commanders and worksite supervisors are becoming familiar with the process to prevent injuries. Success preventing injuries will depend on the commitment of leaders; good quality data to focus prevention efforts; scientific knowledge of what works to prevent injuries; and sustained, selfless collaboration among line, safety, medical, and other organizations and individuals.

Summary

The AFEB work group accomplished several important objectives. Foremost, it documented the significant impact injuries have on the health and readiness of U.S. military personnel. The work group's efforts also illustrated the great value of medical databases for the surveillance and prevention of not only injuries but also diseases. Building a comprehensive military medical surveillance system will provide the foundation for future public health activities and the critical first step toward a systematic injury prevention process. Although the AFEB work group's injury report focused exclusively on injury problems in the military, the types of conclusions and recommendations they made for the prevention and control of injuries have significant application for the civilian community as well.

The opinions and assertions contained herein are the private views of the authors, and are not to be construed as official or reflective of the views of the Department of Defense (DoD).

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Appendix 1
Armed Forces Epidemiological Board Injury Prevention and Control Work Group[a]

The members listed below wrote and edited the report *Injuries in the U.S. Military: A Hidden Epidemic.*

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[a] Reprinted from the AFEB report, pp. vi–vii.

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Appendix 2
DoD Injury Surveillance and Prevention Work Group Members

Chair:

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LtCol Hank Woodcock, U.S. Air Force
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Army Safety Office
Office of the Chief of Staff

Appendix 3
AFEB Injury Surveillance and Prevention Work Group Agendas

—AGENDA FOR FIRST MEETING—

ARMED FORCES EPIDEMIOLOGICAL BOARD
INJURY PREVENTION AND CONTROL WORK GROUP
PREPARATORY SESSION

U.S. ARMY CENTER FOR HEALTH PROMOTION
AND PREVENTIVE MEDICINE
14 December 1994

LTC Bruce Jones, USA, MC, Chair

0830–0900	Introductions
0900–1030	Review of Military Injury Data Sources • Safety Centers • Casualties/Fatalities • Hospitalizations • Disabilities/Compensation • Outpatient Systems • Research • Department of Labor (Civilian Workers)
1030–1045	BREAK
1045–1200	Discussion of Work Group Goals and Objectives
1200–1330	LUNCH
1330–1515	Discussion of Strategies to Achieve Goals
1515–1600	Develop Summary List of Goals and Strategies
1600	ADJOURN

—AGENDA FOR SECOND MEETING—

ARMED FORCES EPIDEMIOLOGICAL BOARD
INJURY PREVENTION AND CONTROL WORK GROUP

HILL AIR FORCE BASE, OGDEN, UTAH
22 February 1995

LTC Bruce Jones, USA, MC, Chair

0830–0845	Introductions	
0845–0900	Administrative Issues	
0900–0915	Background on AFEB	Dr. Hansen
0915–1000	Brief Review of Military Injury Databases • Casualties/Death Records • Service Safety Centers/Agencies • Hospital Record Databases	LTC Jones • Disability Agencies • Outpatient Records • Research Databases
1000–1015	BREAK	
1015–1115	Musculoskeletal Injuries in Military Training Populations:	CAPT Brodine

	Surveillance and Risk Factor Analysis	LCDR Shaffer
1115–1200	Army Training-Related Injury Research	LTC Jones
1200–1315	LUNCH	
1315–1415	Discuss and List Potential Goals and Objectives	
1415–1445	Prioritize Goals and Objectives	
1445–1515	Develop Strategy and Time Line to Meet Goals	
1515–1530	BREAK	
1530–1630	Outline Goals and Strategy for Presentation to AFEB 24 February 1995	
1630	ADJOURN	

—AGENDA FOR THIRD MEETING—

ARMED FORCES EPIDEMIOLOGICAL BOARD
INJURY PREVENTION AND CONTROL WORK GROUP
GREAT LAKES NAVAL TRAINING STATION, CHICAGO, IL
5 July 1995

COL Bruce Jones, USA, MC, Chair

0930–0945	Convene Meeting/Introductions	
0945–1000	Administration and New Business	
1000–1030	Briefing on a Concept for an Integrated Army Injury Control Program	COL Jones
1030–1100	Outline of Injury Report Sections	
1100–1230	Briefings on Topics Relevant to Report	
	• Injuries to Civilian Air Force Personnel	LTC Zelnick
	• Nonbattle Injuries During Operations Desert Shield/Storm	Mr. Writer
	• Outpatient Surveillance During Combat and Deployments	LTC DeFraites
1230–1330	LUNCH	
1330–1400	Outline of Proposed Revisions to Injury Report	
1400–1530	Break into Small Groups (One Per Report Section) • List Conclusions and Recommendations for Each Section • Rename and Reorganize Sections	
1530–1630	Reconvene Large Group • Review Conclusions and Recommendations for Each Section • Revise Conclusions and Recommendations • Select Key Overall Conclusions and Recommendations • Construct Injury Pyramid for Each Military Service	
1630–1700	AFEB Progress Report Planning	
1700	ADJOURN	

Appendix 4
AFEB Work Group Conclusions and Recommendations

Section I. Key Conclusions from Executive Summary

- Injuries have greater impact on the health and readiness of U.S. Armed Forces than any other category of medical complaint during peacetime and combat.
- Disability compensation for injuries alone exceeds $750 million dollars per year.
- Training injuries treated on an outpatient basis may have the biggest impact on readiness.
- Back and knee injuries constitute a significant proportion of morbidity, disability, and limited duty in the services.
- Sports injuries, motor vehicle crashes, and falls are the leading causes of injury for the services.
- Valuable automated databases for medical and injury surveillance exist, but are not routinely analyzed for policy and prevention implications.
- In addition to improved use of surveillance, more research is needed to identify modifiable risk factors and mechanisms of injury, and to evaluate prevention strategies.

Section II. General Recommendations from the Executive Summary

A. Recommendations for Improvements in Surveillance of Injuries

- Establish automated, population-based, medical surveillance systems that will (1) link hospitalization, disability, and fatality data systems at the central medical surveillance site; (2) develop sentinel site outpatient surveillance systems (or other cost-effective surveillance until automated records are available servicewide); (3) continue refinement of surveillance strategies appropriate for combat and other deployments; and (4) routinely link medical surveillance data on injuries with safety center/agency data on causes of injury events.
- Collect at least the minimum data sets recommended by the International Collaborative Effort on Injury Statistics (1994).[12,13]
- Standardize collection, coding, and reporting on injuries across the services.
- Routinely assess the completeness and validity of surveillance data.
- Improve cause-of-injury data collection: (1) collect cause coding for musculoskeletal conditions (ICD-9 codes 716-736); and (2) collect a free text field for cause of injury in surveillance databases.
- Refine definitions and coding of work and nonwork-related injuries.
- Exchange injury data from medical surveillance systems with the service safety centers/agencies and other key prevention stakeholders.
- Convene tri-service workshop on injury surveillance and prevention including key DoD stakeholders (safety centers and others): (1) establish partnerships to facilitate tri-service collaboration and coordination; and (2) prioritize immediate and long-term surveillance, research, and prevention goals.

B. Recommendations for Injury Research

- Prioritize allocation of resources for research based on the magnitude and severity of morbidity, and the probable impact on readiness.
- Conduct research to identify modifiable risk factors and mechanisms of knee and back injuries.
- Develop and test strategies to reduce the incidence and severity of sports injuries.
- Determine risk factors for and circumstances of fall-related injuries.
- Expand resources for training-related injury research to include more than basic trainees/recruits, infantry, and Marines.
- Augment research on the relationships between military training, physical fitness, performance, and injuries.
- Assure adequate resources allocated for injury research.

C. Recommendations for Injury Prevention

- Prioritize resources for prevention programs based on the magnitude of morbidity and the impact on readiness.
- Target knee and back injuries for additional efforts toward prevention.
- Place greater emphasis on prevention of training, sports injuries, and falls.
- Implement program designed to enhance fitness and reduce training injury rates.
- Monitor prevention program effectiveness.

Section III. Summary Conclusions and Recommendations for Each Report Chapter

Chapter 1. Deaths Due to Injury

A. Conclusions

- Injuries today are the leading cause of death in all three services with "accidents" causing more than 50% of all deaths.
- Injury deaths have decreased steadily since 1980, especially accidental deaths.
- Deaths in the military do not have a big impact on readiness in terms of total numbers.
- The Marine Corps experiences the highest rates of injuries, which includes accidents, homicides, and suicides.
- The Air Force experiences the lowest injury rates.
- Overall injury rates are lower for women.
- Rates of homicide for women are higher than for men.

- Infrastructure exists for complete surveillance of deaths.
- For purposes of prevention, more detailed information is needed than is routinely reported on casualties, especially for non-accidents (i.e., intentional injuries).

B. Recommendations

- Collect and report more detailed, standardized data on deaths and death rates.
- Collect the same level of data for all deaths as done by the National Center for Health Statistics, and include at least the minimum basic data set recommended by the International Collaborative Effort on Injury Statistics.
- Collect a free-text field on circumstances and cause (90 characters).
- Examine the medical, safety, and casualty databases for demographics, causes, and so forth, with attention to completeness and complementarity.
- Determine the percentage of injury deaths captured in hospital databases.
- Explore other databases with relevant cause/circumstance data (possible sources may be the military police records, line of duty investigations, hospital records, Judge Advocate General records).
- Identify high-risk populations and target for prevention.
- Devote more resources to prevention of violent injuries and nonfatal injuries.
- Evaluate and validate the accuracy and completeness of current databases.

Chapter 2. Disabilities Due to Injury

A. Conclusions

- Orthopedic complaints are the leading cause of disability for the Army, Navy and Marine Corps, resulting in at least 30% to 50% of Physical Evaluation Board (PEB) cases.
- Impact of disabilities on manpower is high—1% to 2% of service members are evaluated annually; 60% are discharged or permanently retired.
- Costs of injury-related disability probably exceed $750 million annually.
- Disability rates appear to be climbing for the Navy and the Air Force and declining for the Army.
- Low back and knee conditions are leading causes of disability at the PEB level.
- Disability agency data provide a valuable data source for defining the impact of injury on both manpower and costs.
- Medical Evaluation Board (MEB) data from the services are a good source of more precise diagnoses but data are not computerized for the Army or Air Force.
- Preventive measures are not readily apparent from disability agency data.
- Line-of-duty data might be used to determine causes of injury-related disabilities.

B. Recommendations

- The PEBs and MEBs should be used for medical and injury surveillance.
- Collect minimum basic data set recommended by International Collaborative Effort on Injury Statistics and episodically assess completeness and validity of the PEBs and MEBs.
- Link PEB and MEB data to other medical databases and denominators.
- Compare standardized rates of disability/injury among services.
- Obtain better demographic and cause-of-injury data to supplement PEBs/MEBs for disabled/injured database—look at line of duty and similar success.
- Determine the percentage of injury-related MEBs that reach the PEB level.
- Automate and centralize MEB data systems.

Chapter 3. Hospitalization Due to Injuries

A. Conclusions

- Hospital records data indicate that injuries and musculoskeletal conditions have a bigger impact on readiness than any other ICD-9 Principal Diagnostic Group (higher incidence, higher non-effective rate).
- For the Army, injuries and musculoskeletal disorders accounted for 30% of hospital admissions (28,000) and 40% of soldier non-effective days (over 500,000 days on the hospital rolls) in 1992.
- Hospitalization rates for injury appear to be declining for all services (1980–1992).
- Musculoskeletal disorders are increasing in the Army but declining in the other services.
- Major causes of hospitalization include sports injuries, motor vehicle accidents, falls, and jumps.
- Major types of injuries include back and knee injuries as well as fractures.
- Military hospital data are strong compared to civilian data (e.g., cause coding and good linkage potential), but are not being used to full potential.
- Unique personal identifiers facilitate use of data for surveillance and research.
- Good demographic and denominator data exists on entire population; however, there is a need for better exposure information.
- Uniform data do exist among services for some variables but more attention needs to be paid to cross-service comparisons.
- Need to focus on military injuries and other medical conditions with high impact on readiness and cost.

B. Recommendations

- Use hospital records routinely for injury and medical surveillance and research, and report incidence, non-effective rates, and trends.
- Implement consistent definitions and classifications across time, place, and service (e.g., criteria for hospitalization, non-effective days, injury type/acute versus chronic/musculoskeletal/late effects).
- Improve quality of data collection in deployment and combat situations to make consistent with data col-

lection in fixed facilities, especially for the cause-of-injury information.

- Assess quality and consistency of coding and whether there is a need for training of coders.
- Focus research and prevention on sports injuries and falls.
- Develop strategies to more effectively link and use medical and safety data.
- Develop automated outpatient data systems compatible with inpatient systems.
- Investigate family violence and workplace violence.
- Examine work versus nonwork-related injury (cross cutting all databases).
- Evaluate process and quality of data for military active duty treated in civilian hospitals.
- Add free-text field for detailed cause-of-injury information to help design and evaluate prevention strategies.
- Evaluate "late effects of injury" and complications of medical/surgical care.
- Link hospital and disability data to evaluate long-term effects of injury.
- Ensure adequate collection of causes, to include possible E-coding for musculoskeletal conditions (pilot project at sentinel sites).

Chapter 4. Outpatient Care for Training and Other Injuries

A. Conclusions

- Research indicates that high injury rates occur in basic training, infantry, and other vigorously active military units.
- For Army, injury visit rates are equal to illness rates in basic training and infantry units (80 to 100 injury visits per 100 soldiers per year).
- Injury non-effective rates (i.e., rates of days of limited duty) are 5 to 10 times greater than illness rates.
- Lower extremity overuse injuries account for the majority of training-related injuries.
- Modifiable injury risk factors include the amount and type of physical training and level of fitness.
- No uniform servicewide outpatient surveillance systems yet exist that include injury diagnoses and causes.
- A pilot surveillance system in use at Navy/U.S. Marine Corps and Air Force training sites may be a useful model.
- Most research has been done on basic training, with some on infantry and Marines, but there have been few studies on other types of units.
- Testing of training injury prevention strategies has provided successful interventions and cost savings.

B. Recommendations

- Sentinel site surveillance or other cost effective outpatient surveillance system is needed until automated outpatient records are available.
- Include in the minimum data set for outpatient care the following: age, race/ethnicity, gender, diagnosis, profile/disposition, and cause.
- Focus research on high-risk populations and environments with largest impact on readiness.
- Document incidence, severity, time lost, and costs.
- Conduct research to study the effect of equipment design on training and injuries.
- Broaden research effort to more than basic training and infantry.
- Research on physical training practices should concentrate on the intensity, frequency, and duration of training, as well as the type of activity.
- Continue to explore the association of training, fitness, performance, smoking, and injuries.
- Implement and monitor the effectiveness of prevention strategies.
- Allocate/prioritize resources for research based on magnitude and severity of medical problems—injuries clearly deserve priority.

Chapter 5. Casualties During Combat Due to Nonbattle Injuries

A. Conclusions

- Injuries and musculoskeletal conditions cause more hospitalizations during combat than any other category of medical complaints (ICD-9 Principal Diagnostic Group).
- For the Army, 38 percent of hospital admissions during Operation Desert Storm (ODS) (the Gulf War) resulted from injuries and musculoskeletal disorders.
- Injuries are an important cause of outpatient "sick call" during combat deployments.
- Fractures, back injuries, and knee injuries are important types of injuries causing hospitalizations of Army personnel in combat operations and most recently in ODS.
- Sports, falls, and motor vehicle accidents are important causes of injury in combat deployments.
- Good data on hospitalizations are available, but delay of availability during operations limits value.
- Surveillance is possible during operations but needs to be refined and standardized across services.

B. Recommendations

- Use medical surveillance to monitor readiness in peacetime and combat.
- Standardize deployment/combat medical surveillance systems across services—these should be integrated with garrison medical surveillance systems.
- Keep collection of data short and easy for medical personnel to perform.
- Provide weekly reporting of medical surveillance data to line commanders and medical units.
- Collect data on the following at a minimum: date, type of injury, anatomical location, and cause/circumstance of injury.
- Train medical personnel in methods and uses of medical surveillance.
- Identify problems to target for more intense investigation and prevention through analysis of surveillance data.
- Improve communication systems to support routine surveillance and data transmission in combat.

Deaths Due to Injury in the Military

Kenneth E. Powell, MD, MPH, Lois A. Fingerhut, MA, Christine M. Branche, PhD, MSPH,
Dennis M. Perrotta, PhD

Introduction: More military personnel die of injuries each year than any other cause. This paper provides a basic epidemiologic description of injury deaths in the military.

Methods: Using fatality data from the Department of Defense Directorate of Information and Operations Reports and population data from the Defense Manpower Data Center, death rates of men and women in the military services for unintentional injury, suicide, homicide, and illness were calculated for the 1980–1992 period.

Results: From 1980 to 1992, injuries (unintentional injuries, suicides, and homicides combined) accounted for 81% of all nonhostile deaths among active duty personnel in the Armed Services. The overall death rate due to unintentional injuries was 62.3 per 100,000 person-years. The suicide rate was 12.5, the homicide rate 5.0, and the death rate due to illness 18.4. From 1980 to 1992 mortality from unintentional injuries declined about 4% per year. The rates for suicide and homicide were stable. Men in the services die from unintentional injuries at about 2.5 times the rate of women and from suicides at about twice the rate of women. Women in the military, however, have a slightly higher homicide rate than men.

Conclusion: Injuries (unintentional injuries, suicides, and homicides) are the leading cause of death among active duty members of the U.S. Armed Forces, accounting for about four out of five deaths. The downward trend for fatal unintentional injuries indicates the success that can be achieved when attention is focused on preventing injuries. Further reduction in injury mortality would be facilitated if collection and coding of data were standardized across the military services.

Medical Subject Headings (MeSH): wounds and injuries, suicide, homicide, accident prevention, military personnel, military medicine (Am J Prev Med 2000;18(3S):26–32)

Introduction

More military personnel die of injuries every year than from any other cause. Unintentional injuries alone cause more than half of all deaths among military service members. These statistics are not surprising for a young, predominantly male population. Similarly, injuries kill more Americans between the ages of 15 and 34 years, especially young men, than any other cause. In 1994, of the 94,514 deaths in the United States among people aged 15 to 24 years, more than half (53,873) were due to injury: unintentional injury—29% (27,409); suicide—12% (11,342)[1–3]; and homicide—16% (15,122).

This paper examines active duty military personnel and (1) compares the magnitude of injury fatalities to deaths from illnesses/diseases; (2) determines the relative importance of different types of injury deaths (i.e., unintentional, suicide and homicide); (3) provides a basic epidemiologic description of injury deaths; and (4) provides general conclusions regarding surveillance of injury fatalities.

Methods

Deaths in the military are routinely recorded by the service casualty offices and reported to the Department of Defense Directorate of Information and Operations Reports (DIOR). The DIOR routinely publishes *The Worldwide Casualty Report,* which tabulates the overall fatality rates for each service and the frequency of deaths in five categories: accidents (hereafter referred to as unintentional injuries); illnesses; self-inflicted injuries (hereafter referred to as suicides); homicides; and hostile actions.[4]

The published DIOR reports do not provide rates for

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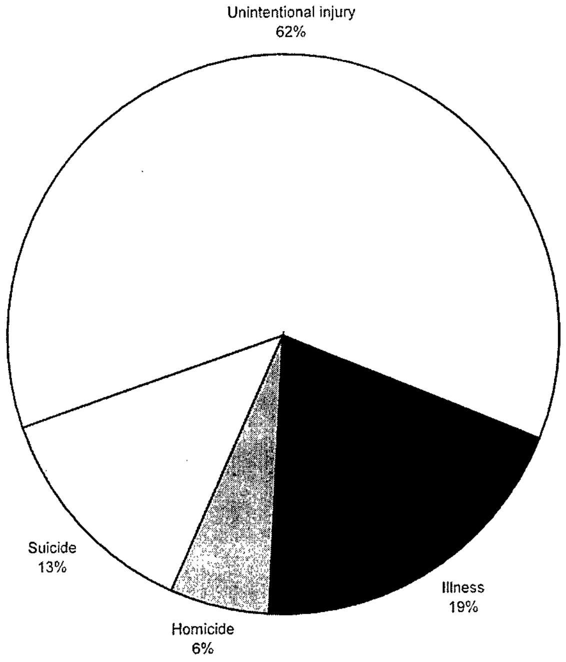

Figure 1. Distribution of nonhostile casualties—unintentional injury, suicide, homicide, and illness—for active duty Armed Forces personnel, 1980–1992 (from *Injuries in the Military*[6])

the separate categories of death or breakdowns of the data by age, gender, military occupation, or more specific cause. However, in an unpublished report, Helmkamp used DIOR data and population data from the Defense Manpower Data Center (DMDC) to calculate the fatality rates of men and women in the military services for each of the five DIOR categories from 1980 to 1993.[5] This paper is based primarily on data Helmkamp shared with the authors because it was the most complete source of rates for the full spectrum of fatal events among military personnel—unintentional injuries, suicides, homicides, and illnesses/diseases.

Other sources of information on deaths in the military services also exist, including service casualty offices, which maintain only administrative death records on a specific service; service medical department hospital records systems, which capture only data on deaths occurring or carded for record in military medical facilities; and service safety centers/agencies, which report only deaths due to accidental causes.

Results

Proportion of Deaths Due to Injury

From 1980 to 1992, injuries (unintentional injuries, suicides, and homicides combined) accounted for 81% of all nonhostile deaths among active duty personnel in the Armed Services, and illness accounted for 19% (Figure 1). Among the services, the proportion of deaths caused by injuries ranged from 78% in the Air Force to 90% in the Marine Corps (Figure 2).

Unintentional injuries were the most common cause of death, accounting for 62% of nonhostile casualties (Figure 1). Unintentional injuries accounted for well over half the deaths in each service, ranging from 59% in the Air Force to 71% in the Marine Corps (Figure 2). Overall, suicides accounted for 13% of the deaths, ranging from 12% each for the Army, Navy, and Marine Corps, to 15% for the Air Force. Homicides accounted for 6% overall, ranging from 4% for the Air Force to 7% for the Marine Corps. (See page 28 for service-specific causes of death in 1994 according to service casualty office data. The variability among services in cause-of-death categories precludes synthesis.)

Rates of Deaths Due to Injury

From 1980 to 1992, nonhostile death rates were as follows:

- Death rate due to unintentional injuries—62.3 per 100,000 person-years
- Suicide rate—12.5 per 100,000 person-years
- Homicide rate—5.0 per 100,000 person-years
- Death rate due to illness—18.4 per 100,000 person-years

Among the services, the unintentional injury death, suicide, and homicide rates were highest for the Marine Corps (Figure 3). Unintentional injury death and homicide rates were lowest for the Air Force. The Navy had the lowest suicide rate. The rate of unintentional injury death ranged from 43.0 per 100,000 person-years in the Air Force, to 79.1 in the Marine Corps (Figure 3). The suicide rate ranged from 11.0 in the Navy to 13.7 in the Marine Corps; and the homicide rate ranged from 2.6 in the Air Force to 7.4 in the Marine Corps. Mortality due to illness was lower than for unintentional injuries and ranged from 11.4 in the Marine Corps to 20.4 in the Army.

Injury Death Rates Over Time

Sizeable reductions in the rate of nonhostile deaths occurred from 1980 to 1992, primarily due to declines in unintentional injury death rates (Figure 4). While fatality rates due to illness/disease also decreased, the absolute magnitude of the decline was smaller and therefore had less impact on overall death rates. Suicide rates varied little over time. Homicide rates, on the other hand, declined gradually until 1989 and then increased through 1992.

Injury Rates by Gender

Overall, the injury death rate for men was about twice that for women (79.8 per 100,000 person-years vs. 36.1) (Figure 5).

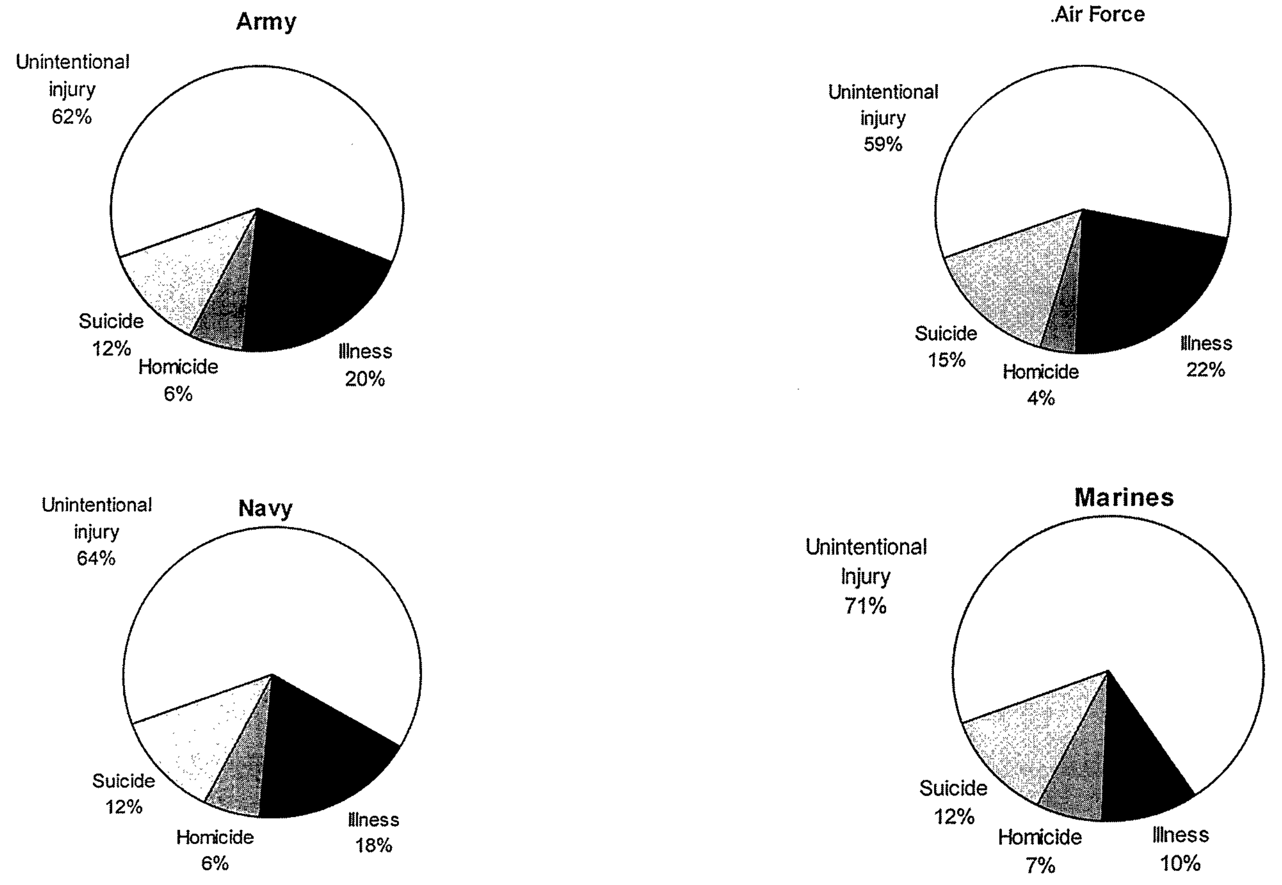

Figure 2. Distribution of nonhostile casualties—unintentional injury, suicide, homicide, and illness—for active duty Army, Navy, Marine Corps, and Air Force personnel, 1980 to 1992 (from *Injuries in the Military*[6])

- The unintentional injury death rate for men exceeded that for women, 62.3 to 24.1 per 100,000 person-years.
- The suicide rate for men exceeded that for women, 12.5 to 5.5 per 100,000 person-years.
- The homicide rate for women exceeded that for men, 6.5 to 5.0 per 100,000 person-years.

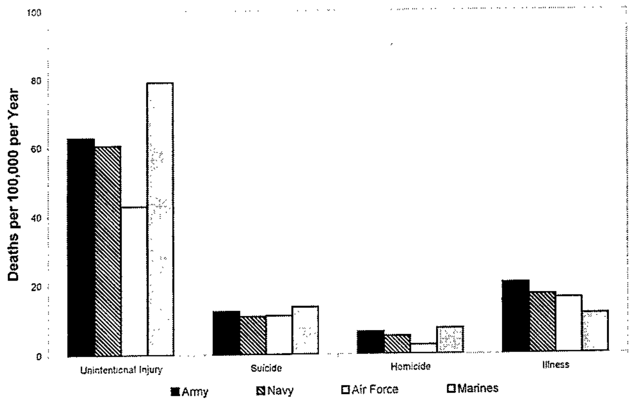

Figure 3. Mortality rates for active duty Army, Navy, Marine Corps, and Air Force personnel, 1980–1992 combined (from *Injuries in the Military*[6])

The mortality gender ratios were similar across the four services, with two notable exceptions: the ratio for unintentional injury deaths was noticeably higher for the Marines, and the ratio for suicide was higher for the Navy (Table 1). The homicide rate for women exceeded that for men in each of the four services. This is notably different from the general population, in which the homicide rate for men is about four times higher than for women.

Specific Causes of Death

The Casualty Offices of each of the military services, located in their respective personnel departments, have their own unique system for coding causes of death. Table 2 through Table 5 display the distribution of causes of death in 1994 for the Army, Air Force, Navy, and Marine Corps, respectively. For all four services, motor vehicle crashes (private- and government-owned vehicle accidents combined) are the leading cause of

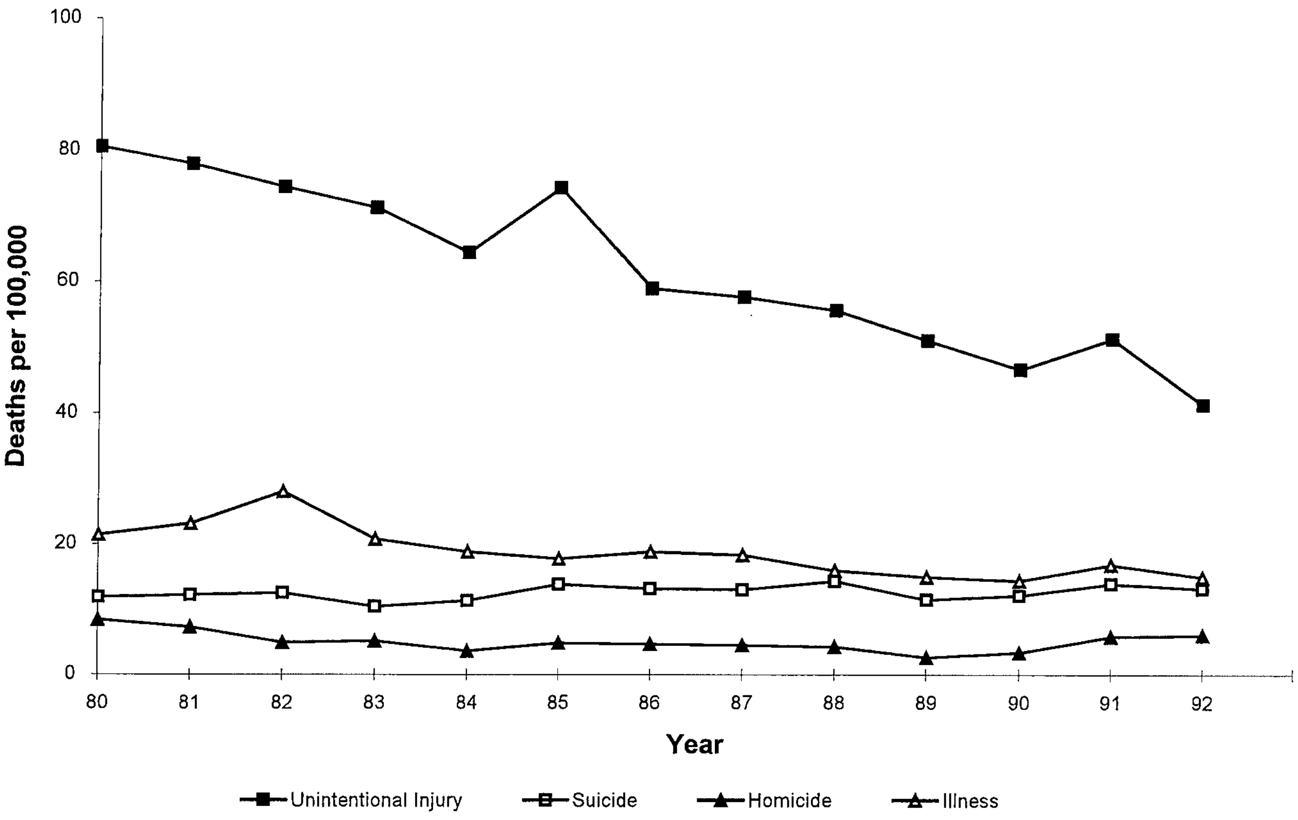

Figure 4. Nonhostile mortality rates for active duty Armed Forces male personnel, 1980–1992 (from *Injuries in the Military*[6])

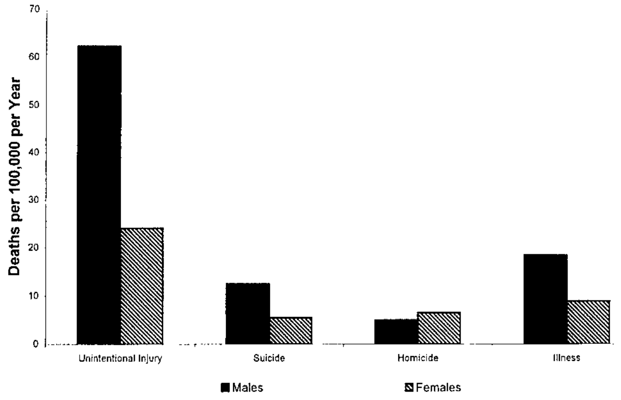

Figure 5. Mortality rates by gender for active duty Armed Forces personnel, 1980–1992 combined (from *Injuries in the Military*[6])

death, accounting for between 30% and 40% of fatalities. For the Army, Navy, and Marine Corps, gunshot wounds from suicide, homicide, and accidents are the second leading cause of death, resulting in about 20% of all fatalities. Heart attacks, the leading cause of death due to disease, cause 6% to 12% of all fatalities in the four services. Other important causes of injury deaths, including aviation accidents, drownings, and falls, vary from service to service.

Conclusions

These data clearly demonstrate that injuries (unintentional injuries, suicides, and homicides) are the leading cause of death among active duty members of the U.S. Armed Forces, accounting for about four out of five

Table 1. Mortality gender ratio (male:female) by service and cause of death for active duty Armed Forces personnel, 1980–1992

Service	All injuries	Unintentional injuries	Suicides	Homicides	Illnesses
All services	2.2	2.6	2.3	0.8	2.1
Army	2.0	2.4	2.2	0.7	2.1
Air Force	2.1	2.4	2.0	0.6	2.4
Navy	2.3	2.5	3.3	0.9	1.8
Marine Corps	2.5	3.6	1.8	0.6	1.7

Source: *Injuries in the Military*[6]

Table 2. Causes of death among active duty Army personnel, 1994[a]

Cause of death	Number of deaths	% of total deaths
Vehicle accident	149	31.5
Gunshot	98	20.7
Heart attack	45	9.5
Fire/burns	25	5.3
Training related	24	5.1
Drowning	13	2.7
Friendly fire	13	2.7
Hanging	11	2.3
Aircraft/land	11	2.3
Stabbing	10	2.1
Fall or jump	7	1.5
Unknown	6	1.3
Cancer	5	1.1
Strangulation	5	1.1
Respiratory failure	3	0.6
Suffocation	3	0.6
Pneumonia	2	0.4
Stroke	2	0.4
Explosive device	2	0.4
Artillery round	1	0.2
Parachute accident	1	0.2
Misadventure	1	0.2
Other	20	4.2
Total	473	100.0

[a]Excludes deaths due to hostile action.

Source: Army Casualty Information Processing System, Facsimile Transmission Document 7/95.

nonhostile deaths. Unintentional injuries are the most common cause of these deaths and account for more than half in each of the four services. The rates of unintentional injury, suicide, and homicide are highest in the Marine Corps. Unintentional injury fatality rates in the military are similar to civilian rates.[7] However, suicide and homicide rates are lower than civilian rates because these rates for men are lower in the military than in civilian life.

Table 3. Causes of death among active duty Air Force personnel, 1994[a]

Cause of death	Number of deaths	% of total deaths
Suicide	67	29.5
Privately owned vehicle—auto	53	23.3
Heart attack	27	11.9
Government owned vehicle—aircraft	20	8.8
Other–illness	11	4.8
Privately owned vehicle–motorcycle	12	5.3
Homicide	9	4.0
Ground–drowning	5	2.2
Privately owned vehicle–other	3	1.3
Ground–fall	2	0.9
Cancer	2	0.9
Privately owned vehicle–pedestrian	2	0.9
Privately owned vehicle–aircraft	2	0.9
Government owned vehicle–auto	1	0.4
Others	11	4.8
Total	227	100.0

[a]Excludes deaths due to hostile action.

Source: U.S. Air Force AL/AOP, Facsimile Transmission Document 7/95.

Table 4. Causes of death among active duty Navy personnel, 1994[a]

Casualty manner/cause	Number of deaths	% of total deaths	% of category
Accidents			
Vehicle loss or accident	87	31.6	64.4
Drowning	9	3.3	6.8
Aircraft/sea	9	3.3	6.8
Aircraft/land	5	1.8	3.7
Fall or jump	4	1.5	3.0
Fell or lost overboard	2	0.7	1.5
Suffocation	2	0.7	1.5
Hanging	2	0.7	1.5
Gunshot or small arms fire	1	0.4	0.7
Parachute	1	0.4	0.7
Electrocution	1	0.4	0.7
Alcohol abuse or overdose	1	0.4	0.7
Strangulation	1	0.4	0.7
Other	10	3.6	7.4
Subtotal	135	49.1	100.0
Illness			
Heart attack	33	12.0	66.0
Cancer	7	2.5	14.0
Stroke or CVA	2	0.7	4.0
Respiratory failure	1	0.4	2.0
Cause not reported	1	0.4	2.0
Other	6	2.2	12.0
Subtotal	50	18.2	100.0
Homicide			
Gunshot or small firearm	12	4.4	70.6
Stabbing	2	0.7	11.8
Strangulation	1	0.4	5.9
Beating	1	0.4	5.9
Other	1	0.4	5.9
Subtotal	17	6.2	100.0
Self-inflicted			
Gunshot or small firearm	41	14.9	74.6
Hanging	6	2.2	10.9
Poisoning (carbon monoxide)	3	1.1	5.5
Fall or jump	1	0.4	1.8
Drowning	1	0.4	1.8
Stabbing	1	0.4	1.8
Drug abuse or overdose	1	0.4	1.8
Other	1	0.4	1.8
Subtotal	55	20.0	100.0
Undetermined	18	6.5	100.0
Total	275	100.0	

[a]Excludes deaths due to hostile action.

Source: Worldwide Casualty System Database.

Military and civilian suicide rates are similar for women; the suicide rate for men in the military is about half the rate for men in civilian life.[8] Military and civilian homicide rates are similar for women; the homicide rate for men in the military is about one-fourth the rate for men in civilian life.[9] The higher homicide rate among active duty women than active duty men is in marked contrast to general population rates.

Table 5. Causes of death among active duty Marine Corps personnel, 1994[a]

Casualty manner/cause	Number of deaths	% of total deaths	% of category
Accident			
Vehicle loss or accident	53	41.4	69.7
Aircraft/land	7	5.5	9.2
Drowning	5	3.9	6.6
Gunshot or small arms fire	4	3.1	5.3
Other explosive device	2	1.6	2.6
Other	2	1.6	2.6
Electrocution	1	0.8	1.3
Parachute	1	0.8	1.3
Fell or lost overboard	1	0.8	1.3
Subtotal	76	59.5	100.0
Illness			
Heart attack	8	6.3	61.5
Cancer	2	1.6	15.4
Other	2	1.6	15.4
Pneumonia	1	0.8	7.7
Subtotal	13	10.3	100.0
Homicide			
Gunshot or small firearm	5	3.9	55.6
Stabbing	2	1.6	22.2
Beating	2	1.6	22.2
Subtotal	9	7.1	100.0
Suicide			
Gunshot or small firearm	17	13.3	81.0
Fall or jump	1	0.8	4.8
Drug abuse or overdose	1	0.8	4.8
Poisoning (carbon monoxide)	1	0.8	4.8
Hanging	1	0.8	4.8
Subtotal	21	16.5	100.0
Undetermined	9	7.0	100.0
Total	128	100.0	

[a]Excludes deaths due to hostile action.
Source: Worldwide Casualty System Database.

From 1980 to 1992, the rate of fatal unintentional injuries declined about 4% per year. The downward trend indicates the type of success that can be achieved when attention is focused on preventing injuries. For example, reductions in motor vehicle fatalities are the result of more frequent use of seat belts, lower tolerance for drunk driving, and improved design of vehicles and roads. Similar reductions in injury fatality in the military (and among civilians) are likely in other areas.

Although violent injury death rates (suicides and homicides) in the military are lower than civilian rates, greater efforts at prevention are warranted. Rates of suicides and homicides combined have not changed appreciably over the last decade and a half. Over this period of time, violent injuries have on average accounted for almost 20% of all nonhostile deaths. However, as unintentional injury fatalities have decreased, this proportion of the total has now risen to 25% to 30% of deaths in the military services. Due to the high incidence rate reported, special attention should be given to preventing homicides among female service members in particular.

Further reduction in injury mortality in the military would be facilitated if collection and coding of data were standardized across the services. Such standardization would facilitate determination of the population at risk as well as enumeration of the events themselves. Valid, reliable, complete, and consistent data from military surveillance systems are critical for (1) identifying the populations most at risk, (2) identifying the most important causes, and (3) determining how well prevention strategies are working.

Specific areas for improvement include capturing information about duty status, place, type, circumstance of casualty, and, when appropriate, information about firearms. Categories of duty status should include on duty, off duty, on leave, inpatient, or other. Type of activity at the time of injury (duty-related or leisure) should be noted. These areas in which the Armed Services should provide additional detailed information are summarized below:

- Place where the injury occurred as well as the place of death because the two locations frequently differ. Place of injury is much more important for prevention purposes than place of pronouncement. The new *International Classification of Diseases, 10th Revision* (ICD-10), has a thorough coding scheme for place of occurrence that could be adapted for military use.[10]
- Type of unintentional injury (e.g., motor vehicle collision, pedestrian injury, drowning) and the method of suicide and homicide (e.g., firearm, cutting and stabbing instrument) using subcategories consistent with the ICD-10 categories used for civilian vital statistics.
- Cause and circumstances of fatal injuries using coding schemes such as ICD-10.
- Ownership and type of firearm involved. This may guide prevention efforts, especially of violent deaths. Firearms are the fatal weapon in 60% of suicides and 59% of homicides in the military.[8,9] Ownership should indicate whether the weapon was military issue or privately obtained, and whether the weapon was the issue or property of the deceased, the perpetrator (for homicide), some other known person, or an unknown person.
- Routine evaluation of information about nonfatal injuries. This is very important because mortality data do not adequately describe the burden of injuries upon military readiness. Nonfatal injuries are more common than fatal injuries and obviously influence soldiers' ability to function at full capacity. Some types of injuries, such as sports injuries, are common, frequently incapacitating, and yet rarely fatal. The full impact of injuries upon military readiness requires information about both fatal and nonfatal injuries.

The opinions and assertions contained herein are the private views of the authors, and are not to be construed as official or as reflecting the views of the Department of Defense.

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Disabilities Due to Injury in the Military

Thomas J. Songer, PhD, Ronald E. LaPorte, PhD

Introduction: Disability is a major health and economic issue in the Armed Forces associated with increased use of medical care, the loss of active duty time, and substantial compensation costs.

Methods: The role of injuries in physical disability from the early 1980s to 1994 was assessed by reviewing administrative data from the U.S. Army Physical Disability Agency, the Naval Disability Evaluation Board, and the Air Force Physical Disability Division. Information on the number of disability cases reviewed in 1994, the leading causes of disability, and the disposition of each case were examined most closely. Also, information from the Department of Defense on the cost of compensating disability cases was reviewed.

Results: Disability generally appears to be significant across the services, ranging from 10 to 30 events per 1000 personnel per year depending on the service. Evidence from the data reviewed indicates that 30% to 50% of disability cases may be due to injury. The leading conditions that bring about board reviews and lifetime compensation appear to be lower back and knee conditions, both commonly thought to be due to injuries. Total direct costs of compensation reached $1.5 billion for fiscal year 1990.

Conclusions: While current disability data systems are maintained for administrative and not research purposes, the information available may be valuable for injury surveillance and research and suggests that injury-related disability is a major health and economic burden for the Armed Forces.

Medical Subject Headings (MeSH): wounds and injuries, disabled persons, musculoskeletal system, military medicine, military personnel (Am J Prev Med 2000;18(3S):33–40) © 2000 American Journal of Preventive Medicine

Introduction

Disability is a major social, economic, public health, and political issue confronting society today. Estimates of the number of disabled persons in the United States vary greatly, ranging from 27 million to 49 million.[1–3] Disability is a particularly significant concern for the military services, as it affects the number of active duty and reserve personnel available for combat/military missions. Physical disability that results in discharge from the service also carries significant compensation costs. In 1993, the lifetime cost of new disabilities compensated by the Army was about $500 million annually.[4]

A complete understanding of the contribution of injuries to long-term disability among military service members has not yet been achieved. While there is a common perception that injuries are a major cause of disability in the young, the multidimensional nature of disability hinders the assessment of its impact. For many years, disability was defined solely by the presence of a physical disorder, such as the loss of a limb. However, the work of Saad Nagi[5] and Philip Wood[6] moved the discussion beyond physical disabilities and into a broader domain. Disability is now often defined in terms of its impact on the individual from a physical, mental, or social health perspective. Further, there is recognition now that the surrounding work environment and family situation can mediate the impact of disability.

For active duty military personnel, disability can be most immediately viewed from two perspectives—whether its impact is permanent or temporary. Permanent disability results in discharge of the individual from the service. Temporary disability results in the loss of active duty status over a period of days, weeks, or years.

This paper reviews the existing data sources for disability in the Armed Forces to identify the relative contribution of injuries, and to identify recommendations regarding the surveillance of injury-related disability in the military. This work emanated from the deliberations of the Armed Forces Epidemiological Board (AFEB) Injury Prevention and Control Work

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Group and the Department of Defense (DoD) Injury Prevention and Surveillance Work Group. The objectives of both groups included:

- Determination of the burden of injuries on the military across the spectrum of health, including disabilities.
- Identification of data sources with potential value for injury surveillance.
- Recommendations for more effective use of these sources for injury prevention and control.

Methods

The first task of this review was to identify the possible sources of disability data within each of the services in the Armed Forces. We found that disability-related data for service members in the Army, Navy and Marine Corps, and Air Force may be compiled from a number of sources. For example, information on the number of days lost to active duty from short-term health conditions is available through the service-specific medical branches.[7–9] Information on the number of persons discharged from service or temporarily released from duty with pay due to physical disability is available from independent disability agencies within each service. Accessibility to this information is variable. The most complete information available and comparable across all three services was that regarding the cases being considered for discharge from active service, 60% to 90% of whom are discharged by the service.

The personnel departments of each of the military services are responsible for the review and disposition of cases where an individual either (1) incurs an injury or disease while on active duty or (2) whose prior health condition may be aggravated by military service and, therefore, may be eligible for some form of compensation. The specific agencies responsible for this assessment are the Army Physical Disability Agency, Naval Disability Evaluation Board (includes Marine Corps), and Air Force Physical Disability Division. Physical evaluation boards (PEBs) designated by each of the military services routinely convene to review each case and determine the individual's fitness for continued active service. Compensation decisions are rendered for individuals where a disability is incurred or aggravated while in receipt of basic pay, or for career members of the service who are unable to complete their careers due to a physical disability. The PEBs consider information from medical evaluation boards (MEBs) and line of duty (LOD) determination reports in arriving at their decisions.

Each disability agency maintains a database to record the cases submitted for review to the PEBs. These databases are used primarily for administrative purposes to track the progress or outcomes of individual cases seen by the PEB. They can also provide summary statistics on the number of cases reviewed, their disposition, and the physical condition causing disability. Summary PEB information formed the basis for this report.

Potential injury-related disabilities were identified in the respective databases through the use of Veterans Administration Schedule of Ratings and Disabilities (VASRD) codes. All service disability agencies use the VASRD system for classifying the physical condition related to the potential disability and for rating the level of severity of the condition.[10] Injuries are typically assigned codes that identify the residual condition on which the rating is based.[10] In situations where a medical impairment is not listed, the service disability agencies apply analogous VASRD codes (i.e., it is rated by analogy to another closely related injury).[10] This system cannot identify the cause of injury or the specific diagnosis for the injury (e.g., fracture, dislocation, sprain).

The outcomes or disposition of the disability cases reviewed by the service agencies were categorized into the following groups:

- Permanent disability—a permanent and stable disability resulting in discharge with full compensation for life.
- Separation with severance pay—disability resulting in discharge with a one-time separation payment.
- Separation without benefits—disability resulting in discharge, the disability existed prior to service and was not aggravated by service, or occurred as a result of intentional misconduct or neglect.
- Temporary disability—a medical disability that could improve (or worsen) over time, to be re-evaluated every 18 months; not fit for active duty.
- Fit for duty—return to active duty.

More details regarding these definitions can be found in the *Atlas of Injuries in the U.S. Armed Forces.*[11]

Further data on disability were also available, in selected instances, from MEB reports. The MEB is responsible for evaluating the medical impairment and the degree of severity for every disability case coming before a PEB review.[11] The results of the MEB report generally form the basis for the decisions made by the PEBs. Since the MEB data result from medical exams at military medical facilities, they provide more details regarding the cause of the disability, the type of injury involved, and the cause of the injury. The MEBs of each military service use similar data forms and classify medical conditions by the use of International Classification for Diseases (ICD) codes.[12] However, at the time of this report, only the Navy maintained a computerized database of MEB reviews. Some Navy MEB data were reviewed, as well as those available from a special surveillance project of MEB reports from one Army Infantry Division.[13]

Information on disability compensation payments is also included in this report. These data were presented

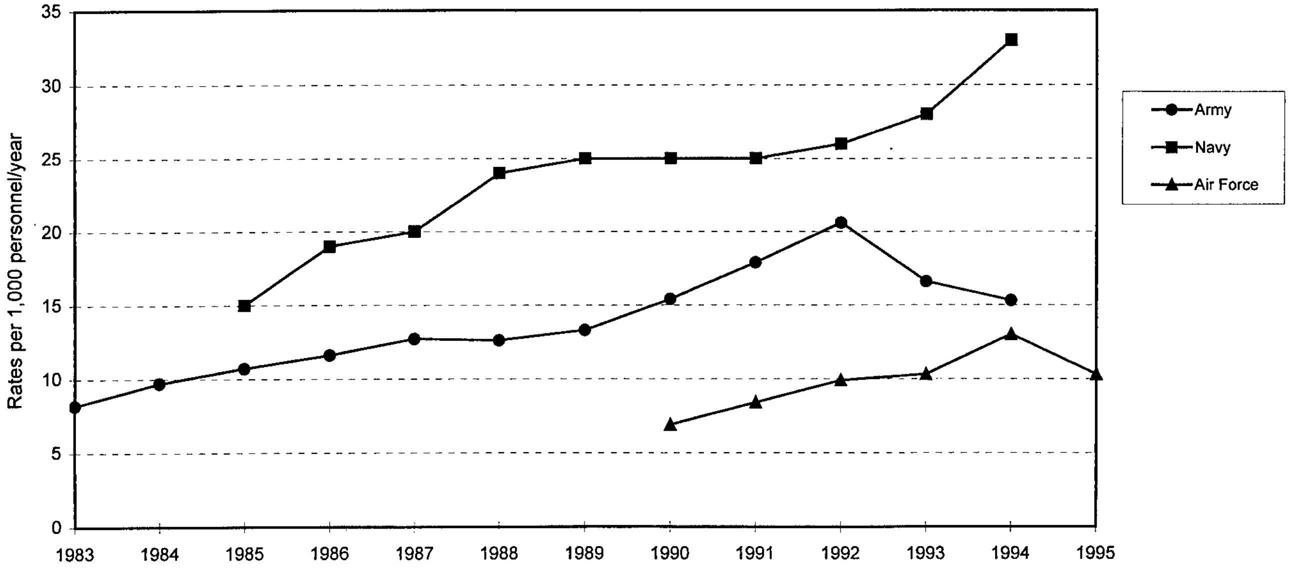

Figure 1. Disability cases reviewed by physical evaluation boards by service. (Source: U.S. Army Physical Disability Agency, Naval Council of Personnel Boards, and Air Force Personnel Center.)

to the DoD Injury Prevention and Surveillance Work Group meetings and represent DoD figures for payments made to personnel discharged from active service due to disability. Disabled persons compensated by the Veterans Administration are not included in these figures.

Results

Overall Frequency of Disability

Figure 1 illustrates the rate in which disability cases have been reviewed by the PEBs in each service (number of cases adjusted by the total population of each respective service for the particular year). For the Army, the rate of disability cases reviewed increased by 87% from 8.2 per 1000 personnel in 1983 to 15.3 in 1994. For the Navy, the rate of disability cases reviewed increased by 120% from 15 per 1000 personnel in 1985 to 33 in 1994. For the Air Force, the rate of disability cases reviewed increased by 49% from 6.9 per 1000 personnel in 1990 to 10.3 in 1995.

There has been a general increase in the rate of disability cases reviewed by PEBs over the last decade. Army and Air Force data show that the rate of cases reviewed declined after reaching a peak in 1992 and 1994, respectively. These data include reviews of both active duty personnel and temporary disability retired list (TDRL) personnel. TDRL personnel are those who have had a previous PEB review. As such, the data may not reflect new cases of disability within each year, and could be influenced by changes in the definition of eligibility for PEB review over time.

The disposition of the disability cases presented to the PEBs of the three services in fiscal year (FY) 1994 is shown in Table 1. Noted differences in disposition exist between the services. The majority of the cases reviewed by the Army and Navy PEBs (76% to 95%) were discharged from service (permanent disability or separation). However, many (41%) of the Air Force cases reviewed were retained. Temporary disability ratings were lowest for the Army.

Injuries and Disabilities

What is the importance of injuries in the military with respect to long-term disability, compensation, and fit-

Table 1. Disposition of disability cases reviewed by physical evaluation boards by service, FY 1994

	Army (*n* = 8413)	Navy (*n* = 10,786)	Air Force (*n* = 3687)
Permanent disability	16%	4%	15%
Separation with severance pay	41%	61%	19%
Separation with no benefits	4%	—	2%
Temporary disability	15%	22%	23%
Fit for duty	24%	5%	41%
Other	—	8%	—

Sources: U.S. Army Physical Disability Agency, Naval Council of Personnel Boards, and U.S. Air Force Personnel Center.

Table 2. Medical conditions associated with disability cases reviewed by physical evaluation boards by service

VASRD Codes	Disease condition system	Army, FY 1994 (n = 6382)	Navy, FY 1995[a] (n = 7682)	Air Force, FY 1994 (n = 3687)
5000–5300	Orthopedic and musculoskeletal system	53.1%	63.0%	22%
9200–9500	Mental disorders	14.2%	9.7%	21%
8000–8900	Neurologic conditions and convulsive disorders	12.1%	9.3%	13%
6300–6800	Systemic conditions and respiratory system	7.4%	6.4%	14%
7700–7900	Blood/skin/endocrine systems	3.3%	3.5%	12%
7000–7100	Cardiovascular system	3.4%	2.7%	6%
7200–7300	Digestive system	2.9%	2.5%	5%
7500–7600	Genitourinary/gynecologic conditions	1.4%	1.2%	4%
6000–6200	Visual and auditory conditions	1.7%	1.7%	2%
	Unknown	0.5%	—	1%

[a] Army and Navy data represent first 9 months of FY 1994 and 1995, respectively.

Sources: U.S. Army Physical Disability Agency, Navy Council of Disability Boards, U.S. Air Force Personnel Center.

ness for active duty? To answer this question, the authors sought information on the reasons why individuals came before PEBs and the proportion of these cases potentially related to injuries. This type of information is available, in part, by reviewing the VASRD codes assigned to the cases.

There are strong, but not precise, indications that injuries are important determinants for disability in the Armed Forces. Table 2 displays the breakdown of the leading reasons for disability as coded by the Army, Navy, and Air Force PEBs, respectively, using the VASRD system. Impairments from orthopedic and musculoskeletal conditions are clearly the leading factors accounting for disability cases reviewed by PEBs in the services, particularly for the Army (53%) and Navy (63%). Many of these impairments could be the result of injuries.

While this information is highly suggestive that injuries may be a major reason for disability in the services, it is difficult to distinguish injury-related from non-injury-related disabilities in the VASRD coding scheme. First, specific injury codes do not exist. VASRD codes for injuries are based on the residual medical condition affected by an injury or disease. Second, a considerable period of time could have elapsed between the time when the injury occurred and the time when the disability case is reviewed. Thus, an event will be coded as degenerative arthritis, for example, with little mention of how this condition developed. Moreover, in situations where a medical condition is not listed, the service disability agencies rate by analogous VASRD codes. Currently, there are no standard methods for classifying codes between the services—each service has developed its own interpretation of codes to use in these situations.

Data from the Medical Evaluation Boards

One potential method to overcome the difficulty of distinguishing injuries in VASRD codes would be to link it with information contained within the MEB reports provided by the medical departments of each service. MEB data classify the medical conditions underlying disabilities by ICD codes. This coding system allows for one to identify more details on the nature of the medical condition involved, and if an injury may be the underlying cause.

In the Naval MEB database, there were approximately 75,000 PEB and associated MEB reports for the period 1989–1993. Of this total, musculoskeletal categories (ICD-9 codes 710–739) accounted for 15,491 board reviews, while injury categories (ICD-9 codes 800–999) accounted for 6634 reviews. A look at the leading musculoskeletal conditions listed in the MEB reports (Table 3) suggests that several of the conditions could have arisen from injuries. Joint disorders, back disorders, and internal derangements of the knee, for example, may represent the long-term sequelae of previous injuries in these relatively young populations.

Table 4 presents the top 10 injury conditions listed in the MEB reports. This information illustrates the common types of injuries directly related to disability cases brought for review. Many of the injuries listed represent severe events, such as fractures.

The LOD reviews for the infantry division showed that 24% of 242 injury cases resulted from athletics, 16% from motor vehicle crashes, 13% from lifting, 10% from self-inflicted wounds, and 7% from fighting.[11,13] Additional MEB data were available from a surveillance project conducted on an Army Infantry Division.[13] The project was undertaken to examine the usefulness of MEB and LOD determination reports as data sources for injury surveillance. Data from 177 reviews in the division in 1994 were examined. There were 83 MEB reviews due to injuries (47%), 88 MEB reviews due to illness (50%), and 5 MEB reviews due to unknown causes (3%). The top 10 reasons for review are shown in Figure 2. Low back pain and knee problems were once again the leading reasons for review.

Table 3. U.S. Navy Medical Evaluation Board—Frequency and distribution (% of total) of top 10 diagnoses of musculoskeletal and connective tissue disorders (ICD-9 code groups 710–739), 1989–1993

Diagnosis	ICD-9 code	Number	%
Joint disorders	719	3578	23.1
Back disorders	724	2572	16.6
Internal derangement of knee	717	1828	11.8
Other derangement of joint	718	1193	7.7
Intervertebral disc disorders	722	1146	7.4
Disorders of muscles, ligament, and fascia	728	744	4.8
Other disorders of bone and cartilage	733	697	4.5
Osteoarthrosis	715	666	4.3
Peripheral enthesopathies	726	589	3.8
Other disorders of soft tissue	729	527	3.4

N = 15,491.
Source: U.S. Naval Medical Information Management System, unpublished data, 1994.

Costs of Disabilities

Disability cases brought for review before PEBs are of interest to the Armed Forces, if for no other reason, because of the compensation costs associated with disabilities. Figure 3 illustrates the trends in disability compensation costs paid directly by the military departments (Army, Navy, Marines, Air Force) for FY 1980–1990 (PJ Amoroso. Personal communication with the Office of the DoD Actuary, Alexandria, VA, 20 August 1998). Overall, compensation expenses have been significant, ranging from $1.2 billion to $1.5 billion in direct payments each year. Individuals with permanent disabilities, who are compensated for life, account for the bulk of this expense, as opposed to individuals with temporary disabilities, who are compensated for a maximum of 5 years (although most ultimately receive permanent disability retirements), or persons receiving a one-time severance payment.

Costs displayed reflect only direct payments to individuals and are based on their disability rating, base pay, and length of service. In addition to the direct annual payments to individuals displayed here, the DoD actuary estimates that the annual obligation for future disability payments is close to $1.5 billion for new disability cases each year. A set-aside of 1% of the total basic pay of all active duty service members is needed to cover this cost.[15]

Discussion

Injury prevention and control remain the primary goals of most injury studies in the military and civilian populations. Achievement of these goals, though, is not possible without solid information systems and injury surveillance activities. As a first step toward these goals, data from the Army, Navy, and Air Force disability agencies were reviewed to identify the possible impact of injury-related disability in the Armed Forces, and to examine the usefulness of the databases for injury surveillance. A number of observations were noted from this effort.

First, from a crude data perspective, the information reviewed suggests that (1) physical disability rates in the Armed Forces are at higher levels this decade than seen in the previous decade; (2) evidence from the data reviewed indicates that 30% to 50% of disability cases

Table 4. U.S. Navy Medical Evaluation Board—Frequency and distribution (% of total) for top 10 diagnoses of injury and poisoning (ICD-9 code groups 800–999), 1989–1993

Diagnosis	ICD-9 Code	Number	%
Dislocation of knee	836	915	13.8
Sprains/strains of knee and leg	844	617	9.3
Ankle fracture	824	444	6.7
Fracture of tibia and fibula	823	338	5.1
Fracture of tarsal and metatarsal bones	825	285	4.3
Fracture of vertebral column without mention of spinal cord injury	805	252	3.8
Sprains/strains of ankle and foot	845	245	3.7
Fracture of radius and ulna	813	232	3.5
Shoulder dislocation	831	192	2.9
Fracture of carpal bones	814	186	2.8

N = 6634.
Source: U.S. Naval Medical Information Management System, unpublished data, 1994.

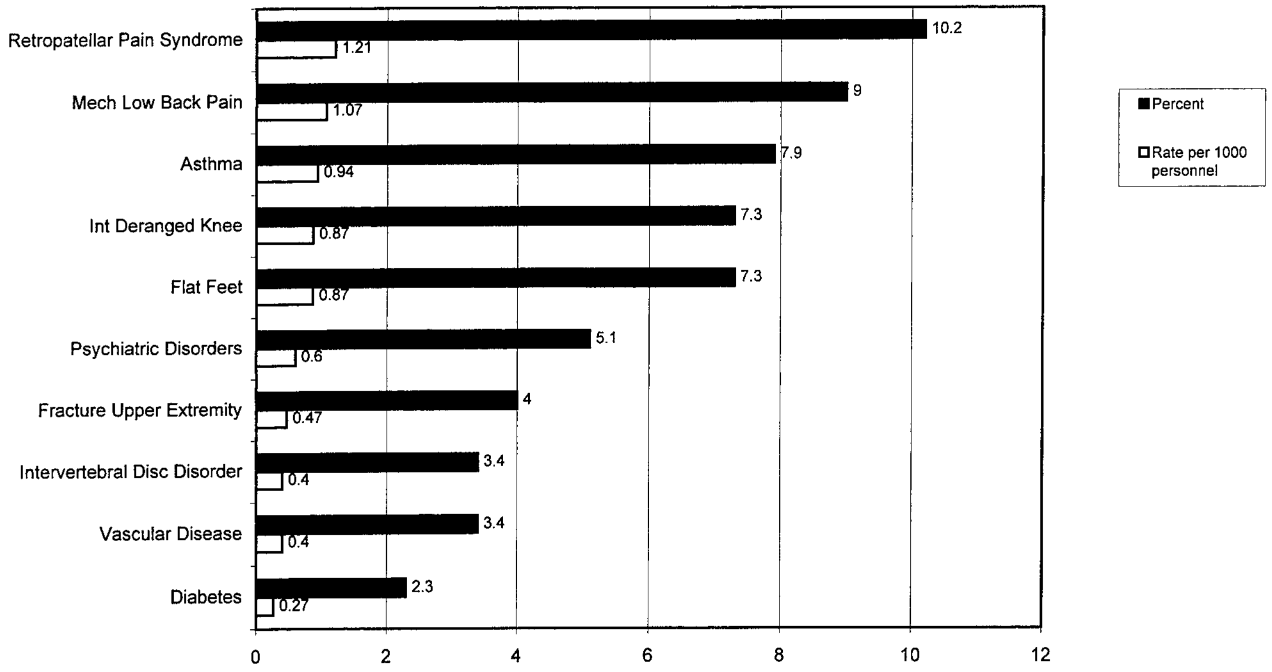

Figure 2. Top 10 reasons for medical evaluation board review in an Army infantry division, 1994 (total medical evaluation board N = 177). Adapted from Page.[13]

could be due to injury; (3) most disability cases under review by PEBs result in discharge from active service; and (4) compensation for these events costs hundreds of millions of dollars.

Second, available information focuses on one form of disability and does not portray the overall burden of disability in the Armed Forces. The information most readily available is found in the administrative data-

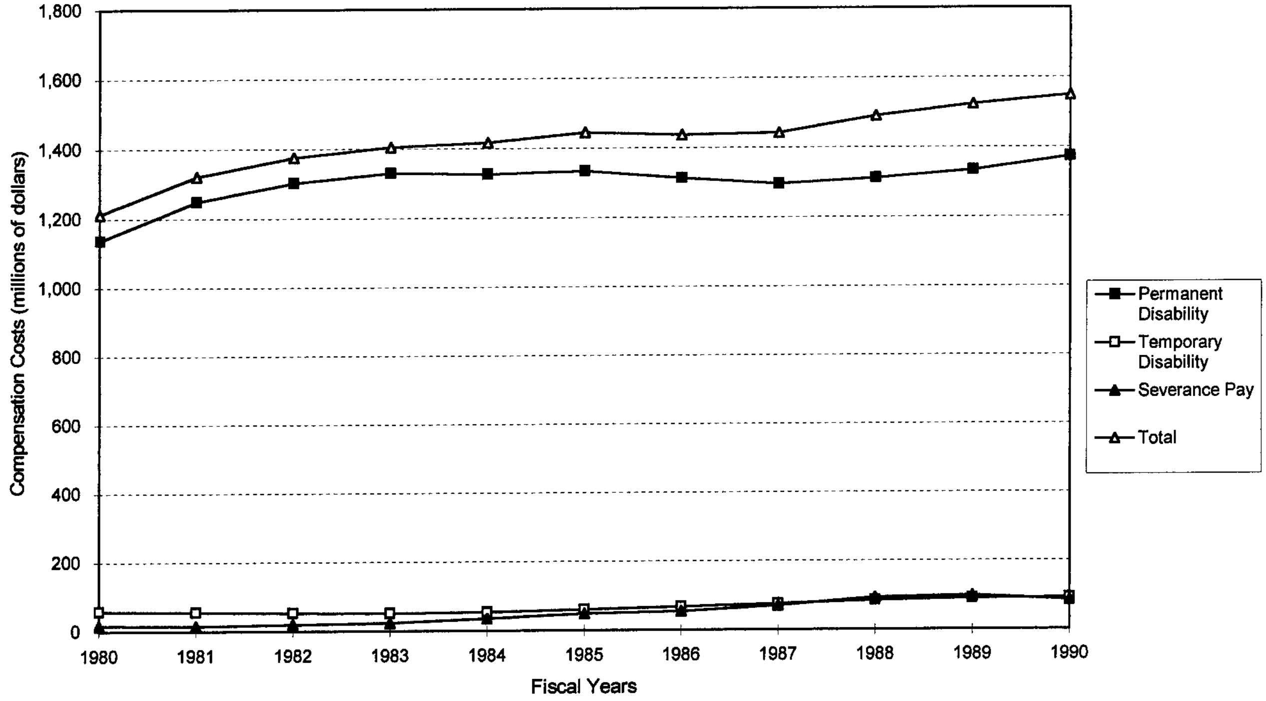

Figure 3. Trends of combined disability compensation costs paid by the military departments (Army, Navy and Marine Corps, and Air Force), fiscal year 1980–1990. Adapted from Military Compensation Background Paper.[14]

bases that characterize cases brought for PEB review and decisions on compensation for disability. The PEB review process serves both a medical/disability function and an administrative function. Thus, there are limitations to its use for research or surveillance purposes. The definition of disability, for example, could change over time. Thus, the temporal trends in the rates of cases reviewed by the services may not reflect true changes, but rather changes in case definitions or changes in the degree to which the definitions are applied.

Third, it is difficult to identify accurately the frequency and burden of injury-related disability in the Armed Forces from existing data sources. Present PEB reports do not reveal/record causes for disability. Further, there are no good injury diagnosis categories in the VASRD coding schemes. While better information on the circumstances surrounding disability are available from MEB and LOD reviews, they have not been integrated with the disability agencies' data sets in any standard and accessible fashion.

A further issue is the difficulty in distinguishing new disability cases in these data systems from cases returning for second and third reviews. This limits the ability to identify the incidence of new injury-related disability and to compare injury-related disability rates among and within the services.

Fourth, evidence from the Naval MEB reports suggest that lower back and knee conditions are among the leading conditions that bring about board reviews and lifetime compensation. Most of these events, while commonly attributed to injuries, were not coded as injuries in the ICD classification, but as musculoskeletal disorders. However, injuries could have been precursors to the ultimate musculoskeletal condition. Unfortunately, the current disability evaluation system focuses on the residual effects of the disabling event, and provides little insight about the potentially preventable initiating causes underlying the disability.

Fifth, perhaps the best use of this information may lie in estimating the long-term costs of injuries from active military service. Economic data can be quite persuasive to decision makers. Evidence from the DoD indicates that the overall compensation costs for disability in active duty personnel are significant, at the level of $1.5 billion per year. The amount associated with injuries is not clear, but could approach $450 million to $750 million per year given that injuries contribute 30% to 50% of all disability cases. In the future, efforts to link compensation costs directly to their associated disabling conditions, such as injuries, could be quite useful for surveillance, prevention, and policy purposes.

Further evaluation of the data sets to determine the associations of risk factors and demographic characteristics with injury-related disability may also prove useful. Assessments such as that by Feuerstein[15] outlining the role of military occupations and gender in disability can identify areas for intervention to reduce disability from injuries and its cost in the future.

Sixth, while the data sets of the disability agencies have been developed to serve an administrative function rather than a surveillance function, there is potential for improving their utility for surveillance of injury-related disabilities. The data sets and reviews of the PEBs and MEBs have unique characteristics that make them useful for evaluating the impact of injuries in the military. For example, these information sources appear to be one of the resources available where similar types of information are collected across the three services using the same medical (ICD-9) codes and (STANAG) cause codes. Moreover, these data sets have the ability to target some of the most important and expensive injuries from a military readiness and cost perspective.

Adding refinements to the data systems, providing checks for quality control, and improving standardization across the military services would likely enhance the usefulness of these data sources for injury surveillance purposes. The following actions should be considered:

- Improve access to information from the Army and Air Force MEB reviews.
- Improve the link between the PEB and MEB data sets.
- Determine the accuracy and completeness of both PEB and MEB datasets in distinguishing injury-related disability.
- Distinguish the initiating events underlying the disability.
- Incorporate elements of the Minimum Basic Data Set for injuries[16] into the MEB and LOD reviews, especially those related to initial causes of disability.
- Include ICD codes in addition to VASRD codes for all disability cases.
- Establish a standardized DoD-wide MEB and PEB database.
- Investigate the potential for linkage of DoD and Veterans Administration databases to allow longitudinal study of the natural history of service-connected disabilities.

It is worthwhile noting that a tri-service disability information system has been proposed. In December 1993, the Deputy Assistant Secretary of Defense (Military Manpower and Personnel Policy) chartered a tri-service work group led by the Office of the Assistant Secretary of Defense (Health Affairs) to study the development of an automated system to provide the capability to link PEB and MEB case files. The current status of this proposal is not clear, but such an automated system across the services could provide a valuable tool to identifying the role of injuries in long-term disability and the costs associated with them—particularly if the criteria for disabilities were standardized and information were available on the precursors to the disabilities observed.

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Hospitalization Due to Injuries in the Military

Evaluation of Current Data and Recommendations on Their Use for Injury Prevention

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Introduction: Injuries inflict the largest health impact on military populations in terms of hospitalization. Hospitalized injuries result in the largest direct costs of medical care and the most lost workdays, include the largest proportion of disabling injuries, and have the largest impact on troop readiness. Efforts are now beginning to focus on how injury surveillance data can be used to reduce the burden of injuries. This article examines the value of administrative hospital discharge databases in the military for routine injury surveillance, as well as investigation of specific injury problems, including musculoskeletal conditions that are frequently sequelae of old injuries.

Methods: Data on hospitalizations for injuries and musculoskeletal conditions were obtained from separate administrative agencies for the Army, Navy, and Air Force. Since 1989, a Standard Inpatient Data Record (SIDR) has been used to ensure uniformity in data collection across the services utilizing standard ICD-9 codes. Cause of injury was coded using special military cause codes (STANAG codes) developed by NATO. Data were analyzed on both nature and cause of injury. Denominator data on troop strength were obtained from the Defense Manpower Data Center (DMDC).

Results: Hospital records data indicate that injuries and musculoskeletal conditions have a bigger impact on the health of service members and military/combat readiness than any other ICD-9 Principal Diagnostic Group (higher incidence and higher noneffective rate or days not available for duty). Hospitalization rates for injury appeared to decline for all services from 1980 to 1992. In 1992, service-specific injury hospitalization rates per 1000 person-years were 15.6 for the Army, 8.3 for the Navy (enlisted only), and 7.7 for the Air Force, while the corresponding hospitalization rate for musculoskeletal conditions was higher in all three services: 28.1, 9.7, and 12.0, respectively.

Conclusions: Military hospital discharge databases are an important source of information on severe injuries and are more comprehensive than civilian databases. They include detailed injury information that can be useful for injury prevention and surveillance purposes. Specifically, it can be used to identify high-risk groups or hazards for targeting prevention resources. These may vary widely by service, rank, and job tasks. Hospital discharge data can also be used to evaluate the effectiveness of interventions for reducing injury rates. Recommendations were submitted to further improve data collection and the use of hospital data for research and injury prevention.

Medical Subject Headings (MeSH): wounds and injuries, hospitalization, military personnel, patient discharge, population surveillance, military medicine (Am J Prev Med 2000;18(3S):41–53) © 2000 American Journal of Preventive Medicine

Introduction

Injuries are an important health problem both in the civilian population[1] and in the military.[2–5] Injuries represent a continuum of severity from minor injuries to those resulting in fatalities. While injury fatalities are an important but relatively rare problem, nonfatal injuries that require hospitalization occur in much larger numbers. Minor injuries are even

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more common but are of generally low impact. Hospitalized injuries result in the most lost workdays, and often result in long-term disability. Hospitalized injuries also represent the most costly group of injuries.[4] For example, in the U.S. civilian population, hospitalized injuries incur the highest total (direct and indirect) lifetime costs—almost twice the costs of fatal injuries and almost three times the costs of nonhospitalized injuries.[6] Among persons aged 15–44 (the age group comparable to most service personnel), hospitalized injuries resulted in the highest costs of any age group. While similar cost data are not yet available for the military, hospitalized injuries clearly represent a major health problem, have the greatest impact on troop readiness, and thus should be given high priority for prevention purposes.

Combat injuries represent a small part of the injury problem in the military. Most injuries in the military occur in similar ways to those in the civilian world. Since 1980, for example, only 2% of military deaths were due to combat-related injuries: 79% of all male and 78% of all female deaths were due to non-battle injuries (unintentional, suicide, and homicide), and only about 20% of all deaths were due to disease.[5] Even in combat situations, noncombat injury hospitalizations are an important cause of loss of readiness in military personnel. For example, data from the Gulf War suggest that injuries and musculoskeletal conditions combined accounted for 39% of all hospitalizations during the operation, but less than 5% of all hospitalizations were battle related.[7,8] Musculoskeletal and connective tissue disorders (ICD code group 710–739) comprised 14% of all hospitalizations, many of which were the chronic or recurrent effects of injuries that occurred before deployment. Because many musculoskeletal conditions are due to long-term sequelae of injuries, they are included in our analyses. Despite the obvious impact of hospitalized injuries on the services, little is known about hospitalized noncombat injuries in the military, how injury data from the services can be used to reduce the burden of injuries, and what lessons can be learned by comparisons with similar problems in the civilian community.

This paper describes the occurrence of hospitalized injuries in the military and examines the usefulness of existing administrative hospital discharge databases for routine injury surveillance and injury control. This paper is based on work initially conducted from 1994 to 1996 as part of the activities of the Armed Forces Epidemiological Board (AFEB) Injury Prevention and Control Work Group. The AFEB is a civilian advisory group on public health matters to the Department of Defense (DoD). The primary objectives of the work group were to determine the magnitude of the problem of injuries in the military relative to diseases and other health conditions, to identify and evaluate sources of medical data with potential for injury surveillance, and to make recommendations for more effective use of available data sources for surveillance, prevention, and research.[2] The findings and recommendations of the subcommittee examining injury hospitalizations are presented in this paper.

Methods

Advice and briefings were provided to the AFEB work group by many military personnel, including those from the DoD Injury Surveillance and Prevention Work Group who provided injury hospitalization data. Each service (Army, Navy, and Air Force) maintains its own separate computerized hospital discharge database. Prior to 1989, each service had created its own independent hospital discharge system, but since then a Standard Inpatient Data Record (SIDR) has been created to ensure uniformity in data collection across the services. The hospitalization databases were set up for administrative purposes as a way of tracking patients and as a medical information system for management of resources and planning service delivery. Their value for injury and medical surveillance has only recently been realized. One of the functions of the AFEB work group was to evaluate the ability of the system to serve this purpose.

The Army data are from the Patient Administration System and Biostatistics Activity (PASBA), and the Air Force data are from the Air Force Medical Support Agency, Medical Information Systems Division (AFMSA/SGSI).[4] Data on the Marines are combined with the Navy data and captured by the Navy Medical Information Management Center (NMIMC). Since one purpose of this study was to examine the suitability of the existing data system for injury surveillance, the authors relied on data as obtained from the original sources. These data have been recently summarized in the *Atlas of Injuries in the U.S. Armed Forces.*[4] The year 1992 was used as the base year for analysis since, at the time of the work group meetings, data for 1992 were the most recent data available. For trend data presented in Figure 1, data up to 1994 were available for the Army and Air Force only.

There were problems obtaining comparable Navy data as the Navy routinely reports its hospitalization data by Major Diagnostic Category (MDC).[9] This method of grouping diagnoses, while based on ICD codes,[10] results in 25 different subgroups rather than the 18 major groups of ICD codes commonly used by the ICD system, and selected for use by the DoD Injury Surveillance and Prevention Work Group. MDCs are formed from Diagnostic Related Group (DRG) codes used in the civilian world for reimbursement purposes. These code groups are based on principal diagnoses or operating room procedures and do not translate well into the ICD groups used by the other two services. Injuries become difficult to separate out using MDCs

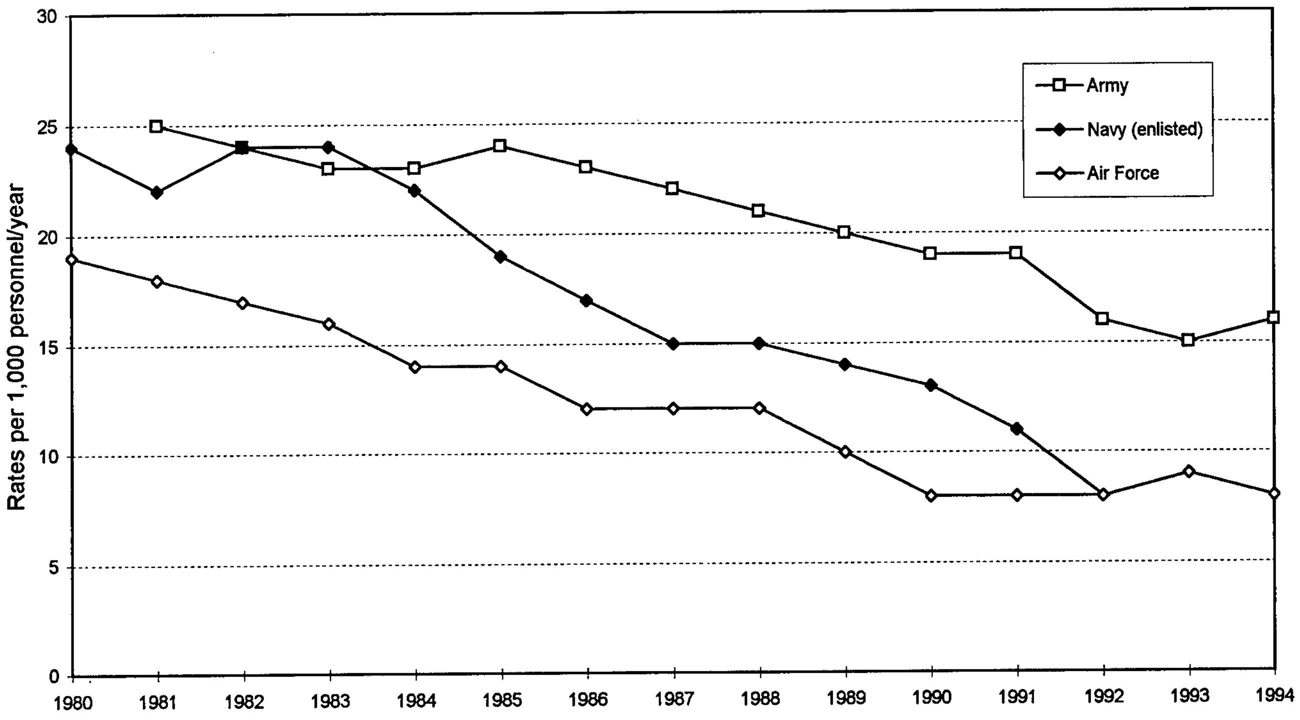

Figure 1. Rates of injury hospitalization by year for Army, Navy, and Air Force personnel, CY 1980–1994 (1980–1992 for Navy only)

because they are coded in multiple places related to the body systems involved (e.g., musculoskeletal; skin; ear, nose, and throat conditions). Thus, it was not possible to obtain comparable ICD-9 group data directly from NMIMC using the 18 ICD-9 code groupings used for the other services. To overcome this difficulty, additional data on injuries by the ICD-9 groups were obtained separately from the Naval Health Research Center (NHRC) in San Diego. At the time this work group was meeting, the NHRC obtained data from NMIMC and used it to build a database of hospitalized injuries for enlisted personnel only and not officers. Therefore, the counts provided by the NHRC do not agree with the standard data reports from the NMIMC, which included officers and provides separate data for Marines.[4] Since the work on this project was completed, the Defense Medical Surveillance System (DMSS), which includes all DoD hospitalization data, has been established and coordinated by the Medical Surveillance Activity Directorate of Epidemiology and Disease Surveillance, U.S. Army Center for Health Promotion and Preventive Medicine.[11] This new system will greatly aid future comparisons between the services.

Denominator data on troop strength were obtained from the Defense Manpower Data Center (DMDC) for all three services. Incidence rates were calculated using mid-year service populations for each year. Data were analyzed by both nature and cause of injury. Detailed analyses of the 10 leading injuries and musculoskeletal conditions were only conducted for the Army to demonstrate the types of injuries involved for the force with the largest population. Similar rankings occur in the other services but not in exactly the same order.[4]

An alternative method used to examine the impact of hospitalizations for injuries focuses on noneffective rates. Noneffective days reflect the nonavailability for service of an individual while in the hospital or on recommended convalescent leave, and combine two variables: length of hospital stay and subsequent off-duty time as a measure of injury severity. A noneffective rate is calculated as the number of persons on the hospital rolls per 1000 personnel per year (sometimes expressed as per day). It is possible to estimate noneffective rates in the Army hospital data using the convalescent leave that a person was assigned upon discharge from the hospital. They are still considered to be on the hospital rolls for this period. Convalescent leave may not, however, reflect actual days off work. More recently, patients are often referred back to their primary physicians straight from the hospital and so the above method of estimating noneffective rates using convalescent leave recommended is less reliable. Other methods to capture convalescent leave should be developed.

Unlike civilian data, which use the external cause of injury (E-code) to describe injury causes, the military uses a modified version called STANAG codes.[12,13] These codes are based on the NATO/STANAG (Standardization Agreement) 2050 coding system and pro-

Table 1. Hospitalization rates (per 1000 persons/year) by principal diagnosis group by service, 1992

Principal diagnosis group	Army	Navy[a]	Air Force
Musculoskeletal conditions	28.1	9.7	12.0
Digestive system	21.2	7.1	21.6
Injury/poisoning	15.6	8.3	7.7
Pregnancy/complications	15.0	9.2	11.4
Respiratory system	11.4	4.6	5.8
Mental disorders	10.3	12.0	7.2
Genitourinary system	8.1	3.9	6.2
Infections/parasitic	7.8	2.3	3.4
Symptoms/ill defined	5.7	3.6	3.4
Other	19.6	11.3	18.9
Total[b]	142.8	72.0	97.3

[a] Enlisted persons only (includes Marines).
[b] May not add due to rounding errors.

vide cause of injury data more suitable to military activities. The four-digit STANAG code has several components. The first digit is known as the Trauma code and describes both the intent of the injury (e.g., battle, self-inflicted) and the duty status (on and off duty, on training), but is not mutually exclusive. The last three digits describe injury cause and activity with the last digit used to describe place of injury for some causes (e.g., at home, in the field, onboard ship). It should be noted that some medical (non-injury) conditions, especially those related to adverse effects and medical complications, can be assigned an external cause code. For musculoskeletal conditions (ICD 710–739), the Army uses STANAG codes only for those that are adverse effects and complications. Their use in the other services has not been examined. As a result of these practices, numbers of admissions using STANAG codes are higher than using ICD injury codes 800–999.

In addition to analyzing injury data, the AFEB work group examined information contained in the hospital discharge databases for each of the services. The strengths and weaknesses of the hospital databases for injury surveillance were evaluated, as was their use for injury prevention program development. Finally, the work group made recommendations as to how the hospital discharge databases could be better used to reduce the burden of injuries to the military. Draft recommendations were circulated for comment to interested groups, including the AFEB, prior to their revision and publication.[2]

Results

Magnitude of the Problem

The leading cause of hospitalization in the Army in 1992 was musculoskeletal conditions (Table 1). In the Navy, mental disorders had the highest rate with musculoskeletal conditions second, while digestive conditions were the leading cause in the Air Force. Injuries were the third leading cause of hospitalization in the Army and Air Force and also the third leading cause in the Navy if pregnancy-related conditions are excluded. In 1992, the 17,718 injury hospitalizations in all three services accounted for 10.9%, 11.6%, and 7.9% of all hospitalizations in the Army, Navy, and Air Force, respectively (Table 2). Service-specific injury rates per 1000 person-years were 15.6 hospitalizations for the Army, 8.3 for the Navy (enlisted), and 7.7 for the Air Force. Hospitalizations for musculoskeletal conditions accounted for 12.3% to 19.7% of all hospitalizations in the three services in 1992 (Table 2). Reported rates of hospitalization for injuries and musculoskeletal and connective tissue disorders (ICD-9 710–739) are substantially higher in the Army than in the other two services, possibly due to differences in risk exposure or discrepancies in reporting cases.

Injury rates declined considerably from 1980 to 1994, but the difference in injury rates between the services has continued (Figure 1). From 1981 to 1992 (years for which we have data for all services), the injury hospitalization rates decreased 38% in the Army (25.1 to 15.6 per 1000 person-years), 62% in the Navy (22.0 to 8.3 per 1000 person-years), and 56% in the Air Force (17.7 to 7.7 per 1000 person-years) (Figure 1). The 10

Table 2. Hospitalization for injuries among U.S. active duty military personnel

	Army		Navy[a]		Air Force	
	1981	1992	1980	1992	1980/81	1992
Hospitalizations						
Number	110,404	91,788	53,707	34,982	86,100	46,059
Rate (1000 persons/year)	142.1	142.8	117.1	72.0	155.0	97.3
Musculoskeletal (710–739)						
Number	12,553	18,050	6,512	4,738	8,400	5,684
Rate (1000 persons/year)	16.2	28.1[b]	14.2	9.7	15.0	12.0
% of all hospitalizations	11.4%	19.7%	12.1%	13.5%	9.8%	12.3%
Injury (800–999)						
Number	19,503	10,011	10,830	4,053	10,005	3,654
Rate (1000 persons/year)	25.1	15.6[b]	23.6	8.3	17.7	7.7
% of all hospitalizations	17.7%	10.9%	20.2%	11.6%	11.6%	7.9%

[a] Enlisted persons only (includes Marines).
[b] Includes carded for record only (CRO) cases (see Table 1).

Table 3. Leading injury and poisoning diagnostic code groups (ICD-9 codes 800–999) for active duty Army personnel hospitalized, 1994[a]

Three-digit diagnosis code group	ICD-9 code	Frequency	Rate[b]
Fracture of ankle	824	452	0.8
Intracranial injury of other/unspecified nature	854	355	0.6
Other complications of procedures, NEC	998	337	0.6
Fracture of face bones	802	330	0.6
Sprains/strains of knee/leg	844	283	0.5
Dislocation of knee	836	280	0.5
Complication peculiar to certain spec procedures	996	227	0.4
Fracture of radius/ulna	813	216	0.4
Fracture of one or more phalanges of hand	818	213	0.4
Open wound of finger	883	179	0.3

[a] Data only available for 1994.

[b] Rates are calculated per 1000 persons per year based on mid-year interval, 1994 DMDC data.

leading types of injuries for the Army are shown in Table 3 to illustrate the types of injuries responsible for hospitalization. Fracture of the ankle was the leading injury type. The injuries listed were only responsible for 41% of all injury hospitalizations, with the balance distributed over a wide variety of different nature-of-injury codes.

Musculoskeletal condition rates exceed those for injuries in the Army (Table 2) and are included in the review because they encompass many sequelae of old injuries or acquired disorders of the musculoskeletal system. In contrast to the trends for injuries, rates for musculoskeletal conditions in the Army increased 75% from 1980 to 1992 (16.2 to 28.1 per 1000 person-years). During the same period, the musculoskeletal hospitalization rates decreased 32% in the Navy (14.2 to 9.7) and 20% in the Air Force (15% to 12%). Most of the 18,050 hospitalizations for musculoskeletal conditions among Army personnel in 1992 were due to recurrent or chronic effects of injuries, such as lumbar and intervertebral disc disorders and internal knee derangement. Internal derangement of the knee is the leading cause of hospitalization in this group for the Army (Table 4). The top 10 musculoskeletal diagnoses alone accounted for 65% of all musculoskeletal and connective tissue disorders in that year and many are effects of old injuries. The increasing rate in the Army may be real or may relate to changes in coding practices. Little is known regarding the epidemiology of musculoskeletal conditions and the individual conditions vary widely. Additional research is needed to fully understand these trends and why musculoskeletal conditions are increasing only in the Army.

Causes of Injury Hospitalization

Analysis of the major STANAG groups for all three services found that reactions, complications, and late effects were the most common condition (Table 5). A more detailed analysis of the 10 leading causes of hospitalization for injuries among Army and Air Force active duty military personnel in 1992 is presented in Table 6. Athletic and motor vehicle–related injuries are prominent in both services. In both the Army and Air Force, athletic injuries were more common than motor vehicle–related injuries in 1992; the reverse was true in both services in 1980 to 1981 (data not shown). Late effects of injury in the Army and complications of medical or surgical procedures in both services are also among the four leading causes of hospitalized injury in 1992. Neither of these latter categories was among the four leading causes of injury in 1980 to 1981. All of the

Table 4. Leading musculoskeletal and connective tissue disorders by diagnostic code groups (ICD-9 code groups 710–739) for active duty Army personnel hospitalized, 1994[a]

Three-digit diagnosis code group	ICD-9 code	Frequency	Rate[b]
Internal derangement of knee	717	2924	5.3
Other derangement of joint	718	1412	2.6
Other/unspecified disorder of joint	719	1276	2.3
Other disorders of synovium, tendon/bursa	727	1258	2.3
Intervertebral disc disorders	722	979	1.8
Other/unspecified disorders of back	724	861	1.6
Acquired deformities of toe	735	859	1.6
Other disorders of bone/cartilage	733	852	1.6
Peripheral enthesopathies/allied syndromes	726	814	1.5
Osteoarthrosis/allied disorders	715	580	1.1

[a] Data only available for 1994.

[b] Rates are calculated per 1000 persons per year based on mid-year interval, 1992 DMDC data.

Table 5. Leading causes of injury hospitalization by major STANAG group by military sevice, 1992

	Rate (1000 persons/year)		
Cause (STANAG codes)	**Army**	**Navy**	**Air Force**
Reactions, complications late effects (250–299)	6.75	3.36	3.55
Falls and other/unspecified (90*–99*)	5.62	3.85	2.81
Athletics, sports, and physical training (200–249)	3.49	2.24	2.76
Land transport (100–149)	2.63	2.03	1.39
Machinery, tools, objects (60*–69*)	2.52	1.38	0.82
Poisons, fire, burns (70*–79*)	1.65	1.06	0.63
Air transport (000–059)	0.87	0.13	0.13
Environmental factors (80*–89*)	0.73	0.29	0.26
Guns, explosives–nonwar (50*–59*)	0.38	0.22	0.06
Water transport (150–199)	0.02	0.15	0.03
Guns/explosives–war (300–499)	0.00	0.00	0.00
Total[a]	24.67	14.72	12.46

* Third digit indicates place.

[a] May not add due to rounding errors.

conditions coded as late effects of injury in 1994 for the Army were musculoskeletal and connective tissue conditions, with ICD-9 diagnosis codes 710–739 (Table 7). The leading causes of late effects were internal derangement of the knee (24%), other disorders of bone and cartilage (18%), other derangement of joints (15%), other and unspecified disorder of joints (12%), osteoarthritis (5%), and other and unspecified disorders of the back (5%).

Based on 1992 data, hospitalizations for injuries were more common among men than women (16.1 versus 11.9 hospitalizations per 1000 person-years in the Army; 8.5 versus 6.5 in the Navy), while hospitalizations for musculoskeletal conditions were less common among men than women (27.2 versus 34.4 in the Army; 9.4 versus 12.0 in the Navy). Comparable figures for the Air Force were available only for 1994; men had higher rates than women for injuries (8.6 versus 7.7 per 1000 person-years) but lower rates of musculoskeletal conditions (13.2 versus 16.9). Similar patterns by gender were observed for Army, Navy (enlisted personnel), and Air Force hospitalizations in 1980. Overall, for acute injuries and musculoskeletal conditions combined, rates were higher in women in the Army, Navy, and Air Force. Analysis of specific causes of injury hospitalization among Army personnel in 1992 found that men were more frequently hospitalized than women for athletic injuries (3.5 versus 1.2 per 1000 person-years) and for fighting (1.0 versus 0.3). Women were more frequently hospitalized for complications of medical or surgical procedures (7.3 versus 2.5 per 1000 person-years) and for poisoning by ingestion (2.5 versus 0.7). Data on race/ethnicity were provided only for Navy enlisted personnel. For this group, 1992 hospitalization rates per 1000 person-years for injuries were 8.5 for Caucasians, 8.7 for African Americans, and 4.7 for other races. Corresponding hospitalization rates by race/ethnicity for musculoskeletal conditions were 9.9, 10.2, and 5.3 per 1000 person-years, respectively. These data have not been adjusted to reflect differences in occupational tasks.

Among all disease groups for the Army, musculoskel-

Table 6. Leading individual cause groups of hospitalization for injuries among U.S. Army and Air Force active duty military personnel, 1992

	Army		Air Force	
Cause of injury	**No. of injuries**	**Rate (1000 persons/yr)**	**No. of injuries**	**Rate (1000 persons/yr)**
Late effects of injury	2762	4.3	276	0.6
Athletics/sports	2045	3.2	1047	2.2
Complications med/surg procedure	1993	3.1	978	2.1
Motor vehicle	1629	2.5	714	1.5
Falls or jumps	1224	1.9	405	0.9
Unknown, unspecified	849	1.3	332	0.7
Machinery/tools	735	1.1	50	0.1
Cutting or piercing objects	659	1.0	163	0.3
Poisoning by ingestion	586	0.9	167	0.4
Fighting (e.g., assault)	583	0.9	107	0.2

This table includes, under injuries, those musculoskeletal and other conditions that received external cause (STANAG) codes for injury (especially those for late effects and complications of medical or surgical procedures).
yr, year.

Table 7. Musculoskeletal and injury ICD-9 diagnostic code groups listed as caused by "late effects of injury" for hospital admissions of active duty Army personnel, 1994[a]

Three-digit diagnostic code group	ICD-9 code	Frequency	% Total
Internal derangement of knee	717	554	24
Other disorders of bone/cartilage	733	403	18
Other derangement of joint	718	344	15
Other/unspecified disorder of joint	719	274	12
Osteoarthrosis/allied disorders	715	111	5
Other/unspecified disorder of back	724	110	5
Other/unspecified arthopathies	716	92	4
Peripheral enthesopathies/allied syndromes	726	79	3
Other disorders of synovium, tendon/bursa	727	69	3
Other disorders of soft tissues	729	61	3
Disorders of muscle, ligament/fascia	728	47	2
Intervertebral disc disorders	722	41	2
Other[b]		118	4
Total		2303	100

[a] Data available only for 1994.

[b] Other represents codes 711, 720, 721, 723, 730, 732, 734, 735, 736, 737, and 738.

etal conditions had the highest noneffective rate (an estimate of time off work) with 331 person days on the hospital rolls per 1000 personnel over a year (data not shown). The next highest noneffective rates were 279 for mental disorders and 182 for injury and poisoning. The noneffective rates vary by injury cause reflecting the severity of the resulting injury. For example, in the Army in 1992, the noneffective rates for motor vehicle-related injury hospitalizations were higher than for athletic injuries, but the incidence rate for motor vehicle injuries was lower than for athletic injuries. It is unknown if similar methods can be used to calculate comparable noneffective rates for the other services. Because of concerns over comparability of data recording, data on noneffective rates are not given for the other services although such data are available from the other agencies.[4]

Strengths and Limitations of Current Hospital Databases

Each of the three services has its own computerized hospital discharge database with records of all hospitalizations for service members. Since 1989, the key database elements have been standardized among all three services using the SIDR system. Data include patient demographics, duty status, outcome, detailed causes and nature of injury codes (ICD9-CM, up to 8 diagnosis fields and 8 procedures), residual disability (about 300 codes but reliability is unknown), and a service-specific code for military occupation (about 1200 codes). The discharge databases are organized on the basis of each individual admission and service person, although transfers from one hospital to the other are recorded as a single episode of care. Specific variables have been added to track readmissions.

A major strength of all military hospital discharge data is the inclusion of a unique personal identifier (ID) number (Social Security Number or an encrypted version) that overcomes many of the problems encountered in analyses of civilian databases. One important area is measuring true injury incidence, because up to 20% of injury admissions to hospitals in the civilian world may be repeat admissions for the same problem.[14] Using the ID number, it is possible to link individual records across multiple admissions for the same injury episode, and to distinguish the first admission for an injury from subsequent readmissions for the same problem or transfers between hospitals. This allows studies of risk factors for frequent readmission to the hospital, such as previous admissions for alcohol problems. Medical records of dependents can also be linked to the common Social Security Number of the service person.

Another important strength of military databases is that excellent denominator data are available from which accurate injury rates can be calculated. The DMDC can provide extensive demographic data on all service members including age, race/ethnicity, gender, pay grade, date of enlistment, occupation, and hazardous duty pay. The DMDC database is updated monthly and data are available for each period. Because many recruits enlist for only 2 to 4 years, accurate data on person-months will often need to be calculated for each person and translated into person-years of exposure, especially in times of rapid changes in the size of the workforce.

Until recently, military hospital record databases were not routinely linked to denominator databases to allow easy calculation of injury rates except for enlisted persons in the Navy. The NHRC has maintained a longitudinal database on enlisted persons and has had considerable experience analyzing hospital discharge data for a variety of health conditions.[15] This database allows linkage of denominator data and identification of repeat admissions for individual persons. Their system provides a model for the use of hospital data for routine medical surveillance. The recent establishment of the DMSS at the Army Medical Surveillance Activity Directorate and the creation of the Defense Medical Epidemiologic Database (DMED) are important new efforts to make hospital discharge data for all branches of the service even more useful for medical surveillance, including injury surveillance.[11]

The DoD also maintains a servicewide hospital data system, the Retrospective Case Mix Analysis System (RCMAS). It combines different hospital discharge databases and contains information (including DRGs) on hospitalized members of the Army, Air Force, Navy, and Marines and their dependents. It represents the first effort to establish a DoD-wide hospital discharge database for use in hospital planning and health service utilization review. It includes data on admissions to all military hospitals (obtained from each service separately), as well as civilian hospitals reimbursed directly for active duty admissions or for other beneficiaries covered under CHAMPUS, the medical insurance program that covers family members and military retirees. This database may be useful for some analyses including checking for civilian hospital treatment for service persons, although retrieval of the entire patient record is understood to be difficult with the current version of RCMAS.

Complete data on cause of injury are available servicewide on all acute hospitalized injuries in the ICD-9 code range, 800–999. The cause is coded using standard NATO/STANAG codes that also include codes on combat-related injuries.[12,13] Unlike civilian E-codes, the military cause codes clearly identify sports injuries by specific types of codes, e.g., 200–249 (Tables 5 and 6). These data provide more detailed cause of injury information, especially for sports, than any civilian database and will provide important information to develop prevention strategies. While this coding system offers some advantages over civilian E-codes, it also has limitations.[16] For example, the Trauma code groups are not mutually exclusive, so an assault on duty cannot be distinguished from an assault off duty using just the Trauma code by itself. Since the ICD code often carries some information regarding intent, it is possible to provide more complete data for a given case by using the ICD code for intent and the Trauma code for duty status, but in practice this is rarely done. Another problem is that over 50% of duty status in the Army (51% in 1992) is described as unknown (code 9), which restricts the ability to examine on-the-job and off-the-job injuries separately. A validation study conducted at an Army Medical Center in 1997 indicates that in almost 80% of those cases there is sufficient information available in the original medical record to determine the work relatedness and duty status of these injuries.[30] Similar data have not been examined for the other services.

Exposure to hazards is an important determinant of injury risk. These may vary widely by service, rank, and job tasks. The ability to use occupational title (Military Occupational Speciality or MOS)[17,18] and pay grade to adjust for occupational exposures is a means of assessing exposure and is enhanced by the development of a revised DoD coding system for occupational titles. This coding system will allow comparison of injury rates for similar occupational groups (MOS) in the different services.[17] This is important in comparing injury rates between different groups such as men and women.[19,20] For example, Zwerling et al.[21] demonstrated that, when adjusted for work-related exposures using occupational titles, female postal workers have higher occupational injury rates than men. Similarly, such analyses of military hospital databases may lead to important insights into specific injury hazards in certain groups. Analyses of hospital data for the Army found that MOS was missing on the hospital file for most cases, but could be obtained by linkage with the DMDC's personnel (demographic) files.

In reviewing available data, the work group had concerns as to the quality of hospital data available during combat and other deployments. The quality and completeness of this data have never been evaluated. One particular problem noted was that a specific cause-of-injury code was available for only 50% of records during deployments.[8] In addition, long time delays in the availability of data were experienced. Another potential problem with the hospital discharge data is that it also contains admissions for National Guard and Reserve soldiers. Especially during periods when these soldiers are activated, such as the Gulf War, they may be coded as active duty soldiers by the hospitals. These cases are, however, not included in the denominator for calculation of injury rates and thus inflate injury rates during times of conflict. This problem can be overcome by matching cases with the active duty demographic files and excluding cases that do not match, which is being done by both the Army TAIHOD system[12] and the new Defense Medical Surveillance Activity.[11]

Rates of injury hospitalizations for the services, particularly the Army, appear to be higher than those for civilian populations[6]; however, military hospitalization rates may not be directly comparable to civilian rates. All service members have free health care and unlimited sick leave so there is no potential barrier to hospitalization, i.e., incurring personal cost. In addition, some injured trainees, especially those living in group quarters with no one to care for them during the day, may be hospitalized for conditions such as stress fractures or other more minor conditions that would not result in hospitalization in the civilian community. In addition, the military hospital system also often creates a record for certain medical events that use their facilities, even though the person may not have been admitted to the hospital as an inpatient. These are called carded for record only (CRO) cases and include deaths not admitted, cases for disability board evaluations, other medical cases of common interest such as rapes or motor vehicle injuries, and some special events that the service wishes to track. Not all cases in the hospital data files were actually admitted to the hospital and so should not be counted when calculating hospital admission or discharge rates. The category of CRO appears to be more widely used in the Army. Recent data from DMED for 1992, which now excludes CROs, reduced the admission rate for musculoskeletal conditions in 1992 from 28.1 (Table 1) to 21.7 and for injuries from 15.6 to 13.8 per 1000 person-years. The role of CRO cases and their influence on calculation of accurate injury incidence rates needs to be examined and is discussed in more detail in our more recent analyses of the Army data.[16,30] All future analyses should exclude CRO cases from analyses of injury incidence.

A small proportion of hospitalizations of military personnel also occurs in civilian rather than military hospitals. In theory, any admission to a civilian hospital is captured by the military hospital discharge database as part of the reimbursement process. However, the quality and completeness of these data for injuries are unknown at this time, especially if patients are not directly transferred back to military hospitals as part of the same episode of care. Similarly, it appears that admissions on board ship are not captured by the Navy hospital database, thus undercounting some injuries in the Navy. More work is needed to determine the effects of interhospital transfers on hospitalization rates for each of the services.

In addition to these concerns, a number of other important questions related to injury hospitalizations were raised in the authors' review and deserve further investigation:

- Little is known regarding musculoskeletal conditions, which represent a significant cause of hospitalization. Some are due to systemic conditions such as rheumatoid arthritis. Which codes of the musculoskeletal conditions should be included and excluded in calculations of rates for hospitalized injuries or their sequelae, so that a common definition can be used across all services? Do changes in coding or admission practices (e.g., outpatient surgery) account for the increasing rate of hospitalized musculoskeletal conditions in the Army while the same rate is decreasing in the Navy and Air Force?
- What accounts for the increasing rates over the past decade of reported complications of medical and surgical procedures and of late effects of injury?
- Do rates of hospitalized injuries vary by age after taking into account differences in risk exposure?
- Can standard methods for ascertaining numerators and denominators for hospitalization rates be used for all services even though the databases depend on different data management systems?
- Are noneffective rates being calculated consistently across the services, and are such rates a better reflection of the true cost of injuries than hospitalization rates? Is it possible to develop more accurate means to estimate the total time off from a hospitalized injury?
- What is the quality of the data available in the various military hospital medical record systems? How reliable are the codes given?
- How well are data for military personnel hospitalized in civilian hospitals incorporated into the military data system?
- Are there differences in the threshold for hospitalization among the services or even within a service depending on geographic considerations?
- How has the threshold for hospitalization changed over time as policies have changed to reduce length of stay?

Discussion

Hospital discharge records indicate that injuries and musculoskeletal conditions are the major causes of admission to hospitals in the military and subsequently account for the largest direct costs of medical care. They are costly because major trauma is associated with long lengths of hospital stay, and musculoskeletal injuries are associated with many expensive hospital procedures. They also have a major impact on troop readiness (larger than any other ICD-9 Principal Diagnostic Group) and result in more noneffective days for soldiers than any other health condition. The combined categories of injuries and musculoskeletal disorders accounted for slightly more than 30% of all Army hospitalizations in 1992. The major causes of hospitalization include sports injuries, motor vehicle crashes, falls, and jumps. Major types of injuries include back and knee injuries as well as fractures. Hospitalization rates for injury appear to be declining for all services over the past decade (less so in the Army) although more research is needed to examine why this has occurred and to determine if the change is real or artifactual. Musculoskeletal injuries are an increasing problem in the Army but are declining in the other services. Reasons for these changes are not known at present and also require further research. Because the purpose of this paper was to comment on the quality of routinely available data and to make suggestions as to how they could be improved, we relied largely on the data provided by the various DoD agencies using their standard procedures for reporting. Since then we have examined several of the databases in detail ourselves and revealed a number of problems with these data. Despite these problems the data clearly demonstrate the burden of hospitalized injuries on the military.

Use of Hospital Databases for Prevention

Hospital discharge data including detailed injury information can be useful for injury prevention and surveillance purposes. The first step is to identify specific high-risk groups or hazards for targeting prevention resources. Hospital discharge data can also be used to evaluate the effectiveness of interventions for reducing injury rates. The following examples illustrate some of the uses of hospital discharge data to develop and evaluate injury prevention strategies.

Comparisons of injury rates among different services, and groups within the same service, may identify significant differences in injury risk and suggest new prevention strategies, since different injury prevention policies or practices may serve as natural experiments. Differences in rates for a particular injury may suggest areas for further research, as in studies comparing injury rates among countries.[22] One example in the military was an observation that there were large differences in injury rates occurring in basic training between different Army companies. This prompted follow-up studies that found differences in training styles and led to advice on new methods to reduce training injuries.[23–25] Similar situations may be found when comparing rates of other types of injuries among different services and could lead to safer ways to carry out certain tasks.

Analysis of injury trends over time can also provide important insights into causes and prevention strategies for specific injury problems. The decrease in motor vehicle injuries in the military over the past decade (noted in Results section) demonstrates the effectiveness of motor vehicle injury prevention strategies. It mirrors a national trend that is due in part to safer vehicles, increased seat belt use, and improved highway engineering.[26] The increase in relative importance of athletic injuries, however, demonstrates the need for continued research in this area.

Caution must be exercised in examining inter-service differences for two reasons. First, there are important differences in exposure to various risks among the services. Second, there are variations in policies and reporting practices among the services. For example, CRO cases must be excluded before meaningful comparisons can be made. These have not been excluded in either the data we obtained or the data in the DoD atlas.[4] There may also be differences in admission practices for hospitalization among the services, particularly in recent years when there is pressure to treat people as outpatients. Figure 1 shows that the decline in injury hospitalization has occurred much faster in the Navy and Air Force. It is unknown if the differences reflect better injury prevention practices or changes in admission criteria. External factors such as a change in admitting practices for minor head injuries, for example, can produce a dramatic change in the apparent rate of minor head injuries, but little change in the rate of serious head injury. One approach would be to examine certain injuries—such as skull fractures—that are always likely to be admitted, and determine change in relation to other injuries. Analyses using stratification by injury severity[27] will be important in examining trend data.

There is increasing realization of the value of a free-text field in surveillance databases for injuries to better describe the causes and circumstances of injury.[28–30] One of the limitations of current hospital databases is that the STANAG or E-codes provide only limited information on the specific causes of injury. The 90-character free-text description on the cause of injury in the New Zealand hospital discharge database, for example, has proven valuable for identifying specific causes or hazardous products and has led to the development of effective prevention strategies.[28] The addition of a similar field to military hospital record databases would greatly increase their usefulness for prevention purposes and would also provide an important means to evaluate coding accuracy.[31] At present, a free-text field is in use by some Army hospitals to describe injury circumstances and is entered by the admissions clerk. The text field can be used to better advantage by recording more specific cause-of-injury information and making provisions for updating once more details of the case become available. The fact that a free-text field is already a component of the Composite Health Care System (CHCS), the software used by all military hospitals, indicates that changes could be implemented rapidly and perhaps without great cost. The text fields would be better completed at discharge when more data are available. The text field should be incorporated as part of the SIDR and be available for analysis for all services' admissions.[16,30]

There is increasing need for more analytical studies in occupational injury research that examine alternative and more cost-effective approaches to identifying preventable risk factors.[31] Linkage of different data files is increasingly being realized as an important and low-cost tool for injury research and surveillance.[29] The existence of the unique ID number in the military permits in-depth analytical studies of various factors through linkage of hospitalized injury cases to other military databases. For example, the Army has been able to link exposure data on individuals from the Health Risk Appraisal (HRA) system with hospitalization data.[12,32–34] The authors have recently applied this approach to study smoking and risk of developing musculoskeletal disability[33] and risk-taking behaviors and motor vehicle risk.[34] Other potentially useful databases include information on detailed injury investigations from the Army Safety Management Information System or on permanent disability from disability board evaluations.[12,32] Still other examples of possible studies include studying injury risk in pregnancy[35] by examining cohorts of pregnant women or conducting nested case-control studies within the longitudinal data set with controls selected from the DMDC database. One could also examine, for example, whether women with a prior hospitalization for assault are at an increased risk of homicide or a repeat hospitalization, and whether the risk increases exponentially with each subsequent hospitalization. This information could be used to develop interventions such as screening programs for women at risk with appropriate follow-up.

Although existing databases can provide useful information for injury prevention purposes, they have some limitations, particularly with regard to exposure issues, details of clinical care, and information on disability. Follow-up studies involving original data collection will often be needed to examine specific problem areas. One such example is the lack of information on many of the long-term consequences of nonfatal injuries. By linking hospital data to existing disability databases, it may be possible to answer some of these questions. However, no data on disabilities are available in databases on intermediate outcomes, especially physical profiles assigned (e.g., restricted duties) or outpatient treatment, and only disability board evaluations for discharge from the military are available.

Another limitation of hospital discharge data is that hospital procedure data is based on ICD-9 procedure codes. These are often outdated or even irrelevant because of the rapidly changing nature and development of surgical techniques. A much more up-to-date system, the Current Procedure Terminology (CPT) codes, has been developed by the American Medical Association and is updated regularly.[36] If these were used for military hospital data, as they are for civilian outpatient data, much more useful information for evaluating treatment outcomes would be available. Similarly, alcohol testing of all trauma patients and inclusion of the data in the record would both greatly enhance patient care and provide important information for developing prevention programs.[37,38]

In recent years there has been increased recognition within the military of the value of hospital discharge data for use in planning and evaluating prevention programs and for research on all health problems, not just for injuries. The recent establishment of the Tri-Service DMSS and the creation of the DMED is an important new effort to make hospital discharge data more useful for medical surveillance, including injury surveillance.[11] DMED was developed to standardize the epidemiologic methods used to collect, store, and analyze Tri-Service data. It includes the capacity for remote access through a user-friendly interface as a means to promote the use of the data for research and policy. Similarly, the NHRC is expanding their data to include all officers. The Army has established the Total Army Injury and Health Outcomes Database (TAIHOD), a relational database for use in ongoing injury research studies; similar efforts are ongoing in the Air Force. These efforts should be encouraged, and will overcome several of the problems noted in this review.

Recommendations

The hospital discharge databases have perhaps the greatest potential of any medical databases (military or civilian) for comprehensive injury surveillance. The following outlines our recommendations for both the increased use of these databases in their current format and potential improvements to aid surveillance, research, and prevention.

- Use hospital records routinely for injury and medical surveillance and research, both for activities within the military and for research by outside experts. Ongoing efforts to develop these should be encouraged.
- Add a free-text field to existing databases included as part of the SIDR that accurately and concisely describes how the injury occurred and all involved factors.
- Implement consistent definitions and classifications across time, place, and service (e.g., criteria for hospitalization, noneffective days, injury type/acute versus chronic).
- Improve quality of data collection in deployment and combat situations to make consistent with data collection in fixed facilities—especially for the cause of injury information.
- Assess quality and consistency of coding and determine need for further training of coders.
- Focus research on prevention of sport injuries and falls, which are both major causes of reduced troop readiness.
- Exclude CRO cases from calculation of injury discharge rates from hospital, and develop means to properly count inpatient transfer records.
- Develop strategies to more effectively link and use hospital and other databases in the military, including those with exposure data. Safety center data, for example, are an important source of information on causes and circumstances of injuries as they often do in-depth investigation of accidents.[39] However, they are linked only in research databases such as TAIHOD and their completeness of ascertainment has not been adequately evaluated.
- Develop automated outpatient data systems compatible with inpatient systems and which include cause-of-injury coding.
- Include CPT codes to better describe hospital procedures and facilitate evaluation of treatment outcomes.
- Use non-effective rates as an indicator of the time lost from work and thus lost readiness. New methods (such as linkage with sick leave) must be developed

to estimate noneffective rates that recognize changes in the way data are recorded in the hospital databases. Computerization of short-term outcome data such as physical profiles should be included in this effort.

- Examine the causes of musculoskeletal conditions and the large increase in their rates in the Army.
- Conduct studies of the factors that account for the declining rates of hospitalized injuries in all three services. Are more injuries being treated in outpatient clinics?
- Investigate family violence and workplace violence using hospital databases.
- Examine work- versus nonwork-related injury (cross-cutting all databases), and establish a policy to require recording of the trauma code to more accurately and completely record the duty status of injured patients.
- Establish a new variable in addition to "on-duty status" to identify work-related injuries as a specific variable. The trauma code does not allow work-related assaultive injuries, for example, to be identified. There should be separate codes for intent and duty status.
- Evaluate processing and quality of data for active duty military personnel treated in civilian hospitals (and if all cases are recorded in the database) and admissions on board ship.

Conclusions

Military hospital discharge databases are an important source of information on severe injuries and are more comprehensive than civilian databases. Although initially collected for administrative purposes and seldom used for epidemiologic studies, the military hospital databases provide a unique opportunity to overcome many of the problems encountered in the use of civilian hospital discharge databases to study injuries. The presence of good external cause codes for the acute injuries and the ability to link repeat admissions and to link with other databases are important strengths of the hospital data. Little or no data on causes are available for the musculoskeletal conditions. Unlike most civilian hospital databases, the military data can be used for separate analyses of both work-related and recreational injuries as well as off-duty motor vehicle injuries. However, improved coding of the trauma code is needed to better record injuries occurring at work/on duty. Studies of military occupational injury problems, therefore, have important implications for both civilian and military populations.

The existence of a unique personal identifier is one of the most important features of the military databases for use in medical surveillance and for subsequent research to address important injury problems in the military. The authors encourage the use of the data by both military and civilian research groups. Good demographic data on military troop strength are available and can be incorporated at the level of the individual patient combined with denominator data. However, other measures of exposure are more difficult to access and require more investigation. Uniform data do exist among services for some variables, but more attention should be paid to cross-service comparisons especially with regard to excluding CRO cases and transfers. Future studies of hospital data for injury should focus on military readiness and costs, and in evaluating the quality of data available, including any free-text data.[16,30,40]

In summary, the military hospital discharge databases provide tremendous potential for injury surveillance in addition to surveillance for other medical problems. To date, the data have been underutilized by the military. The data are especially useful now that they are routinely linked with population-based denominator data from the DMDC. The establishment of comprehensive research and surveillance databases of hospitalized injuries should be a priority in any injury control program in the military. Only through the implementation of these recommendations can the services fully realize the large potential that hospital databases have to improve our understanding of injury problems and reduce the burden of injuries to the military and society as a whole. If previous research in the civilian world is to be used as an example, we can expect major reductions in injuries and significant improvements in troop readiness both in peacetime and combat situations.

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Military Training-Related Injuries

Surveillance, Research, and Prevention

Kenton R. Kaufman, PhD, Stephanie Brodine, MD, Richard Shaffer, PhD

Background: Musculoskeletal physical training-related injuries are a major problem in military populations. Injuries are important in terms of loss of time from work and training and decreased military readiness. The implications of these injuries in terms of patient morbidity, attrition rates, and training costs for military personnel are staggering. This article reviews: (1) pertinent epidemiologic literature on musculoskeletal injury rates; (2) injury type and location; and (3) risk factors for military populations. Suggestions for injury surveillance and prevention are also offered.

Methods: Existing military and civilian epidemiologic studies were used to estimate and compare the size of the injury problem, identify risk factors, and test preventive measures. Most of the military research data obtained was from Marine and Army recruits, Army Infantry soldiers, and Naval Special Warfare candidates. Additional studies conducted in operational forces provided documentation of the injury problem in these populations as well.

Results: Injury rates during military training are high, ranging from 6 to 12 per 100 male recruits per month during basic training to as high as 30 per 100 per month for Naval Special Warfare training. Data collected show a wide variation in injury rates that are dependent largely on the following risk factors: low levels of current physical fitness, low levels of previous occupational and leisure time physical activity, previous injury history, high running mileage, high amount of weekly exercise, smoking, age, and biomechanical factors. (Data are contradictory with respect to age.)

Conclusion: Considering the magnitude of training injuries in military populations, there is a substantial amount of work that remains to be performed, especially in the areas of surveillance, prevention, and treatment. Modifiable risk factors have been identified suggesting that overuse and other training injuries could be decreased with proper interventions. Outpatient surveillance systems are available to capture musculoskeletal injury data but need to be refined. Given the size of the problem, a systematic process of prevention should be initiated starting with routine surveillance to identify high-risk populations for the purpose of prioritizing research and prevention. Properly planned interventions should then be implemented with the expectation of dramatically reduced lost work/training time, attrition, and medical costs, while increasing military readiness.

Medical Subject Headings (MeSH): military medicine, military personnel, wounds and injuries, epidemiology, musculoskeletal system, primary prevention (Am J Prev Med 2000;18(3S):54–63) © 2000 American Journal of Preventive Medicine

Introduction

Musculoskeletal injuries are a major problem in military populations. This category of injuries is treated primarily on an outpatient basis. Unfortunately, Department of Defense (DoD) service-wide outpatient surveillance data have only recently become available. Therefore, we must rely on existing epidemiologic studies to estimate the size of the problem, identify risk factors, and begin to propose and test preventive measures. Most of the research has been conducted on Marine and Army trainees. Army infantry soldiers, Navy special forces, and some others have also been studied. Risk factors have been identified that are amenable to intervention. However, few intervention trials have been undertaken. Outpatient surveillance systems capable of capturing cause-of-injury data have been recently developed to obtain a research-based musculoskeletal injury database in select military populations. The success of these systems sug-

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Table 1. Rate of outpatient musculoskeletal injuries in military operational and training units

				Rate (n/100/month)	
Study	**Year**	**Population**	**Observation period**	**Female**	**Male**
Reynolds et al.[3]	1994	Army Infantry N = 181; all male	52 weeks	—	6.5[a]
Tomlinson et al.[4]	1987	Army Infantry N = 15,295; m = 14,178: f = 1117	8 weeks	3.3[a]	6.6[a]
Knapik et al.[5]	1993	Army Infantry N = 298; all male	26 weeks	—	11.8[a]
Linenger et al.[6]	1993	Naval Special Warfare Training N = 88; all male	25 weeks	—	29.7[a]
Riddell et al.[7]	1990	Royal Marines Commandos	52 weeks		
		N = 18,040; all male	(1985)	—	33.5
			(1981)	—	34.4

[a] All injuries.

gests that simple surveillance tools can provide important data.

This paper reviews the pertinent epidemiologic literature on musculoskeletal injury rates, injury type, and location and risk factors for military populations. It also provides suggestions for injury prevention.

Methods

Information presented to the Armed Forces Epidemiological Board's (AFEB) Injury Control Work Group by scientists from the Navy and Army research organizations was evaluated. In addition, existing published military and civilian epidemiologic studies were used to estimate and compare the size of the problem, identify risk factors, and identify tested preventive measures. The research reviewed pertained primarily to Marine and Army recruits, Army infantry soldiers, and Naval Special Warfare candidates. A few studies conducted in other military training and operational populations were also evaluated.

Size of the Problem

Military physical training (PT) programs are critical to operational readiness. High musculoskeletal injury rates occur as a result of PT (Tables 1 and 2). Injury rates can be calculated to range from 10 to 15 per 100 recruits per month for male recruits, 15 to 25 per 100 per month for female recruits, 6 to 12 per 100 per month for infantry, and 30 to 35 for Navy special warfare candidates.[1–14] The majority of these injuries

Table 2. Cumulative incidence of outpatient musculoskeletal injuries during military recruit and advanced training

				Incidence (%)	
Study	**Year**	**Population**	**Observation period (weeks)**	**Female**	**Male**
Reinker and Ozburne[8]	1979	Army trainees	16	16.3	7.5
Kowal[9]	1980	Army recruits N = 1170; m = 770, f = 900	8	54.0	26.0
Jones et al.[10]	1992	Army recruits N = 310; m = 124, f = 186	8	50.5	27.4
		N = 2245; m = 1349, f = 896		43.5	27.4
Jones et al.[1]	1993	Army recruits	8	50.5[a]	27.4[a]
		N = 310; m = 124, f = 186		44.6[b]	20.9[b]
Jones et al.[11]	1993	Army recruits N = 303; all male	12	—	37.0[b]
Knapik et al.[5]	1993	Army infantry N = 298; all male	26	—	50.7[a]
Almeida et al.[12]	1999	Marine recruits N = 1296; all male	12	—	36.0[a]
Kaufman et al.[13]	1999	Naval Special Warfare N = 449; all male	25	—	33.1[b]
Shaffer et al.[14]	1999	Navy recruits N = 8865; all female	9	37.2[a]	—
		Marine recruits N = 2766; all female	13	44.4[a]	—
		Marine officer candidates N = 303; all female	10	61.7[a]	—

[a] All injuries.
[b] Lower extremity.

Table 3. Incidence of stress fractures among military trainees

Study	Year	Population	Observation period (weeks)	Incidence (%)		Relative risk, F/M
				Females	Males	
Protzman and Griffis[15]	1977	Cadets, West Point n = 1330; m = 1228, f = 102	8	10.0	1.0	10.0
Reinker and Ozburne[8]	1979	Army trainees	8	2.2	0.8	2.8
Kowal[9]	1980	Army trainees n = 417; m = 202, f = 215	8	21.0	4.0	5.3
Scully and Besterman[16]	1982	Army trainees n = 6677; all males	8	—	1.3	—
Brudvig et al.[17]	1983	Army trainees n = 295; m = 144, f = 151	8	3.4	0.9	3.8
Gardner et al.[18]	1988	Marine recruits n = 3025; all male	12	—	1.3	—
Pester and Smith[19]	1992	Army recruits n = 109,296; m = 76,237; f = 33,059	8	1.1	0.9	1.2
Jones et al.[1]	1993	Army recruits n = 310; m = 124, f = 186	8	12.3	2.4	5.1
Winfield et al.[20]	1997	Marine Corps officer candidates n = unspecified; m = unspecified; f = 104	10	11.5	7.9	1.5
Kaufman et al.[13]	1999	Naval Special Warfare n = 451; all male	25	—	8.7	—
Shaffer et al.[21]	1999	Marine recruits	12	—		—
		n = 1286; all male			4.0	
		n = 1078; all male			3.7	
Shaffer et al.[14]	1999	Navy recruits n = 8862; all female	9	3.9	—	—
		Marine recruits n = 2766; all female	13	5.7	—	—
		Marine officer candidates n = 303; all female	10	9.6	—	—

are lower extremity musculoskeletal injuries. The cumulative incidence of injuries during military training of varying durations ranges from 8% to 51% for men (Table 2). The data also suggest that female trainees in any given study experience about twice the incidence of musculoskeletal injury during training as their male counterparts (Table 2). Further, the data suggest that women are at a 1.2 to 10.0 times greater risk of suffering bone stress injuries as men in U.S. military training populations (Table 3).[1,8,9,15–21] However, it has been demonstrated recently that the increased injury rates among women may be due more to lower levels of fitness at the time of entry into training[1,2] and not gender per se.

Comparisons of military training injury rates[1–14] with those of civilian athletes and exercise participants[22–43] provide a perspective for understanding the magnitude of the problem of injuries in the military. The rates of injuries for military recruits and infantry soldiers appear to be about the same or a little higher than for endurance athletes, but considerably lower than for contact sports participants.[22–24] Prospective epidemiologic data on all sports injuries were collected in a casualty ward for one year in a well-defined metropolitan area with 124,321 inhabitants.[25] The incidence of sports injury was 61 per 1000 active sports players per year and 15 per 1000 inhabitants in the catchment population per year. Studies of injuries among distance runners report annual overall incidence ranging from 24% to 65% for heterogeneous populations of recreational and competitive runners (Table 4).[26–30,34–41] These injuries were severe enough to cause a reduction or cessation of training, and 12% to 44% sought medical attention.[26–31] For athletes and exercise participants, annual rates as high as 0.9 to 2.3 injuries per participant (93 to 233 injuries per 100 person-years) have been reported (Table 5).[24,32] In the study by Requa et al.[32] (see Table 5), a majority of injuries (76%) resulted in time lost from activity among exercising adults. Garrick[33] reported that 49% of aerobic dance participants experience injuries over an average follow-up period of 12 to 13 weeks. Twenty percent of these aerobics participants suffered injuries severe enough to require professional medical attention.

Results of studies reported in the literature clearly show that the rates of injury associated with vigorous weight-bearing exercise are high. These high injury rates can be attributed to repetitive strenuous physical activities for both civilian exercise participants and military trainees. Available data suggest that those in-

Table 4. Annual injury incidence among runners in civilian studies

Reference	Year	Gender	N	Duration of study (years)	Annual incidence (%/year)
Jacobs and Berson[34]	1986	m + f	451	2	24
Bovens et al.[35]	1989	m + f	115	1.6	29–36
Blair et al.[36]	1987	m + f	438	1	24
Holmich et al.[37]	1989	m + f	1426	1	31
Koplan et al.[28]	1982	m + f	1423	1	37
Marti[38]	1988	f	428	1	40
Holmich et al.[39]	1988	m	60	1	43
Marti[30]	1989	m + f	4786	1	45
Walter et al.[40]	1989	f	301	1	46
Marti et al.[27]	1988	m	4358	1	46
Macera et al.[29]	1989	f	98	1	49
Walter et al.[40]	1989	m	980	1	49
		m + f	1265	1	50
Macera et al.[29]	1989	m	485	1	52
Walter[41]	1988	m + f	476	1	57
Lysholm and Wiklander[42]	1987	m + f	LDR (28)	1	57
		m + f	All 60	1	65

m, male; f, female; LDR, long distance runners.

jury rates among military recruits and infantry soldiers are higher than for civilian distance runners and about the same as or a little lower than civilian competitive athletes and vigorous exercise participants.

Types of Injuries

The most common types of injuries seen in military and athletic populations are musculoskeletal overuse injuries. The majority of the injuries associated with military training occur at or below the knee (Table 6).[5–7,11,12,14,44] A study during Army infantry basic training reported that the five most commonly diagnosed conditions were pain attributed to overuse or stress syndrome (23.8%), muscle strains (8.6%), ankle sprains (6.3%), overuse knee injuries (5.9%), and stress fractures (3.0%).[11] Among 298 infantry soldiers, the most common injury diagnosis was musculoskeletal pain, followed by strains, sprains, and cold-related injuries.[5] The distribution (percentage) of commonly diagnosed injuries in Army male recruits was low-back pain (7.3%), tendinitis (6.5%), sprains (4.8%), muscle strains (3.2%), and stress fractures (2.4%).[1] In the same training program, the incidence was higher for women, and the distribution of the most frequent injuries was different, with muscle strains (15.6%), stress fractures (12.3%), sprains (5.9%), tendinitis (5.5%), and overuse knee complaints (2.1%) occurring most commonly. Lower-extremity injuries were also found to be common among 1296 male Marine recruits at the Marine Corps Recruit Depot (MCRD) in San Diego.[12] The most common specific injuries seen were ankle sprains (6.2%), iliotibial band syndrome (5.3%), stress fractures (4.0%), patellar tendinitis (2.4%), and shin splints (1.8%). Some of the highest injury rates have been reported in Naval Special Warfare training.[13] Among 449 trainees, the incidence of the most common injuries was stress fractures (13.4%), iliotibial band syndrome (10.9%), patellofemoral syndrome (9.4%), Achilles tendinitis (6.7%), and periostitis (3.1%). The rates and distribution of injuries in various military populations may vary due to differences in training and differences in the definition and classification of musculoskeletal injuries. Musculoskeletal overuse injuries predominate in these studies and are generally considered to be problems of insidious onset associated with repetitive physical activity. Injuries, such as lacerations, contusions, and blisters that have, more or less, acute onset, are less frequent.

Injuries are important in terms of loss of time from work and training and decreased military readiness.

Table 5. Annual injury rates in competitive and recreational athletes

Reference	Year	Population	Observation period (weeks)	Annual injury rate (*n*/100 persons/year)
Watson[24]	1993	Competitive athletes N = 314; m = 243, f = 81	52	93 (overuse) 117 (acute)
Korkia et al.[43]	1994	Triathletes N = 155	8	197
Requa et al.[32]	1993	Recreational adult fitness N = 986; m = 418, f = 568	12	233

m, male, f, female.

Table 6. Musculoskeletal injury distribution by body part in military training

Study	Year	Population	Observation period (wks)	Site (% of injuries)				
				Foot	Ankle	Lower leg	Knee	Lower back
Riddell[7]	1990	Royal Marines Commando Training Center, N = 18,040; all male	52 (1981)	14.7	16.7	3.8	26.7	—
			52 (1985)	11.9	14.2	5.5	18.8	—
Linenger et al.[6]	1993	Naval Special Warfare, N = 88	25	9.8	14.0	11.2	34.3	6.3
Jones et al.[11]	1993	Army infantry, N = 303; all male	12	10.9	10.9	8.6	10.2	5.9
Knapik et al.[5]	1993	Army infantry, N = 298; all male	26	6.6	12.3	2.4	10.4	6.6
Almeida et al.[12]	1999	Marine recruits, N = 1296; all male	12	34.9	12.9	3.1	21.7	4.1
Brodine and Shaffer*	1995	Naval Special Warfare trainees, N = 450; all male	25	9.8	14.0	11.2	34.3	6.3
Shaffer et al.[14]	1999	Navy recruits, N = 8865; all female	9	24.0	22.0	18.7	21.7	9.9
		Marine recruits, N = 2766; all female	13	5.4	14.3	21.4	33.8	8.6
		Marine officer candidates, N = 303; all female	10	13.7	23.5	20.3	24.8	7.5

*(SB, RS. Unpublished data, 1999)

The loss of time varies with the type of injury (Table 7). In a study by Knapik et al.,[5] fractures accounted for the highest number of lost duty days (103.2 days/injury) followed by sprains (16.7 days/injury). Other traumatic injuries, tendinitis, strains, and musculoskeletal pain caused lesser amounts of limited duty per injury.

The implications of these injuries in terms of patient morbidity, attrition rates, and training costs for military personnel are staggering. It has been estimated that injuries among 22,000 male recruits during 12 weeks of basic training at MCRD, San Diego, result in more than 53,000 lost training days and cost more than $16.5 million per year.[44] The morbidity associated with injuries in the military is much greater than that associated with illness. "Sick call" clinic visit rates have been shown to be about the same for injuries and illnesses among male and female Army trainees (Table 8). However, rates of visits provide only a partial picture of morbidity. Examining the amount of morbidity in terms of days of medical restriction reveals a vastly different picture. The rates of days of limited duty for Army trainees have been shown to be 5 to 22 times higher for musculoskeletal injuries than for disease/illness (Table 8).

Causes and Risk Factors for Injury

A key to the etiology, prevention, and treatment of overuse injuries lies in an understanding of the factors associated with these injuries. A number of risk factors have been identified for military populations (Table 9).[1,3–5,11–13,15,21,46–49] The risk factors include past physical activity, low levels of previous occupational and leisure time physical activity, previous injury history, high running mileage, high amount of weekly exercise, smoking, age, and biomechanical factors. The data are contradictory with respect to age. Studies by Tomlinson et al.[4] and Knapik et al.[5] identify younger age as a risk factor for injury among infantry soldiers, whereas the study by Jones et al.[11] states that older age is a risk factor among Army trainees. Overall, many of these risk factors are amenable to intervention.

Table 7. Average limited duty days by type of musculoskeletal injury among infantry soldiers

Injury	Limited duty (days/injury)
Fractures	103.2
Sprains	16.7
Other traumatic injuries	7.6
Tendinitis	7.0
Strains	3.0
Musculoskeletal pain	2.8

Source: Knapik et al.[5]

Recent studies documented the association of low levels of entrance physical fitness and subsequent risk of injury. Much of military training centers on weight-bearing physical training, such as marching or running. A number of studies in both civilian and military populations have demonstrated a dose–response curve in relation to running and weight-bearing activities and injuries.[27–29,46,50] Further, as the frequency, duration, or total amount of training increases, the injuries also increase, until a point is reached at which injuries increase disproportionately with changes in physical fitness.[50]

While much is known about training, fitness, and injury risks, only a few studies have obtained prospective data on biomechanical factors related to the risk of sustaining an overuse injury of the lower limb during training.[11,13,47–49] Some biomechanical parameters studied include back and hamstring flexibility,[11] high arches,[47] bone geometry,[49] genu valgum (knock knees),[48] low arches,[13] restricted ankle dorsiflexion,[13] and increased hindfoot inversion.[13] Several of these biomechanical factors can be modulated through training, equipment, or footwear changes.

The footwear worn by military populations also deserves careful scrutiny. The cushioning characteristic of footwear worn by trainees has been tested using a

Table 8. Rates (n/100 recruits/month) of injury and illness among male and female Army recruits[a]

	Gender	Injury rate	Illness rate	RR[b]
Sick call visits	All	32.6	32.9	1.0
	Men	22.2	26.2	0.8
	Women	39.5	37.4	1.1
Days of limited duty	All	93.4	6.8	13.7
	Men	39.9	7.7	5.2
	Women	129.0	5.9	21.9

[a] Fort Jackson, 1984, 8 weeks, N = 310; men = 124, women = 186.
[b] Rate ratio, injury rate/illness rate.
Source: Jones et al.[45]

mechanical impact tester to compare military boots to commercially available footwear.[51] The test measured the peak impact force at the heel (Figure 1). A shoe with a lower impact force absorbs more shock, and thus transmits less shock to the musculoskeletal system. The military boots (both jungle and leather combat boot) were found to have less shock-absorption capabilities than commercially available footwear. These observations of footwear impact alternatives may have implications for injury prevention. It should be kept in mind, however, that military boots must protect the feet of military personnel not only from impact forces of marching or running but also from sharp objects, rough terrain, moisture, and cold.

Prevention Strategies

Preventive strategies should be directed at the primary factors contributing to risks for musculoskeletal injuries, such as the amount and level of intensity of the training, levels of physical fitness, and possibly equipment (e.g., footwear).

The specific approach to achieving higher levels of physical fitness while minimizing injury rates depends on the particular populations being considered. For example, with military recruits there is limited access prior to arrival to boot camp. Therefore, the most effective way to improve the level of physical fitness may be to alter the training regimen by increasing the duration, frequency, and intensity of the initial training events gradually. This approach accommodates the incoming, poorly fit recruits without compromising the fitness of the graduating recruits.

To reduce injuries and maintain fitness of Marine recruits, the San Diego MCRD conducted a training intervention trial.[44] The intervention included reduction in the amount of running miles, gradual build-up of exercise and military hiking, and emphasis on aerobic activities in early training phases before progressing to anaerobic activities and strength conditioning. Evaluation of this intervention demonstrated a significant reduction in all overuse type injuries. Lower extremity stress fractures were reduced by 55%, which resulted in 370 fewer stress fractures per year with a cost savings of over $4.5 million at the San Diego MCRD. Outgoing recruit fitness, as measured by the 3-mile timed run at the end of training, remained equally high compared to before the intervention (20:53 versus 20:20).

After basic training, individuals are required to maintain at least a modest level of physical fitness regardless of military job requirements. Further, emphasis is placed on maintaining aerobic fitness. However, a high level of aerobic fitness may not be required by soldiers to perform their individual job functions. Therefore, future physical fitness standards need to be more closely linked with specific job requirements for muscular strength and endurance.

A significant etiologic factor for running injuries is the amount of training. Numerous studies in both civilian and military populations have demonstrated a dose-response relationship between running or other weight-bearing activities and injuries. Tomlinson et al.[4] found that soldiers who exercised 10 or more hours per week were at increased injury risk. Kowal[9] stated that training over 3 days per week resulted in a significant

Table 9. Risk factors for developing overuse injuries in military populations

Risk factor	Supporting literature
Low levels of past physical activity	Kowal[9]; Jones et al.[1]; Jones et al.[11]; Almeida et al.[12]; Shaffer et al.[21]
Low level of physical fitness	Kowal[9]; Jones et al.[1]; Jones et al.[11]; Knapik et al.[5]; Reynolds et al.[3]; Almeida et al.[12]; Shaffer et al.[21]
Previous injury history	Jones et al.[11]; Almeida et al.[12]
High running mileage	Jones et al.[46]
High amount of weekly exercise	Tomlinson et al.[4]
Smoking	Reynolds et al.[3]; Jones et al.[11]
Age	Tomlinson et al.[4]; Knapik et al.[5]; Jones et al.[11]
Biomechanical factors	Jones et al.[11]; Kaufman et al.[13]; Cowan et al.[47]; Cowan[48]; Beck et al.[49]

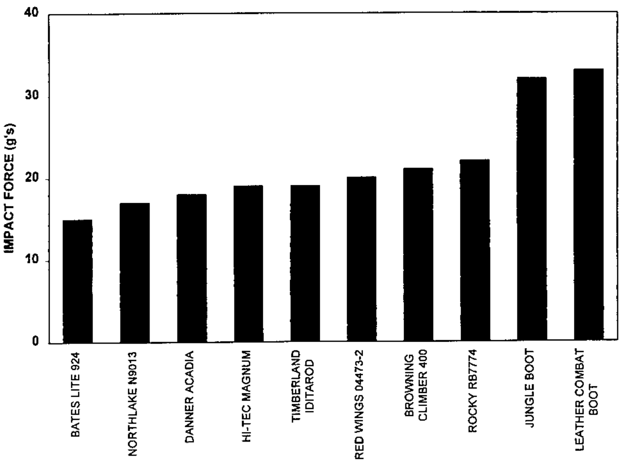

Figure 1. Peak heel impact force of military and commercial boots. A lower impact force indicates that more shock has been absorbed by the boot. Adapted from Williams et al.[51]

increase in the injury rate for previously sedentary women. Similarly, Marti[30] observed that women who ran more than 20 km/week were at increased risk of injury. In a study of men, Pollock et al.[50] showed that as the frequency, duration, or total amount of training increased, the injuries also increased until a point was reached at which injuries continued to increase substantially (200% to 300%) while physical fitness (endurance) increased minimally (less than 10%). Military studies also suggest that thresholds of running exist above which more running results in more injuries, but aerobic fitness does not improve.[44,46] If thresholds of optimal training can be identified for individuals of different fitness and performance levels, then unduly high injury risks due to overtraining can be avoided while maximizing physical fitness.

Another etiologic factor that may reduce training injuries is well-designed footwear. An inexpensive orthotic inserted into the military combat boot may reduce excessive shock loading by 33%, without any alterations to the boot design (Figure 2). However, the choice of orthotic material is crucial. In separate prospective studies during vigorous military training, the addition of a neoprene shock-absorbing insole has been shown to reduce the incidence of overuse injuries,[52] whereas use of a sorbathane insert was not beneficial.[18] Neoprene compacts quickly and has a short useful life, so other more advanced orthotic materials that offer good shock-absorption characteristics and greater durability may be better suited to military needs. These newer materials await prospective testing.

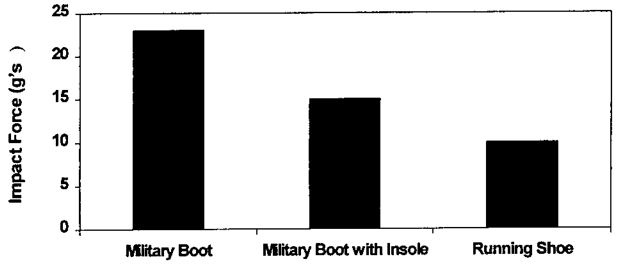

Figure 2. Boot impact test using an impact tester to determine cushioning characteristics. The results illustrate the ability to reduce impact loading in a military combat boot by 33% through the use of a shock-absorbing insole. A comparison is also made to a running shoe. (Test performed by Hagy Biomechanics.)

Military boots lack shock absorption characteristics when compared to running shoes (Figure 2). However, the design of properly functioning footwear requires optimization of many factors. Shock absorption is only one factor to consider. For example, it is desirable to have military footwear that provides good support to minimize ankle sprains while also providing good shock absorption to minimize overuse injuries. These two factors represent competing goals. A shoe that has the best support will, by necessity, be rigid. Conversely, a shoe with good shock absorption will have low stiffness characteristics. Thus, a properly designed military boot will be somewhat different from civilian running shoes. Nonetheless, a redesign of military boots could reduce lower-extremity injuries, and still meet other mission requirements. Such a redesign has occurred for boots used by the U.S. Marine Corps. Reports indicated that these boots have been well accepted. However, further testing is needed to confirm their performance.

Equipment may also play a role in the prevention of other types of training injuries, such as ankle braces to prevent parachute jump–related ankle injuries. A number of epidemiologic studies indicate ankle injuries among paratroopers are a problem. Airborne soldiers have long been among those at highest risk of serious injury. Reported annual injury rates generally range from 1% to 15%.[53,54] Ankle injuries account for 12% to 60% of all military parachute injuries.[53–55] During Operation Just Cause in Panama, 8% of Army Rangers (51/624) sustained ankle injuries.[57] Of these soldiers with ankle injuries, 38% had an injury that was severe enough to prohibit them from continuing with the mission, and an additional 27% had mobility limitations due to the injury. To reduce the incidence of jump-related ankle sprains, a prospective, randomized trial of an outside-the-boot ankle brace was conducted.[58] A group of 745 volunteers from the U.S. Army Airborne School at Fort Benning, Georgia, participated. Of this group, 369 were assigned to wear braces and 376 served as controls. Each volunteer made five static-line parachute jumps. The incidence of ankle sprains was 1.9% in nonbrace wearers and 0.3% in brace wearers (Figure 3) (Risk Ratio = 6.9, $p = 0.04$). Other injuries were not affected by the brace. The parachute ankle brace is a simple device that can be used to reduce injury rates among paratroopers. These

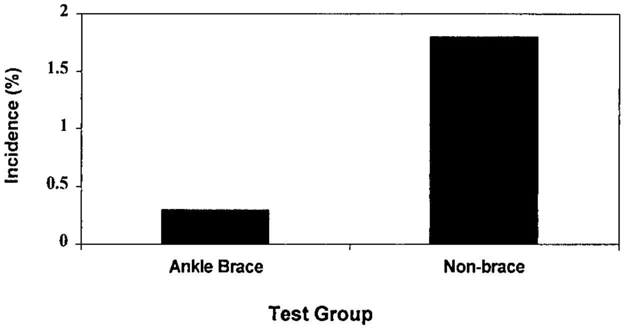

Figure 3. Incidence of ankle sprains in brace (B) versus nonbrace (NB) groups at the U.S Army Airborne School, Fort Benning, Georgia; 745 jumpers, 3674 jumps; risk ratio (NB vs. B) = 6.9; $p = 0.04$. Adapted from Amoroso et al.[58]

data demonstrate the value of developing a program to identify and modify risk factors associated with military operations.

Research such as that described for boot insoles suggests that simply having a good hypothesized strategy to prevent injuries (i.e., more shock-absorbent boots) is not sufficient since some insoles do not protect against injury.[18] Prevention strategies should be tested prior to fielding and once implemented—even successful ones, such as the ankle brace[58]—should be monitored for ongoing success.

Outpatient Surveillance Systems

Unlike inpatient clinical events that have been maintained in standardized tri-service databases for almost a decade, comprehensive outpatient surveillance systems such as the Sports Medicine Research Team System (SMARTS) or the DoD Ambulatory Data System (ADS) are a more recent development.

The Naval Health Research Center has developed SMARTS, a PC-based software application for the purpose of supporting epidemiologic research in musculoskeletal injuries.[59] The system has features of both clinical and research databases. Demographics, clinic visit information, and ICD-9 diagnoses and causes (E-codes) are entered on data entry sheets, which also serve as the hardcopy medical record. The system was also programmed to perform administrative functions and generate required reports. Data from six training sites with operational outpatient surveillance systems have demonstrated the utility of the SMARTS software. Databases have been developed from these sites, which have varying volumes of outpatient encounters and show that musculoskeletal injury incidence is associated with the intensity of training. The highest incidence of injury in men occurs during Naval Special Warfare training (42%), followed by U.S. Marine Corps basic training (26%), and U.S. Navy basic training (11%). Among women, U.S. Marine Corps officer candidate training results in an injury incidence of 62%; U.S. Marine Corps basic training, 44%; and U.S. Navy basic training, 37%.[14] At each site, these databases are also being used to provide clinical outcome information on enrolled subjects in a variety of research study designs.

ADS (DoD outpatient) data is an important component of the Defense Medical Epidemiological Database (DMED), a system that allows web-based, on-line query of population-based inpatient and outpatient events by specific diagnosis. The DMED was developed by the U.S. Army Center for Health Promotion and Preventive Medicine and allows Internet access to selected data contained within the Defense Medical Surveillance System (DMSS). The DMED began collecting outpatient data in 1996. The DMED application provides a user-friendly interface through which users may perform queries regarding disease and injury rates and relative burdens of diseases in active duty populations including the Army, Air Force, Navy, and Marine Corps. The combined military services generate over 2 million annual outpatient encounters related to injuries and musculoskeletal conditions alone, making this a truly robust source of data. The use of client server technologies and database optimization allows DMED users to access the DMSS database. The database contains up-to-date and historical data on diseases and medical events (e.g., hospitalizations, ambulatory visits, reportable diseases) as well as longitudinal data relevant to personnel characteristics and deployment experience for all active duty and reserve component service members. Data from the DMSS are published in the Medical Surveillance Monthly Report (MSMR), the principal vehicle for disseminating medical surveillance information of broad interest.

These systems provide the ability to determine outpatient disease rates, identify risk factors, perform cost-benefit analyses, and design preventive interventions. These automated data collection systems contain information regarding personal demographics, medical presentation, diagnoses, disposition, and other potentially relevant data that greatly facilitate injury surveillance. Such surveillance tools make it possible to identify changes in patterns of injury or disease distribution. Unfortunately, a shortcoming of the ADS is the lack of cause-of-injury coding. Thus, while it is possible to get ICD-9-CM codes for injury type, there is no way to ascertain critical data on cause of injury or duty relatedness of injuries under the current DMED outpatient system.

Summary

Research suggests that musculoskeletal injuries are a significant problem in the military. Although the majority of studies have been conducted in military recruit training populations, studies conducted in operational forces provide documentation that there is a large problem in these populations as well. Data reviewed show a wide variation in injury rates between military units studied, probably varying according to the types and amounts of training performed. Military research has identified a number of modifiable risk factors for injury including the amount of unit training and the physical fitness level of service members. Outpatient surveillance systems are now capable of monitoring outpatient injury rates and patterns throughout the DoD. These outpatient surveillance systems should be used to identify high-risk populations and to prioritize research and prevention activities. Systematic use of these information tools represents important initial steps in the process of prevention and control of injuries in the ambulatory setting.

Some recommendations stemming from this review are:

- Include in the minimum data set for outpatient care at least the following: age, race/ethnicity, gender, diagnosis, profile/disposition, and cause. Cause data are particularly important for prevention efforts.
- Focus research on high-risk populations and environments with the largest impact on readiness.
- Routinely document incidence, severity, time lost, and costs of outpatient injury events.
- Conduct research to study the effect of equipment design, especially footwear, on training and injuries.
- Broaden research effort to more than basic training, infantry, and Special Forces.
- Research on physical training practices should concentrate on the intensity, frequency, and duration of training, as well as the type of activity.
- Continue to explore the association of training, fitness, performance, smoking, and other modifiable risk factors with injuries.
- Implement and monitor effectiveness of prevention strategies using surveillance systems.

The views, opinions, and findings contained in this report are those of the authors and should not be construed as official Department of the Navy or DoD position, policy, or decision, unless so designated by other official documentation. The authors thank Barbara Iverson-Literski for careful manuscript preparation.

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Non-Battle Injury Casualties During the Persian Gulf War and Other Deployments

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Objective: To review injury occurrence and to evaluate various injury surveillance systems used on recent deployments of U.S. military personnel.

Background: Injuries that occur in a deployed military force are more likely to have an immediate and detrimental effect on the military mission than those in garrison or training. These injuries have a direct impact on deployed personnel and unit readiness and consume limited field medical resources.

Methods: Data collected during four recent deployments were evaluated. Administrative databases established for the routine collection of death and hospital admissions were used to characterize mortality and morbidity in the Persian Gulf War. Surveillance teams deployed to Haiti, Somalia, and Egypt provided inpatient and outpatient data for those missions.

Results: Data collected by these surveillance systems are presented. Unintentional trauma accounted for 81% of deaths during the Persian Gulf War and 25% of hospital admissions. During operations in Somalia and Haiti, 2.5% to 3.5% of about 20,000 troops in each deployment sought medical treatment for an injury or orthopedic problem each week. In Egypt, injuries accounted for about 25% of all outpatient visits to medical treatment facilities.

Conclusions: Injuries were the leading cause of death and a leading cause of morbidity during recent deployments of U.S. troops. Comprehensive injury surveillance systems are needed during deployments to provide complete and accurate information to commanders responsible for the safety of the force. Recommendations for establishing such systems are made in this article.

Medical Subject Headings (MeSH): military medicine, military personnel, war, wounds and injuries (Am J Prev Med 2000;18(3S):64–70) © 2000 American Journal of Preventive Medicine

Introduction

Injuries that occur in a deployed military force are more likely to have an immediate and detrimental effect on the mission than those in garrison or training. These injuries have a direct impact on personal and unit readiness and consume limited field medical resources.

The deployment environment contains myriad opportunities for injuries to occur. Although similar opportunities may be present in garrison or on exercises, the deployed service member is more likely to be fatigued, exposed to dangerous materials, physically and mentally stressed, working in unfamiliar surroundings, and placing less emphasis on safety rules and procedures.

The mechanization of the Army, especially the use of motor vehicles, combined with improved treatment and control of many infectious diseases, have increased the relative importance of non-battle injuries (NBIs) during deployments.[1] During the First World War, NBIs were the fourth leading cause of admission after respiratory system, infectious, and digestive system diseases.[2] They ranked third in the Second World War[2,3] and Korea.[2,4] In the Vietnam War, NBIs were the leading type of casualty.[5] A review of U.S. Navy and Marine Corps injury casualty data show that, in deployments this century, injury casualty rates—both battle and non-battle—have remained constant while disease casualties have declined dramatically.[5]

Despite the increasing importance of injuries, there are relatively few published articles on the epidemiology of injuries in deployed military forces.[5–10] This

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historical information can be used to predict losses due to NBIs and help identify the number and composition of medical units to be deployed.[4] Although published articles may be useful in planning future operations, commanders need the routine surveillance and reporting of injuries and other conditions during a deployment. Complete, accurate, and timely surveillance data provide the essential medical intelligence to effectively prevent and treat injuries.

An investigation of recent deployments is especially important because the composition of the forces was significantly different from those of World War II, Korea, and Vietnam. These differences included a greater female presence in the theater of operations,[11] a greater reliance on reserve and National Guard units,[11] and reduced alcohol use by troops.[12]

In this paper, the epidemiology of NBIs on U.S. Army soldiers deployed to four separate operations—encompassing combat, humanitarian assistance, and a training exercise—is described.

Methods

Fatalities During the Persian Gulf War (Operations Desert Shield and Storm)

Data for the analysis of unintentional injury deaths during the Persian Gulf War, also known as Operations Desert Shield and Storm (ODS&S), were collected from the Department of Defense's (DoD's) Worldwide Casualty Reporting System. For this report, the Persian Gulf War is defined as the period 1 August 1990 through 31 July 1991, and includes the troop build-up in the Gulf and the combat and post-combat phases of the deployment. All active duty military deaths are reported by commanders to casualty offices in the respective service branches. Data for each death are recorded on a Report of Casualty (DD Form 1300), entered into computerized databases, and forwarded to the DoD's Directorate of Information Operations and Reports (DIOR) monthly. The computerized files and paper copies of all casualty reports are stored at DIOR. The directorate has routinely collected all military fatality data since 1 October 1979. We reviewed every hardcopy DD1300 from the Persian Gulf War. A full discussion of the review process has been published elsewhere.[6]

Each casualty report contains the date, location, cause, and circumstances of death, as well as data on demographics, next-of-kin, and survivor benefits. The circumstances of death reported on the form is abstracted from death investigation files. Each death is classified by casualty office personnel into one of six categories (accident, homicide, battle, self-inflicted, illness, and undetermined). Although the casualty report is routinely prepared for reasons unrelated to medical surveillance, it has been shown to be of considerable value as a source of complete data on active duty deaths.[13]

Table 1. Non-battle deaths in U.S. forces (Army, Navy, Marine Corps, and Air Force) deployed to the Persian Gulf War (Operations Desert Shield and Storm), 1 August 1990 to 31 July 1991

Cause of death	Number (%)	Rate/100,000[a]
Unintentional trauma (accidents)	183 (81)	69.1
Illness and disease	30 (13)	11.3
Self-inflicted	10 (4)	3.8
Homicide	1 (0)	0.4
Unknown	1 (0)	0.4

[a]Rate per 100,000 soldiers.

Hospital Admissions During the Persian Gulf War

The computerized database of the U.S. Army's Individual Patient Data System (IPDS) was searched for hospital admissions among soldiers in the Persian Gulf War. The database, operated by the Patient Administration Systems and Biostatistical Activity (PASBA), at Fort Sam Houston, Texas, collects detailed data for each admission to all U.S. Army hospitals worldwide, including deployed field and combat support hospitals. Data from deployed hospitals in southwest Asia during the Persian Gulf War were transferred to IPDS, but were not available for analysis until 3 years after the operation. Nevertheless, this was the quickest such records have ever been analyzed. We received data electronically from IPDS and analyzed it to determine the relative importance of injuries versus disease as a cause of hospitalization and to determine what types of injury and what causes of injury resulted in hospitalization.

Routine Medical Surveillance During Deployments

During joint operations in Somalia (1992) and Haiti (1994), comprehensive, uniform theater-wide surveillance was conducted by two of the authors. One author (RFDeF), from the Walter Reed Army Institute of Research, served as a member of disease surveillance teams in Somalia and Haiti. The other author (LWK) was the preventive medicine officer for a deployed unit in Haiti.

In Operation Restore Hope in Somalia, the surveillance team collected reports of all outpatient clinic visits for approximately 90% of a 20,000- to 30,000-member force on a weekly basis, and data on all hospital admissions to the two U.S. military hospital facilities in Somalia. Although data collection continued throughout the operation, the experience of only the first 7 weeks of the operation are included in this report. Diseases (D) and non-battle injuries (NBIs),

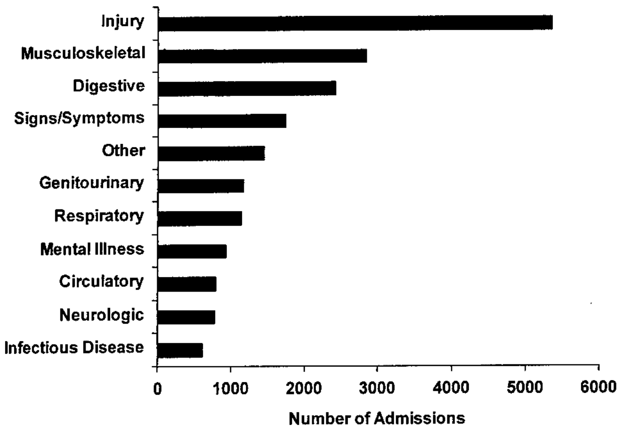


Figure 1. Leading diagnosis categories for U.S. Army soldiers hospitalized during the Persian Gulf War (Operations Desert Shield and Storm), 1 August 1990 to 31 July 1991

DNBIs, observed during the first 2 weeks quickly rose, then settled into a stable rate that remained fairly consistent throughout the remainder of the operation. A similar surveillance approach was used for Operation Uphold Democracy in Haiti in 1994 where approximately 20,000 personnel were deployed.

Although disease and injury surveillance was sporadic during the few first weeks of the Somalia and Haiti missions, by the third to fourth week, over 90% of troops were covered by surveillance. This delay of several weeks was due to the fact that a surveillance system had to be newly created for each deployment.

Special Surveillance Study: Egypt

Information on types and patterns of injury occurring among military personnel deployed to the logistics base of a joint U.S.-Egyptian training exercise in 1993 (Bright Star '94) were collected. Records from the 146 patients treated for injuries at 47th Field Hospital from 23 October to 11 November 1993 were reviewed by one of the authors (LWK). All outpatient records were screened to detect those in which an injury was the chief complaint. Injuries were classified by type and body part injured, circumstance of injury, whether acute or chronic, and the immediate disposition of the injury.

The Somalia, Haiti, and Egypt data presented here are taken from surveillance reports prepared during the operations. No new analysis of this data was conducted for this article.

Results

Fatalities During the Persian Gulf War

Non-battle mortality data for the Persian Gulf War are presented in Table 1. Battle deaths, which are not included in the table, numbered 147. Unintentional trauma was the leading cause of death reported during this deployment.

Transportation-related injuries were the leading cause of non-battle death in all U.S. forces deployed to the Persian Gulf War. Motor vehicle crashes accounted for 62 of 183 NBI deaths (34%). These were followed by aircraft crashes at 47 non-battle deaths (26% of NBIs).

Mortality data collected by the casualty office do not include details of the type of injury resulting in death; therefore it could not be analyzed.

Hospital Admissions During the Persian Gulf War

An analysis of the IPDS database shows that, of 21,655 soldiers admitted to Army hospitals in southwest Asia during the Persian Gulf War, 5342 (25%) were admitted for acute NBIs, the leading cause of hospitalization, and 2825 (13%) were admitted for conditions of the musculoskeletal system, the second leading cause of hospitalization (Figure 1). Digestive diseases were the third leading category accounting for 2410 admissions (11%). In contrast, there were only 956 reported battle-related admissions.

Admissions were reported throughout the deployment with the highest rates in February (433/100,000 soldiers), during the air and ground wars, and March (443/100,000 soldiers), during the clean-up phase of the operation. In contrast, the average rate for August 1990 through January 1991 and April 1991 through July 1991 was only 164 per 100,000 soldiers.

Figure 2 shows the type of injuries reported to IPDS during the Persian Gulf War. Fractures were the leading reason for admission, accounting for 1324 admissions. Fractures were also the leading contributor to hospitalization days.

For injury surveillance, the most useful data field for prevention purposes in the IPDS database could be the one listing the cause of the injury. This field uses a

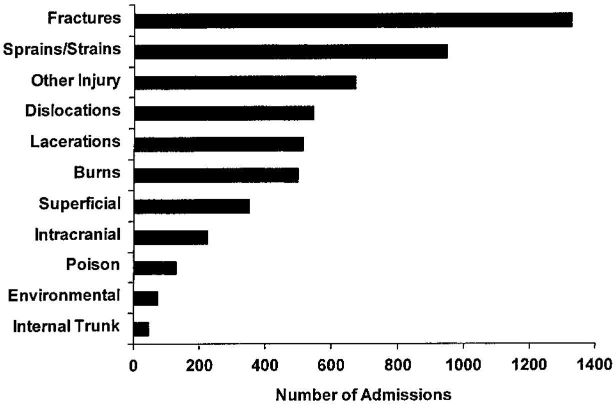


Figure 2. U.S. Army: Leading types of non-battle injury hospitalizations reported in soldiers serving in southwest Asia, 1 August 1990 to 31 July 1991

Table 2. Leading causes of injury among hospitalized U.S. Army soldiers deployed to the Persian Gulf War (Operations Desert Shield and Storm), 1 August 1990 to 1 July 1991

Cause of injury	Number (%)	Rate[a]
Motor vehicle crashes	566 (19)	4.0
Falls	559 (19)	4.0
Sports and athletics	512 (18)	3.6
Machinery and tools	398 (14)	2.8
Other land transport	126 (4)	0.9
Weapons	113 (4)	0.8

[a] Rate per 1000 person-years.

coding system developed for NATO. These cause-of-injury codes are designed for use in military populations and are more informative than the ICD-9 E-codes. For example, injuries caused by weapons can be coded to the level of detail of type of weapon, during or not during battle, and caused by enemy or friendly fire. Unfortunately, a specific cause of injury was not assigned in 2664 (50%) of the records. Table 2 shows the six leading specified causes of injury hospitalization during the Persian Gulf War. Motor vehicle crashes and falls were the leading causes of injuries, followed very closely by sports injuries and injuries involving machinery and tools. These four mechanisms account for 70% of these injuries with specific specified-cause codes.

Routine Medical Surveillance During Non-Combat Deployments

Inpatient care. Injuries resulted in admission to one of the two hospital/holding facilities in Mogadishu, Somalia, in the early weeks of Operation Restore Hope. Figure 3 shows the rate of admission for all and selected causes.

In the fall of 1994, approximately 20,000 U.S. troops deployed to Haiti during Operation Uphold Democracy. Figure 4 shows the rate of admission overall and for selected causes.

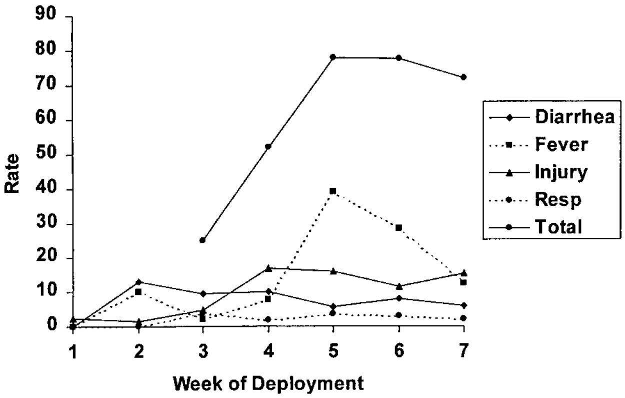


Figure 3. Hospital admission rate by DNBI category, 1st Medical Battalion (1st Marine Expeditionary Force) and 86th Evacuation Hospital, Mogadishu, Somalia, December 1992 to February 1993. (Rate = Number of U.S. military personnel admitted per 100,000 troops/day.)

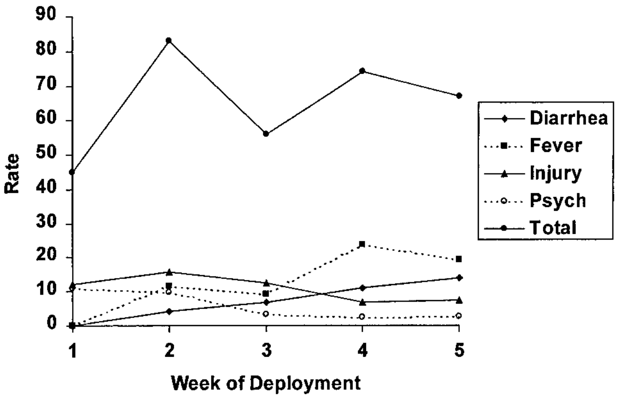
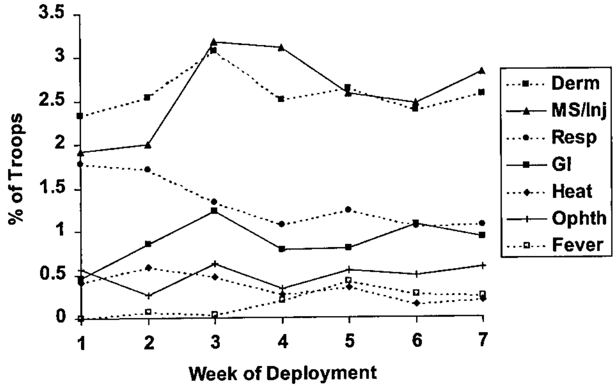


Figure 4. Hospital admission rate by DNBI category, 28th Combat Support Hospital, Port-au-Prince, Haiti, October/November 1994. (Rate = Number of U.S. military personnel admitted per 100,000 troops/day.)

The Somalia and Haiti experiences differ in the rate and pattern of injury admissions. In Somalia, the admission rate climbs during the first 3 weeks before leveling out at about 15 admissions per 100,000 per day. In Haiti, the opposite is reported. Injury admissions started at about 12 per 100,000 per day and decreased in the first 4 weeks to about 5 per 100,000 per day.

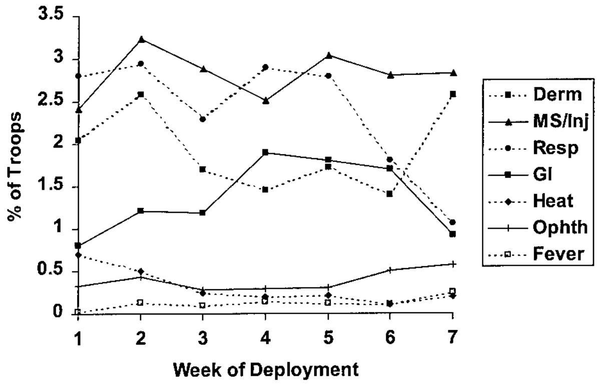
Outpatient care. Up to 32 medical treatment facilities at seven major sites in Somalia were reporting outpatient data. Figure 5 shows the percentage of troops seen each week for an illness or injury. NBIs were the first or second reason for an outpatient encounter in each of the first 7 weeks.

The most important categories of clinic visits are shown in Figure 5. Each week, 2.5% to 3.5% of troops were seen at aid stations for an injury or "orthopedic"



Surveillance Categories: Derm = Dermatologic; MS/Inj = Musculoskeletal or acute injury; Resp = Respiratory; GI = Gastrointestinal; Heat = Heat injury; Ophth = Ophthalmologic; Fever = Fever, not otherwise classified.

Figure 5. Outpatient DNBIs, U.S. forces, Somalia, 13 December 1992 to 30 January 1993. (Percentage of supported troops diagnosed with injuries or illnesses in each Joint Staff category each week.)



Surveillance Categories: Derm = Dermatologic; MS/Inj = Musculoskeletal or acute injury; Resp = Respiratory; GI = Gastrointestinal; Heat = Heat injury; Ophth = Ophthalmologic; Fever = Fever, not otherwise classified.

Figure 6. Outpatient NBIs, U.S. forces, Haiti, 2 October 1994 to 5 November 1994. (Percentage of supported troops diagnosed with injuries or illnesses in each Joint Staff category each week.)

problem. Unfortunately, no additional detail concerning the nature of these injuries or problems is available.

For Operation Uphold Democracy in Haiti, outpatient data were collected in the same manner as in Somalia. Injury rates in Haiti were also similar to those recorded in Somalia; injury was the most common reason for an outpatient visit in Haiti for 3 of the first 5 weeks of surveillance (Figure 6).

Figure 7 shows some additional details about types of injury for Haiti. Deployment surveillance systems in Somalia and Haiti did not routinely collect detailed data on injury hospitalizations, such as types of injuries or days hospitalized. Outpatient systems were also limited in the depth of information available; however, as seen in Figure 7 for Haiti, a small amount of additional information on types of injury seen on an outpatient basis was acquired. Detailed data on cause or circumstances of injury were not routinely collected in Somalia and Haiti.

Special surveillance study: Egypt. The 146 injuries included in this study accounted for approximately one fourth of all disease and injury outpatient visits at the hospital over the 19 days of observation during the exercise. The disposition of the patient after injury was

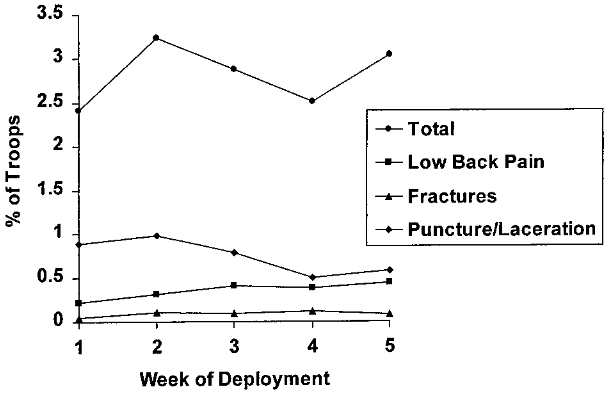


Figure 7. Outpatient non-battle injuries by type, Operation Uphold Democracy, Haiti, 2 October 1994 to 5 November 1994

used as a surrogate measure of impact on readiness. Sprains and strains, the most common injury types, resulted in restricted duty profiles in 70% of cases. Back sprains resulted in quarters or restricted duty in 77% of cases. All five fractures counted in this study resulted in restricted duty; three were transferred out of theater.

Table 3 shows the distribution of injury by anatomical region for the 108 injuries (of 146 total) for which type and location could be determined. Most (74%) of the injuries were acute problems, defined as occurring hours to several days before the visit; the remainder were either chronic or resulted from aggravation of past injuries. Back injuries were more likely than injuries of the extremities to be chronic compared to other injuries (42% vs. 21%).

Sports or play were involved in 26% of the 95 injuries (39% of all sprains) for which appropriate information was available. Twelve injuries occurred while playing basketball, followed in frequency by volleyball (5) and football (4). Back injuries were more likely to be associated with lifting (59%) and moving heavy objects.

Discussion

Injuries were the leading cause of death, hospital admissions, and outpatient visits among U.S. troops

Table 3. Selected types of injury among U.S. Army soldiers examined at 47th Field Hospital during Exercise Bright Star, 23 October 1993 to 1 November 1993

	Location								
	Back		Upper extremity		Lower extremity		Other		Total
Type of injury	*n*	(%)	*n*	%	*n*	%	*n*	%	N
Sprain	22	(33)	19	(29)	21	(32)	4	(6)	66
Laceration	0	(0)	12	(75)	2	(13)	2	(13)	16
Crush	0	(0)	6	(55)	4	(36)	1	(9)	11
Blister	0	(0)	0	(0)	8	(100)	0	(0)	8
Fracture	0	(0)	4	(80)	1	(20)	0	(0)	5
Dislocation	0	(0)	1	(100)	0	(0)	0	(0)	1
Burn	0	(0)	0	(0)	0	(0)	1	(100)	1
Total	22	(20)	42	(39)	36	(33)	8	(7)	108

Table 4. Strengths and limitations of the available data sources for non-battle injuries during deployments of U.S. troops

Strengths	Limitations
Report of casualty (DD1300)	
Already computerized	Limited type, cause, and circumstance of injury death
Easily accessible	Nonspecific, only six broad categories readily available
Complete	Established as an administrative rather than health surveillance and research database
Accurate	
Timely, done monthly	
Ongoing investigations may result in more accurate cause of death data	
Inpatient data (IPDS)	
Already computerized	U.S. military hospitals only
Standardized medical database	Significant delay, 3 years after Gulf War, in getting data
Uses ICD-9 codes, using up to eight per admission	Completeness and accuracy during deployments not validated and unknown
Includes military-specific cause of injury codes	Almost 50% of cause-of-injury codes do not identify a specific mechanism
Admissions are coded as trauma or nontrauma	Established as an administrative rather than health surveillance and research database
Details of diagnosis, disposition, and demographics available	
Easily obtained	
Hospital and sick days available	
Routine medical surveillance during deployments	
Comprehensive, full coverage of deployed force is possible	Ad hoc efforts during deployments lead to delays in data collection
Rapid turn-around, e.g., weekly	Not standardized between deployments
Simple data collection and entry	Requires oversight for quality control
	Limited details available on type, cause, and mechanism of injury
	No personal identifying information, no linkage to other records
	Data must be collected, entered, and reported in a field environment
Special surveillance study: Egypt	
Feasible in field settings	Requires dedicated resources
Can be tailored to a specific situation and to answer specific questions	Ad hoc effort
	Can detract from routine surveillance
	May not be generalized to other situations

during four recent deployments. The data collected during those operations and presented in this paper illustrate the importance and impact of unintentional injuries (NBIs) on a deployed military force. Each incident is a service member who, permanently or temporarily, was unable to perform his or her job. The strengths and weaknesses of each data source are summarized in Table 4.

The mortality and hospitalization data were collected during the Persian Gulf War and analyzed more than 3 years after the end of the operation. They provide historical insight into the incidence and impact of serious NBIs during a combat mission but the picture remains incomplete. Although the mortality data contain the cause of injury, they usually do not provide information on the type of injury sustained. The hospital data do not contain the cause of injury in about half of the admissions but have good information on the type of injury.

The surveillance systems set up during operations in Somalia and Haiti were designed to evaluate the health of the troops on a routine basis during the deployments. The data were used to advise commanders on the readiness of their forces. The data as collected were too general for evaluating the incidence of specific types or causes of injuries, although an unusually high injury incidence in the surveyed troops could have been used to trigger more in-depth studies of non-battle injuries.

The surveillance system established for the Bright Star '94 training exercise provided a more complete and useful description of injury incidence by type, cause, and impact on readiness than the other systems. Data from Bright Star in Egypt provided better information for designing, implementing, and evaluating injury prevention programs.

Unfortunately, data of the detail from Egypt will probably not be available. In 1993, the Joint Staff mandated that outpatient medical surveillance with weekly reporting of rates of DNBIs, categorized by general type of illness or injury, should be conducted on all joint deployments (Army, Navy, Air Force, and Marine Corps). All injuries are captured in a single category called Orthopedic/Injury. This classification combines all acute injuries and chronic musculoskeletal complaints into one general category.

Data on injury incidence extracted from existing databases, such as the hospital records system, have been used for surveillance purposes, with some of the limitations noted above. Ad hoc surveillance systems established during deployments have also provided useful and timely information. Both of these sources are important components in a comprehensive military medical surveillance system. However, they can be improved. The following recommendations are designed to build on the strengths of these systems.

Medical surveillance should be an essential element in monitoring the medical readiness of the military. This activity should be a routine and essential preventive medicine function for deployed and nondeployed forces during or in the absence of a contingency.

The deployment surveillance system should be standardized across the services. Personnel from the Army, Navy, Marine Corps, and Air Force should be using the same data collection forms and techniques. Cause-of-injury data and standard forms should be established for all conflicts and operations; however, flexibility should be maintained to add conflict-specific information as needed.

The data collection form should be short and simple to use. A data collection form that becomes a burden to medical personnel will not be used. It is extremely important that only essential information and not extraneous data be collected. Check boxes should be used where possible rather than text descriptions.

Timely reporting of collected data to medical and line commanders and medical units collecting data is essential. Data should be routinely analyzed and reported to those responsible for the medical readiness of the force and those in military command. Minimum data requirements should include type of injury, location of injury, and mechanism of injury. The type of injury should be classified in six to ten of the most common categories such as fractures, sprains/strains, lacerations/open wound, superficial wound/contusion, burn injury, heat/cold injury, internal trunk, intracranial, or multiple trauma. The location of injury should be classified as head, neck, arm, hand, trunk, leg, or foot. The mechanism or cause of injury should also be classified into six to ten categories such as motor vehicle, aircraft, fall, sports/athletics, firearm, shell/bomb/mine, machine/tool, or fire.

In addition to coded cause data, a short text field should be available for a description of the circumstances of the injury event. This descriptive information may be very important for developing and instituting preventive measures.

These data, both coded and free text, would be useful in assessing types and causes of injuries. The need to keep the surveillance system as simple as possible, however, may require sacrificing detailed information for increased compliance.

Finally, surveillance is not a substitute for research. Injury control research should be conducted to determine circumstances surrounding injury; identifying modifiable risk factors for injuries; and evaluating injury prevention, treatment, and rehabilitation programs.

The opinions expressed by the authors are theirs alone and do not necessarily reflect the opinions or policies of the Department of the Army, Department of Defense, or the United States government.

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Injuries in the Military

A Review and Commentary Focused on Prevention

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Background: In November 1996, the Armed Forces Epidemiological Board (AFEB) Injury Prevention and Control Work Group issued a report that cited injuries as the leading cause of morbidity and mortality among military service members. This article reviews the types and categories of military morbidity and mortality data examined by the AFEB work group and the companion Department of Defense (DoD) Injury Surveillance and Prevention Work Group. This article further uses the injury data reviewed to illustrate the role of surveillance and research in injury prevention. The review provides the context for discussion of the implications of the AFEB work group's findings for the prevention of injuries in the military.

Methods: The AFEB work group consisted of 11 civilian injury epidemiologists, health professionals and scientists from academia, and other non-DoD government agencies, plus six military liaison officers. Injury data from medical databases were provided to the civilian experts on the AFEB work group by the all-military DoD Injury Surveillance and Prevention Work Group. The AFEB work group assessed the value of each database to the process of prevention and made recommendations for improvement and use of each data source.

Results: Both work groups found that injuries were the single leading cause of deaths, disabilities, hospitalizations, outpatient visits, and manpower losses among military service members. They also identified numerous data sources useful for determining the causes and risk factors for injuries. Those data sources indicate that training injuries, sports, falls, and motor vehicle crashes are among the most important causes of morbidity for military personnel.

Conclusions: While the work group recommends ways to prevent injuries, they felt the top priority for injury prevention must be the formation of a comprehensive medical surveillance system. Data from this surveillance system must be used routinely to prioritize and monitor injury and disease prevention and research programs. The success of injury prevention will depend not just on use of surveillance but also partnerships among the medical, surveillance, and safety agencies of the military services as well as the military commanders, other decision makers, and service members whose direct actions can prevent injuries and disease.

Medical Subject Headings (MeSH): military personnel, wounds and injuries, accident prevention, population surveillance, military medicine, injury prevention (Am J Prev Med 2000;18(3S):71–84) © 2000 American Journal of Preventive Medicine

Introduction

In November 1996, the Armed Forces Epidemiological Board (AFEB) Injury Prevention and Control Work Group issued a report that cited injuries as the leading cause of morbidity and mortality among military service members.[1] This finding was not surprising since injuries are also the leading cause of deaths and less severe health outcomes for comparable groups of young civilian Americans.[2–4] The work group also reviewed military injury research that has identified causes and risk factors for injuries and tested prevention strategies.

The AFEB work group concluded that the top prior-

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Table 1. Five steps of the public health approach

1. Determine the existence and magnitude of the problem.
2. Identify causes of the problem.
3. Determine what prevents the problem.
4. Implement prevention strategies and programs.
5. Continue surveillance and monitor/evaluate the effectiveness of prevention efforts.

Adapted from Robertson,[10] Mercy,[11] and Jones.[12]

ity for injury prevention must be the formation of a comprehensive medical surveillance system. They recommended that surveillance data be routinely used to prioritize and monitor injury and disease prevention and research programs. In addition, the work group defined the types of partnerships necessary to implement successful prevention programs. A complete chronology of the work group's investigation can be found at the beginning of this supplement.[5] The work group's recommendations are consistent with those discussed in the injury and public health surveillance literature.[6–9]

In this paper, we review the types and categories of morbidity and mortality data examined by the AFEB and DoD work groups and by authors in the current medical literature and suggestions on how such data contribute to each step of the public health process of injury prevention and control. We discuss the key recommendations and conclusions of the AFEB work group and, most importantly, the creation of a comprehensive military medical surveillance system. This paper also explores future actions that might result from the work group's findings, including a description of the partnerships necessary to implement successful prevention programs.

The Public Health Process

The AFEB work group recognized that a systematic process is necessary to successfully reduce injuries and other public health problems in a population.[7,10] Likewise, a systematic process for evaluating DoD databases was deemed necessary. The work group chose a five-step public health approach as the framework for evaluating the value of military medical information systems for injury prevention and control. The five steps of the process, which were adapted from other sources,[6,10–12] are displayed in Table 1.

Although surveillance may contribute to any step of the public health process, it is most relevant to the first and the last steps. While the primary objective of the AFEB work group focused on evaluating databases with surveillance potential, they also explored research and other data sources that contributed to the third and fourth steps of the prevention process.

To conduct its evaluation, the AFEB convened a panel of 11 civilian injury epidemiologists, health professionals, and other scientific experts drawn from academia and non-DoD government agencies. Civilian panel members were assisted by six military liaison officers selected from military medical and research organizations. Over a period of 23 months, the AFEB work group explored a variety of existing databases to establish the importance of injuries among military service members relative to other health problems and to understand the causes of injuries. The findings from this review and analyses became the foundation for recommendations made by the AFEB to the Assistant Secretary of Defense for Health Affairs and the military service medical departments. Most of the information reviewed by the AFEB work group was provided by the DoD Injury Surveillance and Prevention Work Group, which was composed of all military safety and medical personnel. This DoD work group actively acquired, reviewed, and compiled data from military organizations responsible for maintaining medical, personnel, and safety databases for the military services.[13] These databases included death, disability, hospitalization, outpatient visit, safety, and personnel (population and demographic) data.

The following sections of this paper review data from the same sources examined by the injury work groups. The review illustrates how data contribute to each step of the public health process (Table 1).

Step 1. Determine the Existence and Size of the Problem

The first requisite of the prevention process is to determine what problems exist and how severe they are. Medical surveillance allows for the identification of problems and prioritization of prevention efforts. In this section, we examine the relative importance of injuries compared to other causes of morbidity and mortality in military populations.

Deaths. Accidental (unintentional) injuries remain the most significant health problem for all three branches of the military services.[14–16] Rates of unintentional injury fatalities fell more than 40% among active duty military personnel during the decade of the 1980s and continued to decrease in the early 1990s.[14,15] Despite the persistent drop in rates, "accidents" (unintentional injuries) were still the leading cause of death for all the military services in 1994, accounting for 47% or more of deaths, with annual fatality rates of 50 to 90 deaths per 100,000 military personnel per year (Table 2). Although the Army had the overall highest injury fatality rates in the military, these rates have been lower than for similar U.S. civilian populations.[14,16]

Disabilities. From the early 1980s through 1990, overall rates of medical disability evaluations rose for the military services.[1,17] In the early 1990s, all disabilities

Table 2. Distribution (%) and rates of deaths among active duty personnel in military services, fiscal year 1994[42]

	Army (n = 492)	Navy (n = 274)	Marine Corps (n = 120)	Air Force (n = 222)
Accidents	48%	48%	57%	47%
Suicides	18%	20%	20%	28%
Homicides	9%	8%	9%	4%
Illness	21%	18%	13%	21%
Other	4%	6%	1%	2%
Population (N)[a]	541,323	468,617	174,158	426,327
Rate n/1000 personnel/year	91	58	69	52

[a] Fiscal year frequencies.

due to both injury and disease cost the military services $1.5 billion annually.[1,13,17] In 1990, the Navy and Marine Corps combined had the highest disability case evaluation rate at over 20 per 1000 personnel per year; the Army rate was 16 per 1000 per year; and the Air Force rate was about 10 per 1000 per year. Over 50% of the disability cases reviewed for the Army and Navy were orthopedic, mostly injury-related conditions,[1,13] in contrast to only 20% to 30% of the Air Force cases.[13,17]

Hospitalizations. In the early 1980s, injuries were the leading category of hospitalizations in the Army, Navy, and Marine Corps; however, from 1980 through the mid-1990s hospitalization rates for injuries declined for all branches of the military services.[1,13,18] In 1994, injuries (ICD-9 codes 800–999) accounted for 11% of hospitalizations in the Army, 9% in the Navy, 14% in the Marine Corps, and 8% in the Air Force (Table 3). While acute injury rates fell from 1980 to 1990, musculoskeletal and connective tissue conditions (ICD-9 codes 716–739)—most of which in the military are the late, recurrent, or chronic effects of injuries—became the leading cause of hospitalizations for three of the military services. In 1994, musculoskeletal conditions accounted for 20% of hospitalizations for Army personnel, 17% for the Navy, 21% for the Marines, and 14% for the Air Force (Table 3). The combined percentages of total hospitalizations for injury and musculoskeletal rates ranged from 22% for the Air Force to 35% for the Marine Corps. Combined rates of hospitalization for injury and musculoskeletal disorders ranged from 21.3 per 1000 per year for the Air Force to 48.1 per 1000 per year for the Army (see Table 3).

In wars and conflicts from World War II to the present, the majority of hospitalizations (77% to 96%) resulted from diseases and non-battle injuries (DNBI).[1,19] In contrast, battle injuries accounted for only 4% to 23% of casualties. During recent military operations in Southwest Asia (the Persian Gulf War),[20] and Bosnia (Operation Joint Endeavor [OJE]),[21] non-battle injuries were the leading diagnostic category of hospitalizations. Twenty-five percent of hospitalizations during the Persian Gulf War were due to non-battle injuries (Table 4). Musculoskeletal and connective tissue conditions (ICD-9 code groups 716–739) accounted for another 14% of hospitalizations during the Persian Gulf War (Operation Desert Shield/Storm). The next leading cause of hospitalizations was digestive diseases at 12%. Only 5% of hospitalizations in the Persian Gulf War were due to battle injuries.[1,20] Similarly, injuries caused 20% of the hospitalizations during the first year of U.S. military operations in Bosnia, and musculoskeletal conditions accounted for another 10%[21] (see Table 4).

The Army hospitalization rate during the Persian Gulf War was 159 per 1000 soldiers per year,[1,20] slightly

Table 3. Distribution (% of total hospitalizations) of top categories of hospitalization by ICD-9 principal diagnosis groups (PDG) for active duty military personnel, 1994

	Army (n = 84,785)		Navy (n = 38,718)		Marine Corps (n = 13,452)		Air Force (n = 41,322)	
Principal Diagnosis Group	%	rank	%	rank	%	rank	%	rank
Musculoskeletal	20%	1	17%	1	21%	1	14%	2
Digestive	13%	2	12%	2	11%	3	22%	1
Injury	11%	3	9%	4	14%	2	8%	4
Pregnancy	10%	4	12%	3	5%	5	13%	3
Respiratory	9%	5	7%	5	8%	4	—	—
Genitourinary	—	—	6%	6	5%	6	7%	5
Other	37%	—	37%	—	39%	—	36%	—
Total %	100%	—	100%	—	100%	—	100%	—
Population (N)[a]	547,086	—	478,180	—	177,450	—	426,479	—
Rate n/1000 personnel/year	155	—	81	—	76	—	97	—

[a] Calendar year frequencies.

Source: Defense Medical Surveillance System, U.S. Army Center for Health Promotion and Preventive Medicine.

Table 4. Distribution (% of total) of leading categories of hospitalization during the Persian Gulf War (Operation Desert Shield/Storm) 1990–1991 and Operation Joint Endeavor (Bosnia) December 1995 to November 1996

	Persian Gulf War[1]		Bosnia[21]	
Principal Diagnosis Group	%	rank	%	rank
Non-battle injury	25%	1	20%	1
Musculoskeletal	14%	2	10%	4
Digestive	12%	3	14%	2
Ill-defined signs and symptoms	9%	4	14%	3
Genitourinary	6%	5	9%	5
Other	44%	—	43%	—
Total *n*	21,655[a]		—	
Rate of hospitalizations/1,000 soldier-hours	159		64	

[a] Battle casualties = 4.4%; N = 956.

higher than peacetime rates; the overall hospitalization rate during OJE was 64 per 1000 soldiers per year,[21] significantly lower than in peacetime (Table 4). Figure 1 shows the hospitalization rates of DNBI compared to battle injuries for wars and major deployments from World War II to the present. Of note, rates of DNBI have successively declined in conflicts and deployments since the Korean War.[1,19,20]

Outpatient injuries. Even though injuries treated in outpatient clinics—such as ankle sprains, strained muscles, and stress fractures—are only mild to moderately severe in nature, they result in large manpower losses because of the high number of occurrences. For the Army, outpatient-treated injury rates of 50 to over 150 per 100 soldiers per year have been reported.[1,13,22–25] Rates vary depending on the type of unit[25] and type and amount of training.[26] If we assume average injury rates of 100 visits per 100 soldiers per year, that would translate to about 480,000 outpatient injury visits in the Army per year. Limited duty rates of 40 days to 120 days per 100 soldiers per month have also been reported for different Army populations.[1,22,23,25] Data on Marines are similar to the Army,[1,22,27] but little data are available on outpatient treatment rates for injuries for the Navy and Air Force. During military deployments such as Operation Restore Hope in Somalia and Operation

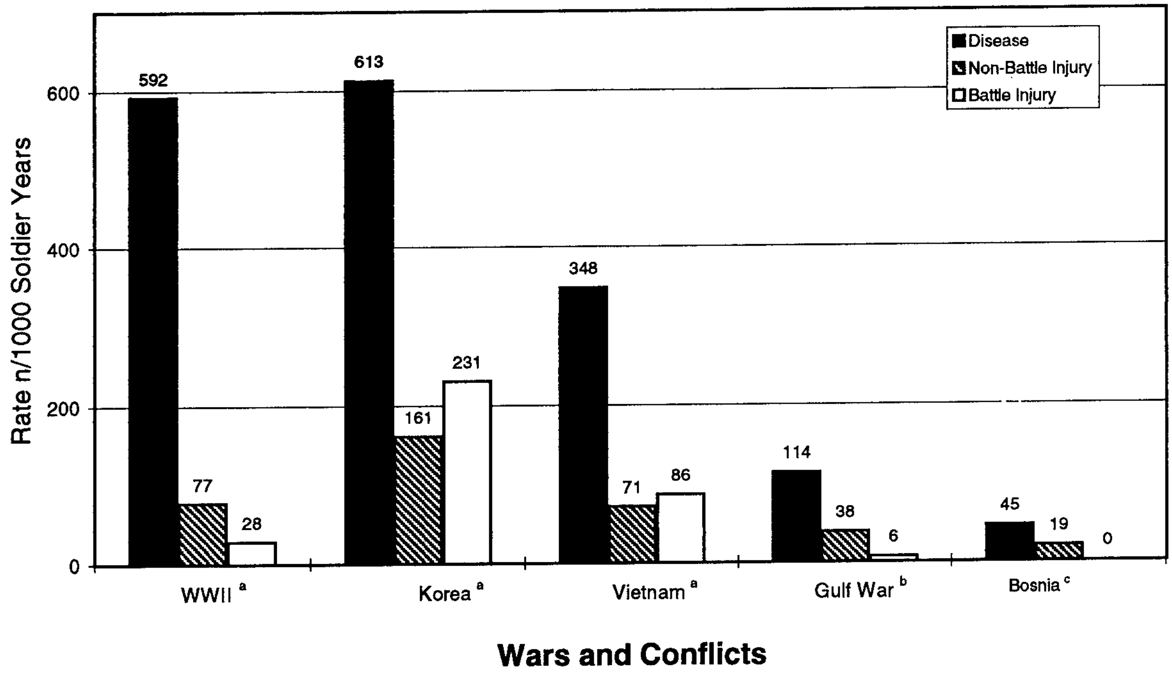
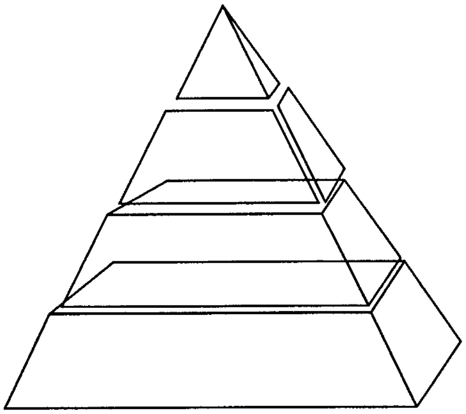


Figure 1. U.S. Army hospitalization rates during selected wars and operations for diseases and non-battle injuries compared to battle injuries. (Persian Gulf War information derived from unpublished data.)[1,19–21]

[a] Neel, Spurgeon. Medical Support of the U.S. Army in Vietnam 1965 to 1970. Department of the Army, U.S. GPO, Washington, DC, 1973.

[b] Unpublished data.

[c] Medical Surveillance Monthly Report, Vol 2(9): p.9, Nov 1996. Gulf War Aug 1, 1990 to Jul 31, 1991, web site: http:\\amsa.army.mil/msmr.htm



Injury Category	Approximate Frequencies Army n	Navy/ Marine Corps n	Air Force n
Deaths	370	300	175
Disabilities	4,000	5,400	850
Hospitalizations[a]	21,500	11,300	9,400
Outpatient[b]	500,000	-- --	--

[a] Hospitalization for Injuries = Musculoskeletal + Injury ICD-9 Principal Diagnosis Groups
[b] Estimated for Army from research studies

Figure 2. Injury pyramid for all military services 1994

Uphold Democracy in Haiti,[1,20] injuries treated in outpatient settings, such as battalion aid stations, were an important cause of morbidity. During these major military operations since the Persian Gulf War, injuries requiring outpatient treatment occurred at rates of 2.5 to 3.5 per 100 soldiers per week (approximately 130 to 182 per 100 soldiers per year), making injuries the leading specific category of morbidity.

Data were evaluated to establish the relative frequencies of injuries with different degrees of severity. The results were summarized with an injury pyramid (Figure 2). For example, among Army soldiers, the injury pyramid statistics for 1994 show that 370 injury fatalities occurred that year and about 500,000 outpatient injuries, or roughly one fatality occurred per 1300 outpatient injuries. The results indicate an inverse relationship between the severity and the frequency of injuries. In turn, prevention efforts should be directed toward less severe but much more common injuries as well as those with fatal or severe outcomes.[5]

Step 2. Identify Causes and Risk Factors for the Problem

To develop effective prevention strategies, it is necessary to go beyond merely determining the magnitudes and distributions of injuries; we must also determine the causes and risk factors.[9–13] Data on causes of injuries are routinely collected. For instance, the service safety centers routinely collect detailed information on motor vehicle and aviation crashes, as well as other unintentional injury events referred to as "accidents" and "mishaps." Also, medical records systems in each branch of the military services record data on causes of injuries resulting in hospitalization. The military medical departments employ a standard NATO coding system for external causes of injury, similar to ICD-9 E-codes.

Table 5 shows the three most commonly reported specific causes of injury events from the Army Safety Center and the Army hospital records systems in 1994.[13] The leading causes of injuries in each system included motor vehicles and sports. The third most common cause category identified by the Army Safety Center was combat soldiering activities, such as tactical parachuting and road marching. The third leading cause of hospitalizations was falls. Air Force data (Table 6) show similar categories to the Army with the exception of more industrial mishaps and no combat soldier injuries.[13] Such data provide important clues about where to focus injury prevention efforts.

In addition to these surveillance activities, several military research centers conduct injury-related studies. The bulk of recent research has focused on the epidemiology and prevention of physical training-related injuries such as sprains, strains, stress fractures, and tendinitis. The emphasis on these training injuries makes good sense for two reasons: a large number of injuries routinely occur as a result of military training, and those injuries result in significant loss of duty time, ranging from a few days to many weeks per injury.

Military research efforts have identified many important risk factors for training injuries,[12] including greater amounts of running,[26] low levels of physical

Table 5. Leading causes of injuries and accidents in the Army, 1994[13]

Army Safety Data[a]—accidents		Hospitalization data[b]—injuries	
Cause	% Total	Cause	% Total
Privately operated vehicle	17%	Sports	18%
Sports	14%	Motor vehicle accident[c]	16%
Combat soldiering	11%	Falls/jumps	11%

[a] Accidents reported to the Army Safety Center; N = 4077.
[b] From the Individual Patient Data System, Patient Administration System and Biostatistics Activity, Fort Sam Houston, Texas; N = 10,003.
[c] Private and military vehicles included.

activity/sedentary lifestyle,[27–29] low levels of aerobic fitness/performance (i.e., slow run times),[23,27,28] high and low degrees of flexibility,[29–31] high arches of the feet[32] and cigarette smoking.[24,29] Some of this research has validated findings of civilian studies and common sense beliefs (e.g., more running results in more injuries,[12,26] low levels of fitness are associated with higher injury rates[12,28]). Other findings have been useful because they were unique, unexpected, or questioned commonly held but unproven hypotheses (e.g., both high and low levels of flexibility[29] are associated with greater risk of injury and high arches are more problematic than flat feet[32]).

Recent research on disabilities in the Army has shown that some military occupational specialties (MOSs) are at greater risk of sustaining injuries that result in long-term disabilities. The average annual disability rate across MOSs is 9 cases per 1000 soldiers per year.[33] Disability rates for infantry soldiers are twice as high as the average (18 per 1000 soldiers per year). Rates for heavy construction and combat engineers are 16 and 13 per 1000 soldiers per year, respectively.[33] These findings are not surprising, given the demanding nature of infantry, heavy construction, and combat engineering occupational specialties in the Army. Such data provide persuasive evidence for focusing prevention efforts on specific target populations.

Other research has shown that alcohol[34] and failure to wear seat belts[35] are risk factors for motor vehicle–related injuries. Hospitalization rates for motor vehicle crashes increase successively for groups of Army personnel reporting less frequent use of seat belts.

From results such as those described, it is evident that despite the small size of military injury research programs, a number of important modifiable causes and risk factors for injuries have been identified. Such risk factor data provide the foundation for future prevention strategies.

Step 3. Determine What Interventions Work to Prevent the Problem

To effectively prevent complex public health problems such as injuries, interventions should be tested and evaluated prior to widespread implementation. The following series of examples illustrates this point.

Reduced running mileage. Lower-extremity injuries during military basic training are very common and great emphasis has been placed on preventing them.[1,12,22] In the mid-1980s, Army research suggested that above certain thresholds of physical training, injury rates increased but fitness did not. In other words, running more miles resulted in higher injury rates, but did not improve aerobic physical fitness.[26] These findings were consistent with the civilian sports medicine literature, which indicated that successively greater amounts (more minutes or miles) of running are associated with progressively increasing risks of injury.[36–38] Furthermore, Pollock[38] showed that while more running resulted in a higher incidence of injuries, aerobic fitness (measured by maximum oxygen uptake) did not improve above certain levels of training frequency and duration.

In a 1995 military study, the Naval Health Research Center demonstrated that reduced running mileage and gradual progression of training resulted in a 50% reduction in the incidence of stress fractures without a degradation of aerobic fitness benefit (as measured by run times).[1,12,22] Putting this knowledge into practice by reducing running mileage at a single Marine recruit training center resulted in a $4 million cost savings in

Table 6. Leading causes of injuries and accidents in the Air Force, 1994[13]

Air Force Safety Data[a]—accidents		Hospitalization data[b]—injuries	
Cause	% Total	Cause	% Total
Industrial mishaps	39%	Sports	23%
Sports	26%	Motor vehicle accidents	10%
Privately-owned vehicles	16%	Falls/jumps	8%

[a] Accidents reported to the Air Force Safety Center; N = 4464.
[b] Injury hospitalized cases for Air Force; N = 4934.[12]

just 1 year. This study confirmed that injury rates can be reduced by decreasing the amount of weight-bearing training (i.e., running) while still achieving the desired aerobic fitness levels.

Parachute ankle braces. Army Safety Center data in the early 1990s indicated that ankle sprains were a significant problem associated with airborne operations (parachuting). Researchers speculated that an ankle brace worn outside of the boot might prevent this common problem. A randomized trial studying the effect of outside-the-boot ankle braces on 745 parachutists demonstrated an 85% reduction in the incidence of ankle sprains among brace wearers.[39] The researchers found that a 0.3% incidence of sprains occurred in the brace group compared to 1.8% in the non-brace group.[39] The ankle brace is now used routinely at the Army Airborne School at Fort Benning, Georgia.

Shock-absorbent boot insoles. In 1985, Marine Corps personnel at a recruit training depot suspected that they had a problem with stress fractures. In response, the Marine trainers proposed issuing shock-absorbent boot insoles to all incoming trainees to reduce the incidence of stress fractures. Before implementing the intervention, researchers were requested to conduct a large randomized trial of the shock-absorbent insole to determine if the insoles would decrease stress fracture incidence. The trial indicated that the shock-absorbent insoles did not reduce the incidence of stress fractures.[40] As a result, the Marine Corps did not issue the insoles, thereby saving the large expense of purchasing an ineffective piece of equipment for every incoming recruit.

These examples of successful and unsuccessful interventions demonstrate the need to test prevention strategies prior to broad implementation.

Step 4. Implement and Evaluate Prevention Strategies and Programs

Successful injury prevention requires integration of diverse organizational and structural elements, data and assessment functions (surveillance, research, and evaluation), policy formation, and intervention activities.

Although program implementation was not the focus of its work, the AFEB work group made recommendations regarding prevention strategies. In addition, the work group report clearly indicated the need to integrate medical surveillance and research into prevention program planning as a foundation for these programs.

Step 5. Continue Surveillance and Monitor Effectiveness of Prevention Efforts

Surveillance and monitoring activities are essential for prevention program success. Demonstrating that interventions work in an experimental setting does not ensure their success in free-living populations. Once programs have been established, surveillance can be used to monitor trends of injury and illness and to assess the effectiveness of prevention strategies.

Until recently, deaths among active duty military personnel were the only medical outcome routinely followed. Fatalities have been reported annually since 1979. Also, each military service is required to maintain a safety program to prevent accidents and mishaps and to track reportable events.[41] Data from the service casualty offices and safety centers compiled by the DoD Injury Surveillance and Prevention Work Group[13] are reviewed in the following sections.

Fatality trends. Figure 3 shows that from 1980 to 1994 accidental (unintentional) injury-related fatalities decreased 56% in the military services, from 78 deaths per 100,000 personnel per year to 34 per 100,000 personnel per year.[42] During the same period, accidental (unintentional) injury-related fatality rates for the U.S. Army decreased 46% from 74 per 100,000 personnel per year to 40 per 100,000 personnel per year. Overall, DoD and Army fatality rates due to accidental injuries continued to decline into the mid-1990s (Figure 3).

Motor vehicle mortality/morbidity trends. By published directives, the DoD, and consequently all the military services, places great priority on the reporting and prevention of motor vehicle– and aviation-related crashes.[41] Army Safety Center data on privately owned motor vehicle crash fatalities show that rates decreased roughly 50% from the early 1980s to 1994, from about 40 per 100,000 soldiers per year to about 20 per 100,000 per year, respectively[13] (Figure 4). With the exception of the 12-month period during the Persian Gulf War military operations (August 1990 to July 1991), military (government-owned) vehicle crash fatality rates remained fairly constant at about 5 per 100,000 soldiers per year from 1980 to 1994.[13] Reductions in motor vehicle crash fatalities accounted for 60% or more of the decrease in overall fatality rates for the Army (Figure 4).

Efforts to prevent motor vehicle fatalities in the Army also had a significant impact on hospitalization rates. From 1980 to 1994, rates of hospitalizations for motor vehicle crash-related injuries decreased over 60%, from 5.6 injuries per 1000 soldiers per year to two injuries per 1000 soldiers per year (Figure 5).[13]

Aviation crash trends. Reduction in aviation crash fatalities provides another example of a successful military safety program. Navy Safety Center data demonstrate an enormous (>90%) reduction in aviation fatalities since 1951.[13] Rates decreased from 55 deaths per 100,000 flight hours in 1951 to 3 per 100,000 flight hours in 1995. Aviation fatality rates in the Navy fell sharply from 1951 to 1961, and then continued to gradually decrease (Figure 6). In the 20 years between

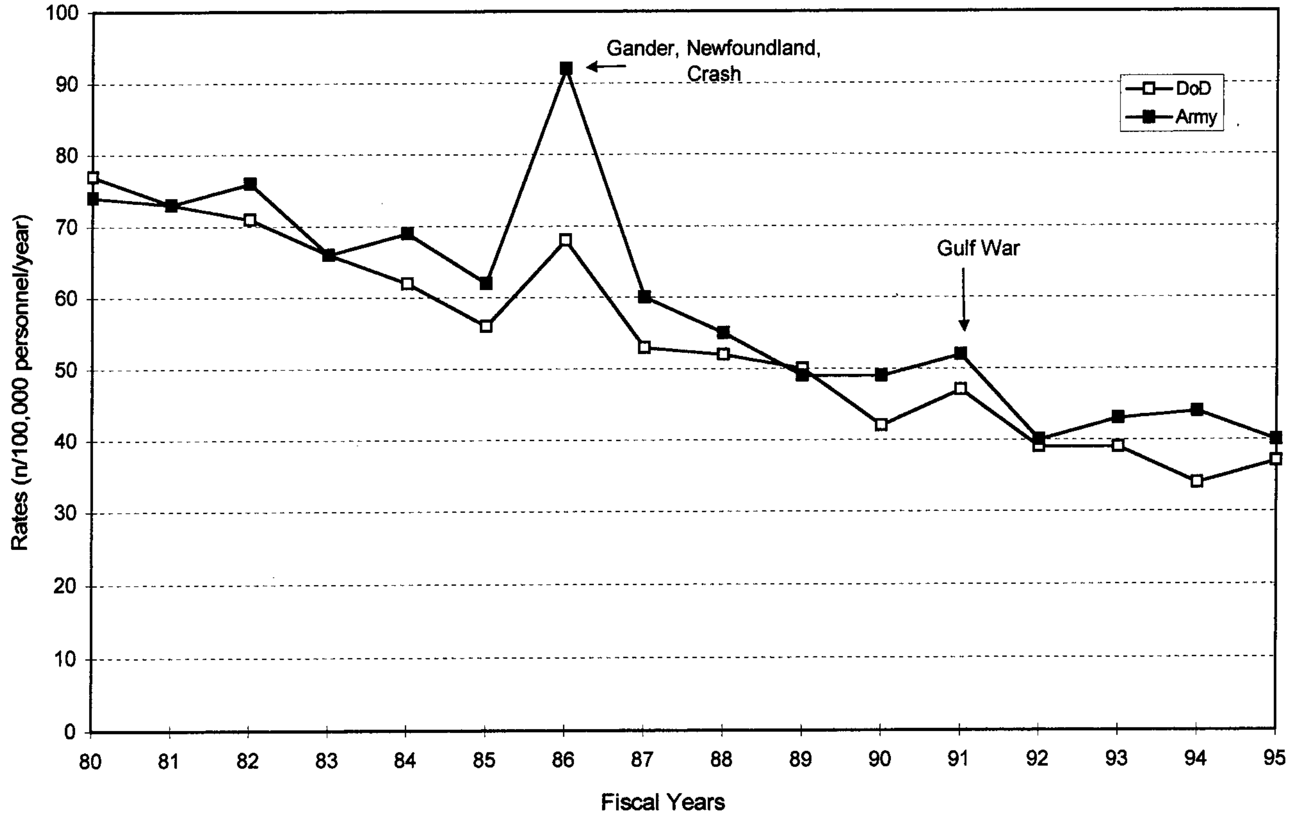


Figure 3. Department of Defense (DoD) and U.S. Army overall rates of death due to accidents (unintentional injuries) among active duty personnel, FY 1980 to 1995[42]

1973 and 1993, Navy aviation crash fatality rates decreased about 60%, from around 9 per 100,000 flight hours to 3 per 100,000 flight hours, so success continues, albeit at a slower rate of change.

Army aviation safety data document similar fatality reduction successes.[13] From 1973 to 1994, Army aviation fatalities decreased about 50% with the exception of a spike in rates during the Persian Gulf War in 1991 (Figure 7).

DoD emphasis on safety and the reporting of injuries and mishaps may in part explain the relatively low rates of deaths in military compared to civilian populations of the same age, race/ethnicity, and gender (as reported by Rothberg et al. in 1990).[16] Furthermore, the great success at preventing motor vehicle crash-related injuries and aviation mishaps in the military can most likely be attributed to emphasis by unit commanders and safety officers and routine surveillance conducted by the service safety centers.

Discussion

After examining data on the health of military service members similar to that reviewed in this article, the AFEB work group concluded that injuries are the most important health problem confronting U.S. military forces. The findings of the work group revealed not only the size of the injury problem but also the richness of medical data maintained by all the military services and its availability for injury prevention purposes. The results of the work group's examination[1,14,17,18,20,22] illustrate the potential potency of these databases for injury and disease surveillance, prevention, and control. While the value of the data reviewed was indisputable, the process of gathering and collating it was extremely labor intensive and time consuming because the data were maintained in independent, widely disbursed, unlinked, medical, administrative, and personnel databases. Therefore, the primary recommendation of the work group and the AFEB itself was that the DoD should create a comprehensive military medical surveillance system to integrate these data.[1,5]

Building a comprehensive military medical surveillance system, as recommended by the work group, will provide the foundation for future public health activities and the critical first step toward a systematic injury prevention process consistent with the vision of public health and surveillance authorities.[6–8,10,43] The AFEB work group concluded that the essential data sources necessary to establish a comprehensive medical surveillance system already exist and are capable of assessing the overall health of the military community much the way Teutsch has described for civilian systems.[7] Key data recommended for inclusion in the system were

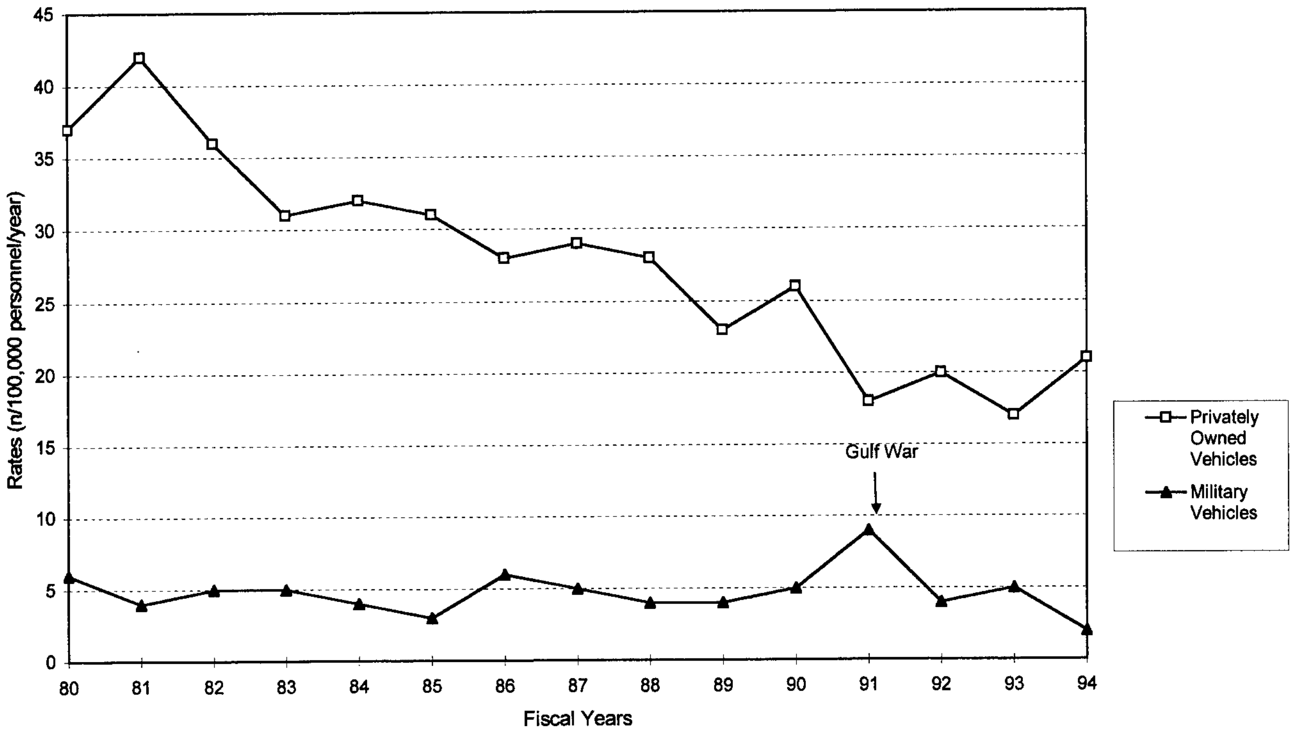


Figure 4. U.S. Army rates of death by privately owned and military vehicles for military personnel, FY 1980 to 1994[13]

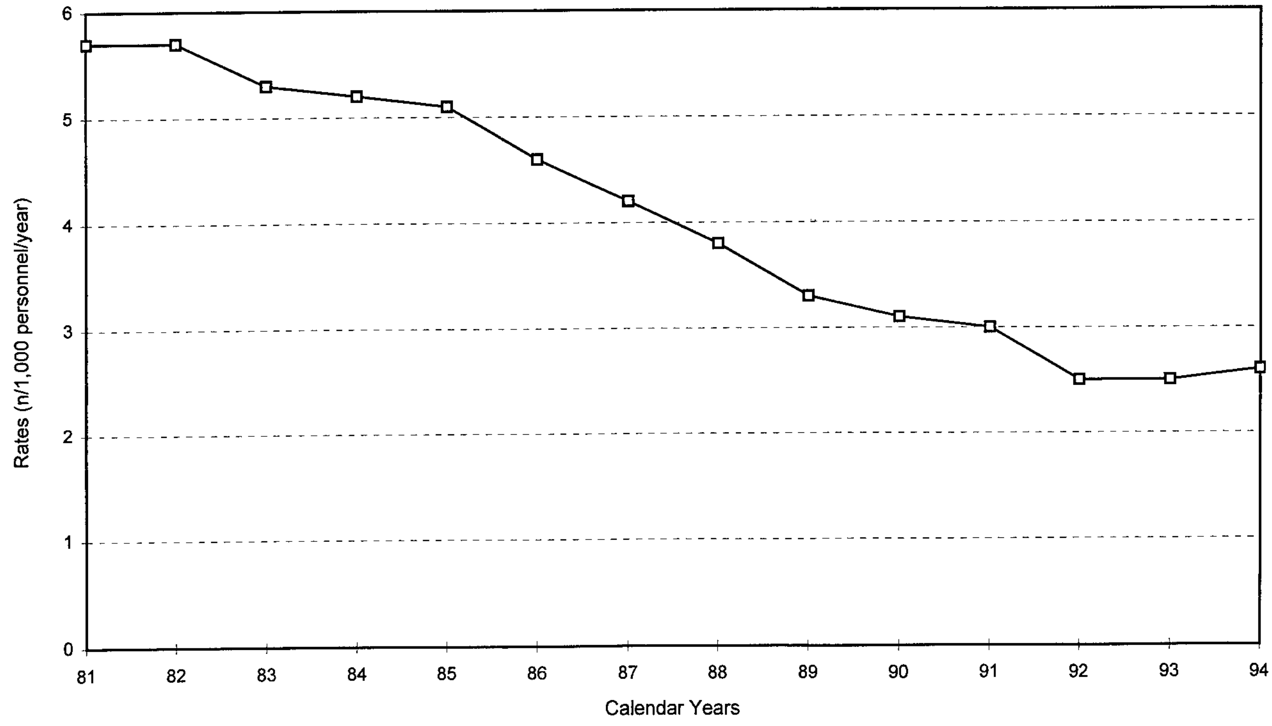
deaths, disabilities, hospitalizations, and outpatient encounters.[1,5]

The AFEB and the Assistant Secretary of Defense (ASD) for Health Affairs both endorsed the establishment of a comprehensive military medical surveillance system. Progress toward this goal was rapid. The Army Medical Surveillance Activity (AMSA) had already been built when the AFEB work group was just beginning its deliberations. In August 1997, the Army Medical Surveillance System at AMSA transitioned into the Defense Medical Surveillance System (DMSS) at the direction of the ASD for Health Affairs. The DMSS is now fully operational and contains tri-service medical outcome data and complete current personnel (population) data.

The DoD has made great progress toward creating a comprehensive medical surveillance system. Currently, for example, data regarding deaths, hospitalizations, outpatient visits, assignment locations (including major overseas deployment participation), military rank and occupation are routinely collected and integrated in an easily accessed, centralized data system. The value of the system could be enhanced, however, by the addition of disability data and more specific environmental and occupational exposure information. In turn, if links could be firmly established between medical outcomes (e.g., hospitalizations, clinic visits) and specific environmental or occupational exposures, then surveillance of the hazardous exposures themselves would be useful.[9,44–46]

Hazards and exposures are generally more numerous than the resultant adverse medical outcomes. It should be recognized that once firm links are established between injuries or diseases and environmental and occupational hazards and exposures, surveillance of these hazards and exposures will provide greater sensitivity for early detection of potential dangers prior to the onset of symptoms.[44–46] Early detection permits early intervention. Thus, surveillance of hazards and exposures should be an additional objective of military medical surveillance beyond that recommended by the AFEB (see Figure 8 for concept model). This type of surveillance should be done with the proviso that the association of the intermediate hazards and exposures with medical outcomes (i.e., injuries or disease) be well established before they are used for surveillance purposes.

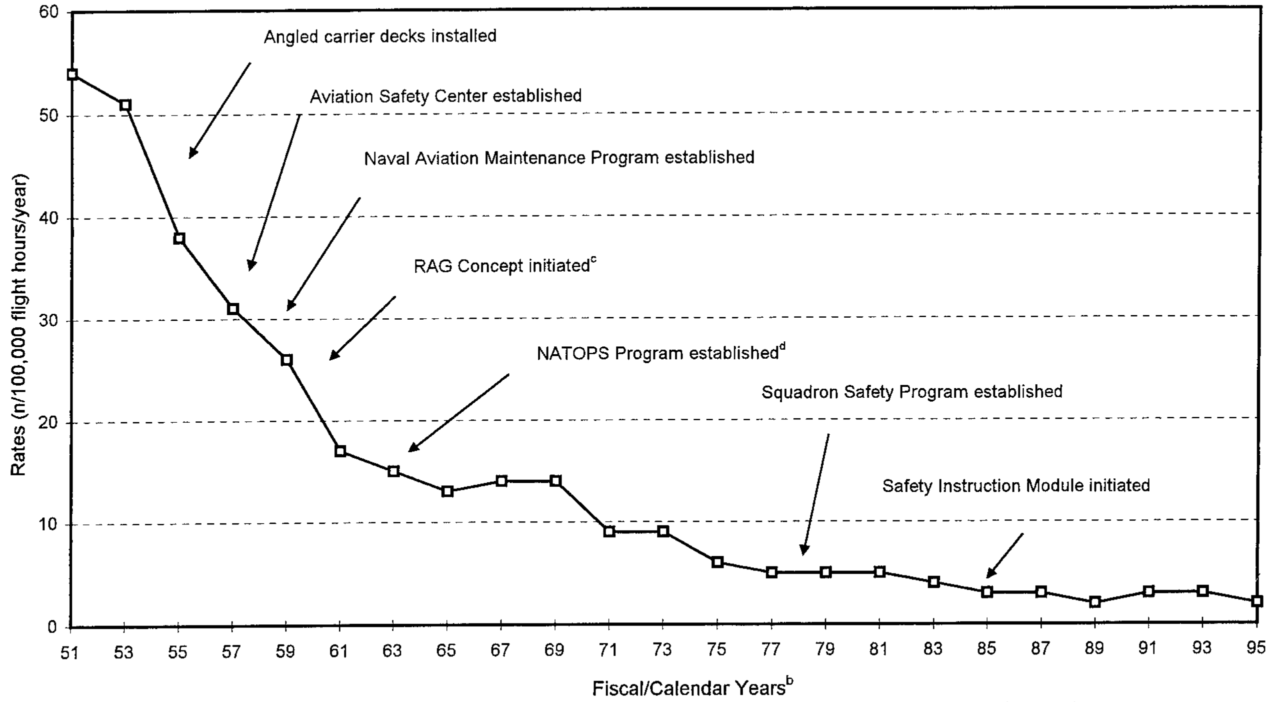
While the scope of the DMSS should be expanded, data quality enhanced, and attention given to minimum basic data sets (MBDS) for injury.[1,5] The top priority must be simply to begin using the data currently available. Even simple, provisional data can be of great value.[8,47] Furthermore, unlike medical research, maintenance of a medical surveillance system implies an obligatory link to action.[7,8,10,12] General responses to surveillance findings include outbreak investigations, research and development of strategies, and programs and policies to prevent injuries and disease.[3,6,7] The responsibility of those in charge of public health surveillance systems, such as the DMSS, is to ensure that the data are utilized and support decisions regarding policies, training, procedures, prac-



[a] NATO Standard Agreement (STANAG) codes.

Source: Individual Patient Data Systems, Patient Administration Systems and Biostatistics Activity, Fort Sam Houston, TX, and the Army Medical Surveillance Activity, USACHPPM, 1994.

Figure 5. U.S. Army rates of hospitalization for motor vehicle crashes[a], CY 1981 to 1994



[a] Class A = Fatality or permanent total disability; $1 million or more in damage, and/or aircraft, missile, or spacecraft destroyed.

[b] All years are fiscal years, except 1971, 1973, and 1975, which are calendar years. 1977 is January - September only.

[c] Replacement Air Group (RAG) concept.

[d] Naval Air Training and Operations Standardization (NATOPS) Program.

Source: Naval Safety Center, 1998.

Figure 6. U.S. Navy and Marine Corps rates of Class A flight mishaps[a] for military personnel, 1951 to 1995[b]

[a] Class A = Fatality or permanent total disability; $1 million or more in damage and/or aircraft, missile, or spacecraft destroyed.

[b] Data include active duty, Reserve, and National Guard.

Source: U.S. Army Safety Center, Washington, DC, 1997.

Figure 7. U.S. Army rates of Class A flight accidents[a] for military personnel,[b] FY 1973 to 1996

tices, equipment, and so forth, that can reduce risks of injuries and illnesses.

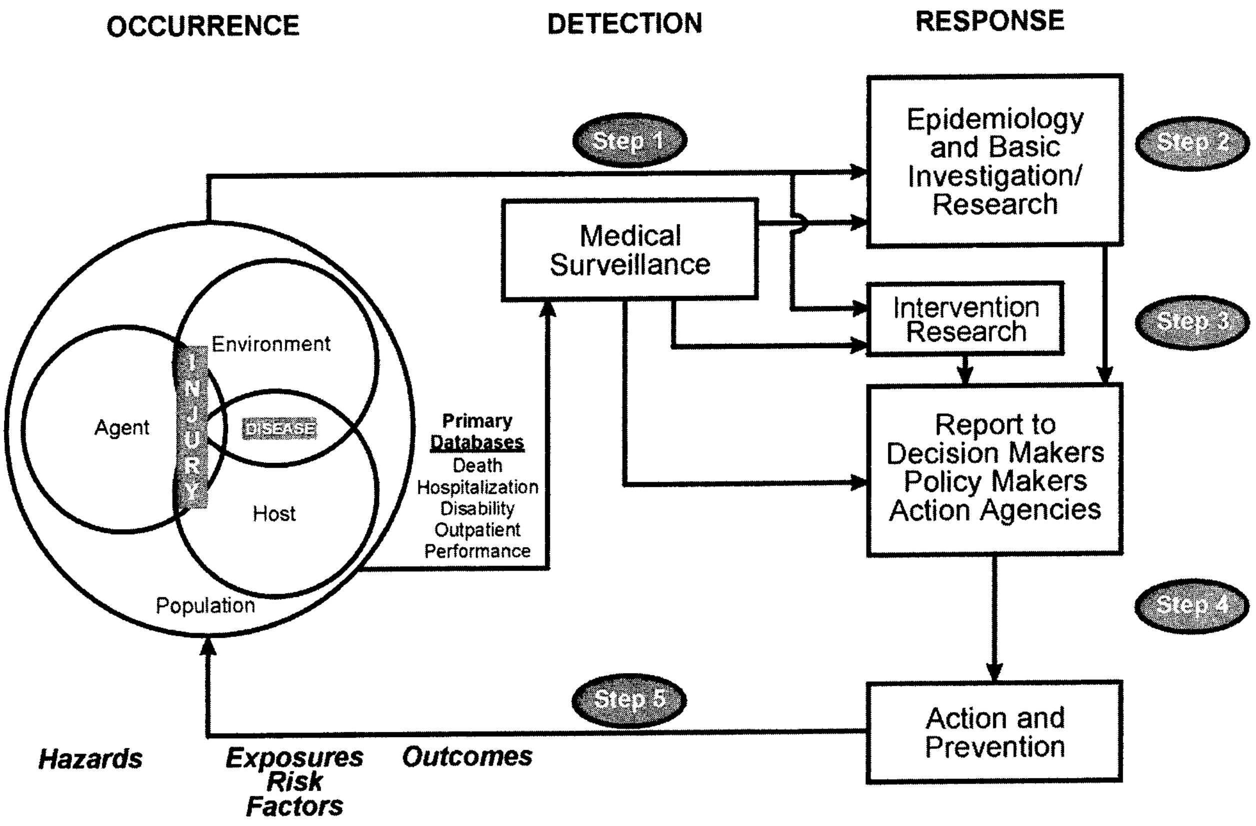
The AFEB work group concluded that ample data exist in the military to characterize public health problems across the spectrum of health—deaths,[1,13,14] disabilities,[1,17] hospitalizations,[1,18] and outpatient visits.[1,13,22] However, the existence of these primary data sources in themselves do not constitute a surveillance system[7]; they must be routinely and systematically integrated, analyzed, interpreted, and disseminated before they become a useful public health system.[7,8,10,12] In addition, surveillance alone cannot prevent injuries.[1,8,46] Recognizing these facts, the work group recommended that the available medical and personnel data be integrated and routinely utilized to identify and prioritize targets for both prevention and research.

In addition, the work group strongly recommended that a meeting of key military line, safety, medical surveillance, and research representatives be convened to share data and establish goals and objectives for using medical surveillance data for the prevention of injuries.[1] In the civilian sector, key injury prevention partners include fire and police departments, hospitals, engineers, schools, community leaders, and citizen action groups.[48] Figure 9 summarizes some of the most essential military injury prevention partners. To help coordinate, focus, and prioritize injury prevention activities in the military, an advisory council of these key partners—safety, research, and surveillance experts among others—should be formed and should meet on an annual or semi-annual basis in addition to the goal-setting workshop recommended by the AFEB.

As an initial prevention step, the AFEB work group identified several preliminary military injury prevention targets. These included injuries caused by physical training, motor vehicle crashes, sports, and falls.[1,5] Also, commonly diagnosed types of injuries, such as knee derangements, back problems, and fractures were identified as priorities. For some of these priorities, such as training injuries[1,22,26] and motor vehicle crashes,[34,35] enough information may exist to begin implementing specific interventions.

For other prevention priorities, more research or intervention testing is required. For sports and fall-related injuries, for example, more information on the circumstances surrounding injury events is needed before prevention strategies can be developed. For knee derangements, back complaints, and fractures, additional research is required to identify risk factors and modifiable causes. For yet other medical problems, such as parachute jump–related ankle injuries for which potential "off-the-shelf" solutions exist,[1,22,39] confirmatory prevention/intervention trials should be conducted in target populations.

Finding solutions to the diverse problems posed by injuries requires a multidisciplinary research approach incorporating epidemiologists, physicians, engineers, biomechanists, physicists, behavioral scientists, and other professionals.[3] In addition to the epidemiologic research reviewed by the AFEB work group, pathophys-



Steps 1-5 = Steps of the Public Health Process

Step 1. Identification of Problems
Step 2. Determination of Causes
Step 3. Determination of What Works to Prevent the Problem
Step 4. Implementation of Programs
Step 5. Monitoring/Surveillance and Evaluation of Program/Strategy Effectiveness

Figure 8. Integrated injury and disease surveillance and prevention model

iologic, biomechanical, safety, engineering, psychosocial, health economics, and other types of research are needed.[3,6,48] As with medical surveillance, much of the infrastructure necessary to conduct meaningful injury research exists in the military. In the future, prevention of injuries will require better coordination of diverse military research and technical organizations. Finally, resources for research that are more commensurate with the documented magnitude of the military injury problem are needed.[1]

Currently, within the DoD, great emphasis is placed on prevention and medical surveillance. This emphasis represents a paradigm shift[49] that has occurred since the end of the Cold War.[45] If the DoD interest in surveillance is sustained, it could have tremendous implications for the future of military medicine and possibly public health in the United States. The National Academy of Science's Institute of Medicine report, *The Future of Public Health,*[43] stated, ". . . policy development in public health at all levels of government is often responding to the issue of the moment rather than benefiting from careful assessment of existing knowledge, establishment of priorities based on data and allocation of resources according to objective assessment of possibilities for greatest impact." The DoD has a unique opportunity to transcend the ad hoc approach to public health by establishing what could be the most comprehensive population-based health surveillance system in existence. With careful planning and coordination of the diverse organizations, public health professionals, and data systems available to contribute to injury and disease prevention and control, the DoD could create model public health surveillance systems and prevention programs.

Summary

The primary conclusion of the AFEB work group was that injuries in the military currently pose the most significant threat to the health and readiness of the

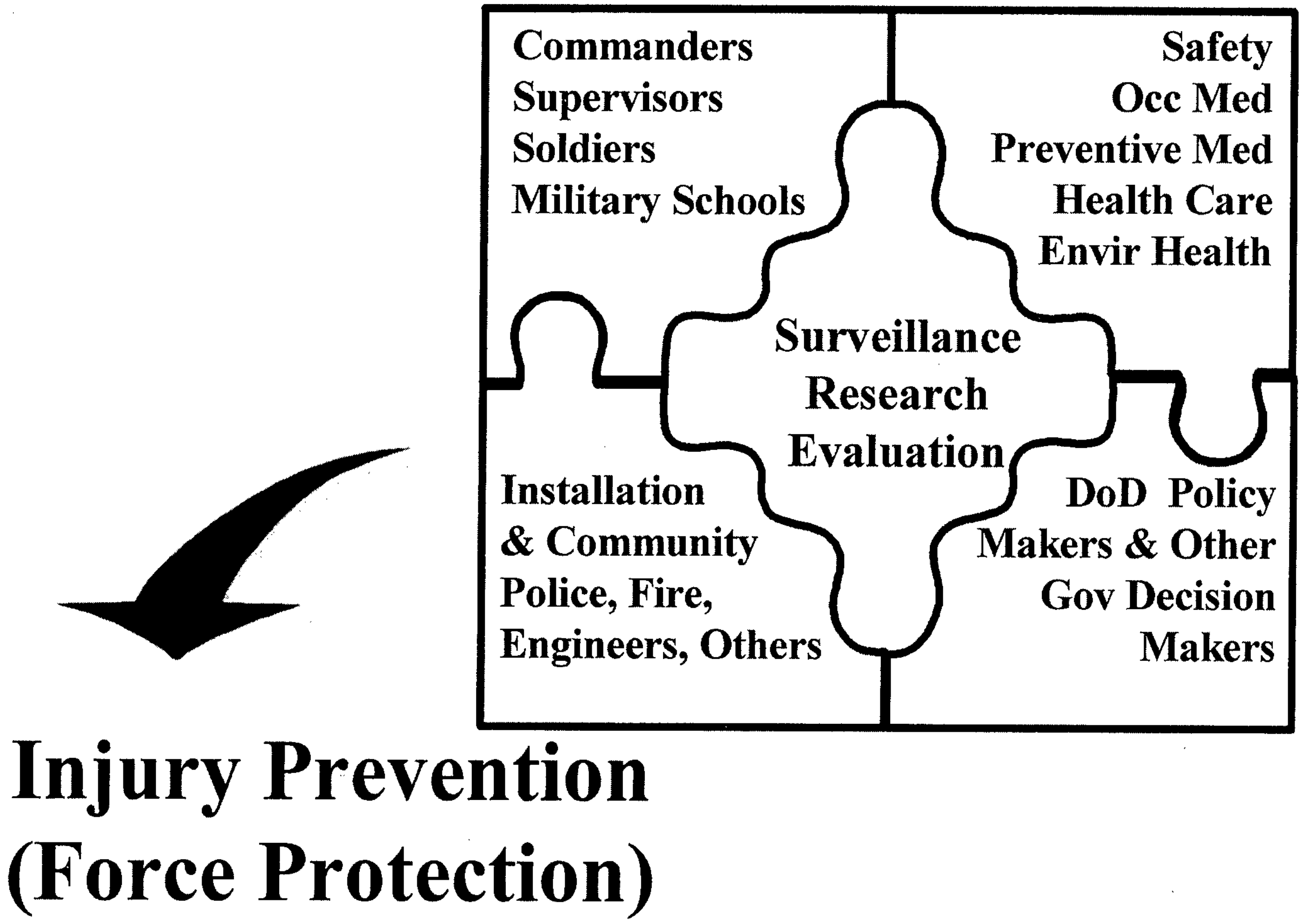


Figure 9. Key military injury prevention partners

U.S. Armed Forces. This article and preceding articles[5,14,17,18,20,22] in this supplement show how the AFEB work group arrived at this conclusion. The AFEB report and the articles in this supplement also illustrate how existing military data sources offer great value to the entire process of injury prevention and control. However, to be of optimal value, these data sources must be routinely and systematically integrated, analyzed, interpreted, and disseminated to those who can act to prevent injuries.[1,7,8,43,45] Consequently, the group's chief recommendation was the formation of a comprehensive medical surveillance system.[1,5] The DMSS was the first step taken toward implementing such a system. However, data included in the system should continue to expand, and results of data summaries and analyses should be disseminated beyond the boundaries of the military service medical departments. DoD policy and doctrine must formally establish active partnerships, not just among surveillance, health care, and safety professionals, but also among military commanders, policymakers, military training centers and military schools. Successful military prevention and control of injuries in the future will depend on the judicious use of surveillance information to guide decision making and the establishment of a unified effort to achieve common goals.

The extraordinary efforts of Ms. M. Barbara Weyandt and Ms. Judith B. Schmitt of LB&B Associates, Inc., made publication of this article and others in this series possible. They coordinated the writing and revisions of all papers in this supplement on injuries in the military. In addition, they produced many of the graphs and tables in this paper, as well as others. Their personal investment in and dedication to seeing the process of publishing this article and the others completed was the critical difference in our success. I and the others involved in this process owe them more than can be expressed in a simple thank you.

The opinions and assertions contained herein are the private views of the authors, and are not to be construed as official or as reflecting the views of the Department of Defense.

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Self-Reported Risk-Taking Behaviors and Hospitalization for Motor Vehicle Injury Among Active Duty Army Personnel

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Background: Motor vehicle crashes are a leading cause of injury in the Army. Behaviors increasing risk for motor vehicle crashes are also prevalent, but research has not linked these behaviors directly to injury outcomes (e.g., hospitalizations).

Methods: To evaluate the relationship between behavior and motor vehicle crash injuries, 99,981 Army personnel who completed Health Risk Appraisal surveys in 1992 were followed for up to 6 years. Cox proportional hazards modeling was used to evaluate speeding, seat belt use, drinking patterns, and demographics.

Results: A total of 429 soldiers were hospitalized for motor vehicle injury. Unadjusted analyses revealed that heavy drinking, drinking and driving, speeding, low seat belt use, younger age, minority race/ethnicity, and enlisted rank were significantly associated with motor vehicle injury, but neither smoking nor gender was. Multivariate models showed a significant trend of increasing injury risk with younger ages. Soldiers under age 21 were injured almost five times more often than those over age 40 (HR 4.89, 2.56–9.33). Also associated with risk for hospitalizations were minority race (HR 1.78, 1.46–2.18), heaviest drinkers versus abstainers (HR 1.81, 1.11–2.94), and seat belt use of 50% or less versus 100% (HR 1.40, 1.07–1.85). Although nonsignificant, there was evidence of an age–drinking interaction where the difference in injury risk between those older and those younger than 21 was greatest at low alcohol consumption levels.

Conclusions: Modifiable risk factors associated with motor vehicle injuries include heavy drinking and low seat belt use. Programs targeting these behaviors that meet the needs of young and minority soldiers are needed. The high density of young, at-risk soldiers residing in base housing may provide a unique opportunity for a residential intervention program.

Medical Subject Headings (MeSH): military personnel, wounds and injuries, hospitalization, alcohol drinking, drinking behavior, automobile driving, risk-taking behavior, military medicine (Am J Prev Med 2000;18(3S):85–95) © 2000 American Journal of Preventive Medicine

Introduction

Motor vehicle–related injuries are a leading cause of death and lost years of productive life in the United States. In 1996, a total of 41,907 people were killed in police-reported car crashes and over 3.5 million were injured.[1] Motor vehicle–related crashes account for 3.2% of U.S. spending on medical care. Alcohol-involved crashes alone cost more than 100 billion dollars a year.[2,3]

Motor vehicle crashes are also a leading cause of death and disability among active duty military personnel. When late effects of injury and complications from medical or surgical procedures are excluded, motor vehicle–related crashes are the leading cause of injury hospitalizations. Unintentional injuries are a problem for all the members of the U.S. Armed Forces, especially the U.S. Army. Injury hospitalization rates are higher for active duty Army personnel than for active duty Navy or Air Force personnel. The Army case rate for motor–vehicle injury hospitalizations in 1992 was 2.5 per 1000 person-years, as compared to 1.5 per 1000 person-years among Air Force personnel.[4]

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Although motor vehicle–related hospitalizations are a significant problem for the Army, there is surprisingly little research to date on risk factors for these injuries among this occupational cohort. Research documenting risk behaviors and their potential influence on motor vehicle injury rates does not generally link the behaviors with actual injury outcomes. The goal of this analysis is to identify and describe demographic and behavioral factors associated with a measurable increase in risk for motor vehicle–related injury hospitalization among Army personnel. Another purpose of this study is to explore the feasibility of using several sources of secondary data, including actual health outcomes and self-reported behaviors, to identify important targets for prevention of injuries in the Army.

Background

Alcohol use, smoking, speeding, failure to wear a safety belt, young age, and male gender have all been associated with greater frequency and/or severity of motor vehicle injuries.[3,5–18] Risk behaviors tend to covary; those who are heavy drinkers in their daily lives are also more likely to drive while intoxicated, speed, and fail to wear their safety belts.[6,19–22] Studies also suggest that an age–alcohol interaction effect exists where younger drivers, who drink even small amounts of alcohol, are at much greater risk of a motor vehicle–related crash than their older counterparts.[23–25]

Studies of health behaviors in military populations suggest that, while typically they are younger and more physically fit than the general population, they are more likely than their civilian counterparts to smoke and drink heavily, which may make them particularly at risk for motor vehicle–related injury.[26–28] There is, in fact, evidence from outcome studies that unhealthy drinking habits increase the risk for motor vehicle–related deaths among military personnel. In a 1990 study reviewing death certificates among Air Force fatalities, 23% of deaths (the majority of which were injuries caused by motor vehicles) could be linked, through the Alcohol-Related Disease Impact computer mapping program, directly to alcohol use.[29]

Some behaviors that may increase the risk for motor vehicle injury covary among military personnel.[30] Fertig and Allen[31] observed a greater likelihood of engaging in risky driving practices among heavy drinkers in the Army. However, these associations are not consistent across all risk behaviors or occupational subgroups in the Army. Fitzpatrick and Shannon[32] found that among Army aviators there was a subculture that supported heavy drinking, as well as driving a car while intoxicated or riding with someone who was intoxicated. However, this same group was more likely to wear their safety belts.

While these prior studies have improved our understanding of the prevalence of some risk-taking behaviors among active duty military, there is still a need for better linkage of health behavior surveillance data with actual health outcomes.[33] More work needs to be completed on the documentation of military personnel subgroups engaging in risky behavior, and to quantify the actual health outcomes associated with these behaviors.

In the civilian sector, Behavioral Risk Factor Surveys (state-conducted surveys for the Centers for Disease Control and Prevention) have been widely accepted as providing important information regarding lifestyles, risk factors, and prevention practices.[34–38] The Army has a similar tool called the Health Risk Appraisal (HRA). This self-administered survey includes a number of items assessing health habits, including those related to motor vehicle safety. To date, these risk survey data have not been linked to health outcomes. The HRA has recently been added to the Total Army Injury and Health Outcomes Database (TAIHOD).[39] The TAIHOD is a large database maintained by the U.S. Army that links individual soldier personnel, hospitalization, disability, and death records using encrypted social security numbers. The inclusion of the HRA in this database provides a unique opportunity to link health behaviors with actual health outcomes.

Methods

Study Population

The study population is comprised of all Army personnel who took an HRA in 1992. A retrospective cohort study design is used to evaluate self-reported risk behaviors and motor vehicle injury hospitalizations among the study population. Demographic characteristics and health outcomes among those in the study population (99,981 who took an HRA in 1992) and those not included in this analysis (673,773 on duty in 1992 who did not complete an HRA) are compared to assess external validity of the findings. Individuals administered an HRA during 1992 are followed until they leave the service, experience the outcome of interest (motor vehicle–related injury hospitalization), or the follow-up period ends (December 1997).

The Data

The TAIHOD, developed and maintained by the U.S. Army Research Institute of Environmental Medicine (USARIEM), links demographic, health behavior, and health outcome information for all soldiers on active duty with the Army between 1980 and 1997.[39,40] The TAIHOD incorporates individual-level data on every active duty soldier since 1980, including personnel records, hospitalization, disability, and death information, as well as accidents resulting in lost time from work.

HRA data measuring health behaviors have recently been added to the TAIHOD. The HRA is comprised of 75 items derived from the Rhode Island Wellness Survey and the Carter Center Health Risk Assessment. It is also very similar to the CDC Behavior Risk Factor Surveys.[35,38] The HRA, which explores various health habits and risk behaviors (including those directly pertaining to motor vehicle safety), is most commonly administered when a soldier is in-processing to the military for the first time or to a new post. The survey may also be given as part of periodic physical fitness exams (usually done twice a year), incorporated as part of regular physical health exams, given when a soldier uses some outpatient or occupational health care services, or for other unspecified reasons.

An assessment of the external validity of the HRA is included as part of this study since its administration is not entirely random, and the potential exists for oversampling those at greater risk for adverse health problems (e.g., those who go to the outpatient or occupational health clinic).

HRA variables used in this analysis include:

- Smoking habits
- Typical quantity of alcohol consumed in a week
- Frequency of impaired driving or times spent accompanying a drunk driver in a car
- Speeding behavior
- Proportion of time a seat belt is worn

Smoking was coded as "never," "former," and "current." Alcohol use responses were obtained for typical weekly quantities consumed. There were, unfortunately, no measures of typical drinking frequency. The weekly drinking quantity variable was grouped as follows: 0 drinks, 1–6 drinks, 7–14 drinks, 15–21 drinks, and >21 drinks. "Drinking and driving" was coded as a simple yes/no dichotomous variable reflecting whether or not the respondent had driven while intoxicated or ridden with a drunk driver one or more times in the past month. The HRA includes only one item to assess exposure to impaired driving. Thus, when a person responds affirmatively to this question it could mean he or she drove after drinking too much alcohol, or he or she rode with someone who had consumed too much alcohol, or he or she was involved in both situations in the past month.

Speeding behavior was evaluated by asking, "On average how close to the actual speed limit do you usually drive?" Responses were grouped as follows: Drive within 5 miles of speed limit, Drive 6–10 miles over speed limit, Drive more than 10 miles over the speed limit, or Don't drive.

Seat belt use was categorized for analysis into a three-level variable reflecting percentage of time the safety belt is typically worn: 100% of the time, 51%–99% of the time and 50% or less. McKnight and Dawson's[37] evaluation of the validity of self-reported seat belt use suggests that those who say they wear their belts 100% of the time are reliable seat belt wearers.

The TAIHOD personnel information includes population demographic characteristics such as gender, race/ethnicity, age, and rank for every active duty person in the Army from 1980 to 1997. For former active duty personnel who have been discharged from the Army, this dataset also contains detailed information about the date and reason for discharge, allowing for very accurate documentation of exposure (denominator) information. Demographic data incorporated in this study included: gender, age (<21, 21–25, 26–30, 31–35, 36–40, and 41+), race/ethnicity (Caucasian and non-Caucasian), and rank (officer, warrant officer, and enlisted).

The Army Individual Patient Data System (IPDS) component of the TAIHOD provides the following data on every active duty Army soldier hospitalized from 1980 to 1997: nature of hospitalization by ICD-9 CM codes and cause of injury coded by Standard NATO Agreement (STANAG) codes of external cause.[41,42]

All hospitalizations of an active duty soldier, whether the hospitalization occurs in a military or civilian facility, are required to be recorded in the IPDS portion of the TAIHOD. Complete case capture is ensured because payment for services rendered outside of the military medical system is linked to recording data in the IPDS. This is important because many motor vehicle injuries occur off duty or away from military hospitals.

IPDS data were used to identify motor vehicle injury hospitalizations—the outcome variable for analysis. The outcome variable is defined using STANAG injury codes (100–102 and 110–112), an external cause-of-injury coding mechanism similar to E-codes, which is available on all injury discharges.[41,42]

STANAG 100–102 codes relating to accidents not involving military-owned vehicles include:

- 100 = driver of vehicle
- 101 = passenger
- 102 = injury is to unspecified occupant of the motor vehicle

STANAG 110–112 relating to accidents involving military-owned vehicles include:

- 110 = driver
- 111 = passenger
- 112 = unspecified occupant of vehicle

Injuries to pedestrians and those that occur while boarding or alighting from a vehicle, operating a pedal cycle or motorcycle, and occupying a tracked or semi-tracked vehicle (e.g., tank, self-propelled gun) were excluded from analysis primarily because key risk factors of interest, such as seat belt usage, were not relevant to these populations.[39–42]

Analysis

Comparisons between the study population who took the HRA in 1992 and those who were on active duty at some time during 1992 but did not take the HRA were evaluated using t-tests for continuous outcomes and chi-square tests for discrete outcomes. Associations among continuous hypothesized risk factors were measured using Pearson correlation coefficients. Interreliabilities among HRA continuous risk factors were evaluated using coefficient alphas for reliability.

There is the potential for a large variation in length of follow-up in the military (hence, "exposure" to the risk of motor vehicle injury hospitalizations) as individuals sign on for varying lengths of time and then leave when their service obligation is complete. Because of the dynamic nature of this cohort, we used standard time-to-event statistical methods (Kaplan-Meier estimates of survival distributions, log-rank tests, and Cox proportional hazards models). Time to motor vehicle injury hospitalizations were calculated from the time the HRA was taken in 1992 until the time the individual left the service, experienced a motor vehicle–related injury hospitalization, or the follow-up period ended (1997). Individuals were censored if they left the military during the follow-up interval or if they did not experience a motor vehicle–related injury hospitalization by 1997. In cases where an individual experienced more than one motor vehicle–related injury hospitalization subsequent to completion of an HRA, the first hospitalization was used for the analysis.

We began initial exploration of the data to study univariate associations between risk factors and demographic variables with motor vehicle injury hospitalizations, using univariate Cox proportional hazards models with likelihood ratio tests and by viewing Kaplan Meier Survival curves. Initial evaluation of interaction effects (e.g., drinking and age) were assessed through stratified chi-square analysis. Potential linear associations were assessed through chi-square tests for trend.

We used information from the univariate and exploratory analyses, as well as theory, to help guide the process of building a final multivariate model to predict hospitalizations for motor vehicle–related injury. We then used the final parsimonious model to test for interaction effects identified during exploratory analyses. All p-values reported are two sided. The SAS version 6.12 and STATA version 5.0 statistical packages were used for these analyses.[43–45]

Results

In 1992, 13% (99,981) of active duty Army personnel took an HRA; they comprise the study population. Like the rest of the Army, the study population is relatively young, mostly male, and most likely to be in an enlisted position. There were few differences between those included in the study population and those who did not complete an HRA during that year, although large sample sizes caused even minute differences to be statistically significant. Examination of differences in the odds of being included in the HRA sample is a better estimate of the size of the differences between the groups, showing only small variations in demographics between HRA takers and nontakers in 1992 (Table 1). In particular, there was no difference in the risk of injury hospitalization between those who took the HRA and those who did not. Although the age of HRA takers and those not taking an HRA was statistically different, the actual values of age were not meaningfully different. The mean age for those taking the HRA was 28.9 years (standard deviation [SD] = 8.0) versus 28.2 years (SD = 7.4) for those not taking the HRA. Similarly, those taking the HRA were of significantly different rank than those not taking the HRA. This difference was driven by a 1 percentage point difference between the groups. Eighty-five percent of HRA takers were enlisted as compared to 86 percent of those not taking the HRA in 1992.

Because the mechanism for administration of the HRA is nonrandom, there was some concern that there may be a two-way causal relationship where the outcome variable and the predictor variables exhibit mutual dependence. Individuals who are more at risk for motor vehicle injury due to their unsafe behaviors might also be more likely to enter a clinic, for example, and be administered an HRA. If this is true, the group administered the HRA as part of a health screening process in an outpatient or occupational health clinic might be at greater risk for motor vehicle injury than those administered the HRA as part of a more random process (e.g., in-processing to the military or new duty assignment). However, the group at highest risk for motor vehicle injury was the group administered the HRA as part of in-processing procedures. There were actually fewer injuries in all the other categories of the HRA administration mechanism, including HRAs administered as part of a health care visit (see Table 2).

Therefore, because the study population essentially mirrors the population in the Army at large, and there is no indication that those at greatest risk for motor vehicle–related hospitalization are also more likely to be administered an HRA (e.g., those administered an HRA when they attended an outpatient or occupational health clinic are not at greatest risk for motor vehicle injury hospitalization), we proceeded with the analysis including all those who took an HRA in 1992, regardless of where the survey was administered.

A total of 429 (0.4%) of the respondents were injured in motor vehicle crashes serious enough to require hospitalization. Median length of follow-up time for the study population was 3.61 years from the time of survey administration. Most of those hospitalized (52%) were drivers. The vast majority of the

Table 1. Demographics of study population and non-HRA takers

Characteristics	Percentage of population Study Population ($n = 99{,}981$)[a]	 Non-HRA takers ($n = 673{,}773$)[b]	Odds ratios[c]	p values[d]
Gender				$p = 0.11$
Men	88%	88%	0.98	
Women	12%	12%	1.02	
Age (years)				$p < 0.001$
18–20	12%	12%	1.87	
21–25	31%	33%	0.88	
26–30	20%	21%	0.93	
31–35	15%	15%	0.92	
36–40	13%	11%	1.06	
41+	9%	7%	1.28	
Race/ethnicity				$p = 0.57$
Caucasian	63%	63%	1.00	
Non-Caucasian	37%	37%	1.00	
Rank				$p < 0.001$
Officer	13%	12%	1.05	
Warrant officer	2%	2%	1.16	
Enlisted	85%	86%	0.93	
Motor vehicle injury hospitalization				$p = 0.52$
Injured	0.4%	0.4%	0.98	
Not injured	99.6%	99.6%	1.03	

[a] Active duty Army who took an HRA in 1992.

[b] On active duty in Army during 1992 but did not take an HRA.

[c] Measure of association reflects comparison of those taking an HRA versus those who did not.

[d] Chi-square tests.

HRA, health risk appraisal.

Table 2. Unadjusted associations between demographic characteristics and risk of motor vehicle injury hospitalizations, univariate Cox proportional hazards models

Characteristics	% of injured ($n = 429$)	% of uninjured ($n = 999{,}552$)	Hazards ratios	p values
Mechanism of HRA Administration				$p < 0.005$
In-processing	65%	53%	1.00	
Physical exam	15%	22%	0.57	
Pre-APFT[a]	<1%	<1%	0.29	
Occupational Health clinic	3%	3%	0.79	
Walk-in clinic	3%	4%	0.65	
Other	14%	18%	0.72	
Gender				$p = 0.723$
Men	87%	88%	1.00	
Women	13%	12%	1.05	
Age (years)				$p < 0.005$
18–20	26%	12%	5.89	
21–25	42%	31%	3.89	
26–30	16%	20%	1.93	
31–35	8%	15%	1.31	
36–40	5%	13%	1.13	
41+	3%	9%	1.00	
Race/ethnicity				$p < 0.005$
Caucasian	51%	63%	1.00	
Minority race/ethnicity	49%	37%	1.59	
Rank				$p < 0.005$
Officer	6%	13%	1.00	
Warrant officer	1%	2%	1.08	
Enlisted	93%	85%	2.62	

[a] APFT, Army Physical Fitness Test (done semiannually).

Table 3. Unadjusted associations between risk exposures and subsequent motor vehicle injury hospitalizations, univariate Cox proportional hazards models

Characteristics	% of injured (n = 429)	% of uninjured (n = 99,552)	Hazards ratios	p values
Smoking				$p < 0.100$
Never	59%	54%	1.00	
Former	11%	15%	0.71	
Current	30%	31%	1.02	
Weekly ETOH Consumption				$p < 0.005$
0 drinks	43%	42%	1.00	
1–6 drinks	35%	42%	0.80	
7–14 drinks	14%	11%	1.34	
15–21 drinks	3%	3%	1.15	
> 21 drinks	5%	3%	1.98	
Drinking and driving				$p < 0.01$
Yes	14%	11%	1.45	
No	86%	89%	1.00	
Speeding				$p < 0.005$
Within 5 miles of limit	53%	57%	1.00	
6–10 miles over limit	32%	33%	1.08	
> 110 miles over limit	8%	6%	1.52	
Don't drive	6%	4%	1.98	
Seat belt use				$p < 0.005$
0%–50% of time	19%	11%	2.22	
51%–99% of time	29%	26%	1.41	
100% of time	52%	63%	1.00	

injured respondents (89.7%) experienced their injury while operating or riding in a privately owned motor vehicle, suggesting they were most likely off duty during the crash.

Tables 2 and 3 provide results from univariate Cox proportional hazards models for demographic and behavioral factors associated with motor vehicle–injury hospitalization. Demographic characteristics associated with increased unadjusted risk for motor vehicle injury hospitalizations include younger age, non-officer rank, and minority race/ethnicity. Gender was not associated with risk of motor vehicle injury hospitalization (see Table 2).

Several behavioral risk factors were predictive of potential motor vehicle injury hospitalizations in unadjusted Cox models. Weekly drinking quantity, drinking and driving/riding with a drinking driver, speeding, and less frequent use of safety belts are all associated with a linear increased risk for motor vehicle injury hospitalization. There was a weak, but linear increase in risk of injury with successively higher quantities of alcohol consumed on a weekly basis with the exception of the lightest drinkers (chi-square for linear trend = 3.74, p <0.06). Those who consumed an average of one to six drinks a week were at lowest risk overall for motor vehicle–related injury hospitalization. Smoking was not associated with an increased risk for motor vehicle hospitalizations in this population (see Table 3).

Because the literature indicates that alcohol may differentially impact younger drinkers making them particularly at risk of injury, we explored the potential presence of an age–drinking interaction effect in this study population. Risk for a motor vehicle crash–related hospitalization was greatest for those aged 21 and under across all levels of self-reported drinking (odds of injury for minors versus those 21 or older was consistently greater than 1 at each reported level of weekly drinking). (See Figure 1.) The overall odds of injury were 2.51 (95% CI 1.99–3.12) for respondents aged under 21 (as compared to those aged 21 and over) across drinking strata. Although the odds ratios were consistently greater than 1 across drinking strata, the magnitude of the effect diminished with successively higher levels of reported weekly alcohol consumption. This suggests the possible presence of a quantitative age–alcohol use interaction (the effect of weekly drinking on risk for motor vehicle injury is modified by age). However, the sparse cells at higher levels of drinking make it impossible to determine whether or not the odds for injury among the heaviest drinkers aged under 21 are significantly greater than the odds of injury among heaviest drinkers aged 21 or older.

Intercorrelations between self-reported weekly drinking frequency (number of drinks), drinking and driving frequency, seat belt use (percentage of time wearing a belt), and age were modest. The strongest correlation observed was between the typical number of drinks per week and drinking and driving habits (r = 0.296). Seat belt usage and age were also slightly correlated (r = 0.2). Coefficient alpha of reliability for these four variables was 0.43.

A multivariate Cox proportional hazards model was

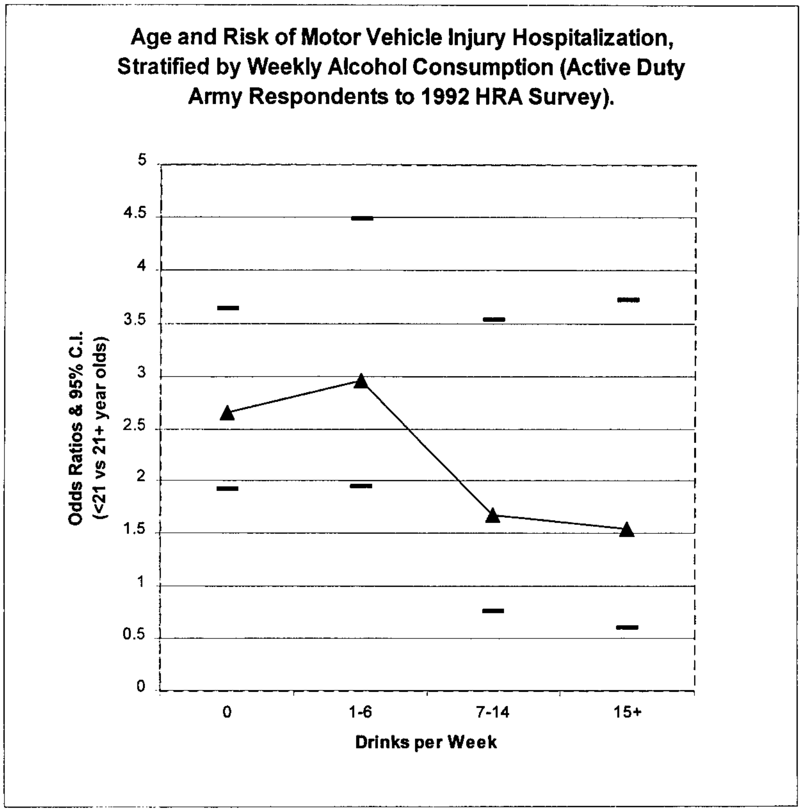

Figure 1. Age and risk of motor vehicle injury hospitalization, stratified by weekly alcohol consumption (active duty Army respondents to 1992 HRA survey).

built using all the main effect variables found to be significant in the univariate models. Young age, minority race/ethnicity, heavy drinking, and low seat belt use (0%–50%) were significant independent predictors of risk of hospitalization due to motor vehicle crash (see Table 4). Rank was bordering on significant, with enlisted populations approximately 50% more likely to experience a motor vehicle hospitalization ($p = 0.09$). Drinking and driving and speeding behavior were not significant predictors of motor vehicle hospitalizations when other factors were controlled for in the multivariate model.

A separate model, which included reported drinking and driving behavior but excluded typical weekly alcohol consumption, was used to assess whether multicolinearity might be causing "drinking and driving" to drop out of the model. However, even though the drinking and driving hazard ratio trended in the expected direction (the hazard ratio was 1.1 for those who drank and drive or rode with someone who had consumed too much alcohol before driving one or more times in the past month), it was not significant ($p = 0.55$). Although not significant in the adjusted model, the drinking and driving factor was included in the final full model because there is theoretical precedence for its association with motor vehicle injury hospitalizations and because it was a significant predictor of injury in the unadjusted model.

We tested for the presence of an age–alcohol interaction in the multivariate model. Since it was not significant in multivariate analyses, the interaction term was excluded from the final model.

In the multivariate model, younger age groups were at successively increased risk of hospitalization, with those aged under 21 being injured at almost 5 times the rate of those over 40. The 21–25 year olds experienced a rate 3.3 times higher; 26–30 year olds had a rate 1.7 times higher; 31–35 year olds were at 1.2 times greater risk; and 36–40 year olds were at 1.1 times greater risk for motor vehicle injury hospitalization. The rate of motor vehicle injuries is 80% higher among minority racial/ethnic groups than for Caucasians. Compared to officers, warrant officers had a nonsignificant 50% increased risk, and enlisted personnel also had a nonsignificant 50% increased risk of hospitalization.

The number of alcoholic drinks per week presented an interesting pattern of risk for motor vehicle injury–related hospitalization. Compared to nondrinkers, the group who drank one to six drinks per week was not at increased risk. The seven to fourteen drinks per week group had a significant 50% increased risk. The 15 to 21 drinks per week group had a nonsignificant 20%

Table 4. Adjusted hazard ratios for risk of motor vehicle injury hospitalization

Characteristics	Hazards ratio from multivariate Cox models	95% confidence interval
Age (years)		
< 21	4.9	(2.6–9.3)
21–25	3.3	(1.8–6.2)
26–30	1.7	(0.9–3.3)
31–35	1.2	(0.6–2.3)
36–40	1.1	(0.5–2.3)
> 40	1.0	
Race/ethnicity		
Caucasian	1.0	
Non-Caucasian	1.8	(1.5–2.2)
Rank		
Officer	1.00	
Warrant officer	1.5	(0.6–4.0)
Enlisted	1.5	(0.9–2.2)
Weekly ETOH Consumption		
0 drinks	1.0	
1–6 drinks	0.9	(0.7–1.2)
7–14 drinks	1.5	(1.1–2.1)
15–21 drinks	1.2	(0.7–2.1)
> 21 drinks	1.8	(1.1–2.9)
Drink and drive		
Yes	1.0	(0.7–1.3)
No	1.0	
Speeding		
Don't drive	1.0	
Within 5 miles of speed limit	1.0	(0.7–1.5)
6–10 over	0.9	(0.6–1.4)
11 or more over	1.1	(0.7–1.8)
Seat belt use		
0%–50% of time	1.4	(1.1–1.9)
51%–99% of time	1.0	(0.8–1.3)
100%	1.00	

increased risk. The 22 or more drinks per week group had a significant 80% increased risk for hospitalization. Low seat belt use (0%–50%) was associated with a significant 40% increase in risk of hospitalization, compared to those who wore their seat belts 100% of the time.

Discussion

Modifiable risk factors associated with injury risk include heavy drinking and lack of seat belt use. Even after controlling for age and other confounders, these factors remain potent predictors of motor vehicle injury hospitalization and should offer guidance for the development of injury prevention efforts. Speeding (more than 10 miles per hour over the speed limit) and driving while intoxicated (or riding with someone who had too much to drink) were not significant in the full model but nonetheless trended in a direction suggesting they may still be important risk factors.

Another notable finding is the increased risk for motor vehicle injuries observed among abstainers (as compared to light drinkers) in univariate models. The same association is observed in the multivariate model, although the confidence interval for the light drinkers' hazard ratio did encompass 1. Other researchers have noted that abstainers are at greater risk for deaths resulting from cardiovascular diseases and cancers, as well as organ injuries and emergency room visits when compared to light and moderate drinkers.[46–50] However, other studies have found abstainers to be at lower risk for traumatic injury when compared to those who consume any alcohol.[51,52] Other factors that covary with light drinking, but which were not controlled for in the model, may explain the apparent weak, but protective association between light drinking and motor vehicle injury hospitalization risk. Also, the alcohol intake measures on the HRA are not likely to represent propensity to use alcohol, among the light and moderate drinkers, in close proximity to driving a motor vehicle. Those who are typically heavy drinkers may also be more likely to have consumed greater amounts of alcohol prior to operating a car. Those who are lighter drinkers, although they may also consume alcohol before driving, may do so at their typically lower levels of alcohol consumption making them less likely to experience motor vehicle crash–related injury.

Interestingly, in this military population gender is not associated with injury risk. This is not consistent with what is observed in the general civilian population, suggesting that exposures are probably different for men and women in the Army, with female soldiers possibly driving more than their civilian counterparts, similar to male soldiers.

Age is the most impressive demographic variable, with those aged under 21 at almost five times the risk of motor vehicle injury as those aged over 40. Age associations with motor vehicle crashes are also well documented in the civilian literature. For example, a recent study in Alaska found teens and young adults (aged 16–20) were at almost three times the risk for motor vehicle–related hospitalizations as compared to older drivers.[53] Programs targeting younger soldiers are clearly needed.

The greater risk for motor vehicle injury hospitalization among those of minority racial or ethnic background is also of concern. Greater injury risk is occurring even though, on average, individuals in these groups report consuming less alcohol on a weekly basis than their Caucasian counterparts. While these data do control for several potential confounders that may be associated with race/ethnicity, it is possible that the race/ethnicity association is related to another variable not contained in the analysis. For example, there may be race- or ethnic-related associations with occupations that increase the risk for motor vehicle injuries. There could also be differences in the propensity to seek health care that are related to race/ethnicity. However, since our outcome was hospital admissions—which are presumably serious and offer little opportunity for discretionary decision making—this seems less likely. More research is needed to better understand the excess risk for motor vehicle injury–related morbidity among those of minority racial and ethnic groups.

Military rank was not significantly associated with motor vehicle injury hospitalizations in the multivariate model, but the direction of the association was suggestive. There appears to be a possible pattern of increased risk among warrant officers and enlisted personnel. Intervention programs should target these socioeconomic groups.

One of the more interesting findings is the possible age–alcohol interaction (see Figure 1). Although no longer significant in the multivariate model, the interaction identified in the unadjusted model examining age and injury stratifying on weekly alcohol consumption is nonetheless intriguing. Younger respondents were at greater risk for motor vehicle–related injuries than their older counterparts across all levels of drinking, but the difference in risk was smallest among the heaviest drinkers. Although the small samples of the very heaviest drinkers caused confidence intervals that encompassed 1, the suggested trend is interesting and worth considering. There are at least three hypotheses that may explain this interaction.

First, bias could explain the unexpected association. The respondents aged under 21 years could all be misreporting their alcohol use because they are under the legal drinking age. If so, those involved in motor vehicle crashes who are in lower alcohol consumption groups should actually be represented in higher consumption categories. This seems unlikely as a number of validation studies indicate that self-reported alcohol use tends to be fairly accurate among civilian and military populations.[28,54–57] However, because this survey was conducted at the worksite by the Army, this possibility cannot be ruled out.

Second, at very high levels of consumption the relative advantages that older drivers may hold due to their driving experience may matter less. Conversely, younger drinkers are likely to be more susceptible to the effects of very low levels of alcohol than their older counterparts. This is consistent with the findings of Zador,[25] Williams[58] and others[59] who note that even at very low levels of alcohol consumption younger drivers are at much greater risk. Young drivers involved in alcohol-related fatal crashes have lower average blood alcohol counts than older drivers.

Third, while being young is a risk factor for injury in this population, some of those most at risk (e.g., heaviest drinkers aged under 21) may be protected because of their occupations. The heaviest drinkers are younger and may be more likely to live in the barracks and often without access to a privately owned motor vehicle. Residing in the barracks might also be protective in that many recreational and social opportunities are presented within walking distance of where the person lives. It also eliminates or reduces the need for a car for work purposes, thereby reducing exposures—particularly among young, at-risk soldiers. More research is needed to better understand the potential interaction between age, alcohol use, and risk for motor vehicle injury hospitalizations.

While residing in the barracks may reduce some exposures to risk for motor vehicle crashes, it may also contribute to unhealthy drinking practices. Studies of college students (similar to young military recruits) suggest that those who reside on campus drink more heavily than those who commute.[60] There is some evidence for a similar association between those who don't drive (likely to live in barracks), young age (those aged under 21), and heavy drinking in our study population as well. Younger soldiers were 1.5 times ($p < 0.00005$) more likely to be in the heavy drinking category (15 or more drinks per week) than those aged over 21. In addition, those who drink heaviest are 1.5 times more likely to say they do not drive ($p < 0.00005$). Those who don't drive are also most likely to be young; respondents aged under 21 were 27 times more likely to say they don't drive than those aged over 40 ($p < 0.00005$). While those aged under 21 comprise 17% of the general population, they comprise 48% of the group who says they "don't drive." The fact that many of the very high-risk population reside in barracks might offer a unique opportunity for interventions implemented in the housing areas.

Most injuries occur in crashes involving personal vehicles and are, therefore, likely to have occurred off duty and not at work. This has important implications for targeting effective intervention strategies in worksite prevention programs. Worksite prevention programs, while setting a good example, may not influence risk at home or in the barracks. Policies that require the use of safety belts while on base are important but may not influence behaviors among soldiers driving off post.

In identifying targets for prevention it is clear that while driver education safety programs are needed, these alone would not be adequate. Eleven percent of the nondrivers say they rode in the past month with someone who had too much to drink. This suggests that interventions that target only drivers will miss some individuals at risk for an alcohol-related motor vehicle crash. Ride sharing, particularly common among younger enlisted soldiers, may contribute to crash risks in other ways as well. Research suggests that, regardless of drinking behavior, younger drivers (aged under 24 years) who have two or more passengers are at much greater risk for motor vehicle crashes than their older counterparts.[58,60,61]

There are several factors that should be considered in interpreting these findings. This analysis is based largely on self-reported data, which is subject to bias (e.g., recall error). In particular, some of the survey items addressed sensitive issues such as drinking. Subjects, especially those under the legal drinking age of 21, may be likely to underreport their true alcohol consumption habits. Still, the large number of subjects who do report drinking alcohol (even among the minors) and who report drinking heavily (15 drinks or more per week) suggest that even if subjects fear reprisal they are, nonetheless, reporting behaviors that are risky. In fact, younger soldiers were more likely to be in the heavy drinking categories. There is ample variation in self-described drinking habits to discriminate between risky and less risky behavior in terms of actual health outcomes. In addition, studies examining the validity of self-reported alcohol consumption suggest that underreporting does not occur as much as one might expect, and where it occurs may not lead to significant bias.[54–57] Analysis of Air Force personnel and self-reported drinking behavior suggests small amounts of underreporting as validated by alcohol purchasing patterns. However, correcting for this did not significantly affect results. In addition, uncorrected self-reported drinking was a good predictor for a number of adverse health outcomes.[28] In addition, underreporting is not likely to be substantially different between the injured and uninjured.

A small portion of soldiers (7.6%) included in the study population had taken an HRA once before the 1992 HRA administration. It is possible that individuals reporting risky behaviors on these earlier surveys could have received interventions or been otherwise influenced to be less forthcoming about their risky behaviors on a subsequent HRA (i.e., the 1992 survey). However, this does not seem to be a particularly likely source of bias due to the small numbers with multiple HRAs.

These results are most useful in understanding the influence of self-reported behaviors and risk of motor vehicle injury among those who complete the HRA. Since the HRA administration mechanism did not appear to oversample from those particularly at risk (e.g., those who took the HRA as part of a self-initiated clinic visit were not at greater risk for subsequent injury hospitalization), and the demographic characteristics of those taking the HRA were very similar to those not included (Table 1), it seems likely that the findings of our study could be used to help guide interventions and policies for preventing motor vehicle injury in the Army at large. In particular, efforts should be made to target interventions directed toward those persons with identified risk factors on their HRA.

This study also demonstrates the value of linking databases in the TAIHOD for use in prevention research. Exposure and actual health outcome data have not been linked in this population prior to this time. Linking these databases—with unique, individual-level identifiers—provides a cost-effective, efficient method for identifying key risk factors and subpopulations at risk in the U.S. Army.[33] This and similar studies have the potential to lead to important efforts to reduce injuries and disabilities from injuries, such as those caused by motor vehicles, and to reduce their impact on troop readiness.

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Cigarette Smoking and Exercise-Related Injuries Among Young Men and Women

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Background: We evaluate whether a recent history of cigarette smoking is a risk factor for exercise-related injuries sustained during Army basic training, controlling for factors such as demographic, physical fitness, and health variables.

Methods: We conducted an observational cohort study in 1087 male and 915 female Army recruits undergoing 8-week basic military training. Data were collected from questionnaires, anthropometric measurements, physical fitness tests, company training logs, and medical records of all clinic visits.

Results: During the 8-week training period, 33% of men and 50% of women had at least one clinic visit for injury, including 14% of men and 25% of women who lost more than 5 days of training due to injury. Recruits who reported smoking at least one cigarette in the month prior to beginning basic training (which was conducted in a smoke-free environment) had significantly higher injury rates during training than those who did not report smoking (40% versus 29% for men, and 56% versus 46% for women). The relationship with smoking history was present most strongly for overuse injuries (32% versus 24% in men and 51% versus 40% in women). Multiple logistic regression analyses controlling for all other factors consistently showed adjusted odds ratios of about 1.5 for injury rate in those with a history of smoking compared to those without.

Conclusions: The association of history of cigarette smoking with injury occurrence was consistent throughout the analyses, with very little confounding by other factors. The detrimental effects of smoking on injuries appears to persist at least several weeks after cessation of smoking.

Medical Subject Headings (MeSH): athletic injuries, cumulative trauma disorders, stress fractures, military medicine, physical fitness, smoking, soft tissue injuries (Am J Prev Med 2000;18(3S):96–102) © 2000 American Journal of Preventive Medicine

Introduction

A high rate of musculoskeletal injury during military training is well recognized in both men and women.[1,2] During the past two decades, the reported occurrence of injuries in trainees during the 8-week Army basic military training (BMT) course has ranged from 15% to 35% for men and from 40% to 60% for women.[3–9] Military researchers have identified a number of risk factors for such injuries, including female gender, older age, lower amounts of prior physical activity, low physical fitness, and cigarette smoking.[10–13]

Training injuries produce considerable morbidity, consume valuable medical resources, increase lost training time, and can leave some individuals with permanent disability. Several studies over the past few decades have attempted to define the extent of the problem. Most of these describe the types, causes, and incidence of training injuries, and some assess methods for reducing injury rates by modifying the training programs or equipment used.[4,10,14–20] Some have addressed specific risk factors and estimation of the likelihood for an individual to sustain injury.[1,14,21–24]

Cigarette smoking has been implicated as a risk factor for musculoskeletal injury during BMT and athletic conditioning in several studies.[10–12,25] A detrimental effect of smoking on tissue repair and greater risk-taking behavior on the part of smokers have been suggested as possible mechanisms to explain this association.[26,27] However, the relationship of smoking with

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Table 1. Demographic and anthropometric characteristics of male and female Army recruits, Fort Jackson, 1988

	Men		Women	
Variable	**Smokers Mean ±SD**	**Nonsmokers Mean ±SD**	**Smokers Mean ±SD**	**Nonsmokers Mean ±SD**
Age (yrs)	20.2 ±3.3	20.0 ±3.2	20.8 ±3.9	19.9 ±3.2
Education (yrs)	12.3 ±1.1	12.4 ±1.0	12.4 ±0.9	12.5 ±1.1
Height (cm)	175.4 ±6.6	175.2 ±7.3	162.3 ±6.4	161.7 ±6.7
Weight (kg)	75.3 ±11.7	75.8 ±12.7	58.8 ±6.5	57.9 ±6.6
BMI (kg/m^2)	24.5 ±3.5	24.6 ±3.5	22.3 ±2.0	22.1 ±2.0

BMI, body mass index.

susceptibility to injury has had limited confirmation in epidemiologic studies, particularly in women.

Army basic military training provides an excellent opportunity for study of exercise-related injuries since it represents a short period of standardized vigorous physical training in a well-defined population of healthy young adults, and health outcomes can be measured objectively. The purpose of this large study of male and female Army recruits in BMT is to evaluate whether smoking is a risk factor for exercise-related musculoskeletal injuries among women and men, controlling for other factors such as demographics, physical fitness, and health variables. If smoking does predispose to greater risk for injury associated with vigorous physical training, then this would have broad implications for prevention of such injuries in both military and civilian settings.

Methods

We conducted a study of enlisted male and female Army recruits entering BMT at Fort Jackson, South Carolina. The study obtained complete information on 915 women and 1087 men who trained in several companies during September to November 1988. Women were oversampled so that similar numbers of men and women were included, making comparisons by gender easier. All analyses were conducted separately for men and women due to their differences in injury risk. Trainees were provided a briefing during in-processing, and those who chose to participate signed informed consent statements. Nearly all recruits in the selected companies volunteered to participate.

This prospective cohort study was conducted in two phases: baseline evaluation and follow-up. Baseline evaluation included the administration of a 10-page questionnaire on demographics, self-assessed fitness and physical activity level, prior sporting activities, prior health, prior injuries, and prior smoking habit. Each recruit was asked about his or her smoking habits prior to entering basic training (e.g., "In the one month before coming in the Army, on the average, how many cigarettes did you smoke each day?"). The questionnaire was administered in a group setting with an instructor guiding the subjects through each question. Height and weight were measured for all subjects, and body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Entry fitness was assessed with the Army physical fitness test (APFT: 1- or 2-mile run-time and number of consecutive pushups and sit-ups completed in a 2-minute period each).

At the conclusion of training, medical records were reviewed to record all clinic visits for illness or injury that subjects sustained during their 8-week period of BMT. Injuries were categorized as traumatic or overuse. Traumatic injury types included fracture, sprain, abrasion, laceration, contusion, blister, and other. Overuse injury types included stress fracture, stress reaction of bone, strain, tendinitis, bursitis, fasciitis, musculoskeletal pain, and other. For recruits with multiple injuries, one traumatic injury and one overuse injury were tabulated as most significant. Injury incidence rates were calculated in these categories as percentage of recruits with clinic visits for that medical condition.

Male and female recruits were first described by each of the study variables using frequencies and rates (percentage of men or women, respectively) for each category of the characteristic. Univariate analyses were then performed on each variable in relation to injury rates. Injury outcomes of interest included at least one injury of any type, traumatic injury, overuse injury, multiple injuries, and those with days of training lost due to injury. Statistical testing of comparisons between smokers and nonsmokers were conducted using *t*-tests and chi-square analysis.[28,29]

Multivariate logistic regression techniques were used to examine the relative importance of various factors for predicting injury.[30] Separate models were built for male and female recruits. These models simultaneously control for multiple risk factors. The following model-reduction methods were used to construct final logistic regression models. First, all variables were entered into a logistic regression model and a backward-selection method was applied whereby nonsignificant predictors were removed one by one. Once best-fit models were constructed, regression diagnostic analyses were conducted. Variables included as potential risk factors and confounders in the models included those in Tables 1

Table 2. Percentage distribution of self-reported ethnic status for male and female Army recruits, Fort Jackson, 1988

	Men		Women	
Ethnic group	**Smokers (N = 380) (%)**	**Nonsmokers (N = 707) (%)**	**Smokers (N = 322) (%)**	**Nonsmokers (N = 593) (%)**
Caucasian	71	49	65	34
African American	19	35	22	55
Hispanic	5	8	6	6
Other/unknown	5	8	7	5

and 2, as well as others that are not shown. Since best-fit and full models provided very similar estimates, we developed a standard set of variables to use for all adjusted models, including age, education, race/ethnicity, body mass index, and physical fitness. Analysis of the data was performed using the statistical package SPSS 8.0 for Windows.

Results

Questionnaire Data

Some of the tabulations from the questionnaire are presented in Tables 1, 2, and 3. The average recruit is a 20-year-old high school graduate, with males being taller and heavier than females and having higher body mass index (Table 1). Most of the male recruits categorized themselves as Caucasian, while women had about equal numbers of Caucasian and African-American recruits (Table 2), and a higher percentage of smokers were Caucasian for both men and women. For the purposes of multivariate analyses, three ethnic groups were defined: Caucasian, African American, and other.

Male recruits reported higher sports participation than did females, and more other vigorous exercise activity (data not shown). More men than women had ever been hospitalized or had surgery for injury. A surprisingly large proportion of recruits reported flu or cold symptoms (27%), fever (11%), or nausea and vomiting or diarrhea (13%) in the prior 2 weeks before entering BMT.

Smoking History and Fitness Measurements

Smoking was common in this population, with 42% of men and 40% of women reporting smoking at least one cigarette in the prior year (Table 3). Thirty-five percent of recruits reported smoking at least one cigarette in the month prior to starting BMT. The amount of heavy smoking was quite low, however, with less than 10% of all recruits reporting smoking more than one pack per day during the prior month. Recruits were not allowed any use of alcohol or tobacco products during the entire 8-week BMT course.

Entry fitness was assessed in the first week of BMT with a physical fitness test consisting of 2 minutes each of continuous pushups and sit-ups, followed by a timed 1- or 2-mile run (Table 4). About half of recruits ran 1 mile and half ran 2 miles. On average, men ran faster and did more pushups and sit-ups than women. Both male and female recruits reporting smoking in the prior month had slightly slower average run-times and fewer pushups and sit-ups than those who did not report smoking in the prior month.

Injuries During BMT

The injury incidence rates are presented in Table 5. During the 8 weeks of BMT, one third of men and half of women had at least one clinic visit for injury. The most frequently recorded traumatic injury type was sprain (35% of all traumatic injuries in men and 44% in women), and only six recruits (0.3%) suffered a traumatic fracture during basic training. The most fre-

Table 3. Smoking-related variables for male and female Army recruits, Fort Jackson, 1988 (% with characteristic)

Variable		**Men (%) (n = 1087)**	**Women (%) (n = 915)**
Smoked at least one cigarette in past year		42	40
Smoked at least one cigarette in past month		35	35
On average how many cigarettes smoked each day in the past month:			
	Didn't smoke	65	65
	1/2 pack or less	15	18
	1/2–1 pack	13	13
	More than 1 pack	7	4

Table 4. Entry fitness testing for male and female Army recruits by smoking history, Fort Jackson, 1988

	Men (mean ±SD)		Women (mean ±SD)	
Variable	**Nonsmokers**	**Smokers**	**Nonsmokers**	**Smokers**
1-mile run (min)[a]	7.56 ± 1.1	7.77 ± 0.9	10.52 ± 1.9	10.86 ± 2.0
2-mile run (min)	16.30 ± 2.2	16.49 ± 2.1	20.30 ± 2.5	20.21 ± 2.0
Pushups (# in 2 min)[a]	31.6 ± 13	28.1 ± 11	10.6 ± 8	9.5 ± 7
Sit-ups (# in 2 min)[b]	44.0 ± 12	41.7 ± 11	35.0 ± 14	32.2 ± 14

[a] $p < 0.02$ for men only, comparing means between smokers and nonsmokers.
[b] $p < 0.01$ for both genders, comparing means between smokers and nonsmokers.
SD, standard deviation

quently recorded specific overuse injury type was strain (22% of all overuse injuries in men and 15% in women). There was a large number of overuse injuries with nonspecific diagnoses—pain and not otherwise specified (30% and 27% of all overuse injuries, respectively). During the 8 weeks of BMT in these 2002 recruits, there were 28 (1.4%) who developed a stress fracture and 66 (3.3%) with a stress reaction of bone, giving rates of 1.2% and 1.6%, respectively, for men, and 1.6% and 5.4%, respectively, for women. Overall, 4.7% of the study recruits developed a stress fracture or stress reaction of bone.

Cigarette Smoking and Injury Occurrence during BMT

Cigarette smoking in the prior month was significantly associated with overuse injury in both male and female recruits and with traumatic injury in men (Table 6). Male smokers had higher injury rates than nonsmokers in five of the six traumatic injury categories, with 1.79 times the overall rate (12.9% versus 7.2%, $p < .01$), and in five of the six overuse injury categories, with 1.30 times the overall rate (32% versus 24%, $p < .01$). Overall, male smokers had 1.38 times higher injury rate than nonsmokers ($p < .01$). Female smokers had higher injury rates than nonsmokers in three of the six traumatic injury categories, with 1.13 times the overall rate (13.4% versus 11.8%, $p = 0.5$), and in five of the six overuse injury categories, with 1.27 times the overall rates (51% versus 40%, $p < 0.01$). Overall, female smokers had 1.20 times higher injury rates than nonsmokers ($p < 0.01$).

Table 7 presents the results of logistic regression models for smoking in the prior month as a predictor for injury during basic training. Best-fit models for both smoking in the prior year and smoking in the prior month were similar, so only results relating to smoking in the prior month are presented here. The crude odds ratio (OR) represents cigarette smoking as a predictor of injury without consideration of other variables (univariate analysis similar to comparison of incidence rates in Table 6). The adjusted model OR comes from including age, education, race/ethnicity, body mass index, and physical fitness as ancillary variables in the logistic regression models, which provides adjustment for these potential confounders. The crude and adjusted models provided similar results, as did the best-fit and full models (not shown). The history of cigarette smoking is associated with about 1.5-fold higher odds for injury during basic training in both male and female recruits.

Separate logistic regression models were examined relating overuse and traumatic injuries to smoking in the prior month, showing similar relationships with smoking, except for no association with traumatic injury in women. Similar results are seen when limited to injuries with at least 1 or 6 days of training lost. An inconsistent dose-response relationship between levels of smoking and injury occurrence was also observed in our data (Table 8).

Table 5. Injury cases during 8-week basic military training per 100 Army recruits by gender, Fort Jackson, 1988

	Male rate (#) (N = 1087)		Female rate (#) (N = 915)	
Variable	%	*n*	%	*n*
Any injury (overuse and/or traumatic)	3	(360)	50	(453)
Traumatic injury	9.2	(100)	12	(113)
Overuse injury	27	(292)	44	(400)
More than one injury (overuse and/or traumatic)	8.9	(97)	18	(162)
More than one traumatic injury	0.9	(10)	1.3	(12)
More than one overuse injury	6.2	(68)	13	(121)
At least one day of training lost	21	(229)	36	(325)
6 or more days of training lost	14	(148}	25	(230)

Table 6. Rates of specific overuse and traumatic injury (per 100 recruits), by gender and smoking status in the prior month, Fort Jackson, 1988

	Male rate (#)				Female rate (#)			
	Smokers (N = 380)		Nonsmokers (N = 707)		Smokers (N = 322)		Nonsmokers (N = 593)	
Variable	%	*n*	%	*n*	%	*n*	%	*n*
Most significant traumatic injury:								
Fracture	0.3	(1)	0.0	(0)	1.2	(4)	0.2	(1)
Sprain	5.0	(19)	2.3	(16)	7.1	(23)	4.6	(27)
Abrasion/laceration	1.1	(4)	1.3	(9)	0.9	(3)	1.9	(11)
Contusion	2.1	(8)	1.6	(11)	0.6	(2)	1.5	(9)
Blister	1.8	(7)	0.8	(6)	1.9	(6)	1.0	(6)
Acute trauma not otherwise specified	2.6	(10)	1.3	(9)	1.6	(5)	2.7	(16)
Total	12.9	(49)	7.2	(51)^a	13.4	(43)	11.8	(70)
Most significant overuse injury:								
Stress fracture	0.8	(3)	1.4	(10)	2.5	(8)	1.2	(7)
Stress reaction	2.6	(10)	1.0	(7)	8.4	(27)	3.7	(22)
Strain	6.3	(24)	5.5	(39)	6.2	(20)	6.9	(41)
Tendinitis/bursitis/fasciitis	3.2	(12)	2.0	(14)	7.1	(23)	5.1	(30)
Pain	8.7	(33)	7.6	(54)	15	(48)	12	(70)
Overuse not otherwise specified	10	(38)	6.8	(48)	12	(37)	11	(67)
Total	32	(120)	24	(172)^a	51	(163)	40	(237)^a
Any injury	40	(153)	29	(207)^a	56	(179)	46	(274)^a

^{a} $p < 0.01$ comparing smokers to nonsmokers.

Discussion

Our results indicate that one third of male and one half of female recruits had at least one injury requiring medical attention during their 8 weeks of BMT. These injury rates include minor injuries, but all required a medical clinic visit. Two thirds of these injuries resulted in loss of at least 1 training day, and one half lost more than 5 training days. These findings are consistent with those from other studies of military recruits.[3,10,11] Examination of the crude, full, best-fit, and adjusted logistic regression models shows considerable consistency; there is very little confounding by other variables in the assessment of the relationship between history of cigarette smoking and occurrence of injury during BMT.

The prevalence of smoking in our study population was fairly high, with 35% of both male and female recruits smoking in the month prior to basic training. This is consistent with the findings of the 1992 worldwide survey of substance abuse and health behaviors among military personnel.[31] Recruits who reported smoking at least one cigarette in the prior month had higher injury rates during BMT than recruits who did not smoke. This association persisted notwithstanding the fact that basic training was conducted in a smoke-free environment. The detrimental effects of smoking on injuries thus appear to persist for a period of time after cessation of smoking. Although this increase in injury rates may not appear large, it actually represents a strong effect due to the high baseline rate of injuries in nonsmokers. For example, when the baseline rate of injury in female nonsmokers is 46%, the maximum effect that can be shown is a 2.2-fold higher rate (i.e., 100%).

Table 7. Logistic regression modeling results for the odds of injury occurrence (odds ratio) for smoking in the prior month versus not smoking (the referent) during Army basic training, Fort Jackson, 1988

		Male OR (95% CI)	**Female OR (95% CI)**
Any injury	Crude	1.63	1.46
($p < 0.01$, M & F)	Adjusted^a	1.48 (1.11, 1.98)	1.61 (1.19, 2.17)
Traumatic injury	Crude	1.90	1.15
($p < 0.05$, M only)	Adjusted^a	1.62 (1.01, 2.59)	1.05 (0.67, 1.64)
Overuse injury	Crude	1.44	1.54
($p < 0.01$, F only)	Adjusted^a	1.32 (0.97, 1.79)	1.71 (1.26, 2.31)
≥1 day lost injury	Crude	1.88	1.53
($p < 0.05$, M & F)	Adjusted^a	1.67 (1.18, 2.36)	1.44 (1.02, 2.02)
≥6 days lost injury	Crude	1.88	1.81
($p < 0.01$, F only)	Adjusted^a	1.47 (0.97, 2.21)	1.75 (1.21, 2.51)

^{a}Odds ratio (OR) adjusted for age, education, race, body mass index, and physical fitness.

Table 8. Logistic regression modeling results for odds of injury occurrence (odds ratio) for different levels of smoking in the last month versus not smoking (the referent) during Army basic training, Fort Jackson, 1988

Smoking in the prior month	Male OR (95% CI)	Female OR (95% CI)
Didn't smoke	1.0 (referent)	1.0 (referent)
1/2 pack or less	1.43 (0.97, 2.10)	1.49 (1.03, 2.14)
1/2–1 pack	1.27 (0.82, 1.95)	1.96 (1.27, 3.03)
More than 1 pack	2.03 (1.22, 3.38)	1.28 (0.63, 2.59)

Odds ratio (OR) adjusted for age, education, race, body mass index, and physical fitness.

The association of cigarette smoking with susceptibility to musculoskeletal injury is supported by evidence in the literature. One study of bone density in female twins discordant for tobacco use found that those who smoked one pack of cigarettes per day through adulthood had an average deficit in bone density of 5% to 10%.[32] There are several studies that cite smoking as a risk factor for fractures because of its detrimental effects on bone mineral density.[33–37] However, other studies have had inconsistent findings.[37–39] It appears that there is little effect of smoking on bone mineral density until older ages, thus providing little help in explaining the association of smoking and injuries in young adults.[37,40]

Studies on smoking and bone fractures in young adults are few. One study of active duty Army women found that current smoking was significantly associated with self-reported history of stress fracture.[41] Slower wound healing was observed as early as 1977 in clinical studies of smokers with wounds resulting from trauma, surgery, or disease.[37,42–44] Smoke extracts and components of the gaseous phase of cigarette smoke have been shown to have direct effects on fibroblasts that influence the injury repair process.[26,27,37] Several investigators have concluded that cigarette smoke and nicotine are inhibitory factors in wound and fracture healing.[37,45,46] Overuse injuries likely result from repetitive microtrauma that leads to inflammation and/or local tissue damage.[47] It is quite plausible that smoking interferes with tissue repair processes, thus making the tissues more susceptible to injury.

This study has limitations in that questionnaire data were provided solely by self-report, which included the information on smoking behavior. Some parts of the data collection were quite objective, however, such as anthropometric measurements, physical fitness testing, and medical record review. Abstracted medical records do not provide clinical information as complete as might be obtained from more intense standardized evaluation, but there should be no bias relating to cigarette smoking behavior, since neither the abstractors nor the investigators reviewing the medical data were aware of the questionnaire results nor of this hypothesis at that time. In addition, of course, abstraction of medical records ignores injuries for which the recruit does not seek medical attention, although these are likely to be minor.

The study has many strengths, since it was population-based, with nearly complete record keeping, and it included a large number of individuals who underwent a standardized and relatively uniform course of vigorous physical conditioning during their 8 weeks of BMT. All subjects were medically screened for military fitness prior to entry into BMT, and they represent a broad cross-section of the healthy young adult population of the United States (although certainly not a random sample). Because all wore the same clothing, slept in the same barracks, ate the same food, and underwent the same training schedules, a large amount of homogeneity in the training environment was maintained.

The primary finding that a history of smoking is associated with higher risk for injuries during physical training provides further evidence of detrimental effects of cigarette smoking on health. The focus here was on risk for training injury, both overuse and traumatic, even after smoking had ceased. Both experimental and clinical data point to a relationship between cigarette smoking and impaired tissue healing: These associations warrant further investigation. In addition, behavioral differences between smokers and nonsmokers may play a role. In our data, smokers had more prior injuries, less physical activity, more prior illness, and lower physical fitness than nonsmokers. However, these variables were all controlled in our regression analyses, and were found not to contribute to the higher injury rates of smokers.

Our findings make smoking a greater immediate concern to military commanders, because smoking can affect injury risk and thereby the readiness of soldiers. Additionally, results should also be of interest to the civilian community because they suggest that youthful smokers will have an immediate reason not to start smoking, or to quit. Soldiers and others do not have to wait 10 to 30 years for heart disease or cancer in order to experience the detrimental effects of smoking. These data show that at least some of the detrimental effects of cigarette smoking may occur at an early age and have immediate consequences.

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Case–Control Study of Discharge from the U.S. Army for Disabling Occupational Knee Injury

The Role of Gender, Race/Ethnicity, and Age

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Background: Occupational injuries are responsible for more lost time from work, productivity, and working years of life than any other health condition in either civilian or noncombat military sectors. Injuries, not illnesses, are the leading cause of morbidity and mortality among U.S. Army personnel. We examined the separate and joint roles of gender, race/ethnicity, and age in the odds of discharge from the Army for disabling knee injury.

Methods: A total of 860 women and 7868 men were discharged from the Army between 1980 and 1995 for knee-related disability and met all inclusion criteria for this study. All women and a subsample of 1005 men were included in these analyses, along with a simple random sample of three controls per case, stratified by gender, drawn from the population of all active-duty enlisted soldiers in each year from 1980 to 1995. We identified predictors of the occurrence or nonoccurrence of discharge from the Army for disabling knee injury using unconditional multiple logistic regression analyses.

Results: We found relations between the risk of knee-related disability and age and race, with marked effect modification by gender. Non-Caucasian men and women were at lower risk than Caucasians at all ages. At most ages, Caucasian women were at higher risk than Caucasian men, and non-Caucasian women were at lower risk than non-Caucasian men. Within race/ethnicity and gender, the risks for men showed an inverted "U" shape with increasing age, and the risks for women showed a "J" shape with increasing age.

Conclusions: Age, race/ethnicity, and gender interactions are important in occupational injury. Differences in risk may be related to differences in work assignments, leisure activities, physical or physiological differences, or the ways in which disability compensation is granted.

Medical Subject Headings (MeSH): occupational accident, knee injuries, persons with disability, military medicine, demography, case–control studies, military personnel (Am J Prev Med 2000;18(3S):103–111) © 2000 American Journal of Preventive Medicine

Introduction

Occupational injuries are responsible for more lost time from work, lost productivity, and lost working years of life than any other health condition in either the civilian sector[1,2] or the peacetime Army.[3] As with other young, fit, and generally healthy populations, injuries and not illnesses represent the leading cause of morbidity and mortality among U.S. Army personnel.[4]

Occupational and leisure-time physical activities are known to be associated with subsequent knee disorders, and this relation has been reported in both civilian and military populations.[5–20] However, most of the published research either relates usual occupation to later diagnosis, or identifies incident injuries for workers in particular jobs. Analyses such as these are useful for generating more complex hypotheses, but do not, in themselves, address potential differences in risk associated with sociodemographic or more specific occupational characteristics.

A few authors have reported an association between injury rates and sociodemographic characteristics. One study of electric utility workers found higher injury rates among men compared to women in crude analyses, but the gender relation was reversed after adjustment for job title and work site.[20] Similarly, a recent report indicated that the risk of occupational musculoskeletal disability among U.S. Army personnel varies

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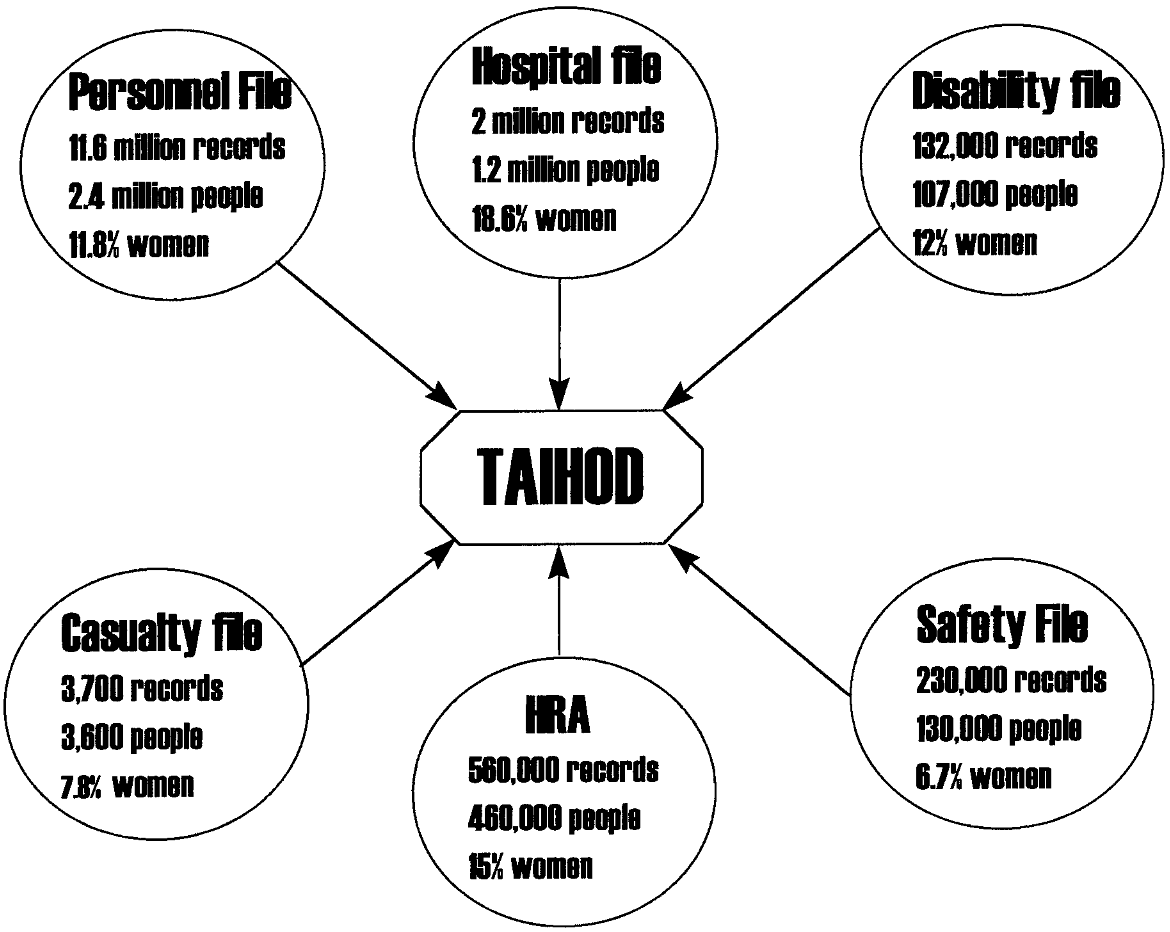

Figure 1. The Total Army Injury and Health Outcomes Database (TAIHOD)[22]

across categories of Military Occupational Specialty (MOS) and by gender, with women generally at higher risk than men.[4] In addition to gender, race/ethnicity and age may be important determinants of work-related injury. Results from the National Health Interview Survey indicate that the crude rate of at-work injuries is slightly higher among African Americans compared to Caucasians, but that the direction of the race relation is reversed in certain age groups.[21] Such findings highlight the potential significance of sociodemographic variations in occupational injuries, and the need to consider them in workplace risk assessment. Evaluations of workplace risks that fail to take sociodemographic characteristics into account may be overly simplistic and generate misleading estimates.

In this report, we describe results of analyses to investigate sociodemographic variations in the odds of disabling occupational knee injury among active-duty enlisted personnel in the U.S. Army. We focused on disability discharge in order to identify severe injuries. Our objective was to determine the separate and joint roles of age, gender, and race/ethnicity differences in the odds of knee-related disability discharge from the Army, as these sociodemographic characteristics are likely to be important variables in future analyses of occupational knee injury.

Methods

The TAIHOD and Source Data Library

Data from these analyses are from a relational database, the Total Army Injury and Health Outcomes Database (TAIHOD). The TAIHOD was developed by the U.S. Army Research Institute of Environmental Medicine in 1994, and has been updated annually. The TAIHOD currently links demographic and occupational information on all Army personnel on active duty between 1980 and 1997 with databases tracking hospitalizations, lost work time injuries, disability determinations, and fatalities. Active duty is defined as the presence of a record in the personnel database (Figure 1). As of 1995, data were available for 2.4 million individuals (11.8% women), including 3600 deaths (7.8% women), and almost 2, million hospitalizations (18.6% women).[22] The structure and population included in the TAIHOD through 1995 are described in Figure 1.

As part of an ongoing investigation of correlates of

Table 1. Disabilities included in initial case definition, based on Veteran's Administration System for Rating Disability (VASRD) Codes: distribution of primary reason for discharge

	Women		Men	
VASRD code name	Count	Percent	Count	Percent
Recurrent subluxation or lateral instability of knee	442	51.6	581	58.0
Impairment of femur[a]	157	18.3	123	12.3
Impairment of tibia and fibula[b]	92	10.7	114	11.4
Removal of semilunar cartilage	35	4.1	40	4.0
Genu recurvatum	6	0.7	0	0
Dislocation of semilunar cartilage	3	0.4	5	0.5
Knee replacement	1	0.1	0	0
Thigh amputation	1	0.1	0	0
Ankylosis of knee	1	0.1	3	0.3
Amputation with loss of extrinsic pelvic girdle muscles	0	0	0	0
Amputation one-third of the distance from the perineum to the knee joint	0	0	0	0
Total[c]	738[c]	86.1[c]	866[c]	86.5[c]

[a] Includes malunion of femur with knee or hip disability.

[b] Includes malunion with knee or ankle instability.

[c] Totals do not sum to total number of cases or 100%, since some cases were included based on secondary disability.

knee-related disability discharge from the U.S. Army, we drew a sample from TAIHOD to construct a "data library." Cases in the data library were defined as enlisted personnel having at least one of 11 disability codes indicating a primary or secondary reason for disability that was broadly related to a knee problem. Table 1 lists all codes included in the initial case definition. Only the first knee-related disability finding qualified for inclusion as a case record. Follow-up findings related to a prior knee-related disability (less than 1% of all potential cases initially identified) were excluded. A total of 860 enlisted women and 7868 enlisted men with knee-related disability discharges met the inclusion criteria for the data library.

The control series in the data library comprises a simple random sample, stratified by gender, from the population of all enlisted soldiers with a record in the TAIHOD. To approximate incidence density sampling, we drew controls for each year in proportion to the number of cases recorded in that year. Any potential control with a prior knee-related disability was excluded. Overall, the data library includes three controls per case. However, as the number of women in the case series is much smaller than the number of men, we used a control:case ratio of 6:1 for women and 1.5:1 for men. This yielded a total of 5109 female and 11,758 male controls in the data library. We oversampled women relative to men in order to ensure a sufficient number of women among both the case and control series to construct gender-specific statistical models.

Analysis Sample

We constructed an analysis sample from the data library by stratified random sampling from the case and control series, with male and female series sampled separately. For women, the case series comprises all 860 women from the data library. The male case series comprises 1005 male cases, representing equal sampling of the data library from each year (1000/15 = 66.7, or 67 cases per year). The control series represents a simple random sample of three controls per case, stratified by gender.

Statistical Methods

We used SAS version 6.12[23] for data management and the development of analytical files, and STATA version 5.0[24] for model building. The survey data analysis module in STATA allowed us to incorporate sampling weights and the stratified sampling plan into the final logistic regression model.

Statistical analyses focused on the occurrence or nonoccurrence of disabling knee injury. In preliminary analyses, we constructed univariate frequency distributions to examine data completeness and describe the analysis sample. Bivariate frequency distributions by case/control status, stratified by gender and year, as well as univariable logistic regression models, informed our choice of candidate predictors for inclusion in the multivariable logistic regression models. We used chi-square and t-tests for preliminary comparisons between cases and controls, and between controls and the population of enlisted personnel. We identified effect modification by examining the graphical representation of estimates generated from stratified models.

Results

Preliminary Comparisons

In preliminary analyses, we compared the demographic characteristics of the controls in the data library with those of the population of enlisted personnel (data not

Table 2. Demographic characteristics of cases and controls included in the pilot study

	Women				Men			
	Cases (N = 860)		Controls (N = 2580)		Cases (N = 1005)		Controls (N = 3009)	
Cases	Count	Percent[a]	Count	Percent[a]	Count	Percent[a]	Count	Percent[a]
Age quintile								
17–21 years	144	19	479	19	146	15	564	20
22–23 years	138	18	504	20	173	19	560	19
24–26 years	150	19	556	22	242	26	588	20
27–30 years	184	24	559	23	198	20	548	18
31–54 years	158	20	399	16	179	19	702	23
Total[b]	860	100	2497	100	1005	99	3009	100
Race/ethnicity								
Unknown	2	0.2	2	0	1	0	0	0
Caucasian	584	68	1233	47	699	71	1896	62
African American	221	26	1147	45	229	22	855	29
Other	53	6	198	8	76	7	258	9
Total[b]	860	100	2580	100	1005	100	3009	100

[a] Estimated population percentages taking sampling weights and stratified sampling into account. See text.

[b] Age totals differ from overall totals due to missing values. Percentages may not total to 100 due to rounding.

shown). While the controls and the population of enlisted personnel had the same average age (25.6 years), the average duration of service was 2.5 months shorter among the controls in the data library compared to the source population. Controls in the data library were slightly less likely to be Caucasian (59% versus 60%) and slightly more likely to be African American (33% versus 31%) compared to the population of all enlisted personnel. Although small in magnitude, the differences in racial distribution were statistically significant due to the large sample size. Differences between the controls in the data library and the population of enlisted personnel with respect to age and duration of service were neither empirically nor statistically significant.

The demographic characteristics of controls included in the study were similar to those of controls in the data library (data not shown). Both groups were, on average, 25.6 years old. Controls included in the study had, on average, 0.2 months (approximately 6 days) longer duration of service compared to those in the data library. Controls in the study subsample were slightly less likely to be Caucasian (56% versus 59%), slightly more likely to be African American (36% versus 33%) and slightly less likely to be a member of an "other" racial group (8% versus 9%) compared to the controls in the data library. Again, although small in magnitude, the racial differences are statistically significant due to the large sample size. The difference between the controls included in the study subsample and controls in the data library with respect to duration of service was not statistically significant. There were neither empirical nor statistical differences between cases included in the study and cases in the data library with respect to age, duration of service, or race/ethnicity distribution (data not shown).

Cases Compared to Controls, Study Analysis Group

Table 2 presents the demographic characteristics of cases and controls included in the study. The percentages shown in the table take the sampling weights and stratified sampling technique into account, and thus represent the estimated age, race/ethnicity, and gender distribution in the source population of cases and controls. Based on preliminary descriptive analyses, we used quintiles of age and race/ethnicity categorized as Caucasian/non-Caucasian in all subsequent analyses.

Separate univariable logistic regression models for women and men showed somewhat different patterns in risk over age quintiles. The risks over age quintiles were relatively stable for women, with a slight increase in the highest age group. The men showed a pattern of increasing risk over age, with a downturn in the two oldest age groups. In all age groups except for the highest, the odds ratios for women were closer to 1.0 than were those for men (Table 3). For both women and men the risk of discharge for disabling knee injury was lower in non-Caucasians compared to Caucasians (Table 3).

Gender appears to modify the effect of both age and race/ethnicity. Figure 2 shows that, after stratifying by quintiles of age and by race, Caucasian women were at higher risk than Caucasian men at all ages except for the 23–27 year age group, and non-Caucasian women were at lower risk than non-Caucasian men at all ages except for the 30–54 year age group.

Figure 3 shows the relative odds of discharge for disabling knee injury with increasing age, stratified by gender and race/ethnicity. The most common age category, 23–27 years, serves as a referent group. These analyses demonstrate that the shape of the relation with

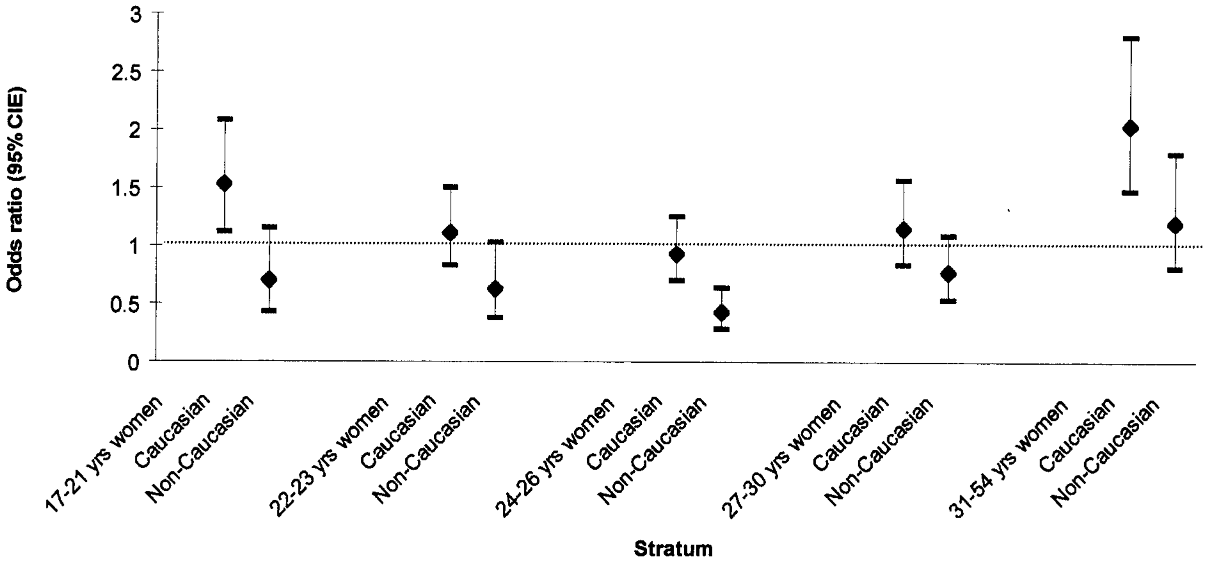

Figure 2. Relative odds of discharge for disabling knee injury among women compared to men, stratified by age and race. Dotted line represents referent group: men within each age and race/ethnicity group.

age was different for the two genders. The function forms a clear inverse "U" for men and a "J" for women. The shape of the curve over quintiles of age was approximately the same for Caucasians and non-Caucasians. However, the effect of age was least strong for Caucasian women: the odds ratios were all closer to 1 as compared with the odds ratios for the other race/gender subgroups.

The risk of discharge for disabling knee injury among non-Caucasians compared to the risk among Caucasians, stratified by quintiles of age and by gender, shows that the race/ethnicity effect was modified by gender, but not by age (Figure 4). Non-Caucasians were at lower risk than Caucasians at all ages and among both men and women. The effect of race was consistent over all age groups, as reflected by the similarity in point estimates for each age–gender subgroup. For example, the odds ratio for non-Caucasian men aged 17–21 compared to Caucasian men aged 17–21 was 0.89, compared to 0.72 and 0.77 for non-Caucasian versus Caucasian men in the next two age categories.

We estimated multivariable logistic regression models to investigate the joint effect of age, gender and race/ethnicity and to take into account the gender–race and gender–age interactions. The multivariable model revealed the same patterns of risk as the stratified analyses: Caucasian women were at higher risk than Caucasian men at all ages except for those aged 23–27, and non-Caucasian women were at lower risk than non-Caucasian men except among those aged 30–54. The odds ratios for disability discharge in women compared to men were nearly identical in the multivariable model and the stratified analyses, but the 95% confidence intervals (95% CI) from the model were substantially narrower (data not shown). In the model, the risk was constant over quintiles of age for non-Caucasians compared to Caucasians, with adjusted relative risks of 0.77 (95% CI 0.53, 0.78) for men and 0.42 (95% CI 0.41, 0.43) for women. We found similar point estimates and confidence intervals after re-running the multivariable model using survey analysis techniques (not shown).

To investigate the possibility of a three-way interaction between age, race/ethnicity, and gender, we constructed a model containing the second order interaction term (age × race × gender) and all first order interactions (age × race, age × gender, race × gender). This is analogous to including all main effect terms in a model evaluating a second-order interaction. No category of the second-order term was statistically significant. Estimates derived from the first order interaction terms were comparable to those from the model containing only first order interactions (not shown).

Discussion

Our long-term interest is in an analysis of a variety of sociodemographic and occupational factors in relation to the risk of discharge from the U.S. Army for knee-related disability. A "traditional" approach to such an analysis would call for focusing on occupational risk factors while evaluating and controlling for confounding by demographic characteristics. Such an approach would have led us to overlook important interactions among demographic factors and, therefore, to inaccurate conclusions. For example, the nonlinear relation we observed between risk of discharge and age would not have been evident had we simply considered age to

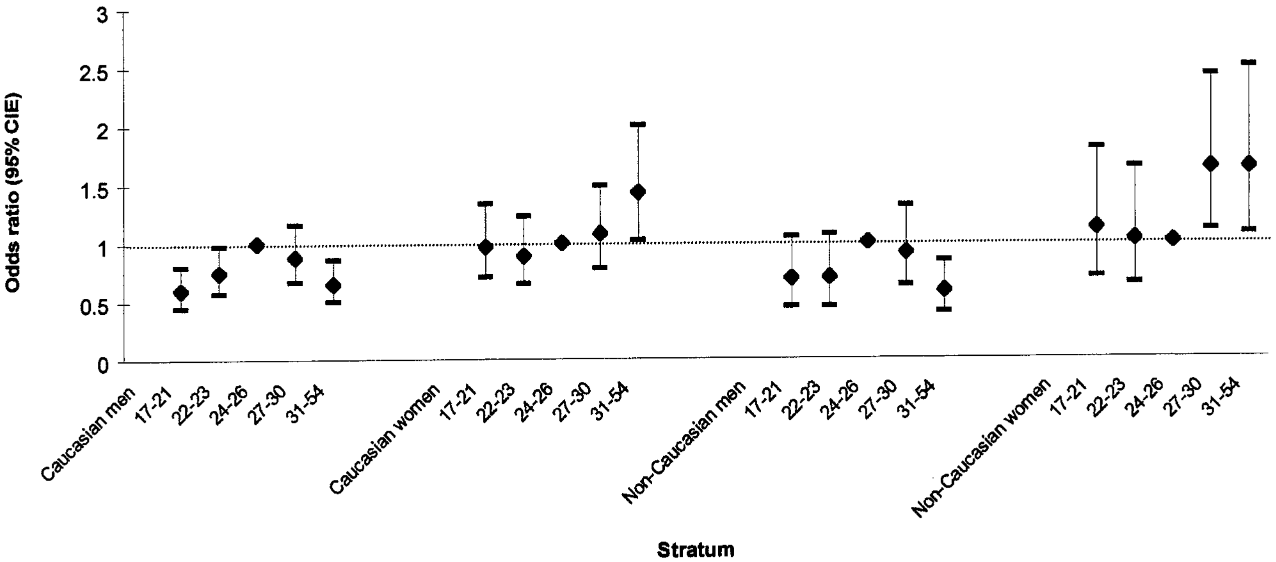

Figure 3. Relative odds of discharge for disabling knee injury with increasing age, stratified by gender and race. Dotted line for OR = 1, odds ratio for referent category.

be a confounder and included it in a multiple logistic regression model. In particular, Figure 5 shows that adjusted odds ratios obtained from a main-effects model containing age in quintiles, gender, and race range between 0.58 (for non-Caucasians compared to Caucasians) and 1.04 (for women compared to men). Although the lower odds ratio for non-Caucasian compared to Caucasian race can still be seen from this model, the strong nonlinear effect of age on risk of discharge is completely hidden, as are the modifying effects of gender on the race/ethnicity and age relations. Thus, our focus in this pilot study was a basic understanding of the roles of age, gender, and race/ethnicity in knee-related disability.

It has become accepted that physical demands are associated with subsequent knee disorders, and that these demands may be the result of either occupational or leisure activities.[5–20] We identified four civilian studies of occupational demands as risk factors for knee problems that included women.[15,16,18,20] One study included too few women with physically demanding occupations to conduct separate analyses.[16] Two of the studies included sufficient numbers of women in physically demanding occupations to have evaluated gender differences in risk, yet neither did so.[15,18] The fourth study specifically addressed gender differences in occupational injury rates. The authors found that, among electric company employees, crude injury rates were higher among men than women over a 12-year follow-up period. In different analyses controlling for a variety of factors including age, job experience, job type, and work site; however, the relative risk of work-related injury was generally higher for women compared to men.[20]

Among enlisted Army personnel, Caucasian women were at generally higher risk of discharge for disabling knee injury than Caucasian men, but non-Caucasian women were at generally lower risk than non-Caucasian

Table 3. Univariable logistic regression taking sampling into account

	Women			Men		
	OR	95% CI	*p* value	OR	95% CI	*p* value
Age (years)[a]						
17–21 years	1.0†	—	—	1.0[b]	—	—
22–23 years	0.90	(0.68, 1.19)	0.47	1.24	(0.95, 1.61)	0.11
24–26 years	0.90	(0.68, 1.18)	0.43	1.69	(1.32, 2.17)	<0.001
27–30 years	1.08	(0.83, 1.40)	0.59	1.40	(1.09, 1.82)	0.01
31–54 years	1.32	(1.02, 1.74)	0.05	1.06	(0.82, 1.37)	0.66
Race/ethnicity						
Caucasian	1.0[b]	—	—	1.0[b]	—	—
Non-Caucasian	0.40	(0.35, 0.49)	<0.001	0.70	(0.60, 0.82)	<0.001

[a] Quintiles of age.
[b] Referent group: most prevalent category or lowest quintile (age).
CI, confidence interval.

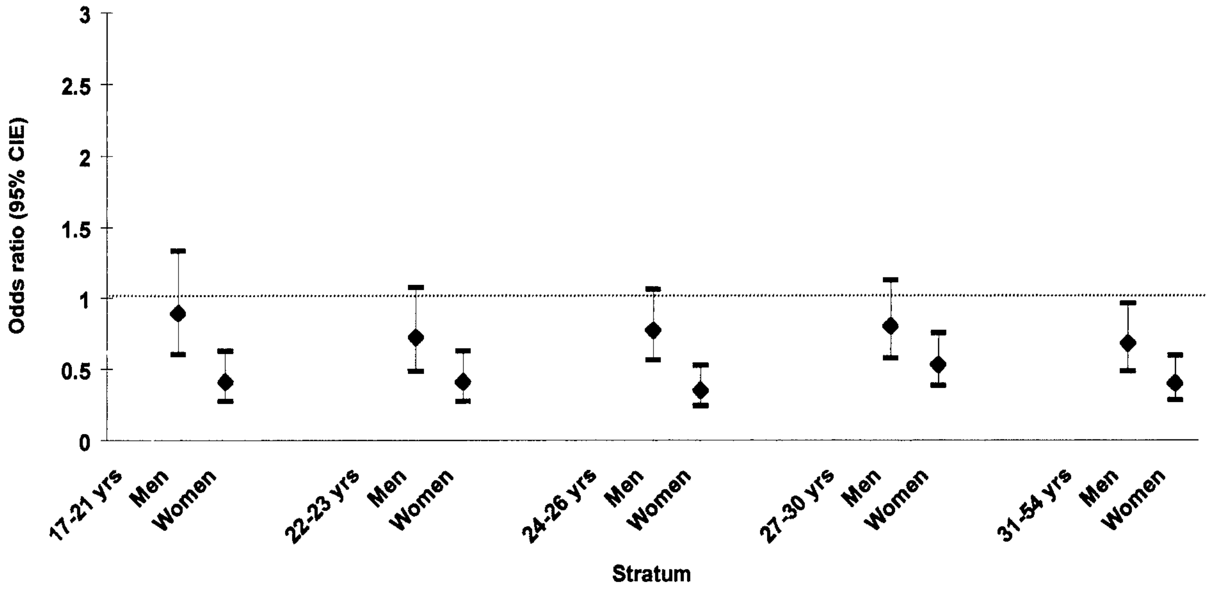

Figure 4. Relative odds of discharge for disabling knee injury among non-Caucasians compared to Caucasians, stratified by age and gender. Dotted line for OR = 1, odds ratio for referent category.

men. Very little previous research on military populations has included women or focused on periods other than basic training.[4–10] Two studies that have included women were of nonspecific conditions, and their results appear to be contradictory. Tomlinson et al.[10] observed a reduced risk of both acute and overuse musculoskeletal injuries for women compared to men stationed at Fort Lewis, Washington, during the period from December 1984 through April 1985, while Feuerstein et al.[4] found that in certain jobs, the risk of discharge for musculoskeletal disability was higher for women compared to men between 1990 and 1994. In a study of risk factors for injury during basic training among Royal Australian Air Force (RAAF) recruits, Ross and Woodward[9] found that the odds of overuse injuries were 4.4 times higher among women than men. These studies neither examined in detail nor adjusted for other sociodemographic characteristics. Differences among these sets of results could be explained by differences in case definitions, time periods and/or risks for incident injury as opposed to discharge for disability.

General injury incidence and mortality rates are known to differ by race/ethnicity in the United States.

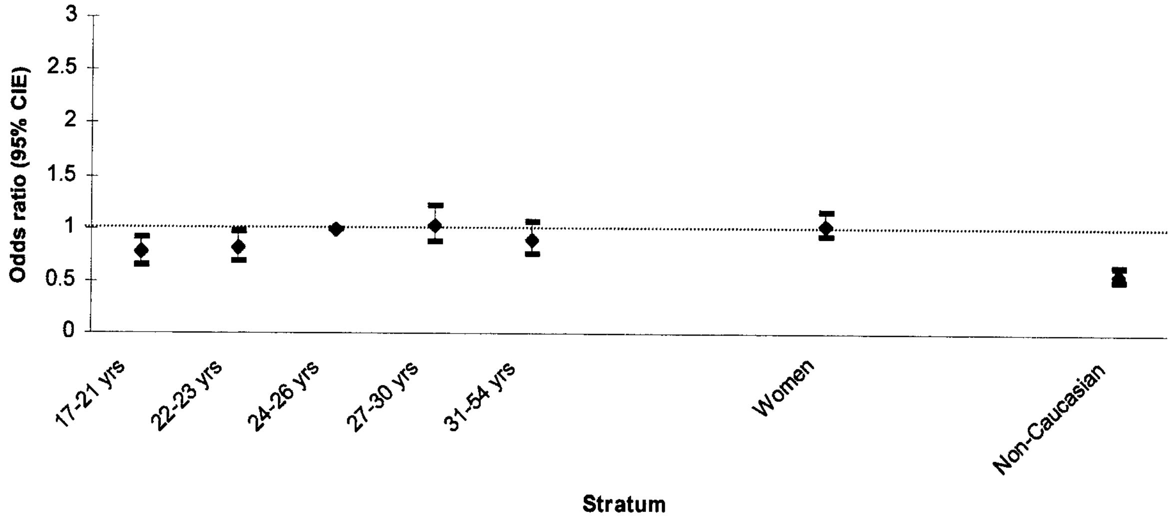

Figure 5. Relative odds of discharge for disabling knee injury based on main effect model (with age+gender+race). Dotted line for OR = 1, odds ratio for referent category.

Wagener and Winn[21] estimated national rates of at-work injury based on the 1983–1987 National Health Interview Survey. The authors report that the rate of at-work injuries among African Americans was 9.2/100 employed persons/year, while the rate for Caucasians was 9.85/100 employed persons/year. Caucasians had slightly higher at-work injury rates than African Americans among both younger (18–44) and older workers (45–64), but Caucasian versus African-American men and Caucasian versus African-American women had about the same rate of at-work injury.[21] Six studies of the relation between civilian occupational or leisure time physical activity and musculoskeletal injuries or disorders,[11,12,14–19] including one that reviewed 19 previously published reports on this topic,[11] failed to include any consideration of race/ethnicity as either a risk factor or effect modifier.

Studies in military populations tend to be conducted at one specific post and, therefore, to have low statistical power due to the inclusion of relatively small numbers of individuals in the analyses. Jones et al.[5] studied physical training injuries among 303 male infantry trainees from two basic training companies. The authors reported a nonstatistically significant 10 to 40% decrease in risk of training injuries among non-Caucasians compared to Caucasians. In their study of incident injuries at Fort Lewis, Tomlinson et al.[10] also reported a nonstatistically significant decrease in risk among non-Caucasians compared to Caucasians. These results are consistent with our findings that non-Caucasians were at lower risk of discharge for disabling knee injury than Caucasians for most age-gender subgroups.

In civilian studies, age has consistently been reported as a risk factor for lower extremity disorders, especially among studies relating physical activity with osteoarthritis and bursitis of the hip or lower extremities.[11,13–15,17] Reports are more heterogeneous among studies in military populations that considered age as a potential risk factor, probably due to the narrow age range of most participants in military studies. Knapik et al.[8] found that age was inversely associated with injury incidence among male infantry soldiers stationed in Alaska, but the highest tertile of age in this group was labeled ">24 years." RAAF recruits undergoing basic training demonstrated low injury rates for all ages less than 30 years; recruits aged 30 years and older were at 70% higher risk than recruits aged 20–24 years.[9] Similarly, U.S. Army infantry basic trainees older than age 24 years showed an increase in risk of training-related injuries compared to younger trainees,[5] and active duty soldiers between ages 22 and 46 years were at increased risk of injury compared to those aged 21 years or less.[10] None of these studies considered that the effect of age on injury risk may be modified by other factors. We found a strong nonlinear association between age and the risk of discharge for disabling knee injury, and the shape of the relation differed for men and women.

The TAIHOD system is unique in its linkage of occupational, demographic, and health information for a population of healthy, mainly young, working people. The database includes information on large numbers of women, including many in heavy trades (e.g., construction) not well represented by women in the civilian sector. As a result, this research could not have been carried out in another (nonmilitary) setting. We anticipate that a result of our long-term research program will be the development of interventions in the military setting to reduce the incidence of disability related to occupational injury. Preventive measures identified as a consequence of this research may also have applications to civilians in heavy trades, including measures that will be protective for women who may begin to enter heavy trades in the civilian sector.

There are certain limitations to this pilot study. The outcome measure is crude (discharge for disability, yes versus no), in that it mixes traumatic and chronic conditions and includes some nonspecific disability types. As a review of the codes included in the case definition will show, some of the reasons for disability discharge are nonspecific. We are currently engaged in developing a more meaningful categorization scheme for coding disabilities. Possible methods for categorizing the cases include definitely/not definitely knee-related problem; chronic versus traumatic knee problem; and hard versus soft tissue injury. The analyses reported here do not consider any occupational risk factors. Ongoing research carried out by our study team is evaluating occupational risk factors, including analyses of MOS codes and physical demands associated with specific categories of jobs. In addition, the study population is currently restricted to enlisted personnel. We placed this restriction due to the large differences in occupational requirements and sociodemographic characteristics known to exist between officers and enlisted personnel in the Army. Future work employing the TAIHOD may be extended to include officers, or may focus on officers exclusively.

Conclusions

These analyses show that the risk of discharge from the U.S. Army for disabling knee injury varies by age, race/ethnicity, and gender, and that there are complicated interrelations among these sociodemographic characteristics. The differences in risk that we observed may be related to differences in work assignments, leisure time activities, physical capabilities, and physiological differences or differences in the ways in which disability benefits are granted. A thorough examination of demographic factors allows for an understanding of the context in which discharges for disabling knee injury occur. This enhanced understanding of the context, when applied to the more detailed examinations of occupational risk factors and types of injury that are already underway, will enable a more complete and accurate picture of the events and characteristics leading to disability determinations in the U.S. Army.

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Prior Knee Injury and Risk of Future Hospitalization and Discharge from Military Service

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Background: Athletic capability is paramount for survival in military basic training and successful service. Orthopedic conditions are common reasons for hospitalization and premature discharge of military recruits. Medical fitness for military service is determined through a medical examination. Individuals medically disqualified may receive a waiver to enter the service on a case-by-case basis. This study was carried out to determine how individuals with a medical waiver for knee problems compared to recruits without a history of knee injury regarding hospitalization and military discharge.

Methods: Two hundred eighty-one enlisted recruits with a history of a waiver for a knee condition were considered high risk. The comparison group was 843 recruits without prior knee pathology. Comparisons were made using frequency and chi-square analyses, relative risk estimates, and survival analyses.

Results: Individuals in the high-risk group were 1.4 (CI 1.0, 2.1) times more likely to be hospitalized for any diagnoses and 8.0 (CI 2.1, 29.9) times more likely to be hospitalized for a knee condition than those in the comparison group. Individuals with a knee waiver were 2.1 (CI 1.3, 3.5) times more likely to be prematurely discharged, and 14.0 (CI 4.6, 39.6) times more likely to be discharged for a knee-related condition than those in the comparison group.

Conclusion: Unfavorable outcomes were more likely in recruits disqualified initially and granted a waiver than in recruits without a history of knee injury. Military service requires intense physical activity; therefore, further research should be conducted to limit knee-related morbidity, especially in those with a prior history of knee injury.

Medical Subject Headings (MeSH): military medicine, military hospital, knee injuries, knee, patient discharge (Am J Prev Med 2000;18(3S):112–117)

Introduction

All uniformed military services depend on the recruiting and accession process to maintain the required military strength. One part of this process is a medical examination to determine medical fitness for military duty. When a recruit applicant is medically disqualified on entrance medical examination, a waiver may be granted. This process consists of additional medical record reviews and possibly a specialist examination, with a final determination by the respective service's central waiver authority. Recruits with a medical condition that existed before enlistment, including those with waivers, who develop a significant clinical recurrence within the first 6 months of active duty, may be discharged with this condition because it existed prior to service (EPTS). After the initial 6 months on active duty, a formalized medical review board is required for a discharge based on a medical condition.

The loss of new recruits during initial training and first military assignment is costly in terms of dollars and military readiness. In 1995, there were 153,228 recruit accessions for the combined services, each costing the Department of Defense (DoD) at least $25,000 (J. Larsen, TRADOC Deputy Chief of Staff Recruiting Office, and K. Cox, January 1998. Personal Communication). Five percent of these (approximately 7600) resulted in an EPTS discharge, amounting to a loss of nearly $200,000,000. Identifying factors that contribute to the medical reasons for some of these early recruit losses have become a priority.[1]

Orthopedic conditions are among the more com-

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mon medical causes for an EPTS discharge, and knee conditions represent 11.3% of all such discharges.[2] Pre-existing knee conditions in the recruit population can be divided into those related to trauma and those unrelated to trauma. A history of knee trauma often involves injury to the menisci or the major joint ligaments. Some require surgical correction and some result in incomplete healing. Differing opinions exist among medical specialists as to whether there can ever be full recovery of the joint without sequelae, regardless of the re-examination and functional assessment results of the joint after rehabilitation.[3–7] Anterior cruciate ligament (ACL) insufficiency, meniscus damage, and meniscectomy are all known risk factors of osteoarthritis.[8]

Physical activity demands are high in all of the uniformed services. This is particularly true in the initial 6-month training period, where daily intense exercise and vigorous training are mandated. Thereafter, service members must participate in organized physical fitness programs at least 3 times a week, and pass semiannual physical fitness tests.

This study examines whether military recruits who obtained a waiver for a prior knee ligament or meniscus condition (e.g., previous knee trauma) were more likely than recruits without such a waiver to have a significant medical outcome. The outcomes examined included hospitalization, EPTS discharge, disability discharge, and discharge for any reason.

Materials and Methods

We conducted a retrospective follow-up study on individuals entering active duty between January 1995 and December 1996 as verified through accession data from the Defense Manpower Data Center (DMDC). The high-risk group was defined as enlisted recruits in the Army, Air Force, and Navy who, based on individual service waiver authority data, obtained a waiver for a ligamentous or meniscal knee injury in 1995. Although a waiver was obtained in 1995, the recruit may not have entered active duty until 12 months after having received the waiver. Only initial enlistments were used. The case definition excluded individuals with waivers for anterior knee or patellar pathology, Osgood-Schlatter disease, congenital abnormalities, infections, rheumatic conditions, and nonspecific knee symptomatology (i.e., unspecified knee pain). Recruits without evidence of prior knee pathology (the comparison group) were randomly selected from DMDC data and matched in a 1:3 ratio on the following: service (Air Force, Army, Marines, Navy), gender, race/ethnicity (Caucasian, African American, other), age within 1 year, and year and month of entry into training.

The high-risk and the comparison populations were followed from entry into basic combat training through June 1997 for outcomes of hospitalization and discharge, resulting in follow-up times from 6 months to 30 months, depending on the date of entry. All outcomes were weighted equally.

Table 1. Distribution of knee diagnoses waived in the high-risk group

	Army	Navy/ Marines	Air Force	Total
Surgical correction	100	93	38	231
Anterior cruciate ligament	69	71	36	176
Collateral	2	1	1	4
Meniscectomy	2	3	1	6
Other/unspecified	27	18	0	45
Ligament injury	13	27	0	40
Other/unspecified	2	7	1	10
Total	115	127	39	281

Medical endpoints were analyzed separately by knee and nonknee-related outcome. Knee hospitalizations, knee EPTS discharges, and knee disability discharges included any knee diagnosis, ipsilateral and contralateral, without restrictions. Arthroscopic knee procedures in 1995 and 1996 were considered inpatient procedures. In 1997, only those with more than a 1-day admission were counted as inpatient procedures. Only the first knee hospitalization was counted when multiple admissions for knee pathology were listed. No specific breakdown of knee diagnoses in the EPTS discharge data is possible for the first 18 months of the study, so all knee-related discharges were counted as outcomes. Because disability data were coded using less specific Veterans Administration Schedule for Rating Disability (VASRD) codes, all knee-related disability discharges were included.

For overall hospitalizations, the first admission was used as the endpoint. Obstetrical and dental hospital admissions were excluded. Time to hospitalization was calculated in days from DMDC entry date to first relevant hospitalization date. Time to discharge was calculated in days from DMDC entry date to DMDC loss date.

Frequency analysis and chi-square analysis were used to evaluate the outcomes of hospitalizations, EPTS discharges, disability discharges, and combined outcomes. Relative risks (RR) with 95% confidence intervals (CIs) were calculated for hospitalization, EPTS discharge, and combined outcome results. The nonparametric Kaplan-Meier (product limit) method was used to estimate the survival function with respect to the outcomes already mentioned. Log-rank, Wilcoxon, and log-likelihood ratio tests were used to compare the probability of survival between the high-risk group and the comparison population. A p value less than 0.05 was considered statistically significant.

Results

Both the high-risk (n =281) and comparison (n =843) groups were similar to the overall recruit population;

Table 2. Hospitalization of recruits at risk and comparison population

	High risk, % (N = 281)	Low risk, % (N = 843)	RR	95% CI
Hospitalizations for any diagnoses	12.5 (n = 35)	8.7 (n = 73)	1.4	1.0, 2.1
Hospitalizations for any knee diagnosis	2.9 (n = 8)	0.4 (n = 3)	8	2.1, 29.9
Proportion of all hospitalizations with a knee diagnosis	22.9	4.1		

CI, confidence interval; RR, relative risk.

14%, 40%, and 46% were in the Air Force, Army, and Navy, respectively. This compared to 18%, 36%, and 46%, respectively, for all recruits in 1995. The study population was 85% male and over 80% Caucasian. Average age for recruits with a knee waiver was 20.8 years; for those without a waiver it was 20.5 years. In addition to being waived for a knee condition, 82% of those at high risk had evidence of prior invasive knee procedures on review of the waiver data (Table 1).

The first medical outcome examined was hospitalization. Of the 281 recruits with knee waivers, 35 (12.5%) were hospitalized for any cause. Eight (2.9%) were admitted with a knee diagnosis, representing 22% of those hospitalized for any diagnoses. Of the 843 controls, 73 (8.7%) were hospitalized for any diagnosis, and three (0.4%) were admitted with a knee diagnosis; 4% of hospitalized controls had a knee diagnosis. The relative risk of admission for the high-risk group for any diagnosis was 1.4 (95% CI 1.0, 2.1); for a knee-related admission it was 8.0 (95% CI 2.1, 29.9) (Table 2). Hospitalization rates for nonknee-related diagnoses were similar for both groups: 9.6% of the recruits at risk and 8.3% of the comparison group.

The second medical endpoint analyzed was EPTS discharge. Of the 281 recruits at high risk, 25 (8.9%) resulted in such an entry discharge, and 18 (6.4%) for a knee-related condition. Seventy-two percent of discharges (18 of 25) among recruits with knee waivers resulted from knee-related pathology. Of the 843 in the comparison group, 35 (4.2%) had an EPTS discharge, and four (0.5%) for a knee diagnosis. The proportion in the comparison group with a knee-related discharge was 11.4% (4 of 35). The relative risk of discharge for any diagnosis for the high-risk group was 2.1 (95% CI 1.3, 3.5); for a knee-related discharge it was 14.0 (95% CI 4.6, 39.6) (Table 3).

The third medical endpoint analyzed was disability discharge. There were only four disability discharges identified, all of them Caucasian Army individuals in the comparison population. None had a knee diagnosis.

An analysis of the risk of experiencing any medical outcome—for example, hospitalization, EPTS discharge, and disability discharge—was performed. Fifty-eight recruits at high risk (20.6%) had at least one such medical outcome; 26 (9.3%) were knee related resulting in 45% (26/58) of these outcomes for cases being due to a knee diagnosis. Of 110 controls (13.1%) who had at least one such outcome, three (0.7%) were knee related. Only 5.5% (6 of 110) of the outcomes for controls were for knee diagnoses. The relative risk of having any medical outcome for any diagnosis for recruits with a prior knee waiver was 1.6 (95% CI 1.2, 2.1), and 13.0 (95% CI 5.4, 31.3) for knee-related medical outcomes (Table 4). Nonknee medical outcomes were similar with 11.4% for those with and 12.3% for those without a knee waiver.

Any discharge was the endpoint used for the overall survival analysis. No difference was found between the high-risk waiver group and the comparison group (p = 0.50). The absence of a difference held in the Air Force and Navy (p = 0.61 and 0.31, respectively). Analysis by gender and race/ethnicity revealed no difference between the two groups.

A significant difference was found between Army recruits with and without a knee waiver ($p < 0.03$). Those with a waiver had a higher and earlier probability of attrition within the first 90 days. The probability of discharge in the study period was 0.32 for Army recruits at risk and 0.23 for controls (Figure 1). Army data were then analyzed for possible demographic determinants of the difference in overall survival (retention on active duty). Our analysis suggested that Army men with knee waivers are less likely to be retained on active duty ($p \geq 0.09$). There was a significantly reduced rate of retention (survival) for Army high-risk women and the respective comparison group ($p < 0.02$) (Figure 2).

Table 3. EPTS discharges for recruits at risk and comparison population

	High risk, % (N = 281)	Low risk, % (N = 843)	RR	95% CI
EPTS discharge for any reason	8.9 (n = 25)	4.2 (n = 35)	2.1	1.3, 3.5
Knee EPTS discharges	6.4 (n = 18)	0.5 (n = 4)	14	4.6, 39.6
Proportion of all EPTS discharges with a knee diagnosis	72.0	11.4		

CI, confidence interval; EPTS, existed prior to service; RR, relative risk.

Table 4. Combined medical outcome[a] of recruits at risk and comparison population

	High risk, % (N = 281)	Low risk, % (N = 843)	RR	95% CI
Combined medical outcome for any diagnoses	20.6 (n = 58)	13.1 (n = 110)	1.6	1.2, 2.1
Combined medical outcome with some knee diagnosis	9.3 (n = 26)	0.7 (n = 6)	13	5.4, 31.3
Proportion of all medical outcomes with knee diagnosis	44.8	5.5		

CI, confidence interval; RR, relative risk.

[a] Hospitalization, EPTS discharge, disability discharge.

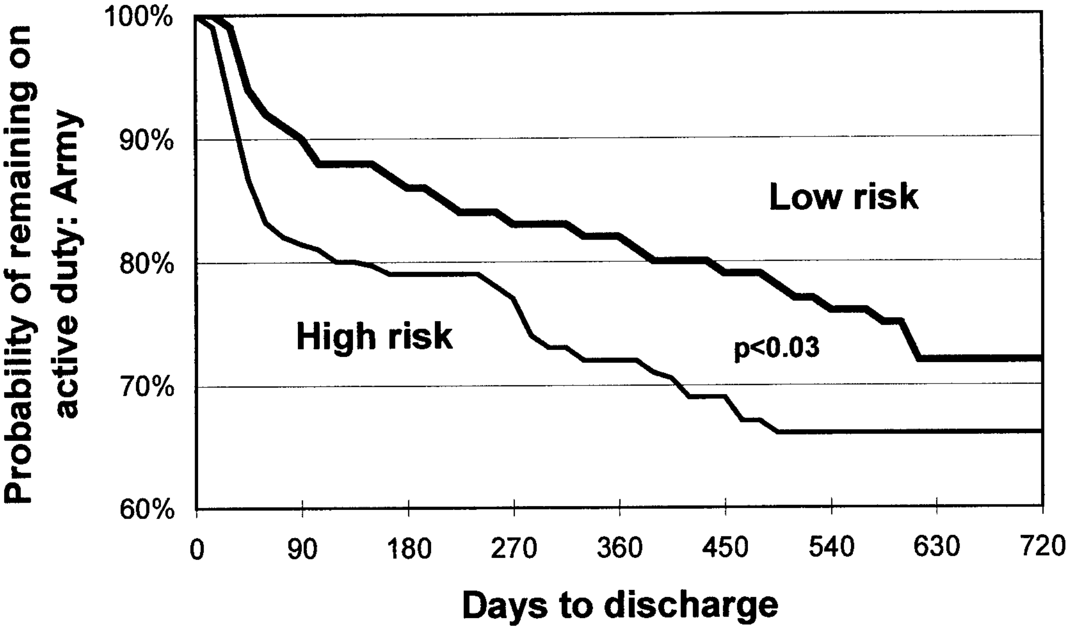

Figure 1. Overall probability of remaining on active duty for Army high-risk recruits ($n = 113$) and the comparison group ($n = 339$)

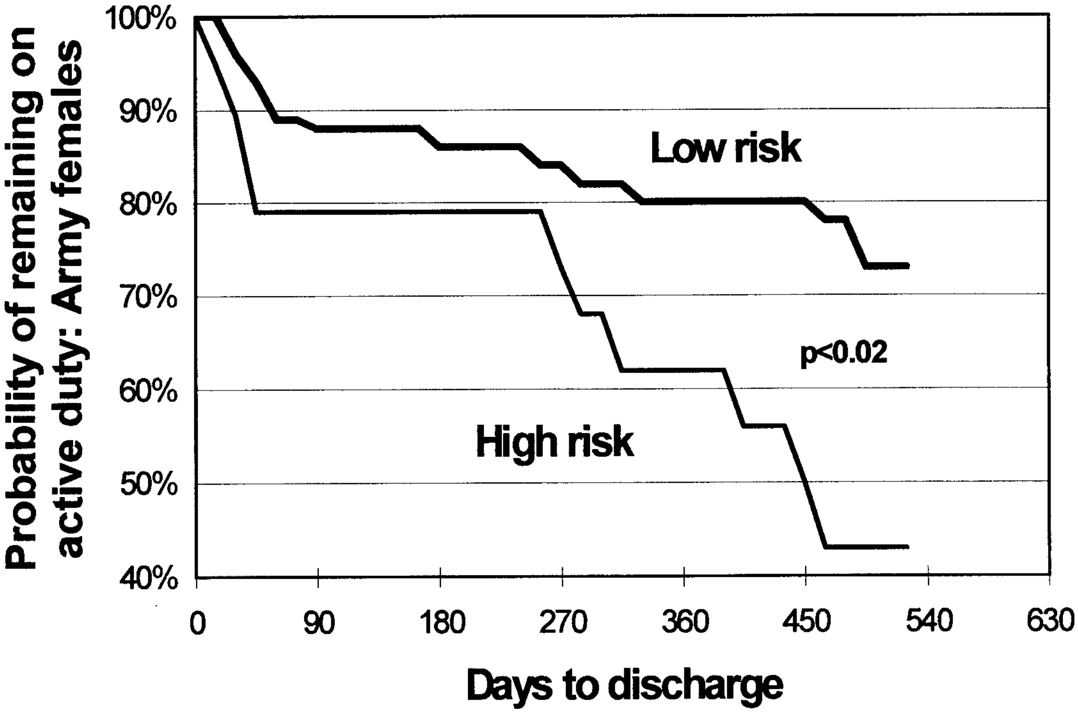

Figure 2. Overall retention of Army high-risk women ($n = 19$) and the comparison group ($n = 57$)

Caucasian Army recruits at high risk also differed from the respective Caucasian Army comparison group (p = 0.02). No differences were noted for other race categories or for age groups.

Discussion

In this tri-service study, knee-related medical outcomes were more frequent for recruits with a knee waiver than those without such a waiver. Individuals receiving a waiver for a prior knee condition were 8 times as likely as the comparison group to experience a knee-related hospitalization and 14 times more likely to be discharged for a knee condition that existed prior to service. This increased risk of knee-related hospitalization and discharge is present despite a medical evaluation indicating a likelihood of good function, a reasonably high level of physical fitness necessary to enter the military, and a desire to perform. These high-risk individuals with prior knee trauma experienced knee-related adverse medical outcomes within the first term of service (less than 4 years after entry into the military), instead of functioning well until the onset of osteoarthritis many years later.

The intense physical nature of military basic training makes it an environment where optimal athletic capacity is crucial. Perhaps not all waived individuals had fully recovered from their initial injuries, or overuse of the contralateral knee resulting from trying to compensate for a weaker knee led to higher injury rates. Medical personnel may have treated those with a prior injury differently, resulting in faster discharge. It could also be that those with prior injury differed in health awareness or behavior toward seeking health care, which can lead to higher use of medical evaluations and interventions.

We found no difference between enlisted personnel with and without a knee waiver for a ligament or meniscus injury with respect to all-cause discharge in their military training and first assignment. The Army, when analyzed separately, showed a difference in overall retention between those at high risk and the comparison group. Most of this appears to be due to the higher discharge rate of Army women with a prior knee injury. However, the numbers involved were small. It could be that these women had differences from the controls that were not controlled for in this study, such as duration since initial injury before entry, degree of rehabilitation, level of fitness, body mass index, or other orthopedic conditions.

We assumed that the two groups did not differ in lifestyle, body composition, sport participation rates, co-morbidity, or behavior toward seeking health care. We also assumed that those with prior injury had all recovered equally well from their waived knee conditions before beginning military training.

There are several limitations to this study. The medical fitness standards for each service differ somewhat. This may cause a shift of recruits less physically fit toward some services. Waiver decisions are made separately for each service and are granted on an individual basis. It is unlikely, though, that the Army waiver authority would have applied different waiver standards to female and male recruits. The coding of waiver data does not reliably separate all ACL pathology from other entities; therefore, some cases were not identified for this study. Additionally, some recruits with prior injury may have been missed due to concealment. This misclassification of those at high risk into the comparison group would have biased our results toward the null. In addition, not all arthroscopic knee procedures would be captured as admissions in 1997 due to changes in hospitalization policy. This potential underreporting of knee-related outcomes would decrease the power of this study to find a significant difference.

Differences with respect to knee-related medical outcomes between those with a knee waiver and those without such a waiver were found in this young active population under the physical stress of military basic training. It is unlikely to be cost effective to change the current mass screening or waiver process for military recruit applicants with a prior knee ligament or meniscus injury and perhaps screen out many recruits who would do well on active duty. Further research is warranted, however, to examine the reasons for these differences and suggest possible strategies during training and military duty to limit knee-related morbidity in the military. Future studies should include an extension of the current study to 36 months of follow-up time for all study subjects. This would allow capture of more outcomes and strengthen the study findings. In addition, a complementary study evaluating recruits with anterior knee pathology and Osgood-Schlatter disease might be considered, given high outpatient utilization for these problems.

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Sports and Physical Training Injury Hospitalizations in the Army

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Introduction: Injuries are the leading health problem in the military services. Sports and physical training activities are an area in which a substantial number of injuries can occur. Although athletic injuries are not often investigated in military populations, the Armed Forces database provides a unique opportunity to investigate sports injuries.

Methods: An Army database of all hospital admissions for active duty Army personnel in the 1989–1994 period was used to study injuries resulting from sports and Army physical training.

Results: For the 6-year time period reviewed, there were 13,861 hospital admissions for injuries resulting from sports or Army physical training: 94% (13,020) of these admissions were men and 6% (841) were women. The rates of sports injuries were 38 and 18 per 10,000 person-years for men and women, respectively. Sports injuries accounted for an average of 29,435 lost duty days each year: Men lost an average of 13 days per injury and women lost an average of 11 days per injury. Acute musculoskeletal injuries in the categories of fractures, sprains/strains, and dislocations accounted for 82% of all injuries. The knee was the most often injured body area in both genders, with the anterior cruciate ligament (ACL) identified as the most frequently injured body part overall. The top seven injuries were virtually identical for men and women, with only slight variations in order. Although the rates of all hospitalized sports injuries were higher for men than women, women had a higher proportion of ACL injuries from basketball and softball, ankle fractures from softball and head injuries from basketball. For men, football and basketball contributed to the highest rates of injuries. The highest injury rates for women were from Army physical training and basketball. For both men and women, Army physical training was the leading cause of lumbosacral strains.

Conclusions: Sports and Army physical training injuries account for a significant amount of lost duty time and impact military readiness.

Medical Subject Headings (MeSH): military personnel, military medicine, athletic injuries (Am J Prev Med 2000;18(3S):118–128) © 2000 American Journal of Preventive Medicine

Introduction

Injuries are the leading health problem in the military services. Costs of injury in terms of manpower losses and monetary expenditures are well documented.[1] The U.S. Armed Forces spend a great deal of time and energy investigating their military training techniques and work environments to evaluate effectiveness; ensure safety in the training and work environment; and reduce injuries resulting in lost duty time.

Musculoskeletal injuries are a frequent occurrence in all military branches, and are usually found more often in combat units due to the nature of the physical activity performed.[2] At a large Army facility, Tomlinson, et al.[2] found that fractures, sprains/strains and dislocations accounted for 53% of all injuries. Similar injury patterns were reported for a sample of 298 male infantry soldiers, but cause of injury was not reported.[3]

Although training and occupational injuries are of major importance, sports are another area that is often overlooked, and where a substantial number of injuries occur. The large majority of the literature on sports injuries is focused on civilian populations. Although active duty military personnel also participate in a large number of sports activities, both on and off duty, their

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injuries resulting from athletic participation have not been closely studied. Depending on their location and duty station, soldiers may either have a very demanding schedule or find themselves with a great deal of free time in which they can participate in sports, on both a recreational or competitive basis. Injuries occurring as a result of participation in sports can lead to prolonged periods away from soldiers' primary duty requirements and can affect their deployment status.

Understanding the extent of sports injuries is important to the Armed Forces since military readiness is a function of the ability of each person to perform his or her full duty.

In partial response to a request from the Office of the Surgeon General of the Army to evaluate the magnitude of the problem of injuries, the Armed Forces Epidemiological Board (AFEB) found that sports injuries were one of the leading causes of serious injury for military personnel.[1] As early as 1962, sports and recreational activities were found to account for a significant portion of lost duty time in the Army.[1] A study in the British Services of the 1969–1980 period found a 6.5 per 1000 person-years rate of injury from sports.[4] During Operations Desert Shield and Desert Storm, sports and athletics were the leading cause of hospitalizations (3.6/1000 person-years), and the second leading cause of hospitalization injuries among U.S. Army and Air Force active duty personnel in 1992.[1] More recently, recreation activities were shown to comprise 19% of all injuries occurring on the flight deck, hangar bay, or gym of a U.S. Navy aircraft carrier, with 25% of injuries resulting in lost duty time.[5]

In the Armed Forces, little is known about sports injuries that result in hospitalization. As part of ongoing research on injuries in the military, this study:

- analyzed all hospitalizations due to sports and physical training in the Army in 1989–1994 to determine the direct impact on the military readiness;
- investigated the characteristics of injuries occurring from sports and physical training;
- investigated the association between individual sports and specific injuries;
- and analyzed the differences between men and women regarding the impact and pattern of sports injuries resulting in hospitalization.

Methods

Data on injury hospitalizations were obtained from the U.S. Army Research Institute of Environmental Medicine (USARIEM) Total Army Injury and Health Outcomes Database (TAIHOD).[6] This large database is a compilation of existing personnel, hospitalization, and medical outcomes data from the Army and various Department of Defense (DOD) sources. The TAIHOD hospitalization data from January 1, 1989, to December 31, 1994, were evaluated, and these data had the following characteristics: (1) the Army uses the NATO/STANAG (Standardization Agreement) 2050 coding system for recording external causes of injury, rather than the International Classification of Disease (ICD) external cause-of-injury codes (E800–E999); (2) the STANAG coding system classifies the activity at the time of the injury, as well as intent and location (code groups 200–249); and (3) the STANAG coding system identifies sports injuries separately, unlike ICD-9 E-coding.

All Army active duty personnel hospitalized due to athletics and sports, including Army physical training, were evaluated. Data were recorded for 17 sports, one physical training category and one "other" category, which consists of all sports activities not specified in the other 18 codes (e.g., running and volleyball). Discharge diagnoses were coded according to the ICD 9th Revision, Clinical Modification (ICD-9-CM).

To determine the body parts most frequently injured with sports/training participation, all primary diagnosis codes were divided into the different body areas sustaining the injury. To find injuries directly caused as a result of a soldier's participation in a listed sport, only the following admissions were included: primary diagnosis of an acute musculoskeletal injury, primary diagnosis of an acute traumatic injury, and soft tissue injuries resulting from recent cumulative trauma.

Primary admission diagnoses coded as an old injury (e.g., old ACL tear) or chronic musculoskeletal condition (e.g., degenerative disc disease) were not included in the determination of body areas affected. In addition, conditions without a distinct body area (e.g., internal organ injuries, superficial wounds) were not included.

The Statistical Software SPSS 6.1 package was used for all statistical analysis. To determine prevalence rates (Armywide, gender, race/ethnicity, and grade-specific population data), year-end denominator data for 1989–1994 were obtained from the TAIHOD technical report T97-10.[7]

Results

Demographics

Of the 120,430 hospital admissions with an external cause of injury recorded, 11% (13,861) of the patients had injuries sustained from sports or physical training (codes 200–249). Men accounted for 94% (13,020) of these admissions and women accounted for 6% (841).

The soldiers admitted for injuries from sports and physical training were aged 17 to 65, and 41% of this population was aged 20 to 24. Approximately 7000 (51%) of all admissions were unmarried soldiers. The

Table 1. Demographics of personnel hospitalized for sports and physical training injuries, U.S. Army, 1989–1994

Variable	Strata	Frequency	Percentage	Population	Injury rate[a]
Gender	Male	13,020	94.0	3,406,093	38.2[b]
	Female	841	6.0	460,567	18.3
Age (years)	17–20	3,184	23.0	554,996	57.4[b]
	21–24	4,244	30.6	1,049,782	40.4
	25–30	3,385	24.4	1,002,706	33.8
	31–35	1,677	12.1	575,682	29.1
	36–40	873	6.3	408,318	21.4
	41–45	362	2.6	193,671	18.7
	46+	123	1.0	81,505	15.1
Race	Caucasian male	8,379	64.4	2,195,216	38.2
	Caucasian female	562	66.8	219,110	25.6[b]
	African American male	4,160	32.0	893,473	46.6[b]
	African American female	257	30.6	202,810	12.7
	Asian male	64	0.5	61,173	10.5
	Asian female	8	1.0	9079	8.8
	Native American male	7	0.1	17,305	4.0
	Native American female	0	0.0	3505	—
	Other male	410	3.1	238,926	17.2
	Other female	14	1.6	26,063	5.4
Military rank	Cadets	1,544	11.1	[c]	[c]
	E1–E4	6,753	48.7	1,802,196	37.5[b]
	E5–E7	3,976	28.7	1,389,046	28.6
	E8–E9	168	1.2	99,093	17.0
	O1–O3	925	6.7	305,622	30.3
	O4–O6	341	2.5	183,996	18.5
	O7–O11	2	.0	2243	8.9
	W1–W5	179	1.3	84,268	21.2
Year	1989	2,008	14.5	758,207	26.5
	1990	2,751	19.8	735,386	37.4
	1991	2,987	21.5	686,950	43.5[b]
	1992	2,326	16.8	596,663	39.0
	1993	2,029	14.6	560,764	36.2
	1994	1,760	12.7	528,690	33.3
Totals		13,861	100	3,866,660	35.8

[a] Rates per 10,000 person-years.
[b] The highest rate within each category/strata.
[c] No denominator data available.

grades (ranks) for all admissions were 79% enlisted, 11% cadets, 9% officers, and 1% warrant officers.

In the soldier population as a whole, the rate of injuries was twice as high for men as for women. By race/ethnicity, Caucasian women and African-American men sustained the highest injury rates among women and men, respectively. By grade, enlisted grades E1 to E4 had the highest injury rates at 37.5 per 10,000 person-years (Table 1).

The data analyzed included ten team sports and eight individual activities. Men experienced the highest overall rate of injuries from basketball and football. Women experienced the highest rates of injuries from physical training and basketball (Table 2).

Injury Characteristics

Injured body parts were classified for 81% (11,280) of the hospital admissions, with only 19% (2581) of the admissions nonclassified (as described in the methods section). The knee was the most frequently injured body part for both men and women, followed by the ankle (Figure 1). Analysis (not shown) revealed that for men, basketball and football caused the most injuries to 16 of 18 of the body parts, while softball and physical training caused the most injuries to 11 of 18 body parts for women.

Four ICD-9 diagnostic categories comprised 83% (11,433) of all admissions, as follows:

- Fractures (codes 800–829)—33% (4580).
- Sprains/strains (codes 840–849)—29% (4051).
- Dislocations (codes 830–839)—15% (2050).
- Intracranial injuries (codes 850–859)—5% (752).

The rates of injuries within each of the above categories vary by sport and gender (Table 3).

The seven leading injuries were the same for both genders, with similar but not identical rankings (Table 4). The most frequent causes of these injuries are displayed in Table 5.

The ACL was the most frequently injured body part

Table 2. Sports and physical activity frequencies and hospitalization injury rates,[a] U.S. Army, 1989–1994

	Overall			Men			Women		
Activity	Frequency	%	Rate	Frequency	%	Rate	Frequency	%	Rate
Basketball	3,208	23.1	8.29[b]	3,082	23.7	9.05[b]	126	15.0	2.70[b]
Football	3,041	21.9	7.86[b]	2,994	23.0	8.79[b]	47	5.6	1.00
Softball	1,151	8.3	2.98	1,061	8.1	3.12	90	10.7	2.00
Physical training	840	6.1	2.17	711	5.5	2.09	129	23.4	2.80[b]
Soccer	792	5.7	2.05	757	5.8	2.22	35	4.2	0.76
Wrestling	594	4.3	1.54	561	4.3	1.65	33	3.9	0.72
Mountaineering/skiing/rock climbing	563	4.1	1.46	493	3.8	1.45	70	8.3	1.50
Baseball	455	3.3	1.18	427	3.3	1.25	28	3.3	0.61
Boxing	243	1.8	0.63	243	1.9	0.71	0	0.0	0.00
Swimming	228	1.6	0.59	208	1.6	0.61	20	2.4	0.43
Handball	207	1.5	0.54	191	1.5	0.56	16	1.9	0.35
Rugby	176	1.3	0.46	174	1.3	0.51	2	0.2	0.04
Horsemanship	107	0.8	0.28	82	0.6	0.24	25	3.0	0.54
Track & field	68	0.5	0.18	57	0.4	0.17	11	1.3	0.24
Tennis	67	0.5	0.17	61	0.5	0.18	6	0.7	0.13
Hockey	52	0.4	0.13	49	0.4	0.14	3	0.4	0.07
Boating	31	0.2	0.08	29	0.2	0.09	2	0.2	0.04
Cricket	14	0.1	0.04	13	0.1	0.04	1	0.1	0.02
Other[c]	2,024	14.6	5.32	1,827	14.0	5.36	197	23.4	4.30
Total	13,861	100.0	35.80	13,020	100.0	38.20	841	100.0	18.30

[a] All rates are per 10,000 person-years.
[b] Top two highest rates for that category.
[c] "Other" consists of all sporting activities not specified (e.g., running, volleyball).

in both genders. The rates of all injuries, including the ACL, were higher for men than for women. Additionally, the majority of the top three injuries for men (within all four diagnostic categories) were related to basketball and football. For women, softball was the most frequent cause of the top three fractures and of concussions, whereas basketball again led in causing the majority of the remaining (most frequent) injuries. Regarding the sports that caused the most injuries, women had a greater proportion of ACL injuries than

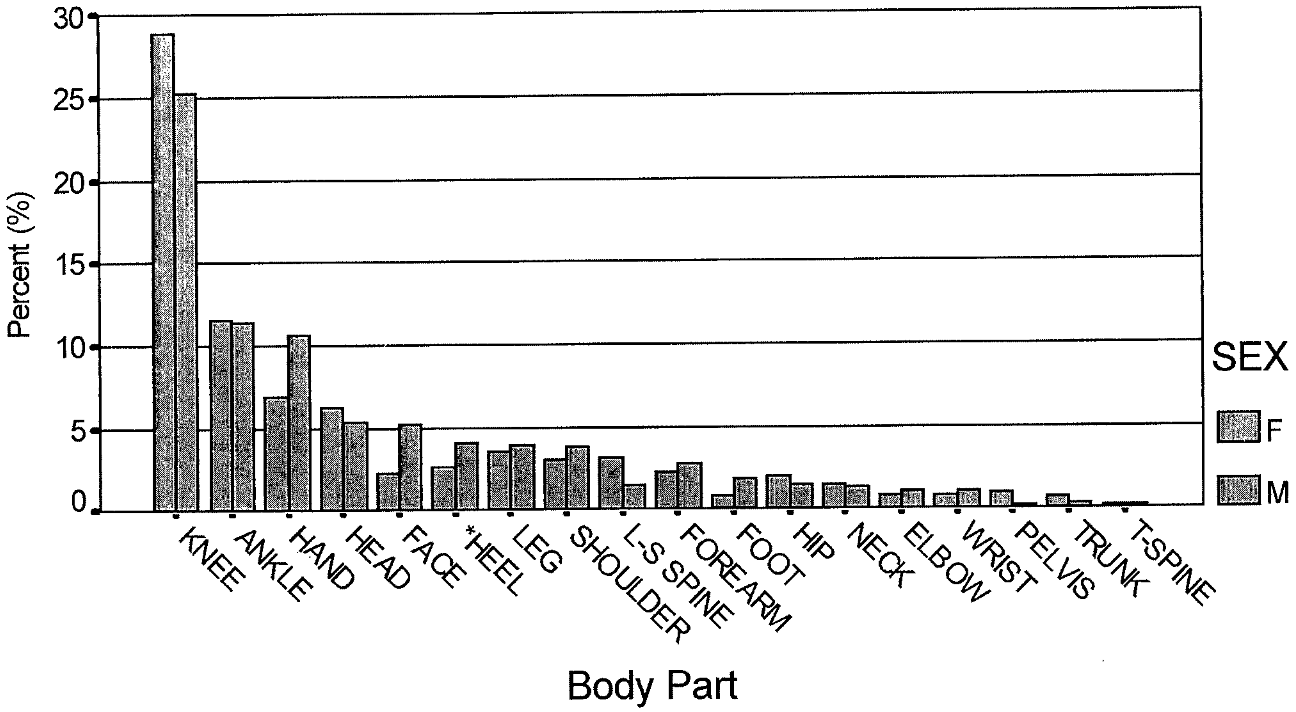

Figure 1. Percent distribution of body areas injured in sports by gender
* Heel = calcaneal fx, achilles tear and sprain.

Table 3. Hospitalization injury rates[a] within the four most frequent injury categories by sport and gender, U.S. Army, 1989–1994

Fractures			Sprains			Dislocation			Intracranial		
(ICD-9 codes 800–829)	Rate		(ICD-9 codes 840–849)	Rate		(ICD-9 codes 830–839)	Rate		(ICD-9 codes 850–859)	Rate	
	M	F		M	F		M	F		M	F
Football	3.47[b]	0.43	Basketball	3.81[b]	1.10[b]	Basketball	1.60[†]	0.50[†]	Football	0.58[b]	0.02
Basketball	2.32	0.46	Football	2.32	0.41	Football	1.08	0.07	Boxing	0.28	—
Softball	1.51	0.98[b]	Physical training	0.72	1.10[b]	Softball	0.47	0.17	Basketball	0.25	0.26[b]
Soccer	0.94	0.33	Softball	0.54	0.43	Physical training	0.37	0.43	Softball	0.14	0.24
Baseball	0.65	0.19	Soccer	0.50	0.22	Soccer	0.33	0.11	Wrestling	0.14	0.11
Mountain/ski/ rock	0.62	0.41	Mountain/ski/ rock	0.43	0.61	Wrestling	0.28	0.04	Soccer	0.12	—
Wrestling	0.54	0.26	Wrestling	0.38	0.13	Mountain/ski/ rock	0.16	0.35	Baseball	0.07	0.04
Physical training	0.37	0.37	Baseball	0.22	0.24	Baseball	0.15	0.07	Rugger	0.07	—
Swimming	0.24	0.13	Handball	0.17	0.17	Handball	0.07	0.04	Mountain/ski/ rock	0.06	0.07
Boxing	0.16	—	Rugger	0.14	—	Swimming	0.06	0.02	Swimming	0.04	0.07
Rugby	0.14	0.04	Boxing	0.07	—	Boxing	0.06	—	Physical training	0.03	0.07
Horseman	0.11	0.28	Track	0.06	0.09	Track	0.04	0.02	Horseman	0.03	0.04
Handball	0.11	0.04	Tennis	0.06	—	Rugger	0.03	—	Handball	0.02	0.02
Tennis	0.04	0.04	Swimming	0.05	0.07	Horseman	0.02	0.07	Hockey	0.02	0.02
Hockey	0.03	0.02	Hockey	0.05	—	Tennis	0.02	0.04	Tennis	0.01	0.02
Track	0.03	0.04	Horseman	0.02	0.02	Hockey	0.01	—	Track	0.00	—
Boating	0.02	—	Boating	0.01	0.04	Boating	0.01	—	Boating	—	—
Cricket	0.02	—	Cricket	0.01	—	Cricket	0.01	—	Cricket	0.00	—
Other	1.45	0.98	Other	1.53	1.50	Other	0.93	0.50	Other	0.18	0.20

[a] All rates are per 10,000 person-years.

[b] The highest rate within each category.

M, male; F, female.

Mountain/ski/rock, mountaineering/skiing/rock climbing.

men in both basketball (18% versus 11%) and softball (11% versus 7%) (Figure 2). In softball, ankle fractures occurred more frequently in women than in men (18% versus 12%). In basketball, women sustained a higher proportion of head injuries than men (10% versus 3%) (not illustrated).

Although physical training is not one of the top three injury causes represented in Table 5, it had one of the highest overall rates of injury in women, as shown in Table 2. There were some clear gender differences in injuries incurred from physical training. For instance, women had a greater proportion of lumbosacral strains (9% versus 5% in men) and men had a greater proportion of ankle sprains (11% versus 4% in women). Overall, physical training was the most common cause of lumbosacral strain in both genders.

Table 4. Top 10 diagnoses for hospitalized injuries sustained during any sporting activity (number, percentage, rate,[a] and rank), U.S. Army, 1989–1994

	Overall				Men				Women			
Diagnosis	*n* (13,861)	%	Rate	Rank	*n* (13,020)	%	Rate	Rank	*n* (814)	%	Rate	Rank
Anterior cruciate ligament	1289	9.3	**3.33**	1	1181	9.1	**3.47**	1	108	12.8	**2.34**	1
Meniscus tear	1261	9.1	3.26	2	1177	9.0	3.46	2	84	10.0	1.82	2
Ankle sprain including Achilles	1086	7.8	2.81	3	1033	7.9	3.03	3	53	6.3	1.15	4
Ankle fracture	982	7.1	2.54	4	916	7.0	2.69	4	66	7.8	1.43	3
Knee sprain—all other ligaments	772	5.6	2.00	5	732	5.6	2.15	5	40	4.8	0.87	5
Phalynx fracture of hand	618	4.5	1.60	6	592	4.5	1.74	6	26	3.1	0.56	7
Cerebral contusion	484	3.5	1.25	7	453	3.5	1.33	7	31	3.7	0.67	6
Malar/maxillary fracture	206	1.5	0.53	8	204	1.6	0.60	8				
Distal radius fracture	194	1.4	0.50	9	188	1.4	0.55	9				
Nasal fracture	172	1.2	0.44	10	162	1.2	0.48	10	10	1.2	0.22	10
Lumbosacral strain	172	1.2	0.44	10					24	2.9	0.52	8
Neck sprain									11	1.3	0.24	9

[a] Rates are per 10,000 person-years.

Table 5. Top three hospitalized injuries within each diagnostic category, overall injury rate[a] and the respective sport most commonly causing each injury and its injury rate, U.S. Army, 1989–1994

Men				Women			
Diagnostic category	**Overall injury rate**	**Most common cause of injury**	**Injury rate from sport**	**Diagnostic category**	**Overall injury rate**	**Most common cause of injury**	**Injury rate from sport**
Fracture				Fracture			
Ankle	2.69	Football	0.69	Ankle	1.43	Softball	0.35
Phalynx of hand	1.74	Football	0.65	Phalynx of hand	0.56	Softball	0.15
Malar/maxillary	0.60	Football	0.24	Tibia	0.37	Softball	0.09
Sprain				Sprain			
ACL	3.47	Basketball	0.96	ACL	2.34	Basketball	0.48
Ankle (incl. Achilles)	3.03	Basketball	1.47	Ankle (incl. Achilles)	1.15	Basketball	0.35
Knee, other[b]	2.15	Basketball	1.02	Knee, other[b]	0.87	Basketball	0.22
Dislocation				Dislocation			
Meniscus tear	3.46	Basketball	1.03	Meniscus tear	1.82	Basketball	0.37
Shoulder	0.44	Football	0.08	Patella	0.13	NP	—
Hand	0.43	Basketball	0.17	Shoulder	0.11	Basketball	0.04
Intracranial				Intracranial			
Brain contusion	1.33	Football	0.34	Brain contusion	0.67	Basketball	0.24
Concussion	0.70	Football	0.23	Concussion	0.48	Softball	0.09
Hemorrhage	0.01	Basketball & football	<0.01	Hemorrhage	0.02	Horseman	0.02

[a] All rates are per 10,000 person-years.

[b] Knee sprain of all other ligaments of the knee besides the ACL (e.g., medial/lateral collateral, tibiofibular ligament).

NP, none predominant.

Lost Duty Time

Lost duty time, the total number of days a soldier is not able to perform regular duties, is a combination of days spent in the hospital; days on convalescent leave (time off given to the soldier for recuperation); and days in a medical holding company (a unit on the hospital rolls where soldiers are assigned when well enough to leave a hospital bed but not well enough to be sent back to their regular units).

Lost duty time as determined from the hospital data

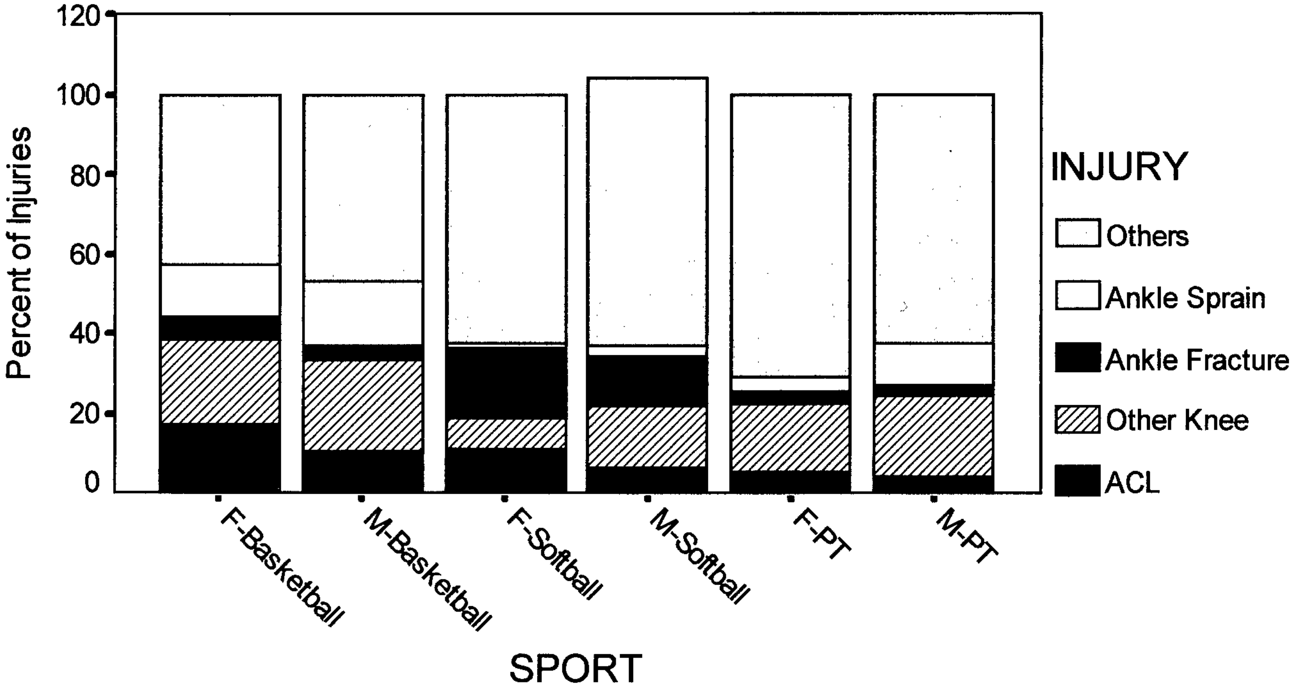

Figure 2. Injury patterns by gender
F, female; M, male.

Table 6. Total lost duty days for hospitalized injuries ranked by activity for men and women (median, mean and standard deviation), U.S. Army 1989–1994

	Men						Women					
Rank	Activity	Median	Mean	SD	Total days lost	*n*	Activity	Median	Mean	SD	Total days lost	*n*
1	Track & field	4	27	88	1519	57	Track & field	3	32	64	354	11
2	Mount/ski/rock	4	26	93	12924	493	Wrestling	4	20	91	669	33
3	Swimming	4	24	62	4984	208	Rugger	16	16	3	32	2
4	Boating	3	18	53	515	29	Soccer	4	14	28	505	35
5	Horseman	4	16	23	1313	82	Hockey	15	13	11	39	3
6	Basketball	4	13	34	41,427	3,082	Basketball	4	12	28	1463	126
7	Physical training	3	13	36	9068	711	Other	3	11	30	2084	197
8	Baseball	4	12	30	5183	427	Physical training	3	11	27	1407	129
9	Soccer	3	12	32	9154	757	Mount/ski/rock	4	10	12	714	70
10	Wrestling	3	12	30	6754	561	Softball	5	10	21	934	90
11	Other	3	12	31	22,726	1,827	Handball	6	9	12	146	16
12	Football	3	12	26	35,357	2,994	Cricket	8	8	—	8	1
13	Softball	3	11	26	11,910	1,061	Horseman	2	7	10	175	25
14	Handball	3	10	30	1899	191	Swimming	3	7	8	133	20
15	Tennis	3	9	15	564	61	Football	3	6	9	298	47
16	Cricket	2	7	12	89	13	Baseball	2	5	9	153	28
17	Boxing	2	5	9	1130	243	Boating	4	4	4	7	2
18	Rugby	2	5	9	807	174	Tennis	1	4	5	22	6
19	Hockey	2	3	3	143	49	—		—	—	—	—
Total		3	13	36	167,466	13,020		3	11	30	9143	841

SD, standard deviation.
n, number of hospital admissions for each sport.
Mount/ski/rock = mountaineering/skiing/rock climbing.

is an estimate; it does not account for any additional days off for outpatient follow-up or due to complications. For all sports combined, there were a total of 176,609 lost duty days over the 6-year period, for an average of 29,435 days lost per year. Men accounted for 167,466 lost duty days (94.8%), followed by women with 9,143 days (5.2%). Despite the fact that football, basketball, softball, and physical training were some of the most frequent injury causing activities, they were not the activities causing the most lost duty time per injury (Table 6).

Men lost an average of 13 days per injury, while women lost an average of 11 days per injury. Track and field accounted for the highest average lost duty days per injury for both genders. Seventy-two percent of the injuries occurring in track and field were musculoskeletal, with ankle sprains and meniscal injuries being the most common. Excluding cricket, rugby, and hockey (all had an *n* <10 in women and median of lost duty days <2 in men), the sport demonstrating the highest median of lost duty days for women was handball. For men, no single sport was predominant (Table 6). Analysis of the 16 injuries incurred from handball for women revealed six injuries to the ACL; two ankle sprains; two open wounds to the knee, leg, or ankle; one venous thrombosis; and miscellaneous sprains/strains and fractures. Women did not incur any eye injuries from handball, whereas 22% of all handball injuries in men involved the eye. Softball, the leading cause of the top three fractures and of concussions for women, had the next highest median of lost duty days after handball.

Disposition

Of the 13,861 hospital cases in the 6-year period, 13,142 (95%) returned to duty; 564 (4%) were transferred to another facility; 130 (0.9%) were separated from the Army; and 18 (0.1%) had an unknown disposition. In addition, there were seven deaths (all men)—two inpatient deaths, four dead on arrival, and one death in the emergency department. Of these seven sports-related deaths, two were from mountaineering/skiing/rock climbing, two were from swimming, two were "other," and one was from boating.

Discussion

This article provides one of the first descriptions of sports and physical training injury hospitalizations in the U.S. Army population. Amoroso et al.[8] determined that athletics and sports were the third leading cause of injuries for men (16%) and fifth leading cause for women (9%) in the 25 largest U.S. Army Military Occupational Specialties (MOS). Our data indicate that sports and physical training injuries account for a large number of lost duty days per year. For the 6-year period studied here, 11% of all hospital admissions that included an external cause of injury were injuries sustained from sports or physical training, averaging 29,435 days of duty lost per year.

Men accounted for 94% of all injuries, with African-American men sustaining the highest rate of injury. Caucasian women, on the other hand, had a rate of injury twice as high as African-American women. The highest frequency of injuries occurred in young soldiers with entry-level ranks. Fifty-four percent of all sports and physical training injuries occurred between the ages of 17 and 24, with the highest rate of injury (57.4 per 10,000 person-years) occurring among soldiers 20 years of age or younger. Similarly, while enlisted soldiers accounted for the majority (79%) of hospitalizations due to sports and physical training injuries, the highest rate of injury occurred among lower-ranking individuals (E1–E4). Although there is no exposure data to support speculation regarding this distribution of injuries, one might assume it is because younger, lower-ranking soldiers are required to participate in physical training and sports as part of their units' physical training (on duty) more frequently than older, higher-ranking soldiers.

The knee and the ankle were the body parts most frequently injured in sports and physical training hospitalizations in this U.S. Army population. For men, basketball and football were the activities leading to the highest rates of injuries. For women, physical training accounted for the highest rate of injury overall, followed by basketball. While lumbosacral strains comprised a greater proportion of injuries among women than men performing Army physical training (9% versus 5%), physical training was the most common cause of lumbosacral strain for both genders.

Other findings of special interest include the differences in injury patterns between men and women. Over the last several decades, the participation of women in male-dominated sports and nontraditional occupations has increased. As this equality in roles has increased, a body of literature has been produced that addresses the differences between men and women.[9–29] Women now make up 14% of the active duty personnel in the Armed Forces, and many occupations that were traditionally barred to women are now open.[30]

Over 20 years ago, it was noted that women had 1.7 to 3.2 times higher hospitalization rates, for all conditions, than men across pay grades in Navy enlisted personnel in 1973–1975.[9] Over one third of the hospitalizations for women were the result of pregnancy-related conditions. When comparing men and women in traditional versus nontraditional jobs, differences were minimal, although hospitalization rates for nontraditional personnel of both genders were somewhat higher than those assigned to traditional jobs.[9] Bishop[10] compared women and men in the Army in both administrative and combat units and found that: (1) women reported having twice as many health problems in the course of a year, yet there were no gender differences in the rate of symptoms or in their behavioral responses to symptoms reported in their health diaries; (2) the rate of symptoms reported in the combat units was twice as high as that in the administrative units for both men and women; and (3) without respect to work unit, the hospitalization rate for sports-related injuries was twice as high for men as women.

Other studies have repeatedly shown that women have a higher rate of injury and lost duty time during basic training than their male counterparts,[11–17] although Bell et al.[18] demonstrated this may be largely due to differences in physical fitness. Feuerstein et al.[19] examined disability rates among Army personnel and found that musculoskeletal disorders made up 51% of all disability cases, with women experiencing both higher overall disability risks and higher musculoskeletal disability rates than men performing the same 20 occupations evaluated.

Regarding sports activities among civilians, there is again a large body of evidence indicating that certain injuries occur more frequently among women.[20–29] The National Collegiate Athletics Association (NCAA) recorded knee injury rates between 1989 and 1993 and correlated the injuries with the activities causing them. Knee injury rates were higher in women than men in comparable activities. Of the activities comparable with men, the sports most likely to be associated with the highest specific knee injury rates were gymnastics—ACL (0.52/1000 athletic exposures in women versus 0.17 in men); soccer—collateral ligament (0.57 women, 0.56 men); basketball—collateral ligament (0.27 women, 0.18 men); and lacrosse—patellar tendon (0.22 women, 0.15 men). Of the sports not comparable with men, field hockey had the highest injury rate at 0.78, followed by volleyball and softball.[20] In women's intramural flag football, injury to the finger was the most frequent (39%), followed by the knee (16%) and ankle (8%). Sprains/strains and fractures accounted for 65% of all injuries.[21]

A study comparing a men's professional basketball team with a women's professional basketball team found that women had 60% more injuries than did men, with the ankle being the most frequent body part injured for both genders.[22] In collegiate-level basketball and soccer, NCAA data revealed that the ACL injury rate was three times higher for women in soccer and two times higher in basketball. The overall injury rate was 2.4 times higher for female soccer players than their male counterparts and 4.1 times higher for female basketball players than their male counterparts.[23,24] Others have reported similar results.[25,26] Women are more likely to sustain noncontact injuries, especially to the ACL, and are more vulnerable to overuse syndromes. Men are more likely to sustain injuries via contact mechanisms.[20,26] Although the reasons for these differences in knee injuries are not clear, they have been attributed to anatomy, physiology, and conditioning.[20,27–29]

The patterns of injury observed in the current investigation of sports injuries in active duty Army personnel were similar to those reported in the literature. The rates of hospitalization of all acute musculoskeletal injuries due to sports were higher for men than women. The ACL was the most frequent knee injury overall in both genders, with an injury rate that was higher for men than women. This is different than expected, based on the literature; however, unlike most studies in the literature, this study focused on sports injuries severe enough to require hospitalization. In addition, the current study lacks a uniform measure of exposure (e.g., number of games played per sport). The proportion of injuries to the ACL in basketball and softball, however, was higher for women than for men. The frequency and rate of injuries incurred as a result of physical training were uniformly higher for women than men. This is of particular importance as physical training is the only activity for which similar exposures can be assumed. Physical training was the leading cause of injury hospitalization for women, compared to the fifth most important for men. Tointon[4] also found physical training to be an important cause of injury and medical discharge in the British Service.

This study found that handball was the sport causing the highest median number of lost duty days among women, and closer evaluation of injuries within this sport led to some interesting findings. No eye injuries were recorded for female handball hospitalizations; however, men experienced eye injuries in 22% of their handball injuries. Protective eyewear is required when playing racquet sports in a military facility. Whether these injuries occurred while playing at a nonmilitary facility or whether men were noncompliant with the use of the eyewear is not known.

The importance of understanding the epidemiology of sports injuries and the principles of effective intervention have been increasingly recognized.[31] The limitations of epidemiologic studies for sports injury are many. As in all epidemiologic studies that review athletic injury rates, the determination of rates and their meaningful comparisons can be compromised by varying exposure of participants to the risk of injury (i.e., denominator data), different definitions for the term "injury" and the data sources used to record sports injuries.

A major limitation of this study is the lack of exposure data for participants within each of the activities. Although the authors have determined rates from the population census, these data may have given a very different picture had rates been calculated based on the amount of exposure each gender had to the activity. This makes meaningful comparison with other studies in the literature difficult. The one possible exception to this limitation is physical training—an activity in which all active duty personnel are expected to participate for a minimum of 1 hour per day, three times a week. Physical training requirements vary widely among military units, especially between officers and enlisted personnel. The important point, however, is that exposure is likely to be similar between men and women, unlike many of the other activities. While the lack of exposure data is a limitation in comparing injury rates between men and women, this study's main purpose was to examine all sports injuries in an Army population and determine the impact of serious (hospitalized) sports injuries on the Army, including its effect on readiness. With the exception of the British study by Tointon,[4] this study is one of the first to examine sports injuries in a broad cross-sectional way.

Another limitation of this study is the lack of a uniform severity scale. One could assume that, because all of the injuries reported were hospital admissions, the injuries were rather severe. In a military setting, however, this may not always be the case. An unmarried soldier living in the barracks may often be hospitalized due to environmental barriers (e.g., stairs) or the absence of a caretaker in the outpatient setting (even though the injury may not be severe). In the active duty population studied, 51% of soldiers were unmarried. At the other extreme, rather severe injuries in a group of soldiers with a high threshold for reporting injuries (e.g., Special Forces and Rangers) may be underrepresented, as they may either self-treat or access care in an outpatient setting without hospitalization. Both extremes have potential to bias the database.

Finally, the referral source for injuries has most likely changed over the 6-year period, whereas the data collection source has not. The highest rate of sports and training injuries occurred in 1991 and 1992 at 43.5 and 39.0 per 10,000 person-years, respectively. The meaning of this data is questionable. It may reflect injuries during Operations Desert Shield and Desert Storm from soldier participation in sports during nonoperational activity. However, it is likely that the gradual decline after 1992 reflects the trend toward outpatient treatment. Such a trend has occurred to a great extent in both the military and civilian settings. If these figures do reflect a trend toward outpatient treatment, the impact of sports and physical training injuries on morbidity and lost duty time may be significantly underestimated in future analyses using Army hospital data.

Suggestions for future work include continuing to make improvements in the available databases. Despite the unclear etiology of the category listed as "other," it is clear that the total number of injuries from sports activities (other than those specifically listed) makes up a substantial number of injuries (15%). This ill-defined group accounted for the third highest injury rate at 14.6 per 10,000 person-years. The "other" category represents a number of different activities (e.g., running, biking, volleyball). Given the large number of injuries coded within this category, it may be beneficial to investigate whether these activities could be better defined into useful, more descriptive categories. Given the size of the Army and the worldwide distribution of soldiers, collecting injury data with the appropriate exposure denominator data will be challenging. On the other hand, all branches of the Armed Forces have very sophisticated computer capabilities. The military inpatient databases using the Composite Health Care System (CHCS) could take better advantage of the free-text injury comment field. Preliminary analyses of these data suggest that they may be useful for ascertaining important details of otherwise poorly defined injury records. In addition, if cause codes can be added to the system, outpatient databases such as the Ambulatory Data System (ADS) might prove useful for gaining a more complete understanding of the etiology of sports injuries. Given military cutbacks and the essential need for all branches of the service to keep their personnel in optimal condition, optimal use of existing databases is essential.

Conclusions

Sports and Army physical training account for a large number of lost duty days per year among both genders. Men and women had similar but not identical injury patterns. The higher proportion of ACL injuries in women compared to men in basketball confirms the findings of others. Women's higher rate of physical training injuries, and the greater proportion of head injuries in basketball and ankle fractures in softball compared to men, is of interest and requires further investigation to identify preventive measures. The fact that 22% of handball injuries among men were to the eye suggests that more stringent enforcement of protective eyewear is needed.

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U.S. Air Force Recruit Injury and Health Study

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Objectives: To assess the types, rates, and risks of injury for male and female USAF recruits.

Design: Outpatient visits for female (5250) and male recruits (8656) were collected and analyzed for rate of injury, types of injuries, and risk of injury throughout a 6-week training period.

Results: One third of female recruits and one sixth of male recruits were injured at least once during recruit training. The overall rate for injuries in women and men was 63.0 and 27.8 per 1000 person-weeks, respectively. The adjusted relative risk for women versus men for all injuries was 2.22, and was consistent (1.67 to 3.27) across injury sites. Despite declining absolute rates of injury by week (106.1–13.4 for women and 53.7–13.2 for men), relative risk of injury for women versus men remained fairly constant throughout each training week. The relative risk for injury serious enough to result in medical hold was 1.69 for women vis-a-vis men. Approximately half of all medical discharges for women and men were for injuries.

Conclusions: Female recruits were injured twice as often as male recruits, and were 1.5 times more likely to be removed from their training cohort for injury. Relative risk for injuries to specific body areas remained fairly consistent, indicating that no gender-specific injuries were occurring. Further efforts to determine the cause of injuries should be undertaken, and interventions aimed at reducing the disparate risk of injuries in women should be developed and evaluated.

Medical Subject Headings (MeSH): military personnel, wounds and injuries, women (Am J Prev Med 2000;18(3S):129–140) © 2000 American Journal of Preventive Medicine

Introduction

Each year, over 35,000 young men and women undergo 6 weeks of basic military training (BMT) at Lackland Air Force Base, Texas, soon after enlisting in the U.S. Air Force (USAF). As no medical surveillance system was in place prior to the study period, anecdotal evidence from USAF BMT training staff and medical personnel indicated that female recruits were experiencing higher rates of injury, illness, and attrition than male recruits. A review of the literature revealed that there are few studies on the injury rates of military recruits, and none on USAF recruits undergoing BMT. However, women have been consistently shown to have higher rates of injury and illness and to use health care services more than men, regardless of being in training, in garrison, deployed, or in civilian life.[1–9] Of the training-related studies, Jones et al.[2] found that the cumulative risk of injury of the 8-week Army basic training cycle is about 50% for women and 25% for men. The authors noted that training-related injuries were the number one cause of morbidity and limited duty due to medical restrictions in Army recruit training. They also found that female trainees suffered nearly twice as many training-related injuries as men. Shaffer et al.[10] found injury incidence rates of 37% for female Navy recruits, 44% for female Marine Corps recruits, and 62% for female Marine Corps officer candidates during their respective training schools, but did not have male data for comparison. However, another study of male Marine Corps recruits by Almeida et al.[11] found an injury incidence rate per trainee-months to be half that of women (0.57 versus 1.08).

Of note, several studies have shown a correlation between low levels of physical fitness, especially endurance performance, and increased risk of training-related injury.[2–4,9,11–16] Kowal[3] found that injury was correlated with lack of conditioning, greater body weight and body fat, and limited leg strength. Jones et al.[4] found that low aerobic fitness and female gender are risk factors for training injuries in Army trainees, but suggested that other factors, such as prior activity levels and stature, might affect men and women differ-

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ently. Burke and Dyer[15] suggest that the relationships shown in data between some physical fitness measures and injury are not strong and, in some cases, are hard to interpret, as in the Army's "Run, Dodge, and Jump" test. However, data do show on some measures, such as sit-ups and heart rate response, that there is a greater likelihood that the less fit individual will sustain some sort of injury during training than will a more fit colleague.

This article represents a portion of a larger study, the USAF Female Recruit Morbidity Study,[17] the primary purpose of which was to assess and compare injuries and illnesses among female USAF recruits and a matched cohort of male recruits. This article will address only the injury portion of that study. Its primary objectives were to:

1. Assess the types, rates, and risks of injuries.
2. Identify the week of training and source of injuries.
3. Compare rates of injury of female and male recruits.
4. Identify gender-specific injuries.

Specific hypotheses of interest included:

1. Female recruits have higher rates of injury than male recruits.
2. Specific injuries are significantly associated with week of training.
3. Female recruits have gender-specific injuries.
4. Female recruits have higher rates of recycling and attrition than male recruits.

It was hoped that the analysis of this data would suggest modifications to the training protocol that might reduce injuries and decrease attrition and recycle rates, thus reducing training costs while producing a healthier airman for the USAF.

Methods

Study Population

Every week, between 500 and 800 recruits are brought to Lackland AFB for 6 weeks (30 training days) of basic military training. The recruits are assigned to one of five squadrons on the basis of their arrival date at Lackland AFB. Squadron members are housed in the same barracks and are divided into smaller groups called "flights" for training activities. Flights usually consist of between 40 and 50 recruits and are segregated by gender.

Most recruits (in this study, 82% of men and 77% of women) stay with the initially assigned flight for the duration of training. Some recruits may change flights and/or squadrons, a process called "recycling." Recycling may occur for several reasons, including behavior, performance, and/or injury. Sometimes a recycled recruit is forced to repeat certain sections of training because of poor performance, lengthening his or her time in BMT. Other times, recruits are recycled into a new flight at approximately the same point in training during which they left the previous flight, so their actual time in training is the same as that of nonrecycled recruits. Recruits can also be recycled into new flights from "medical hold," where they are placed when injured or awaiting discharge. These recruits are housed in the same building, away from the other training squadrons, until recycled or discharged. A small number of recruits do not graduate at all (i.e., they are discharged).

The study population consisted of Air Force basic military recruits who began BMT in eligible flights at Lackland AFB after 1 October 1994 and who should have completed training (graduated, unless discharged) by 30 June 1995. The majority of recruits (73% of women and 74% of men) were between 18 and 21 years of age.

Recruits eligible for analyses were generally restricted to those who were members of "brother-sister" flight pair groups: male and female flights that started training at the same time and within the same squadron. It was assumed that, regardless of gender, all recruits who began training the same date in the same squadron shared the same training environment with respect to facilities and training instructors (TI). Each brother-sister flight group was defined by squadron and training start date, and contained one to two flights of female recruits and one to three flights of male recruits. For the three instances where there were female flights with no corresponding male flights, male flights were selected from the prior week, from the same squadron. All analyses retained the matching on squadron and training start date. In all, there were 102 brother-sister pair groups, consisting of 161 male flights and 103 female flights.

All recruits undergo the same training program. The only differences involved fitness testing and standards. Fitness testing consisted of a 2-mile run for time and timed sit-ups and pushups. The 2-mile run was conducted at the start of BMT, used to place recruits into ability-level groups for physical fitness training (PT), and at the conclusion for graduation purposes. PT consisted of timed runs of increasing duration throughout BMT and calisthenics, resistance training, and stretching three times per week. The ability-level grouping was used only for the 2-mile run. It was designed to allow recruits to exercise and progress at their own starting fitness level while providing peer support and encouragement from other recruits of like fitness. Testing standards varied by gender and were based on population-derived VO_{2max}–equivalent run times from AF Fitness Program standards.[18]

Study Design

The pairing scheme of brother-sister flights allowed valid comparison of gender differences, while minimizing the influence of other potential confounding factors, namely time of year and training environment, or TI influence. Because of this pairing, we did not include in the analysis 7586 male recruits who were not members of flights with associated female flights. Of the 21,496 total recruits enrolled in BMT during the study period, we retained all 5250 women and 8660 men (13,910 total). For certain analyses, the study cohort was further reduced to eliminate recruits who recycled into other flights because recycling breaks the matching by squadron and training start date.

Illness and injury rates were calculated based on the amount of time each recruit spent in the original enrolled flight. These rates were derived by using the number of injury events, divided by the number of person-weeks at risk. Recruits who graduated contributed 6 person-weeks, while recruits who recycled (or who were discharged) contributed the number of weeks (from 1 to 6) until they left their enrolled flight. The date of the first status change (which also included medical hold and emergency leave, in addition to recycle and discharge) was used to determine when a recruit left the flight in which s/he was originally enrolled. This allowed us to include recyclers in the analysis, which is important because recycling may be directly related to injury or other training difficulties, and because recruits who are recycled may account for a disproportionate number of injuries. Events occurring after recycling cannot confidently be attributed to the original training environment or to the brother–sister matched groups and, therefore, were ignored in most analyses. The time period (up to 5 days) preceding the official training start date was also included in considering status changes and clinic visits in that all recruits shared the same risk from arrival at Lackland AFB and until training started.

In this manner, all 13,910 recruits contributed to tables presenting rate of injury, based upon person-weeks of training, although only nonrecycling graduates contributed the maximum of 6 person-weeks. Periods spent on medical hold or emergency leave prior to recycling were not included in person-week calculations.

Information from personnel information systems and daily squadron reports were used to monitor the training status and graduation outcome of all recruits enrolled in the study. A certified nosologist assigned an ICD-9 code for each medical discharge. Medical encounters were captured from copies of standard forms used to document medical care and abstracted into the Navy's Sports Medicine and Research Team System (SMART).[19] SMART is a PC-based, outpatient-encounter tracking and reporting system.

Based on the care provider's diagnosis, the medical abstractor assigned an ICD-9 code to each reason for a clinic visit. The code was selected either from a pop-up menu provided by SMART, or through consultation with USAF medical personnel. Space was provided for entry of multiple diagnoses occurring on the same visit. The SMART program considered each diagnosis to be a unique encounter, resulting in multiple records or encounters for a single clinic visit. Thus, one patient visit with several diagnoses ended up as several encounters in the SMART database, each identical except for diagnosis code. This complicated the analysis as described below.

Outcome measures consisted of injury diagnoses from the SMART database, each of which represents an encounter record. These totaled 17,202 encounters. Since the ICD-9 coding system provides thousands of detailed codes, meaningful analysis required substantial aggregation of these diagnostic data. First, ICD-9 codes were classified as either injuries or non-injuries, in consultation with the nosologist and OPHSA staff. Seventy-five exclusive categories representing injuries and non-injury conditions were developed from the ICD-9 codes occurring among the 17,202 encounters. These included 418 encounters coded with 7999 for unknown diagnosis and 1233 encounters given V codes to indicate visits not directly attributable to an injury or non-injury. All of the encounters with 7999 ICD-9 codes were reassigned to other injuries or conditions. After a review of the records, 48 of the diagnoses with V codes were reassigned to categories for injuries or non-injuries, leaving 1185 encounters to be placed in additional categories that included reasons such as physical examinations and medication refills.

The SMART system treated each diagnosis as a single encounter. While the encounter data included a variable to identify follow-up visits, it was found to be unreliable. Distinctions between new complaints and follow-ups, or between multiple diagnoses for a single complaint, could only be inferred from the date of the encounters and the ICD-9 codes. But given the complexity of the ICD-9 coding system, an ongoing condition could be reported in varying detail using different diagnostic codes, leaving no reliable way to separate unique events from follow-up visits. Therefore, we counted only the first occurrence of an event in each specific category for each recruit. Any subsequent encounter falling within the bounds of a previously used category was assumed to be a follow-up visit for the original complaint, and was excluded from rate calculations. This resulted in the exclusion of 4877 encounters, or 28% of the total. The remaining 12,325 nonredundant injuries are presented by category and gender in Table 1.

Preliminary analysis showed that the data included too few outcomes among the 75 injury and non-injury categories to support the adjustment of rates by squadron and training start week. Because sufficient data were needed in each of the cells defined by squadron and training start date, we selected injuries drawn from the 75 diagnostic categories described and aggregated

Table 1. Descriptive statistics for the study sample

Variable	Category	Men (N = 8660)	Women (N = 5250)	All (N = 13,910)
Gender		62%	38%	
Age (years)		19.6 ± 2.0[a]	19.6 ± 2.1	19.6 ± 2.0
Height (in.)		69.8 ± 2.7	64.6 ± 2.5	67.9 ± 3.7
Weight (lb.)		158.9 ± 22.9	127.6 ± 15.7	147.1 ± 25.5
BMI (kg/m^2)		22.9 ± 2.8	21.5 ± 2.1	22.3 ± 2.7
Race	African American	12.4%	20.8%	15.5%
	Caucasian	79.9%	72.0%	76.9%
	Other	7.8%	7.1%	7.5%
Education level	12th grade	82.5%	81.2%	82.0%
	1st–4th year college	16.5%	18.4%	17.2%
	Unknown	1.0%	0.4%	0.8%
Marital status	Married	11.3%	11.7%	11.5%
	Single	83.9%	83.3%	83.7%
	Unknown	4.8%	5.0%	4.9%

[a]Data are expressed as mean ± standard deviation.
BMI, body mass index.

them into 6 categories for analysis. To facilitate interpretation, we composed the injury groups according to area of the body, rather than type of injury (e.g., we grouped all knee injuries together, rather than grouping all sprains together). The six aggregated injury categories follow:

- Injuries (excluding lacerations, abrasions, and contusions) to the trunk, back, neck, chest, shoulders, and arms.
- All knee injuries, excluding lacerations and contusions.
- Ankle and foot injuries, excluding blisters, lacerations, and contusions.
- Injuries to the hips and legs, excluding the knees, ankles, and feet.
- Lacerations, abrasions, and contusions, all sites.
- Blisters.

These six aggregated categories are mutually exclusive, but are not exhaustive of the original 75 categories. Consequently, not all of the 75 categories were used to develop the six aggregated categories. Totals for these aggregated categories, and for each of the original categories they were defined to include, are shown in Table 2. As with calculations involving the original 75 categories, only the first occurrence of a diagnosis within any aggregated category was included as an outcome. Subsequent visits falling into the same aggregated category were treated as follow-ups. This resulted in fewer total outcomes because they were limited to the first occurrence of events from larger groups. A recruit suffering both a shoulder dislocation and a back sprain, for example, will contribute only once to the aggregate category of "Injuries to the trunk, back, neck, chest, shoulders, and arms," but would contribute two encounter outcomes under the original categories.

An additional aggregated category was defined to describe the overall rate of injury. This included all injuries, even those that were omitted from the six aggregated categories described above, but which were included in the original 75 categories. This category was also limited to the first occurrence of any diagnosis falling within their definitions, resulting in more encounters being treated as follow-ups and a further reduction in total counts.

We used a stratified analysis method to estimate adjusted, gender-specific injury rates occurring during basic training. Rates are first estimated for every stratum defined by squadron and training start date. Adjusted rates are weighted sums of the stratum-specific estimates, where the weights are inversely proportional to the stratum-specific variances.

We adjusted injury rates by squadron and training start date, primarily to control for the potential confounding effects of the training environment. The environment (i.e., the training instructor, the physical training environment, and the season of the year) was deemed likely to be a strong predictor of the risk of injury. Training instructors have not been previously identified as predictors of injury, but were theorized to possibly influence differences in intensity or duration of activities (such as marching) or rates of reporting for minor injuries. Subsequent analysis of the AF Recruit Fitness Study data did not find significant underreporting of illness or injury.[15]

This approach, as in any approach based on stratified data analysis, requires sufficient data in every cell. Therefore, it was not possible to estimate adjusted rates for certain rare injury categories. We designed the disease-outcome groupings described in the previous section to ensure sufficient numbers of injuries in each cell. Similarly, the training start date was expanded from weeks into broader categories to ensure sufficient numbers in each cell. The original study

Table 2. Injuries and non-injuries by gender

Injury/non-injury	Total	Women	Men
All encounters	6014	2979	3035
All injury encounters	3072	1743	1329
Specific injury encounters			
Trunk/back/neck/chest/shoulder/arm	540	269	271
Dislocations/derangements - shoulder	17	9	8
Joint/muscle/other pain - back	205	84	121
Joint/muscle/other pain - arm, shoulder	46	22	24
Joint/muscle/other pain - chest	96	59	37
Inflammation of joint, tendon-arm/shoulder	24	14	10
Disorder of muscle, ligament - back, neck	1	0	1
Disorder of muscle, ligament - arm, shoulder	0	0	0
Bone disorder, other diseases/injuries - arm	2	1	1
Sprains/strains - arm, shoulder	61	23	38
Sprains/strains - trunk, back, neck	171	105	66
Knee injuries	652	374	278
Dislocations/derangements - knee	29	15	14
Joint/muscle/other pain - knee	464	263	201
Inflammation - knee	97	60	37
Sprains/strains - knee	184	107	77
Ankle and foot, excluding blisters	747	497	250
Dislocations/derangements - ankle	3	1	2
Joint/muscle/other pain - ankle/foot	285	190	95
Inflammation - ankle/foot	213	151	62
Stress fractures - ankle/foot	24	18	6
Bone disorder, other diseases/injuries - foot	62	44	18
Sprains/strains - ankle	308	197	111
Hip and other leg injuries	394	250	144
Joint/muscle/other pain - other leg	71	45	26
Inflammation of joint, tendon - other leg	12	9	3
Disorders of muscle, ligament, fascia - leg	4	3	1
Stress fractures - shin/lower leg	12	10	2
Stress fractures - leg	3	3	0
Bone disorder, other diseases/injuries - leg	13	8	5
Sprains/strains - shin splints/lower leg	213	138	75
Sprains/strains - other leg, hip	109	63	46
Lacerations and contusions	321	179	142
Lacerations/contusions - lower limbs	134	76	58
Lacerations/contusions - trunk	22	17	5
Lacerations/contusions - arm, hand	83	52	31
Lacerations/contusions - other	104	51	53
Blisters	812	483	329
Blisters - foot	806	481	325
Blisters - other	15	8	7
All non-injury encounters	4414	2131	2283
Specific non-injury encounters			
Respiration conditions	2605	1162	1443
Respiratory infections/disease/symptoms	2254	975	1279
Allergies/allergic reactions/asthma	510	284	226
Ear/nose/throat conditions	125	51	74
Psychological	297	162	135
Psychological conditions	251	130	121
Sleep disorders	32	19	13
Eating disorders	12	11	1
Drug abuse	3	2	1
Dermatologic	917	441	476
Dermatologic conditions	917	441	476
Gastro-intestinal	586	341	245
Infectious diseases (gastric)	172	100	72
Digestive system conditions	450	268	182

plan called for maintaining the matches based on training start week, for a total of 34 start weeks. For the analyses, we combined these 34 start weeks into four groups, based on start month, to minimize the number of strata with no outcomes. Because eligible recruits were selected based on enrollment in broth-

Table 3. Rates and relative risks of injury and non-injury by gender, adjusted by squadron and training start date for all eligible recruits

	Women			Men			Adjusted relative risk		
Injury/non-injury	**Rate^a**	**(95% CI)**		**Rate**	**(95% CI)**		**RR(f/m)**	**(95% CI)**	
All encounters	109.5	106.9	112.1	65.0	63.2	66.9	1.68	1.62	1.74
All injuries	63.0	60.6	65.5	27.8	26.4	29.2	2.22	2.09	2.37
Specific injuries:									
Trunk/back/neck/chest/shoulder/arms	9.2	8.1	10.3	5.0	4.4	5.7	1.67	1.41	1.98
Knee injuries	12.2	11.0	13.5	4.9	4.3	5.6	2.24	1.91	2.61
Ankle and foot, excluding blisters	16.7	15.2	18.1	4.8	4.2	5.4	3.27	2.81	3.80
Hip and other leg injuries	7.6	6.6	8.6	2.6	2.1	3.0	2.80	2.27	3.47
Lacerations and contusions	5.8	4.9	6.7	2.5	2.1	3.0	2.11	1.68	2.65
Blisters	15.9	14.5	17.3	5.8	5.1	6.5	2.47	2.15	2.84
All non-injuries	77.9	75.4	80.5	48.8	47.1	50.5	1.59	1.52	1.67
Specific non-injuries:									
Respiratory conditions	41.9	39.8	44.1	30.0	28.6	31.5	1.39	1.29	1.49
Psychological	4.8	4.0	5.7	2.4	2.0	2.8	2.03	1.60	2.57
Dermatological	14.9	13.5	16.2	9.5	8.6	10.3	1.56	1.37	1.77
Gastro-intestinal	12.0	10.8	13.3	4.6	4.0	5.2	2.33	1.98	2.74

[a] Rate per 1000 person-weeks.
CI, confidence interval.

er-sister flights, the matching is retained, but is less precise than if the data allowed us to use training start week.

The final analysis was based on 20 strata, defined by five squadrons and the four time periods: October–November, December–January, February–March, and April–May. These time periods represent the month in which the first week of training occurred for all of the eligible flights. Although we collected data through June, the time periods only go through May because recruits had to complete the 6-week training cycle by June 30 to remain eligible for the study. We present adjusted rates only in cases where there is at least one occurrence of the injury in 15 or more of the 20 cells.

Results

Table 2 shows the absolute count numbers for first-time diagnoses in each category. As stated earlier, a recruit with one visit for multiple diagnoses would be counted separately in each diagnosis category. Subsequent visits for diagnoses in the same diagnostic category would not be counted, as they would be assumed to be a follow-up. Aggregate categories did not include all original categories. This explains why the counts in each category in Table 2 do not equal the counts in the aggregate category. It also explains why most tables do not contain male or female sample size counts, as the diagnostic counts used for rates do not represent an equal number of recruits.

Rates of injuries, adjusted for squadron and training start date, were based on person-week calculations drawn from all 13,910 recruits. The adjusted rates for all injuries combined were 63.0 per 1000 person-weeks and 27.8 per 1000 person-weeks for women and men, respectively (see Table 3). For comparison, the adjusted rates for all non-injuries combined are 77.9 per 1000 person-weeks and 48.8 per 1000 person-weeks for women and men, respectively. The adjusted rate for all encounters combined was 109.5 per 1000 person-weeks for women and 65.0 per 1000 person-weeks for men.

Women were at significantly increased risk, compared to men, for all categories of injuries examined in this report. The adjusted relative risk for women versus men for all injuries was 2.22. The relative risks for injuries ranged from 1.67 for upper body injuries (trunk, back, neck, chest, shoulder, arm) to 3.27 for ankle and foot injuries. Both men and women suffered from blisters and knee and ankle/foot injuries more often than they suffered from lacerations/contusions or hip/leg injuries. The relative risk for non-injuries was 1.59 and for all encounters was 1.68. The relative risks for non-injuries ranged from 1.39 for respiratory infections to 2.33 for gastrointestinal disorders.

The analysis shown in Table 4 was limited to recruits who graduated, and investigated whether the results shown in Table 3 could be explained by the substantially increased risk among the subset of recruits who were recycled, discharged, or put on medical hold. Table 4 shows that, in general, the absolute rate of injuries decreased when the analysis was limited to graduating recruits. The one exception for which the absolute rates did not change was blisters. The relative risk remained essentially the same, however, as those shown in Table 3.

The adjusted rate and relative risk for being placed on medical hold as a result of the first occurrence of injury are given in Table 5. Medical hold was used as a surrogate for serious medical condition. The table shows that the increased risk for women for serious injury was approximately the same magnitude as the increased risk for all injuries. The injury rates resulting

Table 4. Rates of injury and non-injury by gender, adjusted by squadron and training start date for nonrecycling graduates

	Women			Men			Adjusted relative risk		
Injury/non-injury	**Rate**^{a}	**(95% CI)**		**Rate**^{a}	**(95% CI)**		**RR (f/m)**	**(95% CI)**	
All encounters	93.6	91.1	96.1	55.2	53.4	57.0	1.69	1.62	1.76
All injuries	52.7	50.4	55.0	21.2	19.9	22.5	2.36	2.20	2.54
Trunk/back/neck/chest/shoulder/arms	5.6	4.7	6.5	2.4	2.0	2.9	1.83	1.45	2.31
Knee injuries	8.6	7.5	9.7	3.3	2.8	3.9	2.56	2.11	3.10
Ankle and foot, excluding blisters	14.2	12.8	15.6	4.0	3.4	4.6	3.40	2.86	4.02
Hip and other leg injuries	5.6	4.7	6.5	1.8	1.4	2.3	2.67	2.09	3.41
Lacerations and contusions	5.2	4.4	6.1	1.9	1.5	2.3	2.25	1.75	2.90
Blisters	15.0	13.6	16.4	5.3	4.6	5.9	2.50	2.16	2.90
All non-injuries	66.9	64.5	69.3	42.5	40.8	44.2	1.57	1.49	1.66
Respiratory conditions	37.0	35.0	39.1	27.7	26.3	29.1	1.35	1.25	1.45
Psychological	2.3	1.7	2.9	0.9	0.6	1.2	2.33	1.61	3.36
Dermatologic	14.0	12.6	15.4	8.9	8.0	9.7	1.57	1.37	1.79
Gastro-intestinal	9.9	8.7	11.1	3.9	3.3	4.5	2.23	1.86	2.67

[a] Rate per 1000 person-weeks.
CI, confidence interval.

in medical hold are lower than the overall injury rate, reflecting the decreased frequency of severe injuries.

Table 6 presents injury rates adjusted by squadron and training start date, stratified by week of training. The goal of this analysis was to determine whether the rates of injuries varied during the course of the 6-week basic training period. Adjusted rates are shown only where there was at least one occurrence of the injury in 15 or more of the 20 cells defined by squadron and training start date. For comparison, non-injury rates stratified by week of training are also shown in Table 6.

For both men and women, most of the absolute injury rates decreased markedly during the course of the 6 weeks of basic training (Table 6). For example, the adjusted rate for women for all injuries combined went from 106.1 per 1000 person-weeks in week 1 of basic training to 13.4 per 1000 person-weeks in week 6. Similarly, the adjusted rate for all injuries combined for men went from 53.7 per 1000 person-weeks in week 1, to 13.2 per 1000 person-weeks in week 5. Two notable exceptions where the absolute rates were constant over time were those for hip/leg injuries in women and for ankle/foot injuries for men. It is striking that none of the adjusted rates increased consistently over time. It was noted that injury rates for men and women in week 3 appeared to hold steady or increase slightly in most injury categories where sufficient data were available for analysis.

Although the absolute rates for many injuries decreased substantially over time, the relative risks, comparing women to men, were fairly constant during the 6-week training period. For example, the relative risks for knee injuries only varied between 1.69 and 2.45. Although the relative risks sometimes appeared to increase slightly in week 6 (e.g., blisters), these later estimates were much less precise than those from the early weeks of training due to decreased sample sizes.

We attempted to investigate whether particular injuries were associated with specific activities (e.g., running, marching, and confidence course). However, we did not have sufficient data to address this question. For example, among all eligible SMART encounters, only 5% identified running as the activity associated with the encounter. Less than 2% of all encounters were associated with marching, and less than 2% were associated with the confidence course. The vast majority of eligible encounters either did not provide an injury activity (24%) or listed the injury activity as "other" (65%), with no further detail.

We estimated the percentage of recruits who were discharged or recycled (for any reason), adjusting for

Table 5. Rates and relative risks of injury and non-injury by gender, adjusted by squadron and training start date for encounters resulting in medical hold

	Women			Men			Adjusted relative risk		
Injury/non-injury	**Rate**^{a}	**(95% CI)**		**Rate**^{a}	**(95% CI)**		**RR (f/m)**	**(95% CI)**	
All encounters	4.7	3.9	5.5	2.2	1.7	2.6	1.80	1.43	2.26
All injuries	2.9	2.3	3.5	1.6	1.2	1.9	1.69	1.27	2.25
All non-injuries	1.6	1.1	2.1	0.8	0.5	1.0	1.73	1.17	2.57

[a] Rate per 1000 person-weeks.
CI, confidence interval.

Table 6. Rates and relative risks of injury and non-injury by gender, adjusted by squadron and training start date

	Women			Men			Adjusted relative risk		
Injury/non-injury	**Rate[a]**	**(95% CI)**		**Rate[a]**	**(95% CI)**		**RR (f/m)**	**(95% CI)**	
All encounters									
Week 1	263.6	251.5	275.6	138.4	131.0	145.7	1.88	1.75	2.02
Week 2	127.6	118.0	137.2	85.1	79.0	91.2	1.48	1.33	1.64
Week 3	99.3	90.6	107.9	61.2	55.9	66.5	1.61	1.42	1.82
Week 4	56.3	49.5	63.0	36.0	31.9	40.2	1.56	1.33	1.83
Week 5	29.1	24.2	34.1	24.6	21.1	28.1	1.31	1.06	1.61
Week 6	12.6	9.2	15.9	6.9	5.0	8.9	1.99	1.38	2.86
All injuries									
Week 1	106.1	97.6	114.5	53.7	48.9	58.6	2.03	1.80	2.28
Week 2	63.3	56.4	70.3	33.5	29.5	37.4	1.88	1.61	2.20
Week 3	70.2	62.8	77.6	25.7	22.2	29.2	2.53	2.14	2.98
Week 4	52.3	45.7	58.9	20.3	17.2	23.5	2.50	2.06	3.03
Week 5	20.5	16.3	24.6	13.2	10.6	15.8	2.15	1.67	2.76
Week 6	13.4	9.9	16.9	—	—	—	—	—	—
Specific injuries: Trunk/back/neck/chest/shoulder/arms									
Week 1	22.0	17.9	26.1	12.1	9.8	14.4	1.56	1.20	2.03
Week 2	8.3	5.6	11.0	6.6	4.6	8.5	1.21	0.77	1.89
Week 3	8.3	5.4	11.1	—	—	—	—	—	—
Week 4	8.2	5.2	11.3	—	—	—	—	—	—
Week 5	—	—	—	—	—	—	—	—	—
Week 6	—	—	—	—	—	—	—	—	—
Knee injuries									
Week 1	14.5	11.1	17.8	9.3	7.2	11.4	1.69	1.24	2.31
Week 2	13.6	10.2	17.0	5.6	3.9	7.2	2.08	1.46	2.98
Week 3	16.6	12.8	20.3	7.6	5.5	9.7	2.45	1.74	3.43
Week 4	9.0	6.2	11.8	—	—	—	—	—	—
Week 5	8.3	5.3	11.3	3.9	2.4	5.5	1.86	1.06	3.28
Week 6	—	—	—	—	—	—	—	—	—
Ankle and foot, excluding blisters									
Week 1	19.0	15.2	22.7	4.3	2.9	5.7	2.81	2.03	3.89
Week 2	9.3	6.6	12.1	4.0	2.6	5.5	2.20	1.47	3.29
Week 3	18.9	14.9	22.9	4.7	3.1	6.3	2.64	1.88	3.72
Week 4	15.3	11.7	18.9	4.9	3.3	6.5	3.22	2.19	4.75
Week 5	10.1	7.0	13.1	3.5	2.0	4.9	3.14	1.93	5.10
Week 6	—	—	—	—	—	—	—	—	—
Hip and other leg injuries									
Week 1	9.3	6.5	12.1	2.8	1.5	4.0	3.44	1.93	6.13
Week 2	8.2	5.4	11.1	—	—	—	—	—	—
Week 3	9.3	6.3	12.2	4.8	3.1	6.5	2.39	1.54	3.70
Week 4	6.5	3.8	9.2	3.8	2.2	5.3	1.89	1.07	3.34
Week 5	8.6	5.5	11.8	—	—	—	—	—	—
Week 6	—	—	—	—	—	—	—	—	—
Lacerations and contusions									
Week 1	8.0	5.5	10.6	4.3	2.8	5.9	1.46	0.92	2.32
Week 2	—	—	—	3.7	2.1	5.2	—	—	—
Week 3	—	—	—	—	—	—	—	—	—
Week 4	10.0	6.9	13.0	4.0	2.4	5.6	2.42	1.46	4.01
Week 5	—	—	—	—	—	—	—	—	—
Week 6	—	—	—	—	—	—	—	—	—
Blisters									
Week 1	22.5	18.4	26.6	10.9	8.6	13.1	2.19	1.69	2.85
Week 2	10.5	7.4	13.6	6.6	4.7	8.4	2.05	1.44	2.90
Week 3	13.4	10.0	16.9	5.8	4.1	7.5	2.23	1.54	3.21
Week 4	12.9	9.6	16.2	3.9	2.3	5.5	2.85	1.84	4.42
Week 5	6.8	4.1	9.5	—	—	—	—	—	—
Week 6	9.6	6.5	12.7	—	—	—	—	—	—

(continued on next page)

Table 6. Rates and relative risks of injury and non-injury by gender, adjusted by squadron and training start date

	Women			Men			Adjusted relative risk		
Injury/non-injury	**Rate**[a]	**(95% CI)**		**Rate**[a]	**(95% CI)**		**RR (f/m)**	**(95% CI)**	
All non-injuries									
Week 1	179.0	168.5	189.6	95.0	88.7	101.2	1.84	1.69	2.01
Week 2	91.3	83.0	99.6	66.9	61.4	72.3	1.30	1.15	1.46
Week 3	72.3	64.8	79.8	45.3	40.7	49.9	1.58	1.37	1.82
Week 4	43.9	37.9	49.9	27.6	23.9	31.3	1.62	1.35	1.94
Week 5	21.9	17.6	26.2	23.7	20.2	27.2	1.17	0.93	1.47
Week 6	10.3	7.1	13.5	4.1	2.6	5.7	1.92	1.21	3.05
Specific non-injuries:									
Respiratory infection/ENT/allergies									
Week 1	70.2	63.1	77.2	44.2	39.8	48.6	1.59	1.38	1.83
Week 2	54.0	47.6	60.5	43.5	39.0	47.9	1.16	1.00	1.35
Week 3	34.9	29.6	40.2	29.0	25.3	32.7	1.38	1.16	1.64
Week 4	20.7	16.5	24.9	15.5	12.8	18.3	1.50	1.20	1.87
Week 5	15.6	11.9	19.3	13.4	10.8	16.0	1.25	0.94	1.65
Week 6	7.5	4.6	10.4	—	—	—	—	—	—
Psychological									
Week 1	13.5	10.2	16.7	7.6	5.7	9.4	1.64	1.20	2.23
Week 2	5.1	2.8	7.4	—	—	—	—	—	—
Week 3	—	—	—	—	—	—	—	—	—
Week 4	—	—	—	—	—	—	—	—	—
Week 5	—	—	—	—	—	—	—	—	—
Week 6	—	—	—	—	—	—	—	—	—
Dermatologic									
Week 1	18.0	14.3	21.8	13.4	11.0	15.9	1.35	1.05	1.72
Week 2	12.4	9.2	15.6	10.0	7.8	12.2	1.24	0.91	1.69
Week 3	15.5	11.8	19.2	7.0	5.1	8.9	1.97	1.40	2.77
Week 4	14.8	11.2	18.3	7.4	5.4	9.3	2.28	1.62	3.19
Week 5	8.5	5.7	11.3	7.8	5.8	9.9	1.42	0.96	2.10
Week 6	—	—	—	—	—	—	—	—	—
Gastro-intestinal									
Week 1	19.9	16.0	23.7	6.0	4.3	7.6	2.33	1.73	3.15
Week 2	13.9	10.6	17.3	6.1	4.3	7.9	1.85	1.29	2.67
Week 3	10.3	7.3	13.3	4.4	2.9	6.0	2.41	1.55	3.73
Week 4	7.0	4.3	9.6	3.2	1.8	4.7	2.28	1.25	4.16
Week 5	7.0	4.1	9.8	—	—	—	—	—	—
Week 6	—	—	—	—	—	—	—	—	—

[a] Rate per 1000 person-weeks.
CI, confidence interval.

squadron and training start date (Table 7). The risk of being discharged was significantly less for men than for women: 8.2% for men versus 11.5% for women. The risk of being recycled did not differ significantly for men compared to women: 9.8% for men versus 10.3% for women.

Table 8 shows the final disposition of the men and women in each squadron. A total of 1375 recruits were discharged from eligible flights during the study period. Of those, 731 were discharged for new or preexisting medical reasons (Table 9). Table 10 shows that, of recruits discharged for medical reasons, 55.6% of men and 46.8% of women were discharged for an injury.

Table 7. Percentage of recruits discharged, injured, and recycled by gender, adjusted by squadron and training start date

	Women			Men			Adjusted difference		
Injury/non-injury	**Percent**	**(95% CI)**		**Percent**	**(95% CI)**		**Percent women/ percent men**	**(95% CI)**	
Discharged anytime	11.5	10.7	12.4	8.2	7.6	8.8	3.4	2.4	4.5
Injured at least once	32.8	31.5	34.0	15.0	14.2	15.7	17.6	16.1	19.1
Recycled at least once	10.3	9.5	11.1	9.8	9.1	10.4	0.7	−0.4	1.7

*Row percentages are not additive due to adjustments.
CI, confidence interval.

Table 8. Recruit final status report by squadron and gender

Squadron	320		321		322		323		331		Total	
Status/Gender	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Enrolled	1344	1094	1413	1022	1915	1040	2123	1063	1865	1031	8660	5250
Discharged	99	160	132	101	166	120	176	135	164	122	737	638
Recycled	120	112	125	107	159	90	232	119	157	83	793	511
Medical hold	12	6	6	8	14	12	8	12	11	5	51	43
OLTF	1	1	1	0	2	0	2	1	2	0	8	2
Graduated	1112	815	1149	806	1574	818	1705	796	1531	821	7071	4056
Graduation %	83%	74%	81%	79%	82%	79%	80%	75%	82%	80%	82%	77%

Final status: Based on last status change regardless of preceding events. Discharges prevail over other previous changes. Each recruit can only contribute one final status.

OLTF, otherwise lost to follow-up. Recruits with unknown final status as of 30 June 1995.

Graduated: with enrolled flight.

Discussion

This study examined four main hypotheses:

1. Female recruits have higher rates of injury than male recruits.
2. Specific injuries are significantly associated with week of training.
3. Female recruits have gender-specific injuries.
4. Female recruits have higher rates of recycling and attrition than male recruits.

In this section, we address each of these hypotheses, discuss possible explanations and sources of bias, and provide our interpretation of the findings.

Echoing the findings in previous studies of recruits, USAF female recruits appeared to be at significantly increased risk, compared to men, for all categories of injuries examined in this report. The relative risk for women versus men for all injuries was 2.22. The relative risks for injury categories ranged from 1.67 to 3.27. This pattern remained after excluding recruits who did not complete training (i.e., who were recycled, discharged, or put on medical hold). The results were also the same when the analysis was restricted to injuries that were serious enough to place a recruit on medical hold.

For both men and women, most of the absolute injury rates decreased markedly during the course of training. Two exceptions where the rates were relatively constant over time were for hip/leg injuries in women and for ankle/foot injuries in men. None of the adjusted rates increased consistently over time, which is remarkable given that the duration of the physical training regimen increases in time over the course of BMT. The absolute decrease may reflect the process of weeding out those who were not able to complete training. It may also reflect the fact that the more weeks a recruit survived, the more durable s/he became. They may also have been more motivated to graduate, making it less likely for recruits to go to the clinic during the later weeks of training.

We noted that the relative risks remained fairly constant during the 6 weeks of basic training. In addition, the twofold increased risk for women remained when the analysis was restricted to those who graduated from basic training (i.e., when those who were discharged, recycled, or put on medical hold were excluded).

Table 9. Discharge reason summary by gender

Reason/Gender	Men	Women	Total
01: Medical - Did not exist prior to service	24	23	47
02: Medical - Did exist prior to service	351	333	684
03: Psychological	116	139	255
04: Fraudulent enlistment	136	80	216
05: Admitted homosexual	26	15	41
06: Performance	59	26	85
07: Not qualified for job which was reason for enlistment	5	1	6
08: Unit request/recalled by guard unit	3	1	4
09: Pregnant	0	9	9
10: Misconduct	4	4	8
11: Other	13	7	20
Total	737	638	1375

Table 10. Most frequent reasons for medical discharge by gender

	Men		Women	
Reason	Number	Percent[a]	Number	Percent[a]
All injuries	208	55.6	166	46.8
Knee pain	61	16.3	51	14.4
Back pain	40	10.7	24	6.8
All non-injuries	166	44.4	189	53.2
Genetic conditions[b]	48	12.8	42	11.8
Allergies/asthma	34	9.1	49	13.8
Nervous systems[c]	33	8.8	37	10.4

[a] Percentages are based on the total number of discharges for medical reasons, by gender (M = 341, F = 325). Total exclude two discharges (one man, one woman) for unknown medical reasons.

[b] Includes sickle cell trait/disease, pes planus, and scoliosis.

[c] Includes headache.

Of note is the fact that injury rates in most categories held or increased slightly in week 3 for men and women. One might hypothesize that this occurred when certain training practices take place, such as running the confidence course, or when new boots or shoes were used for the first time. This also might occur when overuse stresses exceeded physiological adaptation responses. Once again, however, the relative risks, comparing women to men, were fairly constant during the 6-week course of training.

We concluded that female recruits did not appear to have gender-specific injuries. Although the absolute rates were higher for the female recruits, the relative occurrence of specific injuries and non-injuries does not appear to be gender specific. For example, the relative ranking of injury sites for women were ankle/foot, blisters, knee, upper body, hip/leg, and laceration/contusion. The relative ranking for men were blister, upper body, knee, ankle/foot, hip/leg, and laceration/contusion. The percentage of all injuries, excluding blisters and lacerations/contusion, occurring in the lower body versus the upper body were 80% in women and 71% in men. This is consistent with the findings in most other military studies. However, the consistent rate of hip/leg injuries in women and ankle/foot injuries in men over time suggests that closer examination of the data or further study might elicit some gender-specific injury occurrences.

The risk of being discharged (for any reason) was significantly less for men than for women: 8.2% for men versus 11.5% for women. The risk of being recycled did not differ significantly for men compared to women: 9.8% for men versus 10.3% for women.

In summary, female recruits were almost 2.5 times more likely than male recruits to experience an injury during basic training. This increased risk held for all types of injuries examined in this study. Based on prior studies, it is not unreasonable to hypothesize that these results are confounded, in that the observed gender differences may be due to differences in physical fitness level between the men and the women when they enter training. It has been widely reported that women tend to report to recruit training with lower physical fitness levels than men do. Unfortunately, we did not collect entry fitness-level data and, thus, were not able to control for this variable. It is also possible that the results were due to reporting differences between female and male recruits, in that female recruits may have been more likely to report injuries than male recruits. It is doubtful that this explanation would account for all the observed differences, however, because the same results were obtained when the analysis was restricted to injuries and non-injuries that were serious enough to result in the recruit being placed on medical hold.

Limitations of the Study

There is probably some misclassification bias present in the diagnosis coding because of limitations of the SMART system. Data entry staff had to choose ICD-9 codes from a pop-up menu that was not complete and, in fact, contained some coding errors. Misclassification would dilute the numbers of encounters in some specific categories, so we used broad, aggregated categories to reduce misclassification bias. For example, a knee sprain could be miscoded as a knee dislocation, but it is unlikely that a knee strain would be miscoded as an ankle sprain. Thus, we grouped injury diagnoses by body location, instead of by type of injury, to minimize the effects of miscoding. In any case, this random noise would have resulted in underestimates of the true relative risks because there was no reason to suspect that the misclassification occurred differently for men and women.

The true rate of injury could not be determined using the SMART system data because we counted only the first occurrence of a particular problem. For example, if someone had multiple encounters for one knee injury, we counted the injury only once. If someone had repeated, distinct knee injuries, either to one or both knees, we only counted the injuries once. Therefore, the observed rate for all encounters underestimated the overall utilization rate. This may make comparisons to other studies problematic.

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Air Force, the Department of Defense, or the U.S. government.

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High Injury Rates Among Female Army Trainees
A Function of Gender?

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Background: Studies suggest that women are at greater risk than men for sports and training injuries. This study investigated the association between gender and risk of exercise-related injuries among Army basic trainees while controlling for physical fitness and demographics.

Methods: Eight hundred and sixty-one trainees were followed during their 8-week basic training course. Demographic characteristics, body composition, and physical fitness were measured at the beginning of training. Physical fitness measures were taken again at the end of training. Multivariate logistic regression analysis was used to evaluate the association between gender and risk of injury while controlling for potential confounders.

Results: Women experienced twice as many injuries as men (relative risk [RR] = 2.1, 1.78–2.5) and experienced serious time-loss injuries almost 2.5 times more often than men (RR = 2.4, 1.92–3.05). Women entered training at significantly lower levels of physical fitness than men, but made much greater improvements in fitness over the training period.

In multivariate analyses, where demographics, body composition, and initial physical fitness were controlled, female gender was no longer a significant predictor of injuries (RR = 1.14, 0.48–2.72). Physical fitness, particularly aerobic fitness, remained significant.

Conclusions: The key risk factor for training injuries appears to be physical fitness, particularly cardiovascular fitness. The significant improvement in endurance attained by women suggests that women enter training less physically fit relative to their own fitness potential, as well as to men. Remedial training for less fit soldiers is likely to reduce injuries and decrease the gender differential in risk of injuries.

Medical Subject Headings (MeSH): women, exercise, wounds and injuries, military personnel, physical fitness, military medicine (Am J Prev Med 2000;18(3S):141–146) © 2000 American Journal of Preventive Medicine

Introduction

For most injury categories, men are at greater risk than women.[1] However, for sports and training injuries, studies suggest that when exposure is controlled, women are actually at greater risk than men. This has been documented in a number of civilian as well as military studies.[2–12]

Low physical fitness, as measured by sit-ups, run times, and body composition (e.g., high percent body fat) have also been identified as risk factors for training injuries in the military.[12–15] A few studies have suggested that female basic trainees are less physically fit than their male counterparts on entry to basic training.[10,16,17] It is not clear how much the higher incidence of injuries among female trainees can be attributed to their lower level of fitness.

The primary purpose of this study is to examine the relative rates of injury for male and female Army trainees, controlling for physical fitness.

Methods
Data

A cohort of 861 Army trainees (509 men and 352 women) were followed over the course of the standard 8-week basic combat training (BCT) course. The population of potential study volunteers included all women entering female training companies formed for one month during the fall of 1988. One out of four

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Table 1. Body composition and physical fitness of female and male Army basic trainees

	Men		Women		*t*-test
Characteristic	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**(*p*)**
Height (cm)	175.1	7.3	162.0	6.4	.01
Weight (kg)	76.3	12.3	57.8	6.3	.00
Body fat (%)	16.4	5.6	26.6	4.0	.00
Strength (kg)	117.2	21.1	67.3	13.2	.00
Flexibility (cm)	34.8	6.3	32.6	5.9	.26
Initial 1-mile run (min)	7.6	0.9	10.1	1.6	.00
Initial sit-ups (n)	43.7	11.6	30.9	13.9	.00
Initial pushups (n)	32.4	12.4	10.9	7.4	.00
End 2-mile run (min)	14.0	1.1	17.4	1.4	.00
End sit-ups (n)	63.0	10.4	61.3	11.9	.05
End pushups (n)	49.8	12.2	27.9	10.4	.00

male companies, selected on the basis of its proximity to the women's units, was also included for comparison.

All potential volunteers were briefed on the study and offered the opportunity to participate (n=1075); 93% volunteered for the study and signed consent forms (n=1002). Due to scheduling difficulties, anthropometric measures could not be obtained on 14% of these volunteers, precluding them from the analysis. Thus, data for this analysis were available for 861 trainees (86% of volunteers).

Trainees were administered a baseline screening survey that included measures of demographic characteristics such as gender, age, and race/ethnicity.[10,14] In addition, study staff assessed volunteers' body composition and fitness. Body composition measures included height, weight, and percent body fat. Fitness measures included flexibility, muscle strength, muscle endurance, and aerobic fitness.[14]

Percent body fat was estimated by a series of circumference measurements.[16,20] Flexibility was measured by the use of a Bender-Box, which assesses range of motion in a sitting position stretching over the toes.[13] Muscle strength was estimated through an isometric test of maximum hand grip force.[16] Muscle endurance and aerobic fitness were measured through the initial Army physical fitness test, comprised of maximal pushups and sit-ups in 2 minutes and 1-mile run times. Fitness was also assessed at the end of training by timed maximal pushups and sit-ups in 2 minutes and a 2-mile run.

To assess improvements in aerobic fitness, the end of training 2-mile run times were converted to their 1-mile run time equivalents. Run times are highly correlated with maximum oxygen consumption (VO_2 max), a measure of aerobic capacity.[18,19] Using a table listing VO_2 max and run times for given distances, 1-mile run times and equivalent 2-mile run times were matched using their corresponding VO_2 max values.[21]

Medical records for the training period were reviewed every 2 to 3 weeks and all injury diagnoses transcribed. Diagnoses were made by clinic physicians who were blinded to patients' participation in the study. Injury occurrence was defined as any condition causing a trainee to seek medical care that also resulted in an injury diagnosis. An injury leading to 1 or more days of lost duty was used as a measure of serious injury.

Analysis

For analysis, all subjects were split into one of five roughly equal-sized groups (quintiles) based on performance, from low to high levels. Since lower fitness is associated with higher injury risk, the most fit groups were used as the low-risk comparison group for analyses. Continuous fitness and body composition variables were grouped into quintiles to facilitate analysis and interpretation of findings.[13,14,22,23]

Chi-square analysis was used to test the significance of risk ratios and the Mantel-Haenszel chi-square for trend was used to test for linear associations. Multivariate logistic regression models were used to evaluate the association between gender and risk of injury while controlling for the effects of fitness and demographic characteristics. Because body composition (weight and height) is so highly correlated with gender, it was not included in the multivariate models.

Results

The average age for male and female trainees was 20. Male trainees were more likely to be Caucasian than female trainees (men were 58% Caucasian, 33% African American, and 9% other; women were 43% Caucasian, 48% African American, and 9% other). Table 1 describes body composition and fitness characteristics of the male and female study participants. Men exhibited significantly higher entry-level measures of physical fitness than women on all measures except flexibility.

At the end of the training cycle, men still did more pushups and ran faster than women, but women narrowed the gap considerably, particularly through their sit-up performance (Figure 1 and Table 1). Women's sit-up scores improved by 98%, versus a 44% improve-

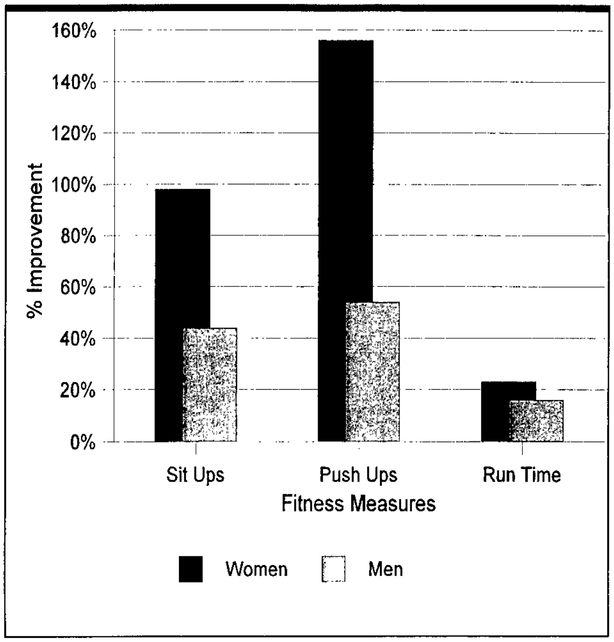

Figure 1. Improvement in physical fitness scores for female and male Army basic trainees over the 8-week training period. Note: End of training 2-mile time scores are converted to their 1-mile equivalents for comparison purposes using VO_2 max conversion tables.[20]

ment for men; pushup scores improved by 156% compared to 54% for men. Women's aerobic fitness, as measured by run times converted to VO_2 max scores, improved by 23% compared to only 16% for men.

Table 2 shows the cumulative incidence of one or more injuries for men and women. Women experienced about twice as many injuries overall as men. Their risk for more serious time-loss injuries was even greater at almost 2.5 times the risk of the male trainees. Most injuries for men and women were to the lower extremity (foot, lower leg).

Figure 2 displays the association between injury and aerobic fitness (run times). The figure depicts a stepwise significant trend (chi-square trend statistic = 87.9, $p < 0.000$) of higher risk of injury for successively lower levels of aerobic fitness (i.e., slower run times). The slowest runners had almost 3.5 times greater risk of experiencing an injury than the fastest runners.

Table 3 shows the gender and injury relationship stratified by aerobic fitness (run times). For the fast trainees, the relative risk of injury for women versus men was near 1 (RR = 1.04, $p = 0.78$). The injury risks for women were close to the risks for men within each quintile of run time, which suggests that aerobic fitness explains much of the injury risk differential.

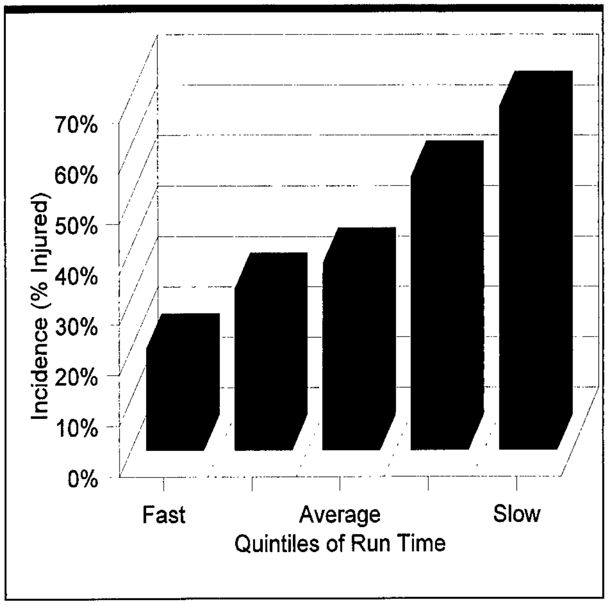

Figure 2. Injury and initial aerobic fitness as measured by 1-mile run times for female and male Army basic trainees

The results of a logistic regression model of one or more injuries regressed on gender, physical fitness, and other demographic factors are found in Table 4. Gender was not significant when physical fitness, age, and race/ethnicity were controlled. Slow run time was the only significant predictor of injury. We also examined the association between gender, fitness, demographic factors, and risk of a time-loss injury (table not shown). Again, gender was not significant ($p = 0.62$), while run time was ($p \leq 0.04$; RR for slowest run time quintile = 3.72, 95% confidence interval [CI] 1.64–8.45). Caucasian race/ethnicity was also a significant risk factor for time-loss injuries (RR = 2.13, 95% CI 1.37–3.32 Caucasian, compared to African American referent group). Poor sit-up performance bordered on significant ($p \leq 0.05$).

Discussion

The crude injury rates indicated that women were at higher injury risk than men. The fitness-adjusted injury rates, however, showed no significant gender differ-

Table 2. Confidence interval (percentage) of injury among female and male Army basic trainees

Injury type	Men	Women	Relative risk[a]	95% CI
One or more injuries	27%	57%	2.1	(1.78–2.50)
Time-loss injury	17%	41%	2.4	(1.92–3.05)

[a]Relative risk of injury for women over men; results from single-variable logistic regression models.
CI, confidence interval.

Table 3. Gender and relative risk of injury stratified on aerobic fitness (1-mile run times) for female and male Army basic trainees

Run time quintile[a]	Relative risk[b]	95% CI	(p)
Fast	1.04	(0.4–2.7)	0.78
Average	1.52	(1.0–2.3)	0.09
Slow	1.17	(0.8–1.7)	0.45
Slowest	1.37	(0.5–3.7)	0.81

[a] The 1-mile run times are grouped according to speed into quintiles. The fastest quintile was too small for calculation of a relative risk—there was only one female trainee in that stratum.

[b] RR, relative risk of injury for women over men.

CI, confidence interval.

ence. Thus, much of the gender–injury relationship appears to be explained by physical fitness, in particular aerobic fitness, as opposed to gender per se.

This is an important finding, particularly given the excess injury burden experienced by women in physically rigorous training programs coupled with the need to maintain a healthy, fit, injury-free fighting force. These results suggest that gender per se is not as good an indicator of injury risk as overall physical fitness, and therefore the excess risk women experience may be reduced through modified training programs.

Table 4. Gender and risk of one or more training-related injuries, controlling for physical fitness, age, and race; results from multiple logistic regression analysis of female and male Army basic trainees

Risk factor	Relative risk	95% CI
Gender		
Men	—	—
Women	1.14	(0.48–2.72)
Run time		
Very fast	—	—
Fast	1.47	(0.68–3.18)
Average	1.54	(0.91–2.62)
Slow	2.52	(1.26–5.04)
Very slow	3.23	(1.59–6.58)
Sit-ups		
Very high	—	—
High	1.05	(0.60–1.81)
Average	0.80	(0.44–1.44)
Low	1.15	(0.63–2.09)
Very low	1.51	(0.78–2.92)
Pushups		
Very high	—	—
High	1.62	(0.90–2.29)
Average	1.19	(0.65–2.19)
Low	1.34	(0.66–2.71)
Very low	1.24	(0.54–2.88)
Strength		
Very strong	—	—
Strong	1.41	(0.80–2.50)
Average	1.61	(0.90–2.88)
Weak	2.10	(0.88–5.04)
Very weak	2.11	(0.83–5.36)
Age		
<20	—	—
20–24	1.50	(1.00–2.23)
25+	1.26	(0.69–2.31)
Race		
African American	—	—
Caucasian	1.31	(0.89–1.94)
Other	0.84	(0.40–1.79)

CI, confidence interval.

The observed associations between injury and run times have a theoretical scientific basis. Most injuries were to the lower extremity, related to weight-bearing activities, so run time, as a marker for weight-bearing fitness, is particularly relevant to predicting these types of injuries.[8,14] In addition, run times have been shown to correlate very highly ($r > 0.80$) with laboratory measures of aerobic capacity (VO_2 max).[18] Aerobic capacity, a reflection of the body's ability to use oxygen when physically challenged, may be a good measure of overall conditioning or physical fitness.[24]

Women had smaller variances than men in mean values for most demographic, body composition, and fitness measures. For sit-up scores and run times, however, women had larger standard deviations than men and a broader range of fitness scores. This suggests that perhaps these two variables were better discriminators of overall physical fitness for women than the other variables. This may help explain why run times were significant in both the multivariate model predicting one or more injuries and the model predicting time-loss injuries, and why sit-ups bordered on being significant ($p \leq 0.05$) in the multivariate model predicting time-loss injuries.

Military training populations offer advantages for the study of gender and injury: first, the historical incidence of injuries is high; and second, the regimented daily activities tend to equalize risk exposures for men and women. Men and women complete essentially identical training objectives, live under similar conditions, adhere to the same daily schedules, are offered the same diet, and have the same access to health care. Many potential confounders of the gender and injury relationship are thereby eliminated because of this unique environment, or are controlled through the prospective study design.[9,10,13,14,25–29]

The demographic and fitness characteristics, as well as the injury rates of trainees in this study, were similar to previous military training studies.[9–12,14,16] The association between physical fitness and injury was also consistent with past studies.[10–14,25] This suggests that our findings are generalizable to other military training populations.

Military populations may also be more representative of the general population and represent a broader range of fitness levels than competitive athletes, the subjects of many civilian studies.[24] Thus, these findings may also provide insight into understanding exercise and training injuries among young civilian adults.

There are some limits to these data and this study that should be noted. First, injuries were defined by reporting to the health clinic. There may be potential gender or race/ethnicity-related bias resulting from self-selection to seek medical care. We conducted some exploratory analysis to check for this potential bias by comparing gender differences in risk for injuries that are consistently recognized and treated, and which offer little option for the injured soldier but to seek treatment. We compared rates of fractures since this condition can be confirmed with diagnostic tests and because it is extremely difficult to continue training with a fracture. Using this nondiscretionary injury outcome only expanded the gender difference suggesting that women were neither malingering nor more likely than their male counterparts to seek care.

Second, there are no statistical tests for sameness. Failure to find an association is not sufficient evidence to claim gender and injury are independent. Thus, we cannot prove that gender is totally unrelated to injury risk, even though it was not statistically significant in the multivariate model controlling for physical fitness. Even if a much larger prospective study were to identify statistically significant differences in risk of injury, it seems unlikely that the differences would be clinically significant.

Third, this analysis describes gender-based differences in physical fitness. But it is not possible to determine whether or not remedial training would, in fact, allow some or all women to improve their level of fitness to a level consistent with the male trainees. However, the substantial improvements in endurance performance for women suggests that women enter training less physically fit relative to their own fitness potential as well as relative to men entering training. Our results demonstrate that women improve their levels of fitness at approximately twice the rate of men, substantially narrowing the fitness gap over the 8-week training period. This is consistent with the work of Patton et al.[17] and others who show that soldiers at lower entry levels of fitness (as assessed by VO_2 max scores) make greater improvements in end-of-training scores than those in the middle or upper ranges of entry-level fitness. While women may not, on average, be able to perform at the same absolute level of fitness as men, they can substantially improve their performance with training.

In addition, women and men of the same level of physical fitness can be expected to have similar injury risks when performing similar physically demanding tasks or training. Men and women with the fastest run times were not statistically different from each other in terms of their overall risk for injury. Likewise, the very slowest groups of men and women also experienced similar injury rates. These results suggest that women and men initiating a vigorous physical training or exercise program, who exhibit low levels of physical fitness, are more likely to be injured by training activities, but will also improve their level of fitness more rapidly than their more fit peers.

Conclusions

Our results suggest that the key risk factor for training injuries is physical fitness, particularly cardiovascular fitness (run times). Gender, after controlling for fitness, is not significantly associated with training-related injury, while fitness, a covariate of gender, is. In the early phase of training it may be wise to assign trainees to fitness-appropriate levels of training and progress slowly to more advanced training as their fitness improves.

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Effect of Rest from Running on Overuse Injuries in Army Basic Training

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Background: It has been hypothesized that a period of rest from running in the early weeks of basic military training will prevent stress fractures among recruits.

Design: Modification of running schedules in companies of Army recruits undergoing basic military training was assigned.

Setting/ Participants: Six male training companies were enrolled and followed during their 8 weeks of basic military training at Fort Bliss, Texas, in summer/fall 1989.

Intervention: Intervention companies were asked to rest from running during the second, third, or fourth week of basic military training.

Main outcome measures: Data were collected from questionnaires, anthropometric measurements, Army physical fitness tests, company training logs, and medical record abstraction of all clinic visits.

Results: Among the 1357 enrolled male recruits, there were 236 (17%) with overuse injury and 144 (11%) with traumatic injury, resulting in 535 clinic visits and 1927 training days lost. Stress fracture/reaction rates varied from 3 to 8 per 100 recruits among the intervention companies and 2 to 7 per 100 recruits among the non-intervention companies. Total injury rates were 18 to 35 per 100 recruits in the intervention companies and 18 to 29 per 100 recruits in the non-intervention companies.

Conclusions: The study provided no evidence for a protective effect on overuse injuries of resting from running for 1 week early in basic military training. There was varied physical training among the companies, however, with variation of injury rates that likely related to factors other than the intervention.

Medical Subject Headings (MeSH): athletic injuries, bone remodeling, cumulative trauma disorders, stress fractures, military medicine, physical fitness, soft tissue injuries (Am J Prev Med 2000;18(3S):147–155) © 2000 American Journal of Preventive Medicine

Introduction

Musculoskeletal injury is common in basic military training (BMT), with reports of clinic visits for injury occurring in 15% to 31% of male recruits.[1–7] These injuries are predominantly of the lower extremities (e.g., strains, sprains, blisters, stress fractures), and most are related to the intense physical activity involved with training. Repeated microtrauma due to repetitive activity and sudden increases in physical activity may result in overuse injuries.[8–10] Overuse injury, most notably stress fracture and stress reaction of bone (stress fx/rx), is a common occurrence in intensive physical conditioning programs. Overuse injuries of the lower extremities are common in the military and have been associated with the rigors of marching, drilling, and running.[1,11–15] These studies have found that 3% to 6% of male Army recruits get stress fx/rx during their 8-week basic training, and 10% to 20% have overuse injuries in general. This rate of overuse injury adversely affects military training, resulting in lost training days and increased medical costs.[16]

The initial stresses of an intensive physical conditioning program produce extensive bone remodeling, with resultant new bone formation that is structurally more stable and resistant to fracture.[17,18] However, a lag between bone resorption and deposition may produce bone that is temporarily weakened and more susceptible to stress fracture. This might occur sometime

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during the second to fourth week after onset of intensive physical conditioning. Scully and Besterman,[19] referring to theories of stress fatigue fractures[13,18,20] and extrapolating from the data of Johnson et al.,[21] proposed that a period of rest during training, specifically the third week, be incorporated to allow for bone repair prior to new cycles of bone stress. A number of military studies have found maximum stress fracture rates during the first 3 weeks of military training, although there is some disagreement.[22–27] On the basis of these observations, many believed that a period of rest from vigorous weight-bearing activities during the early weeks of BMT will reduce stress fractures.[28] Jones[29] proposed an approach that would allow for periods of recovery through alternating days of running and marching, so that training effects would not be diminished and risk of injury would not increase.

In this study an intervention was designed to evaluate whether resting from running for 1 week during the second, third, or fourth week of intensive physical conditioning in the BMT program would reduce the occurrence or severity of stress fracture and related injuries. In the setting of Army BMT, several companies of recruits agreed to participate by modifying their running schedules and permitting collection of detailed training and medical data for evaluation of these hypotheses.

Methods

Basic Military Training

BMT for enlisted recruits in the 1980s became more structured in the areas of organized group physical training and conditioning. The U.S. Army Training Command at Fort Bliss, Texas, conducted BMT in an 8-week course under the direction of drill instructors using standardized guidelines for the conduct of physical training. Recruits were organized into training companies (four platoons per company) where daily routine training drills and skills were executed. Formal physical training included warm-up and cool-down exercises, calisthenics, sit-ups and pushups, and unit (group) runs about 3 days per week. Unit run guidelines were to not exceed 8-minute miles, starting with a duration of 10 minutes in the first week of training and increasing 2 minutes in duration each week until 20 minutes of continuous running was achieved. Informal physical training, conducted under the direction of the drill instructors on the other 2 to 4 days included activities chosen from an option list (e.g., grass drills, guerilla exercises, circuit course drills, and partner-resisted exercises). Participation in physical training was required for all recruits who were not on a medical waiver.[30]

Study Groups and Study Design

At Fort Bliss, 1357 male subjects from six companies of Army recruits in BMT volunteered and were enrolled in this intervention study. Companies of about 250 subjects each began BMT every 2 weeks during the months of July, August, and September 1989. Potential participants were briefed regarding the purposes and risks of the study. Volunteers were assured of confidentiality of information, and consent forms were signed at that time. Following this, a physical activity and health questionnaire was administered in a group session to the volunteer subjects, and individual anthropometric measurements were obtained. Each company of recruits was then assigned to a specific training schedule, which included one of three variations: (1) standard progressive training with weekly marching and running; (2) "cyclic training" with avoidance of running during the second, third, or fourth week; and (3) increased running mileage. Assignment consisted of two companies with no intervention (controls) (Schedule 1), one company designated for increased running mileage (Schedule 3), and three companies each assigned to a week of rest from running during the second, third, or fourth week of training, respectively (Schedule 2). Within a few days of onset of training, the first Army physical fitness test (APFT) was conducted by each company (consisting of 2 minutes each of continuous pushups or sit-ups and a timed 2-mile run).

During the 8-week BMT course, performance on APFTs was recorded, training activities were documented through daily platoon training logs, and all medical clinic visits for injuries and illness were abstracted from the trainees' medical records. The final APFT was conducted during the seventh week of training. BMT was completed during the months of September through November 1989 for the study companies.

Questionnaire and Anthropometric Measurements

The health and physical fitness questionnaire was administered to groups of 50 to 200 volunteers at a time during in-processing at the beginning of BMT. An instructor read each question to the group and provided standard explanations when needed. The questionnaire collected data from the subjects about their demographics, self-rated physical fitness, past physical activity, exercise history, past injuries and illnesses, and smoking history.

Anthropometric measurements obtained on recruit volunteers included height, weight, and neck and abdominal circumference.[31,32] Each measurement was repeated three times and then averaged. Body mass index (BMI) was calculated as weight/height^2 in kg/m^2. Percent body fat estimation was derived from the height and neck and abdominal measurements using the Army and Navy formulas.[32,33] Flexibility was measured using the "sit and reach" toe touching method by having the individual sit on the floor and then push a slide on a ruler toward the toes.[34]

Training Log Review

Daily training logs were maintained by the drill instructors for each platoon. Information requested on the logs included date, day, and week of training; company/platoon and name of person completing log; times training started and ended each day; weather conditions; and the major training activities for the day. "Yes" and "no" responses were chosen to acknowledge activities performed or not performed that day, adding the time spent on each activity. Duration in minutes was filled in if marching to and from any training activity occurred; we then assigned marching mileage based on 20 minutes per mile. Running and road marching (hiking with packs and military gear) required documentation for duration (minutes) and distance (miles). Two long road marches were conducted during the fourth week (6 to 8 miles) and the fifth week (12 to 15 miles).

Medical Record Review

Medical care was provided for the trainees at a medical clinic or through referral to William Beaumont Army Medical Center. Recruit clinic visits for injuries or illnesses were recorded through periodic review and abstraction of pertinent medical information from the individuals' charts. The information recorded for an injury or illness visit was abstracted on medical record review forms designed specifically for this study. These included date of clinic visit, injury or illness diagnosis, body part and side, disposition, and days lost from training. Bone scans and x-rays performed were also recorded (including interpretation and grade).

Injuries were classified as either overuse injury (stress fracture, stress reaction, tendinitis, bursitis, fasciitis, pain, strain, or unspecified/other overuse injury); or traumatic injury (fracture, dislocation, sprain, abrasion/laceration, contusion, blister, or unspecified/other traumatic injury). Strains (usually due to severe delayed onset muscle soreness) were classified as overuse injury, while sprains (usually due to acute trauma) were classified as traumatic injury. For recruits with multiple injuries, the most significant injury of each category was determined. Injuries were included only if the injury resulted in a clinic visit; this is particularly relevant for minor abrasions/lacerations, blisters, and contusions, which often may be managed by the recruit him/herself and not result in a clinic visit.

Table 1. Demographics and smoking history, Fort Bliss 1989 Army recruits (N = 1357)

	N	% distribution
Age		
17	160	12
18	672	50
19	254	19
20–24	210	16
25–29	45	3
30–40	16	1
Ethnic group		
Asian American	25	2
African American	335	25
Hispanic	132	10
Caucasian	832	62
Other	25	2
Missing	8	—
Company		
C1	248	18
C2	208	15
R2	213	16
R3	262	19
R4	200	15
R5	226	17
Smoking history		
Never smoked	894	66
Smoked, but quit	151	11
<10 cigarettes per day	100	7
10–20 cigarettes per day	149	11
>20 cigarettes per day	56	4
Missing	7	—

Analysis

The frequencies and distributions of questionnaire and measured information were tabulated. The cumulative incidence rate of injury (per 100 recruits) was calculated for each type of injury (e.g., stress fracture, overuse, traumatic, and total injury). Statistical testing for comparisons of injury rates between intervention and non-intervention companies were conducted using chi-square tests.[35]

Results

Questionnaire Data

Demographic characteristics of the study subjects (Table 1) show the median age of these male recruits to be 18 years, with a range of 17 to 40 years. The three ethnic groups representing 97% of the male subjects were Caucasian (62%), African American (25%), and Hispanic (10%). The distribution of the 1357 study subjects was fairly equal among the six BMT companies (ranging from 200 to 262 per company). Most of these recruits were nonsmokers, with less than one fourth categorized as current smokers. Smoking was prohibited during the entire 8-week BMT course.

Table 2. Anthropometric and fitness measurements, Fort Bliss, 1989, Army recruits (N = 1357)

	Mean ± SD	(min–max)	Range of company averages
Anthro measurement			
Height (cm)	175.8 ± 6.7	(154–200)	175.4–176.3
Weight (kg)	75.7 ± 11.9	(50–116)	75.2–76.1
Army body fat (%)	18.4 ± 5.7	(4–34)	17.8–18.8
Navy body fat (%)	14.5 ± 6.2	(−1.1–32)	13.9–15.0
BMI (kg/m^2)	24.5 ± 3.4	(17–38)	24.3–24.6
Abdominal circ. (cm)	82.2 ± 9.4	(62–113)	81.8–82.7
Neck circ. (cm)	37.5 ± 2.3	(25–48)	37.0–38.0
Flexibility (cm)	30.2 ± 7.7	(7–49)	28.4–31.5
Physical fitness test 1			
2-mile run time (min)	16.0 ± 2.7	(10.7–34.9)	14.7–19.0
Pushups (#/2 min)	36.9 ± 13.6	(1–93)	35.0–38.3
Sit-ups (#/2 min)	50.2 ± 13.2	(3–96)	45.8–55.7
Physical fitness test 4			
2-mile run time (min)	14.4 ± 1.4	(10.8–29.2)	14.1–14.6
Pushups (#/2 min)	51.0 ± 13.3	(26–102)	49.4–52.8
Sit-ups (#/2 min)	62.9 ± 12.0	(29–106)	59.5–66.1

SD, standard deviation.

Anthropometric and Fitness Measurements

Overall anthropometric and APFT results are displayed in Table 2. The range of company averages for the anthropometric measurements indicates that the companies were similar in this respect. Results from the study recruits' first and last physical fitness tests show that improvement by the end of the 8-week BMT course was 38% for pushups, 25% for sit-ups, and 10% for the 2-mile run time. The ranges of the company averages showed considerable variability in the first APFTs, but much less variability in the final APFTs.

Injuries During Basic Training

There were a total of 867 clinic visits (averaging 0.64/recruit) for illness and injury in this population of 1357 recruits during their 8-week BMT course. Clinic visits for illness (332) were recorded for 257 subjects (19/100 recruits), and 535 clinic visits for injury were documented for 343 subjects (25/100 recruits). The most frequently occurring disposition given to recruits during clinic visits for injury was "no lower body exercise" (41%, restriction on use of the lower body during training activities). Days of restricted duty from training generally ranged from 1 to 14 days. During the 8-week BMT course, a total of 1927 person-days of training were lost among the study recruits due to injuries, or an average of 1.4 training days lost per study subject. Overuse injuries produced an average of 0.9 training days lost per recruit, with traumatic injuries producing an average of 0.5 training days lost per recruit.

Table 3 shows the frequencies of the most significant overuse and/or traumatic injuries and the injured body sites involved. When a recruit had multiple injuries, only one overuse and/or traumatic injury occurrence was deemed the most significant, and only that type and body site are listed in Table 3. During the 8 weeks of BMT, 236 recruits (17%) suffered overuse injury and 144 recruits (11%) suffered traumatic injury. There were 37 recruits who suffered both overuse and traumatic injury. Stress fx/rx had the highest proportion (32%) of the overuse injuries, and sprain (35%) was the most common traumatic injury.

All documented overuse and traumatic injury occurrences of the lower and upper extremities are presented in Tables 4 and 5. These tabulations of both categories of injury reflect the total number of injury occurrences (one or more) per recruit. Overuse injuries of the lower extremities comprised 58% of all injury occurrences. Stress fx/rx was limited to the lower extremities. Most of these occurred during weeks 3 and 6 (Figure 1), accounting for 51% of the recruits with stress fx/rx; the involved body sites were primarily the foot (53%) and shin (28%).

Upper extremity overuse injuries represented only 7% of all injuries, and most of those were described as "pain." Traumatic injuries were primarily sprains, followed by blisters and abrasions/lacerations. Upper extremity traumatic injuries showed a markedly different distribution of injury type than in the lower extremities.

Intervention Implementation

The participating companies were coded to represent running modifications identified after reviewing the training logs (averages for running and marching are shown in Table 6). The two non-intervention companies (controls) that conducted standard progressive training were designated C1 and C2. R2, R3, and R4

Table 3. Most significant overuse and traumatic injuries,[a] Fort Bliss, 1989, Army recruits (N = 1357)

	n	% of total	Rate (% of recruits)
Most significant overuse injury			
Pain	60	25	4.4
Stress fracture	42	18	3.1
Stress reaction	32	14	2.4
Strain	30	13	2.2
Fasciitis	8	3	0.6
Bursitis	7	3	0.5
Tendinitis	5	2	0.4
Other	52	22	3.8
Total	236	100	17.4
Overuse body part injured (most frequently reported)			
Foot	66	28	—
Shin	38	16	—
Knee	37	16	—
Lower back	24	10	—
Toe	16	7	—
Ankle	10	4	—
Most significant traumatic injury			
Sprain	51	35	3.8
Blister	24	17	1.8
Abrasion/laceration	22	15	1.6
Contusion	20	14	1.5
Fracture	14	10	1.0
Dislocation	1	<1	<0.1
Other	12	8	0.9
Total	144	100	10.6
Traumatic body part injured (most frequently reported)			
Foot	33	23	—
Ankle	28	19	—
Knee	28	19	—
Hand (9), wrist (7), finger (6)	22	15	—

[a]The most significant injury was determined for each recruit in overuse and traumatic categories (from all injuries occurring for that recruit) to represent a single most important overuse and/or traumatic injury per injured recruit.

were used to represent the three companies that refrained from running during week 2, 3, or 4, respectively. Company R5 was the increased running mileage company, but during week 4 it withdrew from the intervention and stopped running until week 6 (due to the early impression of high injury rates). The control conditions and interventions were generally implemented by the drill instructors as intended, but the amounts of running and marching varied widely among the companies. All six companies participated in a 6- to 8- mile road march in week 4 and a 12- to 15-mile road march during week 5 of training. All companies except R4 (which had two cases in week 7) had stress fx/rx during week 6, after participation in the road marches during weeks 4 and 5. A decline in stress fx/rx occurred after week 6, with only three cases in week 7, and none in week 8 (Figure 1).

Table 4. Occurrence of overuse injuries of the lower and upper extremities, Fort Bliss, 1989, Army recruits[a]

	n	% of total
Lower extremity injury type		
Pain	80	26
Stress fracture	65	21
Stress reaction	41	13
Strain	38	12
Fasciitis	8	3
Bursitis	5	2
Tendonitis	2	<1
Other	71	23
Total	310	100
Lower extremity injured part (most frequently reported)		
Foot	92	30
Shin	58	19
Knee	53	17
Lower back	44	14
Toe	23	7
Upper extremity injury type		
Pain	21	55
Strain	8	21
Tendinitis	3	8
Bursitis	2	5
Other	4	11
Total	38	100
Upper extremity injured part (most frequently reported)		
Shoulder	13	34
Upper back	5	13
Neck	4	11

[a]N = 1357 recruits, of whom 236 had at least one overuse injury.

Companies C1 and C2 logged about the same marching mileage, but C2 logged more miles of running (52 versus 34 miles). Company R2 logged high marching mileage (127 miles) and no running in weeks 2 and 5. Company R3 logged 5 consecutive days of no running in week 3, but logged the highest total miles run (65 miles) and the lowest marching mileage (55 miles). Company R4 logged no running in weeks 4 and 5, but logged high marching mileage (110 miles) and the lowest total running miles (26 miles). Company R5 logged no running in week 5, but logged the highest marching mileage (161 miles).

Effect of Interventions on Injuries

Table 7 displays a comparison of injury rates among the study companies, including categories of injury with corresponding rates (cases per 100 recruits), clinic visits, and training days lost due to injury. Of special interest were incidence rates of stress fx/rx among the four intervention companies (3%, 6%, 7%, and 8%), as

Table 5. Occurrence of traumatic injuries of the lower and upper extremities, Fort Bliss, 1989, Army recruits[a]

	n	% of total
Lower extremity injury type		
Sprain	51	38
Blister	29	21
Fracture	19	14
Contusion	14	10
Abrasion/laceration	9	7
Dislocation	2	1
Other	12	9
Total	136	100
Lower extremity injured part (most frequently reported)		
Foot	44	32
Ankle	37	27
Knee	36	27
Upper extremity injury type		
Abrasion/laceration	19	37
Sprain	10	20
Contusion	10	20
Fracture	3	6
Dislocation	1	2
Blister	1	2
Other	7	14
Total	51	100
Upper extremity injured part (most frequently reported)		
Hand	14	28
Wrist	9	18
Finger	8	16

[a]N = 1357 recruits, of whom 144 had at least one traumatic injury.

compared to rates in the two non-intervention companies (2% and 7%). Incidence rates of stress fractures varied from 1% to 6%, and incidence rates of stress reaction of bone varied from 1% to 4% among the companies. None of the intervention companies had significantly lower overuse injury rates in any category, compared to the combined non-intervention companies. In fact, Company R2 had significantly higher stress fracture rates (relative risk [RR] = 2.5, $p = 0.02$), Company R4 had significantly higher total overuse injury rates (RR = 1.4, $p = 0.03$), and Company R5 had nonsignificantly higher rates of stress reaction of bone (RR = 2.0, $p = 0.09$) than the combined non-intervention companies. The only intervention company with lower overuse injury rates than the combined non-intervention companies was Company R3 (RR = 0.73, $p = 0.11$). There were no significant differences between the intervention and non-intervention companies for traumatic injuries, but Company R3 had significantly lower total injuries (RR = 0.72, $p = 0.03$) and Company R4 had significantly higher total injuries (RR = 1.4, $p = 0.005$) than the combined non-intervention companies.

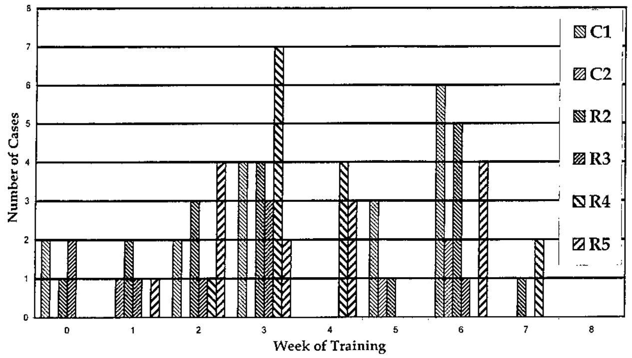

Figure 1. Total stress fx/rx by company and week—Fort Bliss, 1989, Army Recruits (N = 1357).
Injuries in week 0 occurred prior to Day 1 of training.

Among the non-intervention companies, C1 had much higher injury rates than C2. Company C1's total stress fx/rx rate (6.9%) was 3.6 times higher than company C2's rate of 1.9% ($p = 0.01$). During the training period, company C2 had a fairly consistent number of overuse injury cases each week (1 to 4), while company C1 had large variations in the number of overuse injuries each week (0 to 17). Company C1 had injury peaks in weeks 3 and 6 that corresponded to peaks in running mileage.

Of the four intervention companies, only R3 and R4 showed no stress fx/rx for two consecutive weeks after abstaining from running. However, Company C2 also had consecutive weeks (2 to 4) without any stress fx/rx (Figure 1). Companies R3 and C2 had the same drill instructors; this provided a closely matched control for comparison of injury rates between these two companies with different running schedules. This comparison failed to show any reduction in injuries related to resting from running during week 3 of training. Company C2 had the lowest injury rate in every overuse category, with company R3 slightly lower in traumatic and total injuries. In addition, at least one intervention company exceeded company C1's injury rates in every category except clinic visits. The variation in injury rates in the non-intervention companies was matched by similar variation in the intervention companies. Consequently, these data provide no support for the hypothesis that resting from running in weeks 2, 3, 4, or 5 will reduce the occurrence of stress fractures and related injuries.

Injuries Versus Training Practices

Companies C2 and R3 clearly had much lower injury rates than the other four companies, and these were the only two companies that had the same drill instructors. Company R3 had the highest running mileage, miles per run, and number of days run. Company R3 also had the lowest marching mileage (about half of the other companies) and number of days marched, with

Table 6. Reported training activities by company, Fort Bliss, 1989, Army recruits

Company	C1 (n = 248)	C2 (n = 208)	R2 (n = 213)	R3 (n = 262)	R4 (n = 200)	R5 (n = 226)	Total (n = 1357)
Average days run/week	2.3	3.8	3.3	4.1	1.6	3.4	3.1
Average miles/day running	1.9	1.7	2.0	2.0	2.0	2.0	1.9
Average miles run/week	4.2	6.5	6.5	8.2	3.2	6.6	5.9
Total days run	18	30	26	33	13	27	25
Total miles run	34	52	52	65	26	53	47
Average days marched/week	6.0	4.8	6.7	4.0	5.9	6.7	5.7
Average miles/day marching	2.0	2.5	2.4	1.7	2.3	3.0	2.3
Average miles marched/week	12.2	11.7	15.8	6.8	13.7	20.2	13.4
Total days marched	48	38	54	32	48	53	46
Total miles marched	98	94	127	55	110	161	108
Total miles run and marched	132	146	179	120	136	214	155
Final APFT results:[a]							
Pushups–ave # (% improved)	49.6 (40%)	52.8 (38%)	50.8 (45%)	51.5 (37%)	51.9 (41%)	49.4 (29%)	51.0 (38%)
Sit-ups–ave # (% improved)	60.0 (8%)	65.8 (30%)	66.1 (35%)	64.4 (26%)	62.6 (29%)	59.5 (30%)	62.9 (25%)
2-mile run–min (% improved)	14.1 (4%)	14.3 (5%)	14.3 (24%)	14.4 (4%)	14.6 (9%)	14.5 (12%)	14.4 (10%)

[a] Final Army Physical Readiness Test (APFT) results by company averages, with (%) improvement in pushups and sit-ups, and (%) reduction in 2-mile run time when compared with first APFT company results. See also Table 2 for combined averages.

Company C2 having the second lowest marching mileage and number of days marched. These were also the only companies to march less than 5 days per week, while the other companies all marched 6 to 7 days per week. Companies R3 and C2 also ran more frequently than the other companies, 4.1 and 3.8 days per week, respectively, compared to 1.6 to 3.4 days per week for the other companies.

Company R4, on the other hand, had the highest injury rates of all six companies, but had the lowest running mileage. This company had a very inconsistent running schedule, running ≤1 day per week half of the time during the 8 weeks, while Company R3 and C2 ran consistently at least 1 day every week (usually 3 to 4 days per week). Company R2 had the highest stress fx/rx rate, while being the second highest company in total miles marched, and highest in frequency of marching during the 8 weeks.

Discussion

The primary purpose of this study was to evaluate, through an intervention design, whether provision of a week-long period of rest from running would reduce musculoskeletal injuries in recruits during basic military training. When the data were reviewed, there was no demonstration that resting from running during any of these weeks was beneficial in reducing the incidence of stress fx/rx or other injuries. The low overuse injury rates seen in Company R3 were not lower than those in its matched control Company C2. All other intervention companies had either the same or higher injury rates compared to the non-intervention companies.

While the intervention—rest from running in the early weeks of BMT—was appropriately implemented, a wide variation in the amounts of physical training was observed, with associated variation in injury rates apparently more related to variables other than the intervention itself. The two non-intervention companies (C1 and C2) showed disparate injury rates, as did the intervention companies. Four companies (C1, R2, R4, and R5) had high injury rates compared to two low-injury companies (C2 and R3), with stress fx/rx rates ≥6% versus ≤3%; total injury rates ≥25% versus <20%; training days lost from injury ≥390 days versus ≤150 days; and clinic visits for injury ≥87 visits versus

Table 7. Overuse and traumatic injury cases and rates (% of recruits) by type and company, Fort Bliss, 1989, Army recruits

	C1 (n = 248)		C2 (n = 208)		R2 (n = 213)		R3 (n = 262)		R4 (n = 200)		R5 (n = 226)		Total (N = 1357)	
Company	**Rate**	**(#)**	**Rate**	**(#)**	**Rate**	**(#)**	**Rate**	**(#)**	**Rate**	**(#)**	**Rate**	**(#)**	**Rate**	**(#)**
Stress fracture rate	3.6%	(9)	1.0%	(2)	6.1%	(13)	1.9%	(5)	4.5%	(9)	1.8%	(4)	3.1%	(42)
Stress reaction rate	3.2%	(8)	1.0%	(2)	1.9%	(4)	1.1%	(3)	2.5%	(5)	4.4%	(10)	2.4%	(32)
Total stress fx/rx rate	6.9%	(17)	1.9%	(4)	8.0%	(17)	3.1%	(8)	7.0%	(14)	6.2%	(14)	5.5%	(74)
Overuse injury rate	21.4%	(53)	10.1%	(21)	19.2%	(41)	11.8%	(31)	23.5%	(47)	19.0%	(43)	17.4%	(236)
Traumatic injury rate	11.3%	(28)	10.1%	(21)	11.3%	(24)	8.4%	(22)	15.0%	(30)	8.4%	(19)	10.6%	(144)
Total injury rate[a]	29.4%	(73)	18.3%	(38)	28.2%	(60)	17.6%	(46)	35.0%	(70)	24.8%	(56)	25.3%	(343)
Injury days lost	390		138		397		150		409		443		1927	
Injury clinic visits	125		48		97		57		121		87		535	

[a] There were 37 subjects who had both overuse and traumatic injuries. Duplication has been eliminated in total injury rate.

≤57 visits, respectively. The high injury companies all averaged 6 or more days of marching per week, compared to 5 days or fewer marched per week in the low injury companies. They all had more total days marched (≥48 days) and higher total marching miles (≥98 miles) than did the low-injury companies (≤38 days and ≤94 miles, respectively).

The low-injury companies generally had higher running mileage (≥52 miles versus ≤53 miles) and more frequent running (≥3.8 days per week versus ≤3.4 days per week) than the high-injury companies. This appears to support a concept that overuse injuries are minimized with consistent every-other-day running (~2 miles) and at least 2 days per week of rest from marching. A consistent pattern of regular running and marching, allowing for days of rest, may be less injury producing than intermittent schedules of high and low stresses from running and marching. Further study of this concept is warranted.

This study had several strengths, related primarily to its size and the completeness of record retrieval. Over 1300 male recruits were included in the study and followed through their entire 8-week BMT program. There was complete data collection from questionnaires, anthropometric measurements, physical readiness tests, company training logs, and medical clinic visits. The quality of information was quite good for all of these records, with the exception of the training logs. There was little room for bias in collection and interpretation of the medical and anthropometric data, and analyses were conducted without knowledge of intervention assignments to specific companies.

The objective of this study was to evaluate periods of rest from running and their impact on the reduction of stress fractures and related injuries. However, there were variations in marching mileage and inconsistent running and marching schedules. In order to adequately study the specific interventions of resting from running or marching, all other training factors should be held constant. This was the major weakness of the study, since we could not maintain consistent training schedules in the study companies and vary only resting from running. Thus the experimental design was not fully controlled, and as a result the data obtained and analyzed by intervention company may not be properly interpreted. A controlled scientific evaluation of these hypotheses requires better control of other training factors. We did not observe, however, any reduction of stress fx/rx or other injuries in the intervention companies compared to their controls.

We did learn some practical lessons that should be addressed in conducting this type of intervention study of military trainees. Obtaining control over training activities by research investigators is not easily accomplished in the BMT setting. The objectives of the drill instructors are (appropriately) to train recruits, not to conduct research, and thus their adherence to the research protocols cannot be guaranteed. Therefore, observational data must be obtained through training logs; and these must be monitored closely, preferably on a daily basis with investigator observation of the training activities.

Bone remodeling and periods of rest in relation to the effects on stress fracture injuries have been the topics of several articles. Scully and Besterman[19] reported on a 1974 field trial at Fort Knox, Kentucky, where 440 male recruits modified their basic training program "by elimination of running, jumping, and double timing during the third week." This group had a stress fracture rate of 1.6%, compared to 4.8% in 440 recruits in an unmodified program. In 1978, Kowal[1] initiated a study to identify the nature and causes of injuries in 400 female Army recruits as the result of an intense physical training program. Contributions to overuse injury were felt to be the direct result of rapid onset repeated stress from training without allowing for a sufficient buildup in physical conditioning. There is general agreement in the literature that sudden increases in training intensity contribute to overuse injuries and, with the inclusion of periods of rest during intense conditioning programs, a sufficient balance can be provided to reduce the incidence of injury.[1,8,13,14,19,36–38] In these reviews on stress fractures and overuse injuries, there is agreement that rest from continuous stress is desirable; however, there is no agreement on the amount and timing of rest required by the individual. Ross[14] speculated, for example, that rest during the third week of training "may well be followed in the fourth week by a rush of stress fractures merely delayed, not prevented."

Our study showed a stress fx/rx peak in week 3, which is in agreement with several other studies reporting stress injuries in military training.[22,26,28,39–41] However, we also had a peak for most companies during week 6, following road marches that took place during weeks 4 and 5 of training. A close review of the literature indicates that peak stress fracture incidence in military training populations can occur in the early or late weeks of training, as was observed in our study.[27] Marching in BMT appears to be an important factor that contributes to the occurrence of stress fractures.[22,26,39,40] In a study conducted on musculoskeletal injuries in officer training, Heir[41] reported that most injuries were the result of marching, infantry running and field exercises. An injury study conducted in Australian Army recruits compared a marching regimen (N = 170) to a standard running regimen (N = 180) and found similar injury rates, but differences in types and severity of injuries.[40] Resultant training recommendations included reductions in running distance with progressive physical training in the early weeks, so that overtraining might be avoided and lower- limb injuries reduced.[16] It appears that stress fx/rx and other training injuries are related to both running and marching.

Recommendations for adjustments and modifications in training schedules can be found throughout the literature involving studies of injuries in runners and military populations. The literature suggests that increasing the training parameters of exercise (intensity, frequency, and duration) will impart greater risks for injury.[15,42] There is general support for progressive forms of training—a gradual buildup in the frequency, duration, and intensity of exercise, especially early in training.[8,12,41,43] We suggest that a consistent alternate-day running schedule, with 2 days of rest from both marching and running, be included each week.

This study found that sustained rest (5 or more days) from running alone does not prevent stress fractures or related injuries, as has been suggested.[19,28] The data further suggest that other modifications of training, such as the balance and total amount of weight-bearing activities performed (running and marching), along with day-to-day recovery periods, may be important.

The Appendix table can be obtained from the authors—Fort Bliss 1989 company averages for running, total marching, injury cases, and limited duty days, by week.

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Evaluating Risk of Re-Injury Among 1214 Army Airborne Soldiers Using a Stratified Survival Model

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Background: Many factors interact to influence an injured individual's risk of sustaining a second injury. However, the quantitative assessment of subsequent injury risk has been limited, primarily due to methodologic constraints. The purpose of this study is to present analytical methodology not previously employed in injury epidemiology to identify risk factors for subsequent injury.

Methods: Data were collected from a retrospective cohort of 1214 U.S. Army Airborne soldiers. Lower extremity and low-back musculoskeletal injuries were identified from outpatient medical records. The Prentice, Williams, and Peterson (PWP) model, stratified by injury event, was used to identify risk factors for initial and subsequent injuries. A Cox proportional hazards model to the time of last injury was used to determine the magnitude of the increased risk associated with having a previous injury history.

Results: Risk factors for initial injuries were similar to those seen in other epidemiologic studies of military populations. However, this study found that race/ethnicity, physical fitness, medical provider training, and initial injury types (traumatic versus other) were associated with subsequent injury risk. Additionally, the observed risk of injury was seven times greater among previously injured individuals.

Conclusions: In this population, the risk factors for injury differed by event (initial or subsequent injury), and prior injury history was a risk factor for subsequent injury. The associations between demographic characteristics, the nature of the initial injury, and risk of subsequent injury suggest that changes in the evaluation and medical management of injured individuals may decrease the risk of subsequent injury.

Medical Subject Headings (MeSH): risk, wounds and injuries, military personnel, military medicine, proportional hazards models (Am J Prev Med 2000;18(3S):156–163) © 2000 American Journal of Preventive Medicine

Introduction

Individuals in the military, by virtue of their occupation and demographic profile, are at high risk for injury. The reductions in productivity and economic effects of injury are profound. However, there is still an incomplete understanding of the many risk factors for injury. A recent effort by the Armed Forces Epidemiological Board, *Injuries in the Military—A Hidden Epidemic,* culminated in a comprehensive review of the extensive injury problem in the U.S. military.[1] In this report, it is suggested that "previous injury history" and the "late effects of injury" are themselves risk factors for recurrence of a similar injury. The literature review cited therein included two conflicting epidemiologic studies in which previous injury history was examined as a risk factor for recurrent injury. One suggested that previous injury history was a risk factor for later injury,[2] while the other suggested a protective effect (SK Brodine, RA Shaffer. Naval Health Research Center, unpublished data, 1995). The absence of definitive published work in this area suggests that further inquiry concerning the effect of previous injury on subsequent injury in military populations is needed.

The purpose of this paper is to improve the understanding of the effects of previous injury history on risk for subsequent injury, and to determine if risk factors for injury change due to previous injury history.

We examined the following specific hypotheses:

1. The baseline hazard as well as the risk factors for injury are different for the separate events of first and recurrent injury.

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2. History of a recent prior injury (within the study interval) is a risk factor for subsequent injury.

Initial and subsequent musculoskeletal injuries to the lower extremity or low back in a cohort of U.S. Army Airborne soldiers during an 18-month interval are used to evaluate risk factors for injury events.

Background

Injury is recognized as a serious medical problem in a variety of populations, often resulting in temporary losses in productivity, permanent disability, or death. The scenario where a single individual suffers from a recurrent injury has been recognized in the literature. For example, Bennell et al.[3] reported that approximately one third of all injuries to a cohort of track and field athletes were recurrent. Similarly, Stevenson et al.[4] reported that 36% of a cohort of competitive skiers who had ACL surgery required subsequent surgery to the same knee. Chang et al.[5] acknowledge that recurrent tibial stress fractures can be career ending and that these injuries are most common among athletes and military populations. Garcy et al.[6] report that of spinal disorder workers' compensation claimants, 1.3% claimed injury recurrence and 4% claimed injury to another musculoskeletal region in the ensuing 12 months.

Despite the direct observation of re-injury, the field of injury epidemiology has not yet adequately explored this phenomenon. This is perhaps in part due to methodologic constraints. While standard survival analyses are well suited to identify risk factors for events with only one occurrence,[7–9] adaptations to this methodology are needed to study events that may recur, such as injury. There are several recurrent event "survival" models. The Andersen-Gill (AG) model utilizes counting process formulation,[7,10,11] while the models developed by Wei, Lin, and Weissfeld (WLW)[7,12] and Prentice, Williams, and Peterson (PWP)[7,13] each utilize a stratification by event number approach. Each model has its inherent set of assumptions, which may be appropriate in one multiple event setting, but not another.

Application and comparison of these models has been conducted. For example, Therneau et al.[14] used the AG, WLW, and PWP recurrent event models to analyze rhDNase data, and suggest the use of the two former methodologies. We previously implemented the AG and PWP models on injury data and determined that the assumptions inherent in the later model were most appropriate for the study of recurrent injury.[16] This model allows the baseline hazard and explanatory variables to differ by event.[13] Furthermore, to be at risk for a subsequent event, one must have experienced the prior event; this is a very fitting criterion for the study of recurrent injuries. The AG and WLW models make no such assumption.[7,10–12]

The limitation of all of these models is that they do not allow for estimation of the direction or magnitude of risk associated with having a prior event.[7,10–13] Again, in the injury setting this is of great interest. Therefore, we implemented a Cox model to the time of each individual's last injury, using previous injury history as an explanatory variable.[15] We believe this model in combination with the PWP model provides a methodologic framework for identifying injury risk factors while accounting for recurrent injuries. The development and implementation of these two models are presented in this article.

The Data

Data were drawn from a dynamic population of Army Airborne soldiers. A "parent" file was constructed in October 1994 using an electronic personnel roster obtained from division headquarters for one brigade of the 82nd Airborne Division (N=2147) at Fort Bragg, North Carolina. A confidential and unique identifier was assigned to each individual.

Collection and abstraction of study data occurred during seven visits to Fort Bragg between November 1994 and March 1996. Data sources included the "Annual Health Questionnaire for Dental Treatment," outpatient medical records, Army Physical Fitness Test (APFT) score cards, and the Total Army Injury and Health Outcomes Database (TAIHOD).[16] Data were entered into EpiInfo[17] and linked electronically to the parent file via the unique identifier. All data were converted into both SAS[18] and STATA[19] formats for analysis. Details on data collection for each data source are given below.

Parent File

Data collection efforts were focused on two of the three battalions (N=1342) included in the electronic personnel roster. Sixty soldiers were excluded because their arrival date to the study population could not be determined, thus precluding calculation of their person-time of follow-up. For 162 subjects, only electronic personnel roster data were available; therefore, these persons were considered "non-arrivals" and were excluded. Ninety-four subjects not in the original parent file were added. The presence of records for these persons from more than one of the other data sources and the ability to calculate their person-time of follow-up indicated they were missing from the original roster but were present in the cohort. These procedures yielded a final analysis sample size of 1214.

Medical Records

Abstracted medical record information included diagnosis, injured body part, number of follow-up visits, and highest level of medical provider seen for the problem. Musculoskeletal lower extremity and low-back injuries were categorized as traumatic, overuse, or unspecified pain. In our formulation, traumatic injuries were those caused by sudden energy transfer, and overuse injuries were those that resulted from prolonged, repetitive energy transfer. Injuries were classified as unspecified pain when the medical provider was unable to diagnose the patient's complaint. Medical records were completed for 1165 (96.0%) of the study population.

Dental Records

Within each individual's dental record is a Health Questionnaire for Dental Treatment that is updated at least once per year at the time of an individual's routine dental checkup, or more frequently if visits occur for acute dental care. This instrument contains two queries relevant to this study: cigarette and alcohol use.[20] Of the 1214 subjects in the study population, cigarette and alcohol use information from the dental questionnaire data were obtained for 1163 persons (95.8%).

Physical Fitness Data

The APFT consists of a 2-minute timed pushup test, a 2-minute timed sit-up test, and a 2-mile timed run. In addition to these data, information regarding the individual's height and weight are usually included in the APFT score card. Physical fitness scores were obtained on 1019 (83.9%) of the study population. However, height and weight data were available on only 799 (65.8%) individuals.

Personnel Data

Demographic data on 1202 (99.0%) of the 1214 subjects in the study population were abstracted from the TAIHOD.[16] These demographic factors originate from soldier personnel records collected by the Defense Manpower Data Center.

Analytic Approach

We investigated whether a history of musculoskeletal injury to the lower extremities or low back increased the risk of a subsequent musculoskeletal injury to this region. Available for analysis as endpoints in this study were repeated measurements of injury that occurred at any time during the study period. However, only first and second injuries for each subject were included in the analysis.

Potential explanatory variables included indicators of cigarette smoking and alcohol consumption. Also included were the continuous variables corresponding to an individual's performance on the physical fitness test, as well as the anthropometric measure, body mass index (kg/m^2). Demographic information from the TAIHOD included age at entry to the study, age at day of the first injury, marital status, and race/ethnicity.

Additional and potential explanatory variables for predicting a second injury included type of preceding injury (traumatic, overuse, or unspecified pain) and highest level of medical provider seen for the initial injury. An indicator of previous injury history during the study interval was created for the Cox model analysis of last injury.

Preliminary analyses included the calculation of descriptive statistics. Descriptives of the number of total traumatic, overuse, and unspecified pain injuries were calculated, as well as the number of specific injury diagnoses (e.g., fracture) in each of these groups. These descriptives were also calculated separately for the initial and subsequent injury events. Chi-square tests were performed to test the differences in the proportion of injury type and specific diagnoses accompanying the initial and subsequent injury events. Similarly, chi-square tests were performed to test the differences in the proportion of affected body parts in the initial and subsequent injury events.

Each individual's person-time of follow-up was censored, as appropriate, at the length of the medical record review, which was 396 days (13 months) for the first battalion and 549 days (18 months) for the second battalion. If an individual's arrival date occurred prior to the beginning date of the medical record review, person-time was truncated to the maximum time allotted for his respective battalion. We hypothesized that this differing length of follow-up between the two battalions might necessitate that all regressions be stratified by battalion. Therefore, prior to model building, Kaplan-Meier estimates of the survivor function, as well as log-rank tests, were computed to determine if there were significant group differences in these distributions according to unit (battalion) assignment.

Standard methodologies for the analysis of recurrent events were used. Specifically, the PWP model[13] and a Cox proportional hazards model[9] to the time of last injury were implemented to examine the two study hypotheses. The combination of these analyses has been proven valuable to examine risk factors for musculoskeletal injury where subjects are at risk of incurring multiple injury events.[15]

We initially used a stepwise approach to construct the PWP model, with liberal p value thresholds for variable retention, a p value for entry at 0.25, and a p value for removal at 0.80. This approach ensured that potential confounders would not be removed from the analysis prematurely. If a design variable remained in the model after the execution of the stepwise procedure, all design variables associated with the original categorical variable were retained. Examination of the predictive significance of the remaining variables used a backward elimination approach. The log–likelihood ratio test was implemented to determine model improvement.[7] If the removal of a variable created a change of greater than 20% to the coefficient of another covariate, that

Table 1. Descriptive data for age, fitness, and anthropometric variables

	n	Mean	SD
Age at entry to study interval (years)	1202	23.97	5.00
Pushups (repetitions in 2 minutes)	1014	66.83	12.80
Sit-ups (repetitions in 2 minutes)	1018	69.58	11.32
Run time (minutes for 2 miles)	1011	13.69	1.32
Height (meters)	799	1.76	0.07
Weight (kilograms)	799	76.11	9.52
Body mass index (kg/m^2)	799	24.48	2.57

SD, standard deviation.

Table 2. Descriptive data for gender, alcohol and cigarette use, marital status, and race/ethnicity

		n	% yes
Male gender		1214	100.0%
Current alcohol user		1159	55.2%
Current cigarette user		1160	30.4%
Married		1201	38.0%
Race/ethnicity	Caucasian	946	78.7%
	African American	125	10.4%
	Hispanic	64	5.3%
	Other	67	5.5%

variable was considered a confounder and was retained in the model. Design variables associated with a single categorical variable that was nonsignificant and nonconfounding were removed from the model as a group. After ascertainment of the best main effects model, the scale of continuous variables was assessed using smoothed scatter plots of the Martingale residual for the model against the continuous variable of interest.[7] Clinically plausible interactions were explored and added to the model if statistically significant.

The appropriateness of the proportional hazards assumption was investigated through the interactions with the logarithm of time. If a predictor violated the proportional hazards assumption because its interaction with the logarithm of time was statistically significant, a log–cumulative hazard plot was constructed.[8] Near parallel curves suggested that the violation of proportionality was not severe and could be reasonably ignored.

We also developed a Cox model of the time to last injury to determine if previous injury history within the study interval was a risk factor for subsequent injury. Initially, a crude hazard ratio was calculated by having only the variable representing previous injury history as an independent variable. This hazard ratio was then adjusted with respect to explanatory variables, other than those corresponding to the sequelae of care from the immediately preceding injury that were significant in either strata of the PWP model. Variables representing factors associated with the sequelae of care were not included because this information was applicable for only the subjects who had two injuries.

Results

Demographics

This was a young, all-male, predominately Caucasian, physically fit population (Tables 1 and 2). The average age at entry to the study interval was approximately 24.0 (SD = 5.0) years. The average performance for the 2-minute timed pushup test and the 2-minute timed sit-up test was 66.8 (SD = 12.8) and 69.6 (SD = 11.3) repetitions, respectively. The mean performance for the 2-mile timed run was 13.7 (SD = 1.3) minutes. The average height, weight, and body mass index was 1.8 (SD = 0.07) meters, 76.1 (SD = 9.5) kilograms, and 24.5 (SD = 2.6) kg/meters^2, respectively. More than half of the population reported that they were alcohol users, and 30% reported that they were cigarette smokers. Approximately 38% of the population were married and 79% were Caucasian.

Injury

There were a total of 460 initial or subsequent lower extremity or low-back injuries during the study interval. Table 3 summarizes the follow-up periods. The mean time contribution for members of first and second battalion was 340.8 days (SD = 96.4) and 397.3 days (SD = 165.6), respectively. Table 3 also summarizes the distribution of injury event numbers by battalion. For the analysis of the first injury, there were a total of 339 events and 875 censored individuals. There were 121 events and 218 censored subjects for the analysis of the second event.

Chi-square tests suggested that the proportions of first and second injury events are not statistically different in terms of type of injury (e.g., traumatic) or specific diagnosis (e.g., fracture) (data not shown). The only body part not homogeneously distributed between the first and second injury events was the shin/calf

Table 3. Contribution of the analysis of time to event by battalion

	1st battalion	2nd battalion	Total
Person time (days)			
n	614	600	1214
mean	340.8	387.3	368.7
SD	96.4	165.6	138.0
Min	21	19	19
Max	396	549	549
Analysis of first injury			
# of events	170	169	339
# censored	444	431	875
Total	614	600	1214
Analysis of second injury			
# of events	60	61	121
# censored	110	108	218
Total	170	169	339

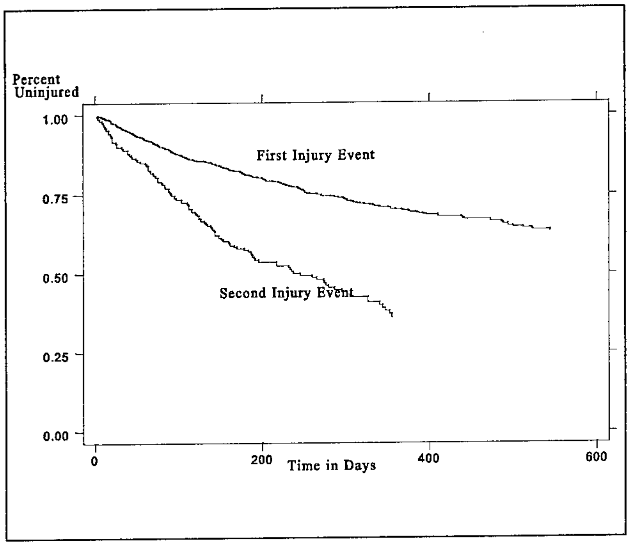

Figure 1. Kaplan-Meier survivor estimates for the two strata (injury events) in the PWP model.

(chi-square p = 0.026), with 24 of the 26 injuries (92.3%) occurring to this region as the first injury.

The distribution of the number of injury events did not differ by battalion (Table 3). Likewise, Kaplan-Meier comparisons of the injury experiences in the two battalions revealed no statistically significant differences. Therefore, battalions were pooled in subsequent analyses. Kaplan-Meier estimates of the survivor function, stratified by injury event, were also calculated. Figure 1 shows that the estimated survivor function for the first injury is consistently less than that of the second injury.

Time to Event (PWP Model)

The first strata (first injury event) of the PWP model resulted in parameter estimates that suggest lower pushup performance, lower sit-up performance, and younger age at entry to study are associated with increased risk of initial injury (Table 4). Self-reported alcohol consumption and being married were also associated with increased risk of injury. Specifically, a 10-unit decrease in upper body strength and endurance as measured by the 2-minute timed pushup test was associated with a 16.2% increased risk of lower extremity or low back musculoskeletal injury (p <0.01). Similarly, a 10-unit decrease in abdominal and hip flexor strength and endurance as measured by the 2-minute timed sit-up test resulted in a 15.2% increased risk of injury (p <0.05). A 1-year increase in age resulted in a 4.1% decrease in risk of injury (p <0.01). Alcohol non-abstainers were at 30.4% greater risk of injury (p <0.05). There is evidence that married subjects had relative odds of injury 27.0% greater than that of their unmarried counterparts (p <0.10). This variable was retained in the final model because of its marginal significance and its relationship as a confounder to age. Removal of the marital status variable from the model resulted in a 32.0% change in the parameter estimate for age (data not shown).

The second strata (second injury event) of the PWP model demonstrated that decreased pushup performance, traumatic first injury, and seeing a medic as the highest level of provider for the first injury were associated with a repeat injury. Additionally, Hispanics were at increased risk of subsequent injury (Table 4).

A 10-unit decrease in upper body strength and endurance as measured by the 2-minute timed pushup test resulted in a 24.9% increased risk of subsequent injury (p <0.01). If the subject's first injury was categorized as a traumatic injury, there was an 83.4% increased risk of subsequent injury than if the first injury was categorized as overuse or unspecified pain (p <0.01). Subjects who saw only a medic, the lowest

Table 4. Association with injury (parameter estimates, SE) from the PWP model

		Parameter estimate	SE	Hazard ratio (95% CI)
Stratum = 1 (first injury)				
Pushups (10 repetition decrease)		0.15	0.056	1.162 (1.042, 1.296)
Sit-ups (10 repetition decrease)		0.142	0.063	1.152 (1.018, 1.305)
Age at entry to study (1-year increase)		−0.04	0.015	0.961 (0.933, 0.989)
Alcohol user (vs. abstainer)		0.265	0.121	1.304 (1.028, 1.653)
Married (vs. nonmarried)		0.239[a]	0.141	1.270 (0.963, 1.675)
Stratum = 2 (second injury)				
Pushups (10 repetition decrease)		0.223	0.083	1.249 (1.062, 1.470)
Previous traumatic injury		0.607	0.217	1.834 (1.200, 2.804)
Highest level of medical provider from previous injury: (medic vs. all others)		0.54	0.251	1.716 (1.049, 2.808)
Race/ethnicity (referent = Caucasian):	African American	0.037	0.374	1.038 (0.499, 2.160)
	Hispanic	1.446	0.368	4.246 (2.023, 8.738)
	Other	−1.243	0.726	0.289 (0.070, 1.120)

Model chi-square = 69.289, 11 df (p = 0.0001).
[a]Confounded with age (1st stratum).
SE, standard errors.

Table 5. Crude and adjusted parameter estimates for history of previous injury from Cox regression model for last injury

		Parameter estimate	SE	Hazard ratio (95% CI)
History of Previous Injury	(crude)	2.005	0.117	7.426 (5.905, 9.338)
	(adjusted)	1.941	0.131	6.965 (5.394, 8.992)

Model chi-square for history of previous injury (crude) = 228.15, 1 df ($p = 0.0001$).
Model chi-square for history of previous injury (adjusted) = 220.44, 9 df ($p = 0.0001$).
SE, standard errors.

level of medical provider, for the initial injury were 71.6% more likely to undergo a subsequent injury ($p < 0.05$). In this study, Hispanic individuals had more than four times the risk of experiencing a second lower extremity injury than did Caucasian individuals ($p < 0.001$). Two thirds of the Hispanic subjects who were at risk to experience a second lower extremity injury did so, compared to 34.3% of the remainder of the subjects (data not shown).

Time to Last Injury (Cox Model)

The PWP model presented in Table 4 suggests that risk factors for injury differ between injury strata. It provides no information, however, regarding the direction or magnitude of the change in risk for injury after experiencing a previous injury. Crude and adjusted values of parameter estimates, standard errors, and hazard ratios for the history of previous injury are presented in Table 5. The adjusted model includes the following variables that were statistically significant in the PWP model: pushup performance, sit-up performance, age at entry to study, alcohol user (versus abstainer), marital status, and race/ethnicity. The crude parameter estimate suggests that previous injury history is responsible for a 7.4-fold (95% CI = 5.9–9.3) increased risk of injury. The adjusted parameter estimate did not differ considerably (7.0 [95% CI = 5.4–9.0]).

The effect of previous injury history was also examined by a log-rank test for equality of the survivor functions between those with and without a prior injury history. Table 6 illustrates that if previous injury history was not a risk factor for subsequent injury, only 25 of the 339 injury events would have been a second injury event. The actual number of second injury events (individuals with a previous injury history) was 121, a value that is almost five times greater than the expected number of subjects with previous injury history.

Table 6. Log-rank test for equality of survivor functions for previous injury history

	Observed	Expected
No previous injury history	218	314
Previous injury history	121	25
Totals	339	339

Chi-square = 400.5, 1 df ($p < 0.0001$).

Discussion

The stratified Kaplan-Meier survivor estimates (Figure 1) revealed that the estimated survivor function for the first injury was consistently less than that of the second injury. This suggests that once an individual experiences a musculoskeletal injury to the lower extremity or low back, he may be at increased risk to undergo a similar, subsequent injury. This led to the hypothesis that the baseline hazard and risk factors for injury may vary by event. The PWP model was implemented to examine this possibility.

The PWP model proved to be a valuable tool in exploring injury in the multiple-event setting. In this study that there were two injury events (strata) that were examined using this analytic approach. Each yielded a very different set of risk factors, suggesting that risk factors for subsequent injuries are in fact different from those related to initial events.

The first strata of the PWP model yielded risk factors that were similar to those seen in previous injury epidemiology studies of military populations.[1,21] The decreased risk of injury associated with increasing age agreed with other studies of infantry soldiers.[22,23] This finding is likely driven by a correlation between younger age and lower rank. Lower-ranking enlisted soldiers may be less likely to have control over their daily activities than their higher-ranking counterparts. They are also more likely to be living in the barracks. These factors may result in differential behaviors regarding both high-risk physical activities that may cause injury, as well as the seeking of medical care after injury.

Marital status is a risk factor for injury that has not been thoroughly investigated. Although this factor was retained in the model because of its confounding influence, the fact that previously uninjured (first stratum) married soldiers are 27% more likely to sustain an injury than their unmarried counterparts ($p < 0.10$) warrants further examination. This marginal significance may suggest that marital status is a proxy for demographic, socioeconomic, and/or behavioral factors that are associated with musculoskeletal injury in military populations.

Alcohol consumption is commonly regarded as a risk factor for injury in a variety of settings. This association has not been widely studied in military populations.

However, Westphal et al.[24] reported a positive association between injury risk and increasing self-reported alcohol consumption among female Army trainees. Our finding of increased risk for initial injury associated with alcohol consumption closely parallels these results. Recent research has also suggested that there is an association between tobacco use and injury.[25–27] Direct toxicity, distractibility, smoking-associated medical conditions, and confounding factors were listed as potential reasons for this relationship.[25] This study, however, found no evidence of an association between tobacco use and injury in either stratum of the PWP model.

Interestingly, the risk factors associated with the second injury, with the exception of upper body strength and endurance as measured by the 2-minute timed pushup test, were very different. Our finding of a highly significant difference in the risk of a second injury among different race/ethnic groups, although provocative, warrants further study before any specific conclusions can be drawn from it.

Perhaps more noteworthy are the risk factors associated with a second injury that are related to the nature of the first injury. We found that individuals whose immediately preceding injury was traumatic (as opposed to an overuse or unspecified pain injury) had an 83% increased likelihood of subsequent injury. This increased risk may be a result of inadequate recovery time after the initial traumatic injury. If this association can be confirmed in future studies, it would certainly suggest that changes in the medical management of these individuals should be considered.

There was also a significant risk of second injury associated with the highest level of medical provider seen for the immediately preceding injury. Those individuals who saw only a medic after their initial injury were at a 72% increased risk of incurring a subsequent injury. Medics are the only military medical providers who do not have the authority to order restriction on an individual's activity. This suggests the possibility that certain individuals are not gaining access to appropriate levels of medical care. Such a possibility should also be further examined to determine if simple changes in the evaluation or medical management of injured individuals might provide simple injury-control measures.

This study did not examine high-risk occupational or physically demanding activities that may confound risk of injury. These types of activities are of particular importance in this population, which has a primary occupational requirement to parachute from aircraft. The increased risk of re-injury may be associated with an increased frequency of airborne operations. Realizing the possible confounding influence of this factor, a post hoc analysis of variance (ANOVA) was conducted on the 1139 (93.8%) subjects who had available airborne operations data. The ANOVA did not reveal any statistically significant differences between these groups.

The Cox model of time to last injury provides information regarding the magnitude of the increased risk associated with having had a previous injury. Both the crude and adjusted analyses showed that previous injury increases the risk of a subsequent injury approximately seven-fold. The similarity between these models suggests that this association is independent of other predictors for subsequent injury. Moreover, this seven-fold increase in risk associated with previous injury history may in fact be an underestimate of the true risk. This analysis examined only the first and second injury events in an 18-month interval. Therefore, if the increased risk associated with previous injury is cumulative, examination of this occurrence over a longer duration of time and for a larger number of injuries might yield an even greater risk associated with previous injury history. Conversely, it is possible that the increased risk associated with previous injury history will subside with time. Examination of injury–re-injury over a longer duration is needed to investigate the importance of time as it relates to the risk of subsequent injury.

While it may not be surprising that injured individuals are at increased risk for a subsequent injury, this phenomenon has thus far not been adequately explored. Risk of subsequent injury may be associated with continued exposure to the risks that resulted in the initial injury. However, an injured individual may also be temporarily removed from the risk pool during the recovery period. While this study did not allow for the direct observation of these factors, future studies should control for the post-injury activity and duty status of study subjects.

The analyses conducted in this study provide evidence that risk factors for injury may differ with respect to prior injury history. Perhaps the most notable differences pertain to the nature and medical management of the initial injury. This suggests that simple changes in the evaluation and medical management of injured individuals may decrease the rate of subsequent injury. Furthermore, previous injury history itself may be a powerful predictor of subsequent injury. The possibility of a cumulative effect of prior injuries, the effect of time on risk of re-injury and the effect of post-injury activity levels all warrant further examination. The methodologies utilized in this study should be further developed as they apply to the epidemiologic study of injury.

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Viewpoint: A Comparison of Cause-of-Injury Coding in U.S. Military and Civilian Hospitals

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Introduction: Complete and accurate coding of injury causes is essential to the understanding of injury etiology and to the development and evaluation of injury-prevention strategies. While civilian hospitals use ICD-9-CM external cause-of-injury codes, military hospitals use codes derived from the NATO Standardization Agreement (STANAG) 2050.

Discussion: The STANAG uses two separate variables to code injury cause. The Trauma code uses a single digit with 10 possible values to identify the general class of injury as battle injury, intentionally inflicted nonbattle injury, or unintentional injury. The Injury code is used to identify cause or activity at the time of the injury. For a subset of the Injury codes, the last digit is modified to indicate place of occurrence. This simple system contains fewer than 300 basic codes, including many that are specific to battle- and sports-related injuries not coded well by either the ICD-9-CM or the draft ICD-10-CM. However, while falls, poisonings, and injuries due to machinery and tools are common causes of injury hospitalizations in the military, few STANAG codes correspond to these events. Intentional injuries in general and sexual assaults in particular are also not well represented in the STANAG. Because the STANAG does not map directly to the ICD-9-CM system, quantitative comparisons between military and civilian data are difficult.

Conclusions: The ICD-10-CM, which will be implemented in the United States sometime after 2001, expands considerably on its predecessor, ICD-9-CM, and provides more specificity and detail than the STANAG. With slight modification, it might become a suitable replacement for the STANAG.

Medical Subject Headings (MeSH): hospital records, military personnel, military medicine, emergency service, medical records, population surveillance, epidemiology, wounds and injuries (Am J Prev Med 2000;18(3S):164–173) © 2000 American Journal of Preventive Medicine

Introduction

Intentional and unintentional injuries remain the leading cause of morbidity and mortality for the U.S. Armed Forces.[1–8] The ability to collect and evaluate quality cause-of-injury data is of fundamental importance to understanding the scope and magnitude of injuries and their impact on the mission and readiness of the Armed Forces, and to the development and evaluation of effective intervention strategies. The term external cause of injury or "E-code" refers to a supplemental code used to provide additional detail to certain ICD codes within the range 800–999. E-codes are used to classify environmental events, circumstances, conditions, and activities leading to injury, poisoning, or complications of medical treatment.

Among civilian hospitals in the United States, E-codes currently come from the clinical modification of the ninth version of the International Classification of Diseases (ICD-9-CM). Military hospitals use an entirely different system originating from an agreement among nine NATO nations during the 1950s, Standardization Agreement (STANAG) 2050. This injury-coding system will hereafter be referred to as the STANAG.

The purpose of this paper is to describe the STANAG system, subjectively discuss its strengths and weaknesses relative to the ICD-9-CM and draft ICD-10-CM systems of external cause of injury coding, and make policy recommendations about future coding of military injuries applicable to the full spectrum of injury severity including fatalities, hospitalizations, and outpatient visits.

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Background

In order to understand the importance of a good standardized injury-coding system for the military, it is necessary to first discuss the general purpose behind efforts to capture the nature and cause of injuries. The ability to understand, classify, and analyze causes of injury consistently and accurately is of fundamental importance to any injury prevention and control effort.[9,10] Cause codes allow for the identification of excess morbidity and mortality associated with specific injury mechanisms; the identification of occupational groups or other populations particularly at risk for certain injury events; and the targeting and evaluation of intervention programs designed to reduce specific types of injuries. Having injury data without cause codes is akin to recognizing the manifestations of a disease without knowing its etiology (e.g., diagnosing lesions on the skin but not knowing what causes them).

Currently, classification of nonfatal injuries in the United States is accomplished using the Clinical Modification of the 9th Revision of the International Classification of Diseases manual, or ICD-9-CM. The ICD-9-CM represents a significant modification of the original World Health Organization ICD-9, first approved in 1974. The clinical modification of ICD-9 was accomplished in order to better reflect morbidity, meet needs for indexing medical records, and provide data useful for statistical analysis. The ICD-9-CM is the primary coding tool used in U.S. health care facilities and is particularly important for analysis of hospital discharge data. The ICD mortality coding scheme has historically been revised and updated only once per decade, while the clinical modification can be updated annually. The ICD-10 has recently been implemented in the United States for coding of deaths, including fatal injuries, but the clinical modification of the ICD-10 is still being finalized and is not expected to be available for use in U.S. health care facilities until sometime in the year 2002.

The ICD system has traditionally used two components for classification of injuries: a code for the nature of an injury (N-code) and a code for the external cause of the injury (E-code).[11–15] Under the ICD-9-CM, for example, the nature of an injury is represented by codes between 800 and 999, which are used to classify an injury according to type (e.g., contusion, burn, sprain, strain, or fracture). External causes are coded using special supplementary codes from E800 to E999 to describe how the injury occurred (e.g., gunshot wound, motor vehicle crash, drowning, or hanging). ICD-9-CM E-codes reflect both the method and intent of the injury (e.g., E953, suicide by hanging, versus E978, legal execution by hanging). Technically, the ICD-9-CM codes injuries along a single axis, incorporating information about intent and place of occurrence using individual codes. Place of occurrence is conveyed using one of 10 possible E-codes ranging from E849.0 to E849.9. Prior to October 1996, these codes could be used only in conjunction with E850–E869 and E880–E928. Since that time, all restrictions on the use of location codes have been removed. This coding system contains a large assortment of codes for unintentional causes of injury and a smaller number of codes available for coding injuries resulting from interpersonal or self-inflicted violence. As a result, there is often more detailed information available to researchers on unintentional injuries than on intentional injuries. Nonetheless, while minimum basic data sets for intentional and unintentional injuries have been defined,[16,17] no coding system in widespread use is capable of capturing even this basic set of variables. Military health care facilities also use the ICD-9-CM system for recording the nature of an injury. However, cause-of-injury codes used in military hospitals are derived exclusively from the STANAG. One exception to this rule is for certain complications of vaccine administration, which are assigned E-codes from the ICD-9-CM.

NATO Standardization Agreements, such as the one establishing the protocol for the recording of military injuries, are common whenever there are concerns about military efficiency or effectiveness. They are intended to help allies collaborate and improve military operational effectiveness and to use resources efficiently and consistently across military alliances. The STANAG system originated at the time of ICD-6 (1948), and appears to have remained somewhat independent of the ICD and its regular modification processes since that time. The STANAG system was ratified by all nine NATO nations by the early 1960s and was subsequently adopted by another five nations that later joined NATO.[18–22] While the present edition of the STANAG (version 5) lists itself as Annex A of the ICD-9, the ICD-9 has no such annex (Andre L'Hours, World Health Organization (WHO), Personal Communication). The ICD has been through five major revisions since the publication of ICD-5. The STANAG, however, although also in its fifth edition, has undergone only very minor modifications.

The STANAG Coding Process

The STANAG injury coding system, unlike the ICD, uses two components, or axes, to code intent and cause/activity. For some types of injuries there are also subcodes that indicate the place where the injury occurred. The STANAG system begins with a Trauma code—a single-digit code with 10 possible values intended to specify the intent and work-relatedness of an injury. The Trauma code distinguishes among battle-related, nonbattle-related intentional, and nonbattle-related unintentional injuries. It also provides information about whether the injury occurred while the person was on or off duty and whether the on-duty

Table 1. 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 (including basic training), and assault courses
	8	Occurring while on duty
	9	Unknown whether on or off duty

Source: STANAG edition 5, amendment 2.[21]

activity was specific to certain training activities or exercises. While the 10 possible Trauma codes are not mutually exclusive, STANAG coding guidelines assign war-related injuries the highest priority, followed by intentional injuries and then unintentional injuries. An assault occurring on duty (e.g., a military police officer assaulted during an arrest) should therefore be coded as (3) "assault," and not (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 a (5) "off duty" (see Table 1).

The injury is next assigned a three-digit Injury code that indicates the activity or event leading to the injury. Table 2 displays the 12 major categories of Injury codes in the STANAG system. In order to provide a more detailed review of components, several of the more important injury subgroups are also displayed. In particular, this review includes subgroups related to military-specific activities, as well as those activities that represent the most frequent causes of injuries in military populations, namely sports injuries, privately-owned motor vehicle crashes, and falls.

Five categories of the STANAG Injury codes require Place of Occurrence modifiers: injuries resulting from guns and explosives (50*–59*), machinery or tools (60*–69*), poisons or fires (70*–79*), specified environmental injuries (80*–89*), and falls and miscellaneous injuries (90*–99*). Table 3 displays the Place of Occurrence modifiers for these STANAG Injury code series. For example, an injury from a power tool could occur in the home, on a ship or at an industrial plant. The ICD-9-CM also uses place of occurrence codes, but differs in that coding place of occurrence requires the use of a separate, additional E-code. While the STANAG and ICD-9-CM both have 10 place-of-occurrence codes, these codes are not the same in both systems.

The net effect of a modification code, such as the place-of-occurrence modifier, is to increase multiplicatively the number of possible code combinations, as a product of the basic codes and all possible modifying codes. However, while providing details on place, they do not provide any additional information on the circumstances of the injury. Furthermore, not every potential combination of Trauma, Injury, and Place of Occurrence codes will necessarily make sense. For example, in the STANAG system an injury occurring in water transport could logically be assigned only a Place of Occurrence modifier (1), "on board ship or other water transport, or in water." A similar phenomenon also occurs with certain Injury and Trauma code combinations. For example, Injury codes 300–479, "Instrumentalities of war, employed during wartime," can logically be paired only with Trauma codes (0) and (1) pertaining to battle wounds or injuries. Similar circumstances limit the potential combinations of Place of Occurrence codes in ICD-9-CM as well.

Comparing the STANAG and ICD Injury Coding Systems

Strengths of the STANAG

The STANAG system has four chief advantages over the ICD-9-CM system of coding injury cause. First, it is a simple yet robust system that allows for a significant level of detail on the basis of a relatively small, manageable number of basic codes and modifiers. Second, it has had a long, stable history, with few major revisions, making it a useful tool for the study of longitudinal trends in injury morbidity. Third, it meets the needs of the military very well with respect to certain types of injuries that are of particular importance to the military, such as war-related injuries. Fourth, the way it has been implemented in military health care facilities renders very complete data about cause of injury. The degree of compliance with coding requirements in military hospitals is impressive, and yields useful and fairly comprehensive information for the study of injury etiology.

Simplicity of the STANAG system. Despite its apparent simplicity, the STANAG system provides significant

Table 2. STANAG injury causes codes

Category	Major group	Minor group	Category description
1	000–059		Accidents in air transport, as specifically defined, spacecraft accidents and escape system injuries
		000–029	Air transport involving military aircraft
		030–039	Air transport involving nonmilitary and unspecified aircraft
		040–049	Accidents involving spacecraft
		051–057	Escape system injuries
II	100–149		Accidents in land transport, as specifically defined
		100–109	Private vehicle
		110–119	Military vehicle
		120–129	Nontraffic private
		130–139	Nontraffic military
		140–149	Rail and other land transport
III	150–199		Accidents in water transport, as specifically defined
IV	200–249		Athletics and sports, including physical training
V	250–299		Reactions, complications, and misadventures in medical or surgical procedures and late effects
VI	300–479		Instrumentalities of war, when employed by the enemy in wartime
		300–319	Agents of nuclear warfare
		320–339	Agents of chemical warfare, excluding incendiaries
		340–359	Agents of biological warfare
		360–399	Other unconventional instrumentalities of war
		400–419	Conventional weapons injury to occupant of aircraft
		420–439	Conventional weapons injury to person on board ship
		440–459	Conventional weapons injury to person on and or in unspecified location
		460–479	Indirect or secondary effects of instrumentalities of war, when employed as such in wartime
VII	480–499		Accidents in connection with own instrumentalities of war, when employed as such in wartime
VII	50*–59*		Guns, explosives, and related agents, except when used as instrumentalities of war in wartime
IX	60*–69*		Machinery, tools and selected agents
X	70*–79*		Poisons, fire hot, or corrosive substances
XI	80*–89*		Specified environmental factors
XII	90*–99*		Falls and miscellaneous other or unspecified agents

Source: STANAG edition 5, amendment 2.[21] Third digit of Injury codes 500–999 reflect place of occurrence (see Table 3).

detail. Unlike the ICD-9-CM, the STANAG system uses two axes for coding cause of injury—the Trauma code for intent or duty-relatedness and the Injury code (with the Place of Occurrence modifiers) for activity or cause. Simplification of the statistical analysis of injury data is one advantage of using separate axes for intent and cause. For example, to study self-inflicted injuries one would look at all records coded with the Trauma code (4). To study all football injuries, one would look at the Injury code (226). Another important advantage of such a system is the potential to clearly identify occupational or "on-duty" injuries. However, that potential, as is true with the use of the ICD, will be diminished to the degree that coding is inaccurate or incomplete.

Another benefit of the two-axis system is that it results in a larger number of possible codes in the STANAG system than are available in the ICD-9-CM system. The multiplicative effect of the separate coding axes results in more total permutations of codes in certain categories and, therefore, the potential for greater specificity in coding. An example of this can be found by comparing the way the two coding systems handle firearm injuries. In the STANAG category, "Guns and Explosives" (50*–59*), there are 10 basic codes, but combining these basic codes with the Trauma code and Place of Occurrence modifiers yields a total of 800 possible code permutations that can be used to describe firearm injuries. In contrast, the ICD-9-CM has 25 basic codes for injuries caused by guns and explosives, which can be combined only with a Place of Occurrence modifier. Thus, in the ICD-9-CM, there are 250 possible permutations of firearm injury codes. Because the STANAG contains more codes in certain categories, such as firearm injuries or sports injuries, than the ICD-9-CM, records for some types of injuries may be coded with a greater degree of specificity in the STANAG system. Arguably, Place of Occurrence codes do not add much useful information regarding cause, and not all possible combinations actually make sense. Still, even without consideration of place of occurrence, the STANAG has 80 codes for firearm injuries versus approximately 25 for the ICD-9-CM.

Table 3. STANAG and ICD-9-CM codes for place of occurrence of injury

STANAG code	Place of occurrence[22]
0	On board aircraft or spacecraft, or in the air, or in space
1	On board ship or other water transports, or in water (sea, rivers, lakes, etc).
2	On land and at an airfield
3	On land and at a dock
4	On land and at an industrial plant (e.g., ordnance factory, supply warehouse, repair shop)
5	On land and on a firing range or drill field
6	On land and on obstacle course
7	On land and in kitchen (other than home), mess hall, or bakery
8	On land and in the home, quarters, or barracks.
9	On land other or unspecified
ICD-9-CM code	**Place of occurrence[15]**
849.0	Home (e.g., apartment, boarding house, farm house, garage, etc.)
849.1	Farm (e.g., buildings, land under cultivation)
849.2	Mine and quarry (e.g., gravel pit, sand pit, etc.)
849.3	Industrial place and premises (e.g., dockyard, factory building, etc.)
849.4	Place for recreation and sport (e.g., baseball field, gymnasium, etc.)
849.5	Street and highway
849.6	Public building (e.g., airport, bank, courthouse, etc.)
849.7	Residential institution (e.g., dormitory, hospital, prison, etc.)
849.8	Other specified places (e.g., canal, dock, parking lot, etc.)
849.9	Unspecified place

In summary, the STANAG system accomplishes a greater degree of specificity and a greater total number of injury codes for classic military activities, in spite of the fact that it contains fewer basic codes than the ICD-9-CM. Once STANAG coders have learned the core list of Injury code categories and mastered the application of the dual-axis system of modifiers, they can code most injuries within these simple and elegant parameters. In contrast, the ICD-9-CM system codes both intent and mechanism of injury in a single code. This approach necessitates a larger number of basic codes. For example, to code suicide by hanging under the ICD-9-CM system, one would select (E953.0), "suicide by hanging." In contrast, using STANAG, one would indicate intent using Trauma code (4), for "intentionally self-inflicted," and "hanging" from the 960–969 series of Injury codes ("hanging, suffocation, strangulation"), depending on the place of occurrence.

Stability of the STANAG system. Since its inception in 1956, the STANAG system has been characterized by infrequent revisions and only minor modifications consisting mostly of the addition, elimination or clarification of a few codes. The relative constancy of the STANAG codes over the past 35 years has resulted in data that can be readily evaluated for temporal changes. Thus, researchers using the STANAG to examine longitudinal changes or trends in injury morbidity and mortality are unhampered by changes in the coding system, such as they might face if they were using the ICD system. Moreover, the STANAG system allows for ready comparison of injuries between branches of the U.S. Armed Forces or the armed forces of other NATO member nations. The STANAG system is still in use by the 15 nations who ratified the agreement in the 1950s and 1960s, including some nations, such as Great Britain, that are already using the ICD-10 system for hospital coding.

Military-specific codes in the STANAG system. The STANAG system was developed to meet the specific needs of military populations. In particular, it contains codes for injuries caused by so-called friendly fire (see Table 2, Own Instrumentalities of War, 480–499), while the ICD-9-CM system lacks codes for these types of injuries. The STANAG also encompasses a greater degree of specificity (more codes) for nuclear, biological, and chemical weapons-related injuries than the ICD-9-CM system.

Another strength of the STANAG system as compared to the ICD-9-CM system concerns sports-related injuries. The ICD-9-CM E-code system contains only 11 possible codes for sports-related injuries, and they are not all-encompassing but rather describe certain situations that occur in sports. All sports injury causes cannot be extracted in a civilian hospitalization database using ICD-9-CM. In the STANAG system, 280 possible sports codes can be examined. This is important since sports activities are a cause of significant morbidity in the Armed Forces[23] (see Table 4). However, under the STANAG, the coding of sports injuries is still imperfect. The STANAG system contains codes for specific sports, (e.g., football, baseball, soccer), which, for some purposes, is an improvement over the ICD-9-CM. However, these codes do not allow us to determine the precise cause of a sports-related injury, such as a fall, trip, push, shove, or fight. The ICD-9-CM system, in contrast, adequately codes mechanism but not activity. For example, the ICD-9-CM coding system will specify whether a person sustained an injury in a fall from a cliff or a fall at the same level, but it does not specify whether that injury was related to sport, work, or recreation. The ICD-9-CM cannot identify specific sports, nor indicate whether a sports injury took place as part of a person's employment, as it might for a professional baseball player.

Table 4. Distribution of Injury and Trauma codes, all active duty Army hospitalizations worldwide, 1980–1997

	0 Enemy action	1 Other battle	2 Legal intervention	3 Assault	4 Self-inflicted	5 Off duty	6 Exercises	7 Other training	8 On duty	9 Unknown duty status	Missing	Total
Military aircraft	0	102	13	2	5	142	2,081	3,537	2,477	625	0	8,984
Air transport, nonmilitary	0	0	0	0	0	52	12	6	26	43	0	139
Spacecraft	0	0	0	0	0	0	2	2	2	0	0	6
Escape system	0	0	0	0	0	3	11	9	10	6	0	39
Military vehicle	0	75	5	6	6	396	1,363	1,282	2,237	866	0	6,236
Nontraffic military vehicle	0	20	1	1	4	38	232	262	718	173	0	1,449
Nonmilitary vehicle	0	20	8	60	46	16,833	4,121	577	4,205	13,098	5	38,973
Nontraffic private vehicle	0	0	0	2	3	195	40	23	99	261	0	623
Other land transport	0	2	0	0	0	43	27	11	66	77	0	226
Water transport	0	0	0	1	1	54	28	20	53	66	0	223
Athletics and sports	0	76	31	38	10	11,200	3,645	2,673	8,081	12,113	0	38,867
Complications, medical	0	6	14	7	14	1,449	193	890	3,248	7,628	12	13,461
Conventional weapons, air	2	26	0	0	0	0	0	0	0	1	0	29
Conventional weapons, land	13	627	0	2	2	1	1	3	18	279	2	948
Conventional weapons, ship	0	3	0	0	0	1	0	0	1	1	0	6
Indirect/secondary war	2	131	0	0	0	0	0	0	3	1	0	137
Own instrument of war	0	67	0	0	0	1	1	0	10	12	0	91
Guns and explosives	0	36	15	742	287	1,194	1,217	1,129	1,247	988	2	6,857
Machinery and tools	0	56	16	1,816	2,025	5,652	2,505	2,864	6,326	6,857	2	28,119
Poisons	0	38	3	166	7,157	4,229	1,241	1,075	2,909	4,823	0	21,641
Environmental	0	0	2	7	5	624	1,578	2,460	2,225	1,346	4	8,251
Falls and miscellaneous	0	206	69	9,647	540	14,415	6,273	6,850	14,682	22,890	6	75,578
Missing	0	1	0	0	0	2	0	3	1	3	313	323
Total	17	1,492	177	12,497	10,105	56,524	24,571	23,676	48,644	73,157	346	**251,206**

Source: Total Army Injury and Health Outcomes Database (TAIHOD), U.S. Army Research Institute of Environmental Medicine, Natick, MA.

Implementation of the STANAG system. Finally, the implementation of the STANAG system has resulted in much more complete information about cause of injury than has historically been achieved with the use of the ICD-9-CM system.[24] Military hospitals in the United States have thoroughly supported the STANAG coding system to the extent that virtually 100% of injury hospitalizations receive STANAG codes for cause of injury. In contrast, civilian hospitals report external cause-of-injury inconsistently across hospitals, cities and states. Currently, only 23 states have mandatory external cause of injury coding requirements for hospitals. Yet, even among those states that mandate external cause of injury, evaluation research has shown that on average only about 70% of the injury-related discharges are actually assigned codes. States without mandated external cause of injury coding had much lower completion rates, with only a little over half the injury discharge records coded (58%).[10] It should also be noted, however, that although external cause-of-injury coding has been sporadic in the past, it is likely to improve as more states mandate cause of injury coding in hospital discharge data and as a result of the implementation of ICD-10-CM (within which the codes are no longer "supplemental" but are integrated into the overall coding system).

A separate report examines the accuracy of STANAG coding, and while it may not be much better than comparable civilian systems,[24] an examination of Injury and Trauma codes for worldwide Army hospitalizations occurring between 1980 and 1997 reveals that only about 0.2% lack a cause code (Table 4). Table 4 also provides an overview of the types of injuries most commonly resulting in hospitalization among Army service members.

Weaknesses of the STANAG

In spite of the advantages described above, STANAG 2050 is not a perfect system for coding injuries. In addition to the limitations inherent in any coding system, the STANAG has a few particular limitations. First, it lacks detailed codes for some injury events that are common or important among military populations. Second, as in other systems, it is possible for coders who administer the system to introduce errors in coding or overuse the missing/unspecified category option. Third, the fact that the categories of injury specified in the Trauma code are not mutually exclusive renders it difficult to get complete information about certain types of injuries. Finally, the STANAG codes are not directly comparable to civilian hospital discharge data.[24]

Lack of sufficiently detailed codes for certain injuries. While the STANAG has many more codes addressing war-related injuries than the ICD-9-CM, Table 4 demonstrates that most military injuries do not occur during times of war (although it should be noted that the time span covered by the table, 1980–1997, was characterized by few major wartime operations). Rather, they are occurring in privately-owned motor vehicles (mostly off duty) and athletics or are due to machinery/tools, poisoning and falls. While the STANAG has some distinct advantages over the ICD-9-CM for categorizing sports injuries, the STANAG, by comparison, does a poor job of distinguishing among different types of fall-related injuries. Upon examining Table 4, we see that falls and "miscellaneous" events comprise 30% of the military injury hospitalization discharges, yet there are only 10 basic STANAG codes to describe these events. In contrast, the ICD-9-CM offers 61 codes to detail the many different circumstances describing falls alone (e.g., fall at the same level, fall from ladder, fall from scaffolding).

Overuse of "other/unspecified" codes. The combination of the Trauma code and Place of Occurrence modifier should theoretically enhance the descriptive power of the STANAG codes for events such as falls. While these codes provide data on where injuries occur, they do not provide additional data on how they happened. Furthermore, the majority (68%) of such injuries are coded with the "other or unspecified" Place of Occurrence modifier (Table 5). Thus, while the STANAG coding system and usual practices do result in virtually 100% of records receiving a Trauma and Injury code, the Place of Occurrence code used most frequently is nonspecific, and thus does little to enhance the specificity and utility of the coding. It appears that 10 codes are inadequate to cover the complete range of places of occurrence. Similarly, duty status as designated in the Trauma code is also frequently coded as "unknown," thereby limiting the utility of this measure.[24]

A potentially more serious limitation of the STANAG system is the lack of specific codes for sexual assaults or rape. The ICD-9-CM, in addition to E-codes, contains a series of supplemental codes (V-codes) to classify factors influencing health status and contact with health services, including admissions associated with sexual assaults. Although V-codes in the ICD-9-CM system usually do not require an external cause-of-injury code, within the military hospital record coding system, V-codes in the range V71.3–V71.9 (i.e., suspected injuries) do. Since there is no specific Injury code category for sexual assault in the STANAG system, such injuries must be coded with Trauma code (3), "assault," and Injury code (98*), "other specified agents not classifiable elsewhere." Currently, in a military hospital, a rape victim can be coded as indicated above and/or by the use of a V-Code (e.g., [V71.5], "observation or examination for alleged rape or seduction"), which in the case of a confirmed rape may not be an accurate reflection of the diagnosis. Although not calling for a

Table 5. Distribution of STANAG Injury and Place-of-Occurrence codes, all active duty Army hospitalizations worldwide, 1980–1997

Place of Occurrence	Environmental	Falls and miscellaneous	Guns and explosives	Machinery and tools	Poisons	Grand total
Air/Space	35	160	39	31	30	295
Ship/Water	62	76	4	47	26	215
Airfield	32	123	6	56	59	276
Dock	10	66	4	37	1	118
Industrial Plant	33	562	57	917	131	1,700
Firing range/drill field	1,952	3,311	1,506	2,102	915	9,786
Obstacle course	456	2,279	92	310	137	3,274
Kitchen/mess	70	311	15	245	166	807
Home/barracks	520	13,710	970	7,087	8,370	30,657
Other/unspecified	5,081	52,390	4,164	17,287	11,806	90,728
Grand total	8,251	72,988	6,857	28,119	21,641	137,856

Source: Total Army Injury and Health Outcomes Database (TAIHOD), U.S. Army Research Institute of Environmental Medicine, Natick, MA.

STANAG code, and used rarely, (V15.41), "history of psychological trauma—rape," is an ICD-9-CM code that could potentially be a useful code for identifying sexual assaults in military hospital data.

Lack of mutually exclusive and exhaustive code categories. The STANAG Trauma code categories are neither exhaustive nor mutually exclusive, and proceed according to the hierarchy shown in Table 1. Thus, information about intent takes precedence over duty status, so that information about duty status may not necessarily be captured in the medical record. As a consequence, the opportunity to study the full spectrum of duty-related injuries is diminished, though possibly still superior to the ICD-9-CM, which has no way of determining work-related injuries.

Limited comparability to civilian hospital data. Another potential limitation of the STANAG is the lack of equivalent code groupings between military and civilian hospital databases. It is difficult to compare civilian and military fall-related occupational injuries and deaths, for example, because of the limited codes available for falls in the STANAG system. The impetus for the STANAG system was to serve military needs during wartime, and as such, it does not contain a full range of codes for peacetime injuries. Even though the proportion of injuries related to hostilities over the past several decades has been relatively small, a major conflict involving U.S. Armed Forces could erupt at any time. It is imperative that the ability to code war-related injuries accurately and specifically is retained. Moreover, as NATO member nations continue to share responsibility for peacekeeping missions, it will be important for the allies to be able to share information about casualties.

Still, there are other compelling reasons to consider either a significant revision to the STANAG system or to abandon it for a better system, if one were available. For example, the majority of beneficiaries of military medical care are not active duty members, but spouses, children, retirees, and civilians admitted to military hospitals on an emergency basis. The ability of the STANAG coding system to handle the coding of injuries in these populations, although not specifically addressed here, may be inferior to the ICD. This fact and the growing need for comparability of data systems for reimbursements and accreditation make the need for standardization with civilian systems greater than ever before. In addition, such data are needed to plan and evaluate appropriate injury prevention activities for other beneficiaries.

Recommendations for Improving the Coding of Injuries in the Military

The STANAG system, while possessing a number of noteworthy attributes, and having served its purpose well for several decades, may now be outdated relative to other available coding systems. The present system does a poor job of coding peacetime injuries, which in recent history have represented the greatest costs and have been the chief cause of lost readiness.[25] The largest numbers of hospitalized injuries appear to occur within areas that are poorly differentiated under the STANAG system (e.g., falls). There are two options for improving the quality and completeness of injury cause data coded by military hospitals: either revise the STANAG to improve and expand the existing coding frame, or adopt another system for categorizing injury causes.

Revising the STANAG to the extent necessary for it to be as useful as other available systems would require extensive work and considerable time. At a minimum, the codes for machinery/tools, poisoning, and falls would require particular attention. Some categories of transportation-related injuries should be added or expanded, such as railway-related injuries. The categories for violent injuries, including self-inflicted injuries and assaults, would need to be expanded. The Trauma code should be expanded to make its categories exhaustive and mutually exclusive, and to capture information on intent and duty-relatedness separately. Finally, the list of Place of Occurrence modifiers should be expanded to include more possible locations, so that coders are less often forced to choose "other/unspecified."

The development of other injury coding systems such as the International Classification of External Causes of Injuries (ICECI)[26] or the Nordic Medico-Statistical Committee (NOMESCO)[27] system may provide a model to be followed in the revision of the STANAG or in discovering a suitable replacement. The ICECI was designed primarily for morbidity coding and may be better suited for use in emergency department settings. It has a multiaxial, modular, and hierarchical structure and was designed to allow collection of basic information relevant to safety policy and research, including traffic safety, occupational safety, consumer safety, and violence prevention.

The NOMESCO Classification of External Causes of Injuries (NCECI) was developed with nonfatal injuries in mind and is a truly multiaxial system. This system has not, however, been completely tested outside the Nordic countries. The NCECI system was designed for a computer-based environment and works best when legal as well as medical information is available. Its principal benefit may therefore be for specific studies even if it does not easily lend itself to routine hospital data collection.

Perhaps the best option would be to adopt the ICD system as is or modify it when the clinical modification for version 10 goes into effect. The ICD-10-CM, as it currently exists in draft form, already offers many advantages over either the ICD-9-CM or the STANAG. The draft ICD-10-CM contains over 50,000 possible codes. With the exceptions of athletics and sports injuries and own instrumentalities of war, ICD-10-CM has a more detailed coding frame than either the STANAG or ICD-9-CM. The greatest difference appears to be in the coding of transportation-related injuries where there are over 25,000 potential codes versus less than 500 in the STANAG. With few modifications, the currently proposed ICD-10-CM provides a more comprehensive and detailed coding of injury causes than the STANAG. Since ICD-10-CM is near the end of its development process there is very limited time for the needs of the military to be considered in its first version. But, even if there is not sufficient time to bring about an official modification to the ICD-10-CM, an unofficial set of add-on codes could be derived to describe military-specific causes, using extra digits to the ICD-10-CM that describe in more detail the specific injuries covered under current STANAG codes. In fact, using extra digits in lieu of additional codes may be advantageous in that all subcodes would collapse down to a relevant category of ICD-10 and thus still be useful in national or international comparisons.

Finally, it is important to keep in mind that in the United States, the STANAG system's principal use is for inpatient hospitalizations. It is not being used widely for the cause coding of injury deaths or outpatient encounters. Surprisingly little information is readily available on specific causes of death[28] and even less is available on outpatient injury cases. The Department of Defense (DoD) has recently established an Ambulatory Data System (ADS) that covers all U.S. military hospitals, clinics and emergency departments. This comprehensive system is designed to capture information on all outpatient encounters and to collect ICD-coded diagnoses for each outpatient visit. This system does not currently use cause-of-injury coding, but such codes would be extremely useful, and would greatly enhance our ability to study the etiology of nonfatal injuries. Active duty service personnel make almost 3 million annual outpatient visits for musculoskeletal conditions and injury-related diagnoses. Given current national and DoD agendas calling for increased use of existing data,[29–32] any decision regarding changes to the military's cause of injury coding system should be made only after careful consideration of the impact these changes might have on all injury surveillance, research and prevention efforts. Given that external cause-of-injury codes are an integral part of the main body of ICD-10-CM (i.e., no longer supplemental), it would make sense to include them in data coding. Otherwise, military hospitals will end up adopting ICD-10-CM while ignoring one of its chapters (Chapter 20, External Causes of Morbidity, code groups V01.00–V99.99, W01.00–W99.99 and X01.00–X99.99) and reverting to a less robust method of coding external causes of injury.

In summary, the STANAG system has served the U.S. military well over the past 40 years, but it is not as robust as the draft ICD-10-CM. The military needs a system for coding cause-of-injury data that distinguishes among different types of non-war-related injuries with more clarity and specificity than the current iteration of the STANAG, and that will permit meaningful comparison with civilian hospital data. Reliable, accurate, and detailed coding is essential to the effective management, tracking and prevention of injuries in the military. As we draw nearer to the implementation of ICD-10-CM, the military has a unique opportunity to take a more proactive approach toward the collection of meaningful cause-of-injury data. Various international groups of experts have worked for decades on refining the ICD system—the military might benefit from adopting this system and devoting its efforts toward ensuring the adequacy of the ICD for military needs rather than maintaining a separate coding system. In implementing such a change, the DoD should be careful to apply the new system to inpatient and outpatient data systems as well as fatality reporting systems so that the data collected are maximally useful and render the most complete information on injury causes possible.

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Qualitative Assessment of Cause-of-Injury Coding in U.S. Military Hospitals: NATO Standardization Agreement (STANAG) 2050

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Background: Accurate injury cause data are essential for injury prevention research. U.S. military hospitals, unlike civilian hospitals, use the NATO STANAG system for cause-of-injury coding. Reported deficiencies in civilian injury cause data suggested a need to specifically evaluate the STANAG.

Methods: The Total Army Injury and Health Outcomes Database (TAIHOD) was used to evaluate worldwide Army injury hospitalizations, especially STANAG Trauma, Injury, and Place of Occurrence coding. We conducted a review of hospital procedures at Tripler Army Medical Center (TAMC) including injury cause and intent coding, potential crossover between acute injuries and musculoskeletal conditions, and data for certain hospital patients who are not true admissions. We also evaluated the use of free-text injury comment fields in three hospitals.

Results: Army-wide review of injury records coding revealed full compliance with cause coding, although nonspecific codes appeared to be overused. A small but intensive single hospital records review revealed relatively poor intent coding but good activity and cause coding. Data on specific injury history were present on most acute injury records and 75% of musculoskeletal conditions. Place of Occurrence coding, although inherently nonspecific, was over 80% accurate. Review of text fields produced additional details of the injuries in over 80% of cases.

Conclusions: STANAG intent coding specificity was poor, while coding of cause of injury was at least comparable to civilian systems. The strengths of military hospital data systems are an exceptionally high compliance with injury cause coding, the availability of free text, and capture of all population hospital records without regard to work-relatedness. Simple changes in procedures could greatly improve data quality.

Medical Subject Headings (MeSH): military medicine, military hospital, wounds and injuries, forms and records control (Am J Prev Med 2000;18(3S):174–187) © 2000 American Journal of Preventive Medicine

Introduction

Despite tremendous progress over the past several decades, injuries remain the greatest health problem for members of the U.S. Armed Forces both in peacetime and during times of war.[1–5] As in the civilian sector, one important source of information used to study and track injuries are injury hospitalization databases.[6,7] Although there is a great deal of information on the quality and utility of injury data from civilian hospitalizations,[8,9] very little has been done to describe and evaluate the quality of hospitalization data from the military health care system that uses a unique injury cause coding system based on a NATO Standardization Agreement (STANAG 2050).[10]

As recognition of the importance of injuries to the military grows, the value of hospitalization databases for research, surveillance, and policy development is also growing. However, there is little published information describing the impact of data coding and management processes on the quality of military hospital discharge data, nor are there any published studies of the quality or reliability of cause of injury data in military hospitals.

The purpose of this paper is to describe and evaluate the attributes of the military system for coding hospital

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data, especially the causes of injury, to describe the resultant data availability and data quality, and to make recommendations for policies and programs to improve the quality and utility of data coding in military facilities.

Background

The completeness and accuracy of cause-of-injury coding in civilian settings has been well-described in the civilian literature.[11] Historically, compliance with cause-of-injury coding in civilian hospitals has been poor, and there are still no reliable nationwide data on injury causes. Only recently have states begun mandating E-codes on hospital discharge data. In addition, even among states where compliance is high, there is reason to believe that data quality and accuracy are suboptimal.[12]

Because accurate and detailed cause-of-injury coding are also essential to injury prevention and control efforts within the military, a careful assessment of hospital coding in military hospitals is warranted. Interpretation of military hospital data is complicated, due in part to the unique attributes of military populations (e.g., high level of physical activity, hazardous worldwide duty, unlimited access to free medical care) and a unique medical record system (virtually all hospitalization records captured, military cause-of-injury coding system used exclusively). In addition, the approach used for documenting and describing injuries is unique to the military systems in the United States and other NATO nations. However, to date, no descriptive or validation studies of cause-of-injury coding in U.S. military hospitals have been published. The inclusion of hospital data in research and surveillance databases such as the Total Army Injury and Health Outcomes Database (TAIHOD),[13,14] the Defense Medical Surveillance System (DMSS),[15] and the Epidemiology Interactive System (EpiSys)[16] has further increased the importance of this data to the military services and highlighted the need for a review of military hospital injury data quality and completeness.

The Military System for Coding Injury Hospitalizations

The nature of injuries (i.e., sprain, strain, fracture) in military hospital discharge databases is coded using the ICD-9-CM, the same as in civilian hospitals. Causes of injuries, however, are not coded using ICD-9-CM E-codes, but rather STANAG cause codes. This system, and its similarities to and differences from the ICD system, are discussed in detail elsewhere.[10] In general, all injury hospitalizations with ICD codes from 800 to 999 are given a cause-of-injury code from the STANAG system. This coding system is adapted from the ICD external cause-of-injury coding system, but differs in a number of important ways. The STANAG offers more detail on war and weapons-related injuries, and uses a biaxial coding system with variables for intent and duty status (Trauma code) on one axis, and mechanism (cause), activity, and place of occurrence (Injury code) on the other.

The STANAG system has four digits, beginning with the Trauma code—a single digit code with 10 possible values (0–9). The Trauma code must convey both intent and work activity, while distinguishing between battle-related, nonbattle-related intentional, and nonbattle-related unintentional injuries. A three-digit Injury code is used to indicate cause or activity at the time the injury occurred. When applicable, the third digit of the Injury code can be modified to indicate place of occurrence.

In military hospitals, the first opportunity for data collection occurs at the time of the initial admission. If an individual is not seriously ill or injured, he or she is sent directly to the admissions department. At this step, a determination is made by the admissions clerk as to whether the person to be admitted is an "illness case" or an "injury case." If the person has an acute injury, then the admissions clerk will likely ask the patient a series of questions in order to understand the activity and cause of injury. The admissions clerk at this step then enters the Trauma code into the patient's record. In many cases the Injury code, if it can be determined, is also entered. An "injury comment" field may also be completed at the discretion of the admissions clerk. This injury comment field is a free-text field with no absolute character limit. The admissions clerk can enter any information deemed pertinent to the injury including more details regarding the injury mechanism, intent, activity, or time of day. There appears to be no formal guidance on how to enter the Trauma or Injury codes, nor are the clerks provided with a specific set of questions to be answered for completion of the injury comment field.

Management of the patient's record throughout the patient's stay is similar to the process followed in any U.S. hospital. Daily notes, physician orders, procedure reports, lab and x-ray results, reports of operations, history and physical forms, and a narrative summary dictated by the attending physician at the time of discharge all become standard components of a patient's record. The medical records coders thus have all of this information as well as the information entered by the admissions clerk to use in determining the proper choice of injury codes. Once coding is complete, a computer-generated cover sheet is affixed to the patient's record and it is filed. This sheet includes the patient's demographic data, a list of diagnoses and procedures, a listing of the Trauma and Injury codes, and the injury comment field.

An inpatient record can be coded with up to eight diagnoses related to the nature of the injury, but may be assigned only one set of STANAG codes (i.e., one Trauma code and one Injury code). The STANAG code always applies to the principal diagnosis, unless the principal diagnosis is not an acute injury, in which case it applies to the next listed diagnosis that falls within the ICD range 800–999. The coder enters the STANAG code, if it has not already been entered during the admission process. Alternatively, the coder may change a code if a previously assigned code is deemed incorrect. However, anecdotal reports suggest that once the codes are in the record they are generally left unchanged.

A set of programmed error checking routines is used to screen for missing or incorrect assignments of STANAG codes. Any record with an ICD code in the 800–999 range that does not have a STANAG code is returned for review, and any record that has a STANAG code but does not have a diagnosis falling within the 800–999 range is also returned for re-evaluation. (There are several minor exceptions to this rule in that certain V-codes pertaining to examination or observation for suspected injuries—for example, V71.3, observation following accident at work—also receive a STANAG code, and certain complications of vaccine or drug administration.) All such discrepancies are resolved before the discharge data are reported to the services' medical records central database in the form of a Standard Inpatient Data Record (SIDR).

Hospital Patient Records Not Representing True Admissions (CROs)

Another coding practice unique to military hospital data systems is the development of a hospital record, including assigned diagnoses, cause, and nature-of-injury codes, for some patients who are never actually admitted to the hospital. The first such group includes patients who undergo day surgery, although the counting of these cases as inpatients has been discontinued during the past several years (since 1996). The second category of patients are those referred to as "Carded for Record Only" (CRO). Although these patients are not actually admitted to the hospital, CRO admissions records are created for them to help track hospital resource utilization. CRO cases fall into three general categories: (1) deaths occurring in the emergency department or individuals pronounced dead on arrival, (2) patients discharged from the military for service connected disabilities, and (3) cases not admitted but involving illnesses or injuries that are either of great concern to the military or medical leadership or that are of particular legal interest (e.g., certain motor vehicle accidents, rapes). This final category is referred to as "CRO other."

Criteria for including ambulatory cases as CROs vary across facilities and over time in the same facilities. Not all deaths or disabilities are captured by this system. Approximately two thirds of deaths and two thirds of individuals ultimately discharged from the Army with a documented disability will receive a CRO record. Still, CRO records offer an important source of information not available in civilian systems. The greatest value of these records from a research standpoint is the ability to obtain diagnostic codes related to disabilities and diagnostic and cause codes (ICD-9-CM) on deaths (approximately 80% of which are injury related). This information might be used, for example, to supplement information on the manner of death provided by the service casualty offices—a system that currently does not include complete information on causes of death.[17] The Department of Defense's (DoD) routine mortality tracking system, the Worldwide Casualty System Database (WCS),[3] reports only general information on manner of death (i.e., combat related, accident, illness, suicide, or homicide).

Methods

To evaluate the quality of data obtained through the military's injury coding system, we began by examining the worldwide distribution of acute injuries and musculoskeletal conditions of active duty Army personnel hospitalized in Army or civilian facilities from 1986 to 1995. We used the TAIHOD,[14] a relational database containing electronic extracts of all Army hospitalization records since 1971, to identify frequencies of hospitalizations across different types of Army medical facilities. The TAIHOD links hospitalization records to demographic data from personnel records and allows one to identify hospitalizations occurring in different types of medical facilities. To provide context for the in-depth validation step to follow and to understand the distribution of cases on a worldwide basis, we compared Trauma and Injury code distributions in facilities of different types during the 1993–1997 period. The facility comparisons were done for a more recent period in order to control for temporal changes in the use of different types of facilities and to more accurately reflect the current situation. We also examined the relative frequencies of CRO records for the 10-year period 1986–1995.

To test methodologies for a larger validation study and to study the accuracy of medical record coding in more detail, we also selected a single facility with a broad distribution of cases and generated a small systematic random sample of all active duty hospital records from cases seen in this facility for detailed review. The facility selected was the Tripler Army Medical Center (TAMC) in Honolulu, Hawaii. TAMC was selected because it was the Army medical center with the largest number of injury hospitalizations among active duty soldiers, and because it has a clearly defined catchment area with fewer beneficiaries likely to be seen in civilian hospitals or other military treatment facilities. As a referral site for the Pacific, and as a tertiary care facility located near large troop concentrations without access to a smaller Army hospital, it might also be expected to receive a broad mix of patients and health conditions. All records for cases seen in 1994 were eligible to be included in our sample. Army medical centers keep hardcopy records for 5 years after the date of the patient's discharge. We selected 1994 because it was long enough prior to the planned date for record review that all records would be expected to be complete and relatively few would be in use for the care of current patients. The record review was conducted in January of 1996.

Case Selection for Review of Tripler Hospital Records

We selected cases from 1994 without regard to CRO status. We requested a total of 141 records for review, stratified by the case's principal diagnosis. There were 75 injury hospitalizations (ICD 800–999), 50 musculoskeletal condition hospitalizations (ICD 710–739), and 16 records from the remaining major ICD code groups (we excluded perinatal conditions and congenital anomalies, neither of which is an important cause of hospitalization for the population of interest). We purposely selected this combination of records in order to directly evaluate the accuracy of the STANAG in coding injuries and to assess the potential error rate in terms of injuries missed as a result of being misclassified as a musculoskeletal condition or other non-acute injury. A relatively large sample of musculoskeletal condition records was selected primarily to assess the acute versus chronic nature of these conditions and, therefore, the appropriateness of the ICD coding, but also to evaluate the adequacy of the records to determine if the condition was the direct result of prior injury. Since the differentiation between acute injury and chronic injury under the ICD-9-CM system is not adequately defined, there is no absolutely correct coding on this issue. In general, the approach taken by the reviewer was to determine if the hospitalization was the first encounter of an appropriate level of care given the injury's severity and whether sufficient time had passed so that any acute effects of injury would have healed (e.g., the initial effects of pain, inflammation, or edema were not present).

The selection of the few records that were neither acute injuries nor musculoskeletal conditions was exploratory and used primarily to inform validation studies that may be conducted in the future. The opportunity to detect injury-related conditions, late effects of injuries, or complications of medicine and surgery was also of interest (e.g., ENT conditions resulting from fights, suicide attempts coded as psychiatric conditions, or sexual assaults coded as OB/GYN problems).

Permission to review the records was obtained by the Office of the Army Surgeon General after approval of the research protocol by the U.S. Army Research Institute of Environmental Medicine (USARIEM) Human Use Review Committee. A computer-generated random sample of cases meeting the diagnostic case-mix criteria described earlier was obtained from the TAIHOD, and the case IDs were sent to the hospital. The records were pulled and placed in a review area.

Record Review

A single injury epidemiologist (first author) who is also a physician, but not a trained nosologist, reviewed all records over the course of a 1-week time period. Information extracted from the records was entered onto a separate data extraction form and later entered into a computer database. While records were selected based on principal diagnosis, a certain percentage contained secondary diagnoses within ICD 800–999. While only one STANAG code is assigned to a given record, the fact that they are also assigned to secondary diagnoses (i.e., cases where the principal diagnosis is not an injury) resulted in greater numbers of STANAG codes to evaluate than the simple number of injury records pulled initially. Each record was evaluated using the following criteria:

- Did the reviewer agree with the coding of the Trauma code?
- Did the reviewer agree with the coding of the Injury code?
- Did the reviewer agree with the coding of the Place of Occurrence codes, if applicable?
- Were the diagnostic codes (ICD-9-CM codes) accurately reflecting whether or not the patient's injury (if the hospitalization was injury-related) was acute or chronic?
- Was there additional information available in the record that reflected the patient's height, weight, and use of alcohol and tobacco (information not directly pertinent to validation of STANAG coding but relevant to validation of other data in the TAIHOD)? For records where the reviewer was unsure of the coding, outside experts were consulted.

In addition to the records review described above, an examination of hospital admission and records keeping was conducted. This process led to the discovery of the free text field on all injury admissions. Free-text data are not part of the Standard Inpatient Data Record (SIDR) and are not routinely sent outside the hospital. (The SIDR is an electronic hospital record extract that all military hospitals send to a central database.) In order to understand the content and utility of the free-text data for research purposes, we requested annual extracts of the free text from three facilities (including TAMC) and analyzed them independently of the 1994 TAMC inpatient records sample generated for hardcopy review.

Results

Table 1 provides a general overview of hospitalizations by major diagnostic group for all cases seen in Army hospitals worldwide and displays the frequency and distribution of CRO cases. Injuries and musculoskeletal conditions were the two leading causes of admissions, each representing more than 13% of the total. Overall, CRO cases represent 8.7% of all cases in the hospital database, 5.3% of all injury cases, and 33.1% of all diseases of the musculoskeletal system and connective tissue. Thus, the incidence rate and admissions for acute injuries would be overestimated by 5.3% if CRO cases were not excluded from analysis. Not all deaths or disability cases are captured by the hospital databases, but linkage studies conducted using the TAIHOD reveal that approximately two thirds of all deaths and disability cases are recorded as CROs (data not shown). The largest number of disabilities recorded as CROs (53%) are related to the musculoskeletal system, while the vast majority of deaths are related to injury (83%) or cardiovascular disease (13%).

Table 2 provides a general view of Trauma (intent and duty status) coding among Army hospitals grouped according to size. Army patient records from civilian hospitals are also presented for comparison purposes. Duty status was coded as unknown at overall rates ranging from 40% to 76% depending on facility type. Army medical centers seem to code the highest proportion of records with "unknown" duty status, followed by civilian hospitals. Smaller Army facilities, which tend to be at locations with higher concentrations of active duty soldiers, seem to do best in coding duty status, but still code 40% as unknown. On-duty injuries (e.g., schemes and exercises, scheduled training, and on duty) accounted for 8% of injuries recorded at the TAMC and up to 34% for small- and medium-sized Army hospitals. Trauma coding compared across all individual Army hospitals revealed "unknown" coding ranging between a low of 3% and a high of 85% (data not shown).

The use of codes for both assaults and self-inflicted injuries appeared relatively consistent as a proportion of all injuries across the different hospital types with the exception of TAMC. At TAMC, injuries coded as self-inflicted totaled little more than 1%. Interestingly, all facility types report fewer Trauma codes for assaults than they do Injury codes for fighting (Tables 2 and 3). A total of 1331 cases (3.9%) were coded as due to fighting but only 1065 cases (3.1%) were coded with the Trauma code for assault. War-related injury hospitalizations were rare during this period.

Based on the aggregate data, TAMC appears to have a different combination of patient mix and/or coding practices from what is observed among other medical centers, small hospitals, or civilian facilities. In particular, TAMC appears to have more Trauma codes falling into the "unknown duty status" category and fewer falling into the "on-duty" category. Discussions with coders at TAMC revealed a default decision rule to use the "unknown" Trauma code for active duty patients. Anecdotal discussions with hospital coders at several other facilities revealed equally arbitrary and inconsistent decision rules for assigning Trauma codes.

The major causes or activities associated with injuries treated at different military and civilian facilities are shown in Table 3. These represent causes irrespective of intent. There was considerable variation in the distribution of injury types by facility, as reflected by the Injury code (Table 3). However, our sample facility, TAMC, does not appear to be very different from the other medical centers as a whole (with the possible exception of the recording of "other specified agents," a code meant to reflect a known agent for which there is no specific code). TAMC had a higher proportion of cases in this category than the other medical centers, but was about equal to the civilian hospital group.

Of the 141 hardcopy records requested, charts could be located for 139 (99%). Due to time constraints, only 118 records were ultimately selected (at random) for full review. Trauma coding was reviewed on a total of 73 records; 69 with a principal diagnosis of injury (including complications) and 4 that were from records with a principal diagnosis that was not injury related but had received a STANAG code based on a secondary diagnosis of injury. Table 4 provides a matrix that displays the Trauma code from hospital records on the y axis versus the Trauma code assigned by the reviewer on the x axis (for the 60 true injuries, excluding 13 complications). Hospital coding and reviewer opinion were discordant in 52% of the cases. The biggest discrepancy came from those cases coded as unknown by the hospital. Of the 49 cases assigned the unknown duty status code by the hospital, only 15 (31%), in fact, lacked sufficient information in the record to correctly determine the Trauma code. A majority of the unknown duty status (21 of 49, 43%) were found on careful examination of the entire record to be off-duty injuries. An additional 9 (18%) were found to be duty-related and two (4%) were due to assault. Most of the cases were coded as unknown by the hospital and only 10 (17%) had a Trauma code other than unknown (1 missing). Overall, 70% (7 of 10) of records not assigned unknown codes were concordant with reviewer opinion, as were 100% of the self-inflicted injuries (3 of 3), 0% of the assault cases (0 of 1), 50% of the off-duty injuries (1 of 2), and 60% of on-duty injuries (3 of 5). If records that remained unknown after review are not considered, it appears that almost half (49%) of the remaining codable cases represent off-duty injuries, while almost a third (31%) represent on-duty injuries. The remainder comprises assaults and self-inflicted cases. The hospital did not correctly identify any of the four assault cases.

In general, Injury coding was more accurate than

Table 1. Carded for Record Only (CRO) cases in context of worldwide active Army hospitalizations, by principal diagnosis group, 1986–1995

	Hospitalizations				CRO disability records			CRO death records			Other CRO records		
ICD-9-CM Group	Total records	Actual admissions	Total CRO records	CRO as % of total records	N	% relative to actual admissions	% of all CRO disability records	N	% relative to actual admissions	% of all CRO death records	N	% relative to actual admissions	% of CRO other records
Injury and poisoning (800–999)	134,901	129,660	5,241	4	2,513	2	3	2,166	2	83	562	<1	16
Diseases of the musculoskeletal system and connective tissue (710–739)	172,277	129,464	42,813	33	41,743	32	53	4	<1	<1	1,066	1	31
Diseases of the digestive system (520–579)	120,870	118,674	2,196	2	1,825	2	2	5	<1	<1	366	<1	11
Complications of pregnancy, childbrith, and the puerperium (630–676)	94,807	94,769	38	<1	27	<1	<1	0	0	0	11	<1	<1
Diseases of the respiratory system (460–519)	95,766	90,620	5,146	6	4,971	5	6	19	<1	1	156	<1	5
Mental disorders (290–319)	90,854	84,452	6,402	8	6,357	8	8	7	<1	<1	38	<1	1
Infectious & parasitic diseases (001–139)	68,768	67,388	1,380	2	1,300	2	2	3	<1	<1	77	<1	2
Supplementary classification (V01–V82)	63,026	62,067	959	2	683	1	1	2	<1	<1	274	<1	8
Diseases of the genitourinary system (580–629)	54,966	53,349	1,617	3	1,495	3	2	1	<1	<1	121	<11	4
Symptoms, signs, and ill-defined conditions (780–799)	38,051	35,297	2,754	8	2,582	7	3	57	<1	2	115	<1	3
Diseases of the circulatory system (390–459)	30,966	27,666	3,300	12	2,770	10	3	337	1	13	193	1	6
Diseases of the nervous system and sense organs (320–389)	33,338	27,285	6,053	22	5,886	22	7	3	<1	<1	164	1	5
Diseases of the skin (680–709)	25,098	23,564	1,532	7	1,495	6	2	0	0	0	39	<1	1
Neoplasms (140–239)	21,087	19,522	1,565	8	1,462	7	2	3	<1	<1	100	1	3
Endocrine, nutritional, metabolic disorders (240–279)	10,699	9,679	1,020	11	940	10	1	2	<1	<1	78	1	2
Congenital anomalies (740–759)	7,861	4,951	2,910	59	2,867	58	4	4	<1	<1	39	1	1
Diseases of the blood (280–289)	3,259	2,890	369	13	354	12	<1	0	0	0	15	1	<1
TOTAL	1,066,594	981,297	85,297	100[a]	79,270	8	100[a]	2,613	<1	100[a]	3,414	<1	100[a]

[a] May not total due to rounding errors.

Table 2. STANAG trauma coding for injuries (exclusive of complications) by type of U.S. Army hospital, 1993–1997

	Large Army medical centers/hospitals		Tripler Army Medical Center (TAMC)		Other Army hospitals[a]		Civilian hospitals		All hospitals combined	
Trauma Codes (STANAG)	N	%	N	%	N	%	N	%	N	%
0. Enemy action	3	<1	0	0	12	<1	0	0	15	<1
1. Other battle	8	<1	0	0	152	1	0	0	160	<1
2. Legal intervention	3	<1	0	0	20	<1	0	0	23	<1
3. Assault	99	3	41	4	827	3	98	4	1,065	3
4. Self-inflicted	137	4	12	1	718	3	83	3	950	3
5. Off-duty	213	6	109	11	4,789	18	509	20	5,620	16
6. Schemes/exercises	113	3	19	2	1,982	7	61	2	2,175	6
7. Scheduled training	92	2	20	2	1,409	5	67	3	1,588	5
8. On duty (other)	631	17	42	4	5,921	22	311	12	6,905	20
9. Unknown duty status	2,417	65[b]	778	76	10,781	40[c]	1,413	55	15,389	45
Missing	1	<1	—	—	170	2	17	1	188	1
Grand Total (row %, all injuries)	3,717	11	1,021	3	26,781	79	2,559	8	34,078	

[a] Other includes small, medium and field hospitals, and Army soldiers hospitalized in Navy and Air Force facilities.
[b] Among Army medical centers unknowns range from 50% to 85%.
[c] Among the 20 Army hospitals (other than medical centers) with the most injury admissions, unknowns ranged from 3% to 83%.

Trauma (intent and duty status) coding. Of the 73 records with Injury ICD codes (800–999), all were assigned a STANAG code. Forty-seven (64%) had no errors, and only 9 (12%) contained a major STANAG code group misclassification (see Table 3). Most of these were related to injuries that were assigned non-specific codes when, in fact, sufficient information existed to provide a more accurate code. In several cases there was some ambiguity. For example, in one such case an individual receiving an electrical shock fell from a ladder breaking his wrist. The injury was coded as an electrocution when it could have been coded as a fall from a height. In cases such as these, the Injury code was accepted as it was recorded. In other instances there was no apparent logic to the misclassification. Eight records (11%) were not actually acute injuries; 6

Table 3. Leading STANAG injury codes by type of hospital, U.S. Army, 1993–1997

	Large medical centers/hospitals		Tripler Army Medical Center (TAMC)		Other Army hospitals[b]		Civilian hospitals		All hospitals combined	
Injury Codes (STANAG)	N	Col %	N	Col %	N	Col %	N	Col %	N	Col %
Athletics and sports (200–249)	589	16	159	16	5,001	19	205	8	5,954	17
Personal motor vehicle (100–109)	544	15	151	15	2,815	11	911	36	4,421	13
Complications—therapeutic (280–289)	665	18	142	14	2,405	9	78	3	3,290	10
Other specified agents (98*)	238	6	169	17	1,695	6	417	16	2,519	7
Parachute—military aircraft (020–026)	79	2	7	1	1,605	6	31	1	1,722	5
Cutting/piercing instrument (64*)	179	5	55	5	1,390	5	89	3	1,713	5
Fall/jump—different level (91*)	140	4	51	5	1,319	5	113	4	1,623	5
Ingest toxic substance (70*)	172	5	26	3	1,094	4	128	5	1,420	4
Fall/jump—same level (92*)	152	4	47	5	1,133	4	55	2	1,387	4
Fighting (97*)	142	4	75	7	1,010	4	104	4	1,331	4
Twist, turn, slip (no fall) (94*)	101	3	24	2	869	3	10	0	1,004	3
Guns and explosives (50*–59*)	119	3	10	1	610	2	96	4	835	2
Military motor vehicle (110–119)	63	2	8	1	681	3	67	3	819	2
Excessive heat (80*)	27	1	16	2	591	2	17	1	651	2
Fall/jump—stairs or ladder (90*)	48	1	12	1	401	1	34	1	495	1
Other (all else)	459	12	69	7	4,162	16	204	8	4,894	14
Total (row %)	3,717	11	1,021	3	26,781	79	2,559	8	34,078	100[c]

[a] Third digit = place of occurrence codes 0–9.
[b] Includes MEDDACs (medium-sized hospitals), community hospitals, field hospitals, and Army soldiers hospitalized in Navy and Air Force hospitals.
[c] May not total due to rounding.

Table 4. Concordance grid of hospital Trauma coding versus reviewer opinion, Tripler Army Medical Center, 1994 injury hospitalizations (excluding complications)

Reviewer's Coding of Records

Hospital's Coding of Records	0	1	2	3	4	5	6	7	8	9	Missing	Total	% Concordance
0 enemy action													
1 other battle													
2 legal action													
3 assault													
4 self-inflicted					3							3	100%
5 off-duty				1		1						2	50%
6 exercises							1		2			3	33%
7 training													
8 on-duty									2			2	100%
9 unknown duty				2	2	21	2		7	15		49	30%
Missing				1								1	—
Total				4	5	22	3		11	15		60	
% of Total				6%	8%	36%	5%		18%	25%			

Excludes complications (13 cases)

(8%) had minor discrepancies (e.g., football vs. soccer), and 3 (4%) otherwise correct records had incorrect Place of Occurrence codes, although if Place of Occurrence coding is examined independently of the issues presented above, only 6 of 34 (18%) were incorrect. The most common misclassification of Place of Occurrence codes (5 of 34, 15%) was for injuries coded "on land unspecified" that actually occurred at home or in the barracks (data not shown).

We initially set out to include in our study an evaluation of how well height, weight and use of alcohol and tobacco were documented in the medical record. While height was generally available, weight was not. Thus, this part of the review was abandoned early in the review process. Likewise, information on alcohol use was rarely present and review of this factor was also abandoned. Tobacco use (yes/no) was documented with greater regularity and was present in 84 of 118 records (71%). Of the records documenting smoking status, 35 of 84 were tobacco users (42%). This value is somewhat higher than smoking rates usually reported for the general Army population.[18]

Table 5. Qualitative assessment of injury relatedness abstracted from medical records

Principal diagnosis	Number of records	Hospitalization injury related?		Type of injury				Chart contains details of a specific event?			
				Acute[a]		Chronic					
		N	%	N	%	N	%	Yes	%	No	%
Injury (800–999)	69	69	100	58	84	11	16	64	93	5	7
Actual injury admissions (800–995)	53	53	100	42	79	11	21	48	91	5	9
Complications admissions (996–999)	15	15	100	15	100	—	—	15	100	—	—
CRO, death	1	1	100	1	100	—	—	1	100	—	—
Musculoskeletal conditions (710–739)	33	25	76	—	—	25	100	19	76	6	24
Actual admissions	23	17	74	—	—	17	100	12	71	5	29
CRO, disability	10	8	80	—	—	8	100	7	88	1	13
Other groups	16	3	19	1	33	2	67	3	100	—	—
Actual admissions	15	2	13	1	50	1	50	2	100	—	—
CRO, disability	1	1	100	—	—	1	100	1	100	—	—
TOTAL	118	97	82	59	61	59	61	86	89	11	11

[a] Acute injury is defined as the first encounter at an appropriate level of care (given the injury's severity) and with proper consideration of whether sufficient time had passed so that any acute effects of injury should have healed (e.g., the initial effects of pain, inflammation, or edema are not present).

Table 5 contains data related to the acute versus chronic nature of conditions assigned principal diagnoses within the ICD ranges of 800–999 (Injury and Poisoning) or 710–739 (Musculoskeletal Conditions). Musculoskeletal condition cases were also evaluated to see how often the condition could be linked to a prior injury based on clinical or historical information in the hardcopy records. We made no attempt to specifically validate the ICD-9-CM nature of injury codes, except to confirm that an injury-related condition was coded correctly in relation to its chronicity (710–739 versus 800–999). While there is no widely accepted definition of acute versus chronic injury, it can generally be stated that the injury is acute at the time of the first hospitalization as long as so much time hasn't gone by that the injury has healed or largely stabilized, with no symptoms of an acute event such as bruising and swelling. The records pertaining to acute injuries contained the specific details of the injury event in over 90% of the cases. All hospitalizations with injury diagnoses (800–999) were indeed injury related, although only 79% of them represented acute injuries. Additionally, 75% of the musculoskeletal condition hospitalizations could be related to an old injury or injuries, and 71% of those had details of the specific injury-causing event documented in the chart. None of the cases, on close examination, appeared to be the result of an acute injury occurring just prior to hospitalization (and therefore all were appropriately placed in the 710–739 ICD range).

The management system for electronic records within the military health care system is called the Composite Health Care System (CHCS).[19] Three hospitals responded to a request to generate an annual sample of free text (injury comment field) from the CHCS. The samples were obtained from TAMC (1993); Madigan Army Medical Center (MAMC), Fort Lewis, WA (1997); and Womack Army Hospital, Fort Bragg, NC (1997). A simple review of data in each file revealed that this field was usually completed, although less often if the diagnosis was a complication (Table 6). A significant number of injury records, however, were either blank (4% overall) or listed only the STANAG code or its definition (14%). However, a substantial number of records in all three hospitals (82%) provided important details of the injuries, including time, date, place of occurrence of the injury or a description of the mechanism of injury (e.g., "patient slipped in bathtub striking his head on the wall").

There appears to be considerable variation in the way this field is used by the hospitals. There was also substantial variation in the proportion of injured patients who were on active duty. At Womack Army Hospital (which is not a major medical center), 59.5% of the injured patients were active duty, versus 19.2% for TAMC and 13.7% for MAMC. There was also some variation in the amount of text put into the injury comment field. While the CHCS computer system does not set an arbitrary limit on the length of the text that can be entered, the actual maximum field length in these samples was 181 characters (29 words) for Womack Hospital, 222 characters (35 words) for TAMC, and 290 characters (50 words) for MAMC.

Discussion

Hospital discharge data are an important tool for injury surveillance but, as noted in the recent Armed Forces Epidemiological Board (AFEB) report,[7] there is an urgent need to assess the quality and consistency of cause-of-injury coding in military hospitals. This study is the first we are aware of to systematically evaluate the coding of injuries in the military. Although only a pilot study, the findings of this study nonetheless provide significant insight into the weaknesses and potential strengths of the military system for coding injury causes.

This work highlights some of the unusual attributes of the military health care system that have not yet been fully exploited for the study of injuries in the military. These results also suggest researchers using military data need to be careful in defining their study population and their selection criteria. Similarly, our findings make it clear that agencies reporting military hospitalization rates need to be mindful and clear in their reporting about whether or not CRO cases have been included since in several cases they are present in sufficient numbers to represent a substantial proportion of a particular hospitalization diagnostic group. Our research indicates that CROs comprise about 59% of the congenital conditions groups; for example, 33% of the musculoskeletal conditions group and 4% of all injuries. Thus, inadvertently including CROs will result in the calculation of erroneously high incidence rates for hospitalization. On the other hand, CRO cases may provide a previously untapped source of important information for researchers if properly evaluated. For example, our review of CRO cases shows how important injuries are as a cause of mortality and disability although these events are not completely counted by the hospital data collection system. CRO records may also represent the only routinely available source of ICD-9-CM diagnostic codes for military deaths or disabilities. Thus, tracking and evaluation of CRO cases might provide important insights currently not being included in injury research efforts.

The injuries documented at TAMC are similar to those documented in other military and civilian major medical centers. They did differ from those reported in smaller Army facilities. These differences may reflect in part the different missions of medical centers as referral centers versus community hospitals that are the main facilities available to active duty soldiers. Medical centers, as tertiary care facilities, might be expected to see more complications, and more seriously ill patients

Table 6. Attributes of free-text injury comment field, from three Army hospitals

	Injuries (800–995)				Complications (996–999)				Others[d]				
	TAMC[a]	MAMC[b]	Fort Bragg[c]	Total Injuries	TAMC[a]	MAMC[b]	Fort Bragg[c]	Total complications	TAMC[a]	MAMC[b]	Fort Bragg[c]	Total others	Grand Totals
Total # of records	968	511	598	2077	323	265	46	634	157	904	137	1198	3909
# providing important additional details of injury (%)	842 (87)	399(78)	457(76)	1698(82)	24 (7)	21 (8)	41(89)	86(14)	118 (75)	257(28)	97(71)	472(39)	2256(58)
# with blank comment field (%)	31 (3)	59(12)	1 (0)	91 (4)	35(11)	220(83)	0 (0)	255(40)	10 (6)	574(63)	13 (9)	597(50)	943(24)
# with repetition of STANAG code (%)	4 (0)	0 (0)	0 (0)	4 (0)	31(10)	0 (0)	0 (0)	31 (5)	5 (3)	4 (0)	0 (0)	9 (1)	44 (1)
# with repetition of STANAG code definition (%)	100 (10)	41 (8)	140(23)	281(14)	233 (72)	8 (3)	5(11)	246(39)	17(11)	50 (6)	23(17)	90 (8)	617(16)
# with only time of injury (%)	17 (2)	38 (7)	6 (1)	61 (3)	0 (0)	2 (1)	0 (0)	2 (0)	3 (2)	15 (2)	0 (0)	18 (2)	81 (2)
# with only date of injury (%)	572 (59)	83(16)	152(25)	807(39)	23 (7)	10 (4)	25(54)	58 (9)	68(43)	89(10)	43(31)	200(17)	1065(27)
# with both time and date of injury (%)	167 (17)	163(32)	102(17)	432(21)	0 (0)	4 (2)	0 (0)	4 (1)	18(11)	95(11)	4 (3)	117(10)	553(14)

[a] All hospitalizations at Tripler Army Medical Center, Honolulu, HI, 1993.
[b] All hospitalizations at Madigan Army Medical Center, Fort Lewis, WA, 1997.
[c] All hospitalizations at Womack Army Hospital, Fort Bragg, NC, 1997.
[d] Others include all hospital records that had principal diagnoses that were not between ICD 800–999, but which did have a secondary diagnosis in the 800–999 range.

than small or medium hospitals. In general, regarding the distribution of injuries observed in our pilot validation facility, TAMC compares well to other large facilities and suggests that TAMC provides a reasonable source of information by which to validate injury coding at large Army medical centers. These results are less generalizeable to smaller Army facilities as the types of injuries seen in smaller facilities are different and coding practices appear to vary somewhat (e.g., fewer missing codes for duty status are seen in medium and smaller Army facilities).

Results from our pilot review indicate that in approximately half the cases, work activity at the time of the injury and intentionality of the injury (Trauma Code) is coded "unknown" and this severely limits our ability to describe and track occupational injuries. This occurs in spite of the presence of sufficient data in the medical records to determine intent and work-relatedness over 50% of the time. Careful review of the "unknowns" indicates that in about half of these cases the correct code should have been "off-duty" and for about a third of the cases "on-duty." The other "unknowns" that could be coded using information in the medical record comprised assaults and self-inflicted injuries, which often occur off duty. Given this, the true proportion of off-duty injuries is likely to be closer to two thirds. This has obvious and important implications for prevention and intervention efforts.

Smaller Army facilities appear to be doing a better job at coding duty status. It is not clear why this is the case. Perhaps the proximity of these facilities to day-to-day Army operations and training results in greater understanding and appreciation for the characteristics of these injuries. Perhaps greater command interest at these locations has some influence over the quality and completeness of injury records. The achievement of a 3% rate of unknown Trauma coding at one facility (Gorgas Army Hospital, Panama) suggests far greater potential for the other Army hospitals. The general inability to identify work-relatedness represents a deficiency both of coding and recording of critical information in the patient records. Since the reviewer spent more time with each record than the average hospital coder would be able to, early and complete documentation of injury data will also be necessary. With the combination of better documentation and coding practices, however, the ability to identify the occupational nature of injuries could quickly be turned into a major strength of the present STANAG coding system.

The considerable variation in the percentage of self-inflicted and assault Trauma codes recorded suggests that these may be underreported as well. Injuries resulting from fights should have received a Trauma code for assault but in many cases were instead coded as "unknown." This resulted in a greater number of records with an Injury code = "fighting" than there were Trauma codes = "assault." Since fights are only one possible activity associated with assaults, the fact that they are coded so much more frequently than assaults in general may be indicative of widespread underreporting of assaults. Greater command interest in complete hospital data record keeping and training of admission clerks and nosologists would be useful in trying to improve the quality of data around intentional injuries, both on and off duty. Part of the problem with data quality derives not just from improper procedures but also from inadequacies of the STANAG system itself in coding modern injury problems. Injuries from combat have represented a relatively minor problem in recent history, a period characterized by few major conflicts. Active duty patients still do not represent the majority of the patient population for the average military hospital, further supporting the need for a system that captures adequate data for all types of injuries, not just injuries associated with armed conflict.

The coding of injury mechanism (Injury code) was generally very good in comparison to reported civilian systems.[8] Qualitative review suggests that the choice of STANAG Injury codes is generally accurate despite the fact that a small percentage of the cases may have been more properly coded as musculoskeletal conditions. Cases coded as musculoskeletal conditions were found reliably in the expected range of ICD-9-CM 710–739. The documentation present in the records provides insight into the history of musculoskeletal conditions. Indeed, one of the most important findings of this study might be the fact that the majority of musculoskeletal conditions appear to be the direct result of prior injuries. Unfortunately, current computer edits, as well as systemwide policy, preclude the coding of injury cause for musculoskeletal conditions that, despite being chronic in nature, nonetheless result from prior injury (this also holds true under ICD-9-CM and thus is not a unique shortcoming of STANAG). We demonstrated that most records already have sufficient information to code for this if the record systems could be modified to allow musculoskeletal conditions to receive a cause of injury code.

While some may speculate that misclassified injury cases might cause policymakers and researchers to overestimate the true injury burden faced by the military, we found evidence to suggest that just the opposite is probably occurring. While the growing trend toward managing acute injuries on an outpatient basis is a major force reducing injury hospitalization rates, the incidence of hospitalized musculoskeletal conditions and disabilities in the Army has been growing steadily for the past decade. In this small sample from TAMC, we found that the vast majority (75%) of musculoskeletal conditions were related to old injuries. This indicates that the true burden of injury is probably far greater than that reflected by the typically used acute injury principal diagnostic group (ICD 800–999). In addition, the proportion of disabilities related to the musculoskeletal system is eye opening and serves as further compelling evidence that injuries are the greatest health problem of the modern Army.

The STANAG coding system is simple. In order to code injuries, a coder selects one of 10 Trauma codes and one of approximately 293 Injury codes. While having few codes can potentially limit the specificity of the coding system, it does make it easier to achieve complete coding on all records. The use of a system of computer edits also prevents missing cause codes or erroneous assignment of codes to records that do not call for them. Unfortunately, the computer edits presently employed also preclude the recording of injury data on "musculoskeletal conditions," many of which represent old injuries.

Trauma and Injury codes may be entered by individuals who might lack medically appropriate training. However, unlike nature-of-injury diagnoses, cause data are much easier to code. If these data are not reviewed and changed when appropriate (such as upon discharge when the full history of the hospitalization course is available), they will not reflect accurate information. The Trauma code is not exhaustive nor mutually exclusive, so recording complete information regarding intent and work-relatedness is not possible.[10]

There is little or no formal guidance provided on use of the Trauma code or on completion of the free-text field (Injury comment field). The free-text field, already available in the current version of the military hospital data system software (CHCS) may be used by hospitals for recording important details of injury events. This free text has the potential to provide important information for planning and evaluating prevention programs. This information has not previously received formal evaluation, but has proven extremely useful elsewhere in studies of injury hospitalization, particularly in New Zealand where such data are routinely reported on the hospital discharge file.[10,20–23] Free text is especially useful for providing additional details on the cases but perhaps less useful as an alternative means of finding all specific cases due to inconsistencies in recording free text data.[24] This text should become part of the Standard Inpatient Data Record (SIDR) and consideration should be given to training admissions clerks to record as many of the components of the minimum basic data sets for intentional[25] and unintentional[26] injury as possible at the time of admission. Recording this information on hospital injury cases was one of the major recommendations of the AFEB report on improving hospital data.[7]

The military, as a closed system, accomplishes a very complete capture of hospitalizations. In order for a hospitalization to go undetected, an individual would most likely have to be on leave, be hospitalized in a nonmilitary hospital, and either pay the cost of the hospitalization entirely out of pocket, or by the use of a spouse's health insurance. However, the military has a very strict requirement for complete accountability of active duty personnel, including both on- and off-duty time, and is thus likely to record the hospitalization. In addition, because military service members have unlimited sick leave, a failure to report (or an attempt to conceal) a hospitalization outside military hospitals results in sick days counting against vacation time, a further disincentive to seeking care outside the military medical care system.

Another important aspect of military hospitalization data is that a composite record that includes all hospitalizations for the same episode of care can be constructed. Thus, if a soldier experiences a car crash, is admitted to a civilian hospital, is subsequently transferred to a specialized military hospital, and later transferred back to the military hospital closest to his home, this entire episode of care can be considered as a single event. The use of unique identifiers and "transfer in" and "transfer out" codes in military medical records databases make it feasible to evaluate each episode of care and to avoid overcounting single injury events as multiple injuries when they are simply transfers for the same injury to other facilities. Analyses using the TAIHOD indicate that between 4% and 7% of the total number of admission records (depending on diagnostic code group) represent transfers (PJA, unpublished observations, 1999). As with the CRO records, failure to account for these transfer records will result in an overestimation of injury events (by as much as 7%). In civilian hospitals, a similar situation would be recorded by three separate hospitalization records that could not even be identified as the same episode of care.[27]

The apparent lack of attention to the available detail in the hardcopy records as well as a general failure to capitalize on the unique data collection system already in place in military hospitals represents an important missed opportunity to more accurately describe injuries. The STANAG coding system has been used to cause-code virtually 100% of injury records spanning almost 4 decades and the CHCS has offered an unlimited injury comment field for over 5 years! There is no comparable injury data source in any civilian hospital record system that has data going back as far. With the size of the population served exceeding 1.5 million healthy workers, military hospital discharge databases provide an excellent source of research data.

The lack of availability of basic information in the chart pertaining to the health habits of individual patients (such as alcohol intake) is disappointing from a research or prevention priority perspective. For many individuals, hospitalizations represent the most significant interaction they will ever have with the health care system. An opportunity for intervention is available that could be used to greater benefit. While information on tobacco use was present in a majority of the inpatient records, alcohol intake was not, and even basic anthropomorphic details such as height and weight were not reliably present. A health habit survey administered to all hospitalized patients with key components included in SIDR would be a good place to start. The recent DoD initiatives establishing tobacco and alcohol control[28] and injury prevention as three top prevention priorities might also be served by such an activity. The relationship of alcohol use to injury risk is well established,[29–31] and in addition to the already well-established health risks of tobacco, the understanding of the influence of tobacco on risk of injury is growing.[32–34]

Hospitalized injuries represent an important cause of morbidity in the military as they are a costly group of injuries both in terms of direct treatment as well as decreased military readiness. A few changes in the current system could have enormous implications for improving policy and injury intervention efforts. For example, it is essential to have good data on both cause and duty status in order to develop effective prevention policies. As this study indicates, the system exists to provide this information but it is limited by the quality of the information provided to the coders and the degree to which coders are trained or required to use it. In the small series of cases reviewed, information on duty status was still not possible to ascertain in 25% of the cases. This finding is not unique to one hospital but is a systemwide problem. Training is needed both for better coding practices and for better documentation of critical patient data in the record. A mechanism needs to be set up to ensure the accurate and reliable coding of duty status. Off-duty injuries could be the major cause of lost readiness, but without a valid means of studying the duty status of injured soldiers this cannot be accurately assessed. Similarly, it is very difficult to identify preventable on-the-job injuries under the current system. Determination of more precise statistics in this regard will have important implications for planning prevention programs since programs tailored to the more tightly controlled military work environment will differ substantially from those designed to target off-duty injuries, a realm that the military has far greater influence over than civilian employers might expect.

Additional study of the quality of injury coding is needed, particularly of small- and medium-sized military treatment facilities and the hospital systems of the Air Force and Navy. However, even with the small sample used here, there is compelling evidence to consider changes to current Army hospital procedures. Increased staff training, greater involvement of command in hospital data quality assurance and serious discussion about the merits of maintaining and improving the use of the STANAG system seem warranted. The new ICD-10-CM will be fully implemented in several years, and any changes proposed to the STANAG system should first consider the possibility of using the ICD-10-CM to replace the STANAG entirely. Greater utilization and standardization of the free-text fields should begin immediately and the data should be made available in a centralized database along with the currently formatted standard inpatient records.

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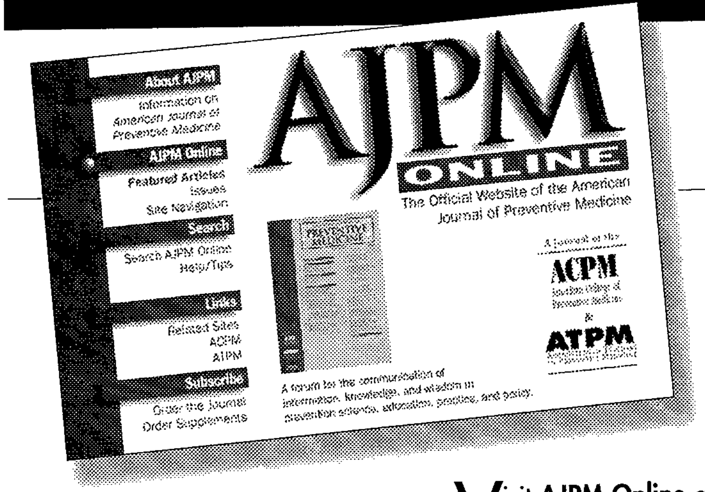

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