

## Measuring the Public Health Impact of Injuries

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Received for publication April 16, 2003; accepted for publication April 24, 2003.

Abbreviations: ADL, activities of daily living; AIS, Abbreviated Injury Scale; DALYs, disability adjusted life years; EuroQoL, European quality of life; FCI, Functional Capacity Index; IADL, instrumental activities of daily living; QWB, quality of well-being; SF-36, Short-Form Health Survey; YPLL, years of potential life lost.

### INTRODUCTION

In its groundbreaking 1985 report, *Injury in America: A Continuing Public Health Problem*, the Institute of Medicine's Committee on Trauma Research stated that "injury is caused by acute exposure to energy, such as heat, electricity, or the kinetic energy of a crash, fall, or bullet. It may also be caused by the sudden absence of essentials, such as heat or oxygen, as in the case of drowning. Injury may be either unintentional (accidental) or deliberate (assaultive or suicidal)" (1, pp. 3–4). The extent, severity, and impact of injury are largely determined by the amount of this energy concentrated outside the band of human tolerance. Records on the impact of injuries date back to biblical times, when we are told about the massive drowning that occurred when "the waters returned and covered the chariots and the horsemen and all the hosts of the Pharaoh that had followed [the Israelis] into the sea; not so much as one of them remained" (Exodus 14:28).

Although the specific mechanisms by which injuries happen may have changed over time, the collective impact on society of all fractures, sprains, cuts, contusions, and the many other forms of injury has been felt since the beginning of history. Measuring this impact and its characteristics has been critical to our efforts to identify priorities for programs and policies aimed at reducing injuries and their consequences. In contrast to other reviews, which present scales to measure the impact of injuries at the individual level (2), in this paper we focus on metrics used to quantify the burden of illness and injuries to populations. We present the evolution of these metrics and discuss their application to injury. We start with those that quantify the burden related to fatal injuries. We then cover metrics that expand the measurement to

nonfatal injuries. Lastly, we discuss metrics that integrate fatal and nonfatal consequences. For each metric, we summarize its characteristics, advantages, and disadvantages. When possible, we also present what knowledge each has contributed to our understanding of the "burden" of injuries. Table 1 lists all of the metrics reviewed, together with the principal reference describing their development. Table 2 summarizes the extent to which the metrics cover fatal and/or nonfatal consequences, whether they apply to subpopulations, and whether there are population norms for them (at least in the United States).

### MEASURING THE BURDEN OF INJURIES—METRICS BASED ON MORTALITY

Counts of the absolute numbers of injury deaths and their relation to other causes of death have been one of the primary means of quantifying the burden of injuries. They remain an important metric for establishing injuries as an important public health problem. The first published leading cause-of-death report in the United States showed unintentional injuries as the fourth cause of death over all ages, suicide as the 12th, and homicides as the 18th for the year 1949 (3). In 2000, the latest year for which similar statistics are available, the 97,900 fatal unintentional injuries constituted the fifth leading cause of death, after diseases of the heart, malignant neoplasms, cerebrovascular disease, and chronic lower respiratory diseases (4) (table 3). Suicides ( $n = 29,350$ ) have increased in rank from 12 to 11 and homicides ( $n = 16,765$ ) from 18 to 14 (5). Taken together, all injuries (unintentional and intentional) constitute the fourth leading cause of death over all ages.

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**TABLE 1. Measurement of the public health burden of injuries according to all metrics reviewed in the text**

Metric reviewed*	Year of publication	Author(s)	Reference no.†
Death counts		N/A‡	N/A
Leading cause of death		N/A	N/A
Death rates		N/A	N/A
Years of potential life lost	1947	Dempsey	7
Counts of health care utilization (e.g., hospitalization, emergency department use)			N/A
Abbreviated Injury Scale	1970	AAAM‡	18
Costs			
Activities of daily living/independent activities of daily living	1965 and 1963	Mahoney and Barthel; Katz and Lyerly	32, 33
Short Form 36	1992	Ware and Sherbourne	38
Quality of well being	1982	Kaplan and Bush	56
European quality of life (EQ-5D)	1990	EuroQol group	59
Health Utility Index	1995	Feeny et al.	65
Health and activity limitations	1995	Erickson et al.	68
Functional Capacity Index	1996	MacKenzie et al.	69
Injury Impairment Scale	1994	AAAM	71
Disability adjusted life years	1997	Murray and Acharya	75
Healthy days	2000	CDC‡	81
Healthy expectancy	2001	Molla et al.	44
Short Form-6D	2002	Brazier et al.	84

\* Listed in the same order as in the text; some rows do not contain any relevant information.

† The principal reference describing development of the metric.

‡ N/A, not applicable; AAAM, Association for the Advancement of Automotive Medicine; CDC, Centers for Disease Control and Prevention.

Further breakdowns of the leading causes of death by age and gender provide interesting additional information on the burden of injuries. For example, among children and young adults aged 1–34 years, unintentional injuries, homicide, and suicide constitute the first, second, and third leading causes of death, respectively. More lives of persons aged 1–34 years are lost to injury than to all other causes of death combined (table 3). For males of all ages, unintentional injuries are the fourth leading cause of death, suicides the eighth, and homicides the 14th; among women of all ages, unintentional injuries are the seventh leading cause of death and suicide the 19th (for females, homicides do not rank in the top 20 leading causes of death) (5).

Within injuries, the leading mechanisms of death are related to motor vehicles and firearms, accounting for 31 percent and 19 percent of all injury deaths in 2000, respectively, or one half of all injury deaths when taken altogether. Falls account for an additional 9 percent of injury deaths and poisonings for 13 percent. However, the distribution of injury deaths by mechanism varies widely by age and gender (5), although a detailed description of those distributions is beyond the scope of this review.

To better measure the aggregate impact of injury as a leading cause of death among children and young adults, we move from looking at absolute counts of deaths to summarizing years of potential life lost (YPLL) (6). Introduced in 1947 (7), YPLL measures combine information about age at

death with potential years of life left to live. Some of the earliest applications of YPLL showed that “accidents” were already the second leading cause of standardized lost years of life in 1940, after diseases of the heart (8). Several variations of YPLL have been reported depending on whether one uses age 65 years, age 75 years, country- or gender-specific life expectancy data, or any other arbitrary definition of an age before which it is “premature” to die. Each variation is likely to be labeled slightly differently, such as potentially productive years of life lost, working years lost, or reducible burden of disease. Regardless of the specifics of the definition, however, YPLL continues to be a powerful metric for quantifying the overall burden of injury in terms of lives lost. Figure 1 presents the leading causes of YPLL in the United States in 2000. Injuries are the leading contributor to YPLL before age 65 years, accounting for 28.5 percent of all YPLL. Unintentional injuries alone account for 18 percent and constitute *the* leading contributor to YPLL, followed by malignant neoplasms (16.6 percent), heart disease (12.2 percent), perinatal-period conditions (8.1 percent), suicide (5.6 percent), and homicide (4.9 percent). Human immunodeficiency virus, another health condition affecting disproportionately younger persons, represents 2.8 percent of all YPLL (5).

Somewhat different patterns of the burden of injury emerge when counts of deaths are translated into rates by dividing by an appropriate denominator. In the United

**TABLE 2. Selected characteristics regarding measurement of the public health burden of injuries according to all metrics reviewed in the text**

Metric reviewed*	Fatal	Nonfatal		Applicable to			US population norms available
		Short term	Long term	Children	The elderly	Special populations	
Death counts	Yes	No	No	Yes	Yes	Yes	N/A†
Leading cause of death	Yes	No	No	Yes	Yes	Yes	N/A
Death rates	Yes	No	No	Yes	Yes	Yes	N/A
Years of potential life lost	Yes	No	No	Yes	Yes	Yes	N/A
Counts of health care utilization (e.g., hospitalization, emergency department use)	Yes	Yes	Some	Yes	Yes	Yes	N/A
Abbreviated Injury Scale	No	Yes	No	Yes	Yes	Yes	N/A
Activities of daily living/instrumental activities of daily living	No	Yes	Yes	Yes/No	Yes	Yes	Yes
Short Form 36	No	Yes	Yes	Yes‡	Yes	Yes	Yes
Costs	Yes	Yes	Yes	Yes	Yes	Yes	No
Quality of well-being	Yes	Yes	Yes	Yes	Yes	Yes	No
European quality of life	Yes	Yes	Yes	Yes	Yes	Yes	No
Health Utility Index	Yes	Yes	Yes	Yes	Yes	Yes	No
Health and activity limitations	Yes	Yes	Yes	Yes	Yes	No§	Yes
Functional Capacity Index	Yes	Yes¶	Yes	Yes#	Yes	No	Yes
Injury Impairment Scale	No	Yes	Yes	No	Yes	Yes	No
Disability adjusted life years	Yes	Yes	Yes	Yes	Yes	Yes	Yes**
Healthy days	No	Yes	Yes	No§	Yes	No§	Yes
Healthy expectancy	Yes	Yes	Yes	No§	Yes	No§	Yes
Short Form-6D	Yes	Yes	Yes	Yes	Yes	Yes	Yes††

\* Listed in the same order as in the text.

† N/A, not applicable.

‡ The Child Health Questionnaire (92) is based heavily on the Short Form 36.

§ The US National Health Interview Survey may not adequately sample this subpopulation.

¶ If the Abbreviated Injury Scale-F12 is used, only longer-term consequences are evaluated.

# A pediatric version of the Functional Capacity Index is nearing completion (C. Gotschall, National Highway Traffic Safety Administration, personal communication, 2003).

\*\* Not US specific, but within-region specific.

†† But with preferences from the United Kingdom.

States, people die from injuries at an overall rate of 34.4 per 100,000 persons per year. However, the risk of injury death varies considerably by age and gender, with the elderly at greatest risk (figure 2). The annual injury death rate for persons aged 75 years or older is 169 per 100,000—almost five times higher than the rate for all ages combined. In fact, although persons aged 65 years or older comprise only 13 percent of the US population, they account for approximately 26 percent of all injury deaths (5).

Although the most commonly used denominators are population size or person-years, others better reflect exposure to injurious events, such as million vehicle (or kilometer) miles traveled or hours worked. The annual motor vehicle death rate has declined by 90 percent, from 18 per million vehicle miles traveled in 1925 to 1.7 per million vehicle miles traveled in 1997 (9). Deaths from unintentional work-related injuries also declined 90 percent, from 37 per 100,000 workers in 1933 to 4 per 100,000 in 1997 (10). In fact, because of the decline in these rates over the years, the

Centers for Disease Control and Prevention (Atlanta, Georgia), in looking forward to the 21st century, identified motor vehicle safety and safer workplaces as two of the top 10 greatest public health achievements of the 20th century (11). On the other hand, the rate of homicides has fluctuated over the last decade, from a low of 5 per 100,000 during the 1950s to a high of about 11 per 100,000 in the mid-1980s, while the rate of suicide has remained relatively stable (12).

### BEYOND FATAL INJURIES: COUNTING SURVIVORS, THEIR INJURIES, AND THEIR OUTCOMES

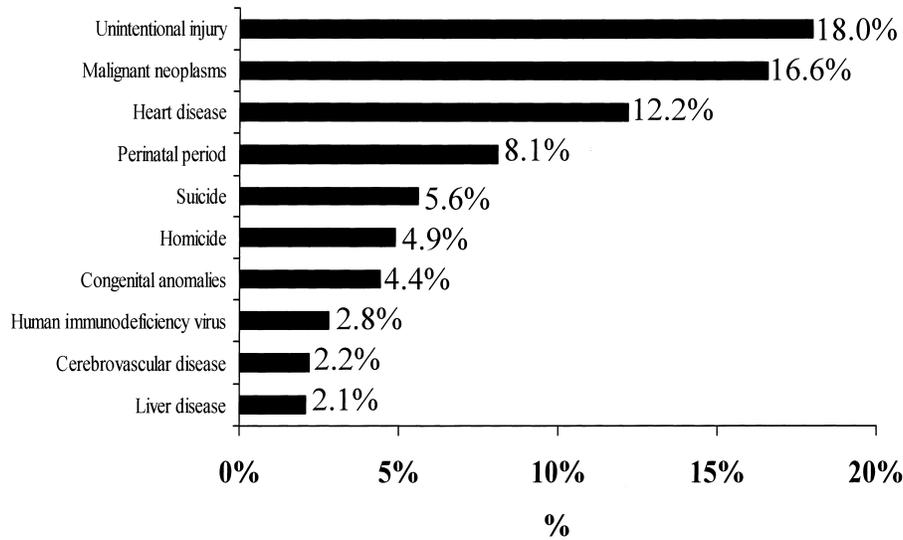
Although the number of deaths from injury is still unacceptably high (e.g., nearly 148,000 per year in the United States alone), a steady decline over time has increased interest in quantifying the burden of nonfatal injury. Early estimates of the number and rate of nonfatal injuries were based primarily on use of the health care system. Counts and rates of health care encounters, such as hospitalizations, visits

TABLE 3. The 15 leading causes of death for all races and both sexes, by age group, United States, 2000\*

	<1 year	1-4 years	5-9 years	10-14 years	15-24 years	25-34 years	35-44 years	45-54 years	55-64 years	≥65 years	All ages
1 Congenital anomalies	Unintentional injury	Malignant neoplasms	Malignant neoplasms	Malignant neoplasms	Heart disease	Heart disease					
2 Short gestation	Congenital anomalies	Congenital anomalies	Malignant neoplasms	Malignant neoplasms	Homicide	Suicide	Unintentional injury	Heart disease	Heart disease	Malignant neoplasms	Malignant neoplasms
3 Sudden infant death syndrome	Malignant neoplasms	Malignant neoplasms	Malignant neoplasms	Suicide	Suicide	Homicide	Heart disease	Unintentional injury	Chronic lower respiratory tract disease	Cerebrovascular disease	Cerebrovascular disease
4 Maternal pregnancy complications	Homicide	Homicide	Homicide	Homicide	Malignant neoplasms	Malignant neoplasms	Suicide	Liver disease	Cerebrovascular disease	Chronic lower respiratory tract disease	Chronic lower respiratory tract disease
5 Placenta cord membrane	Heart disease	Heart disease	Heart disease	Congenital anomalies	Heart disease	Heart disease	HIV†	Cerebrovascular disease	Diabetes mellitus	Influenza and pneumonia	Unintentional injury
6 Respiratory distress	Influenza and pneumonia	Heart disease	Benign neoplasm	Heart disease	Congenital anomalies	HIV	Liver disease	Suicide	Unintentional injury	Diabetes mellitus	Diabetes mellitus
7 Unintentional injury	Septicemia	Chronic lower respiratory tract disease	Chronic lower respiratory tract disease	Chronic lower respiratory tract disease	Cerebrovascular disease	Diabetes mellitus	Homicide	Diabetes mellitus	Liver disease	Alzheimer's disease	Influenza and pneumonia
8 Bacterial sepsis	Perinatal period	Influenza and pneumonia	Influenza and pneumonia	Cerebrovascular disease	Chronic lower respiratory tract disease	Cerebrovascular disease	Cerebrovascular disease	HIV	Nephritis	Nephritis	Alzheimer's disease
9 Circulatory system disease	Benign neoplasm	Septicemia	Septicemia	Influenza and pneumonia	Influenza and pneumonia	Congenital Anomalies	Diabetes mellitus	Chronic lower respiratory tract disease	Suicide	Unintentional injury	Nephritis
10 Intrauterine hypoxia	Chronic lower respiratory tract disease	Cerebrovascular disease	Cerebrovascular disease	Benign neoplasm	HIV	Liver disease	Influenza and pneumonia	Viral hepatitis	Septicemia	Septicemia	Septicemia
11 Neonatal hemorrhage	Cerebrovascular disease	Perinatal period	Perinatal period	HIV	Diabetes mellitus	Influenza and pneumonia	Chronic lower respiratory tract disease	Septicemia	Influenza and pneumonia	Pneumonitis	Suicide
12 Atelectasis	Meningitis	Anemias	Anemias	Anemias	Septicemia	Chronic lower respiratory tract disease	Septicemia	Influenza and pneumonia	Aortic aneurysm	Parkinson's disease	Liver disease
13 Necrotizing enterocolitis	Anemias	HIV	HIV	Septicemia	Benign neoplasm	Septicemia	Viral hepatitis	Homicide	Hypertension	Hypertension	Hypertension
14 Homicide	Meningococcal infection	Meningitis	Meningitis	Diabetes mellitus	Complicated pregnancy	Nephritis	Nephritis	Nephritis	HIV	Atherosclerosis	Homicide
15 Chronic respiratory disease	HIV and nephritis (tied)	Meningococcal infection	Meningococcal infection	Meningitis	Nephritis	Complicated pregnancy	Congenital anomalies	Hypertension	Benign neoplasm	Aortic aneurysm	Pneumonitis

\* Source: US National Center for Health Statistics Vital Statistics System, Washington, DC (5).

† HIV, human immunodeficiency virus.

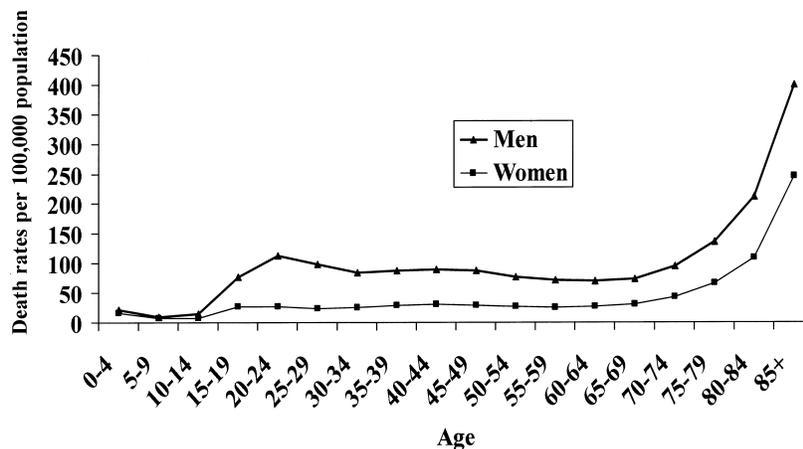


**FIGURE 1.** Leading causes of years of potential life lost before age 65 years, percentage by cause for both genders and all deaths, United States, 2000.  $N = 11,261,211$  years of potential life lost; the remaining 23.1% due to an assortment of causes. Adapted from the National Center for Health Statistics (5).

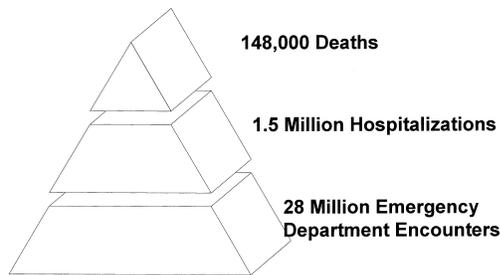
to emergency departments, or admissions to rehabilitation facilities, are still commonly used to describe the frequency as well as the severity of nonfatal injuries. It is estimated that, in the United States every year, approximately 1.5 million injured patients are discharged from hospitals (13). These discharges represent almost 8 percent of all hospital discharges, making injuries the second most common first-listed diagnoses in hospital discharge summaries after heart disease (14). At least 28 million people require a visit to an emergency department each year because of injuries, and injuries account for 30 percent of all emergency department visits (15). These figures quickly show that deaths from injury represent only the tip of an “injury pyramid”—a graphic representation of the burden of injury first intro-

duced in 1984 (16). The shape of the “pyramid” (i.e., the ratios between levels) may vary by geographic location, by age, by injury mechanism, or over time; figure 3 shows an example for all injuries that occurred in the United States in 2000, where, for each injury death, there were 10 injury-related hospitalizations and some 190 emergency department visits (5).

However, nonfatal injuries vary widely in their severity. Even though treatment is, by itself, an indication of the severity and intensity of the resources needed to treat patients, a number of other metrics have been developed to more directly assess these aspects (17). The severity measure most widely used in epidemiologic studies is the Abbreviated Injury Scale (AIS), first developed by the Association



**FIGURE 2.** Injury death rates by age group (years) and gender, United States, 2000. Adapted from the National Center for Health Statistics (5).



**FIGURE 3.** Example of an injury pyramid for all injuries occurring in the United States in 2000. Adapted from the National Center for Health Statistics (5).

for the Advancement of Automotive Medicine in 1970 (18) and currently in its 1998 revision (19). It principally measures threat to life on an ordinal scale that ranges from 0 (no injury) to 6 (virtually unsurvivable). Scores for single injuries can be combined to estimate the effect of multiple injuries sustained by a given person. While the most commonly used metric in this regard is the Injury Severity Score (20), the New Injury Severity Score (21), the Anatomic Profile (22), and the Anatomic Profile Score (23) have recently been shown to outperform the Injury Severity Score (24).

The US National Highway Traffic Safety Administration incorporates the AIS into their National Automotive Sampling System Crashworthiness Data System (25). This population-based probabilistic sample collects in-depth investigations of crashes for which a police report is filed; when at least one of the vehicles involved is a passenger vehicle, light truck, minivan, or utility vehicle; and when at least one of those vehicles is towed away from the crash scene. On the basis of this database, the agency estimates that among the 5.3 million victims of nonfatal crashes who sustained some injury during 2000, 89 percent had an AIS score of 1 for their most severe injuries, 8 percent had an AIS score of 2, 2 percent had an AIS score of 3, and less than 1 percent had AIS scores of 4 or 5 each (26).

The AIS can also be applied to injury data coded by using the *International Classification of Diseases*, Ninth Revision, Clinical Modification (27), one of the most widely adopted coding systems of injury descriptors (28), through a computerized algorithm first developed in 1989 (29). Applications of this algorithm to population-based hospital discharge records enable the distribution of the severity of injuries in those settings to be characterized. As an example, Nathens et al. applied the algorithm to hospital discharge data from 18 states and estimated the rate of major trauma (discharges with overall Injury Severity Scores of >15) to be 44 per 100,000 person-years, or approximately 11 percent of all hospital trauma discharges (30).

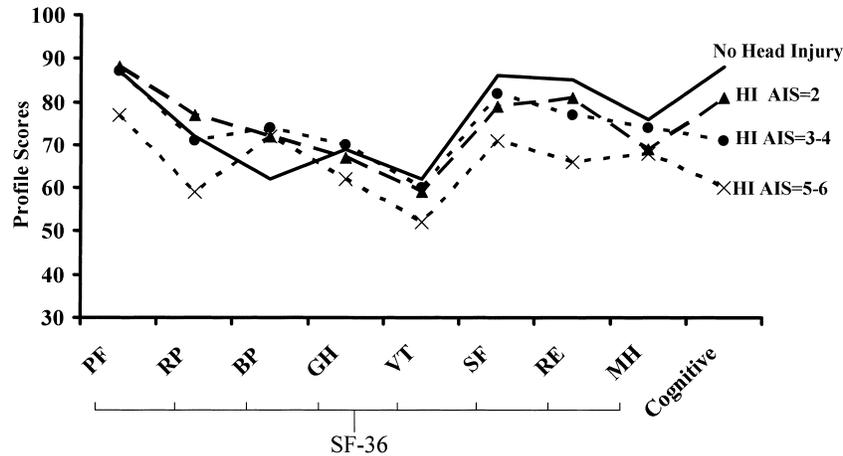
It is clear from our preceding discussion that we know a lot about the incidence of both fatal and nonfatal injuries and have developed the tools to disaggregate nonfatal injuries by severity. Although these measures of severity provide some understanding of the relative seriousness of injuries in terms

of threat to life and resource utilization, they still fall short in measuring the longer-term impact of nonfatal injuries on the person, his or her family, and society at large. Although many nonfatal injuries are minor and result in only 1 or 2 days of restricted activity, many others have far-reaching consequences and are often significant enough to limit employment and recreation for the remaining lives of the persons injured. These considerations have challenged the field to move beyond counting injuries by severity alone to measuring their direct impact on health-related quality of life.

Measures of functional outcome and general well-being are becoming increasingly important in evaluating strategies to reduce the burden of injury (31). Early measures of functional outcome focused on assessing limitations in activities of daily living (ADL) (32) and instrumental activities of daily living (IADL) (33). ADL measures typically assess limitations in self-care only (e.g., bladder and bowel control, toilet use, grooming, bathing, dressing, feeding, transfer), whereas IADL measures include a broader set of daily activities that community-based living demands (e.g., shopping for personal items, preparing meals, performing light and heavy housework, and managing personal finances). Although ADL and IADL measures were originally developed to monitor function and independent living among the elderly, they have been widely applied in both clinical and population-based studies to describe the long-term consequences of a variety of conditions, including injuries. In an analysis of ADL and IADL information derived from the 1994 US National Health Interview Survey Disability Supplemental Phase I (34), injuries were reported to be responsible for chronic disabilities among 5.6 million people aged 18–69 years, and IADL and ADL problems were reported by 1,256 and 370 persons per 100,000 population, respectively.

Although ADL and IADL measures remain a standard for measuring outcome among the elderly, the chronically ill, and the severely injured, they are not as sensitive to variations in outcome at the higher levels of functioning more typical of orthopedic injuries or mild-to-moderate brain injuries (35). To more appropriately measure the impact of these injuries, a variety of health status measures have been proposed that incorporate a broader definition of outcome to include elements of role activity, social functioning, psychological well-being, and general health perceptions. These measures typically describe health status across a set of domains of function, and they yield separate scores for each domain usually presented in a profile format (although one or more summary scores may also be available). Most of these measures could be referred to as *psychometric measures* of health status, a term coined to describe scales derived by using the principles of psychological theory (36). They stand in contrast to a set of *preference-based measures* that incorporate values for health states and allow death to be one of the possible health states (37); *preference-based measures* are reviewed later in this paper.

An example of one of the most commonly used psychometric-based measures for assessing the impact of injury is the Short-Form Health Survey (SF-36) (38). This survey has gained popularity as a tool for measuring injury outcomes,



**FIGURE 4.** Short-Form Health Survey 36 (SF-36) and cognitive functioning scores for patients with head injury (HI) but no orthopedic injury, by Abbreviated Injury Scale (AIS) level. PH, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role emotional; MH, mental health. Adapted from MacKenzie et al. (42).

largely because of its well-established reliability and validity, versatility (i.e., it is available in paper, telephone, and computerized versions and has been translated into several languages), brevity (it takes 5–10 minutes to complete), and availability of population norms. The SF-36 consists of 35 items that cover eight domains: physical functioning, role limitations due to physical health, pain, social functioning, role limitations due to emotional problems, mental health, vitality, and general health perceptions. A 36th item relates to changes in health status during the year prior to the interview. Besides the profile resulting from the scores for the eight domains, two summary scores can be derived to describe physical and mental health. Several examples of its application to injured patients and populations are available (39–42).

For example, a recent population-based analysis in New Zealand of drivers in motor vehicle crashes in which at least one occupant required hospital admission showed that being the hospitalized driver increased fivefold the likelihood of having a worse health status 18 months after injury than age-, gender-, and ethnicity-matched “control” drivers not involved in similar crashes (and despite having a similar SF-36 score at baseline). It also showed that being a nonhospitalized driver in such a crash also increased significantly the probability of having a worse health state than that of the general driver population, although this increase was only threefold (43).

Except for researcher-initiated applications of the SF-36 to investigate long-term effects on injured populations or to quantify SF-36 population norms, we are not aware of any population-level database that routinely incorporates this scale; such a database would enable researchers to monitor the impact of injuries over time or to investigate the differential impact of different injuries in the population. (In addition, we are not aware of any other psychometric-based metric routinely collected in any population-based data set.)

Several applications of the SF-36 have uncovered a few areas of concern, such as the lack of items specifically relating to cognitive function (36, 42) or to genitourinary and sexual function (39), areas of special interest for injured populations. Figure 4 illustrates the potential to better characterize populations with traumatic brain injuries if a cognitive function domain were added to the SF-36. It displays mean domain-specific SF-36 scores for 180 major trauma patients who sustained a head injury but no orthopedic injury. Added to the standard SF-36 is a cognitive function score based on an additional four survey items. As evident from this figure, the standard SF-36 profile does not discriminate well between patients with no head injury and those with a head injury of varying AIS injury severity (ranging from mild (AIS 2) to severe (AIS 5–6)). Adding the cognitive function score helps to better discriminate among these subgroups of the trauma population. Results of this study argue for supplementing the SF-36 with a measure of cognitive function when it is used to measure the burden of injury resulting from trauma involving head injury.

Even if the scales reviewed above were more comprehensive and sensitive to the long-term impact of injuries, they are still limited in measuring the full burden of injury because they are undefined for people who die. A single unit that synthesizes fatal and nonfatal short- and long-term consequences is needed by epidemiologists to monitor health (or burden) levels over time; by program developers and health care planners who need to design, implement, and evaluate prevention strategies; and by decision analysts and economic evaluators who want to investigate the efficiency of interventions and help prioritize implementations. The need to develop a single metric that integrates changes in longevity with changes in disability, functionality, pain, and emotional distress has been stressed by bodies as varied as the World Health Organization, the Organization for Economic Cooperation and Development (44), and the US Institute of Medicine (45). In the next several sections, we

describe the availability of such measures and their application to injury.

### ECONOMIC COSTS OF FATAL AND NONFATAL INJURIES

A common and often powerful single measure of the burden of injury and/or illness is the sum of the economic costs associated with the incidence or prevalence of a particular condition. In an incidence-based approach, all new injuries that occur within a defined time period (e.g., a year) are identified and the costs associated with those injuries delineated. For example, lifetime costs can be calculated if that is the time frame chosen to describe the long-term impact of those incident injuries. A prevalence-based approach, on the other hand, involves identifying all costs associated with injury-related consequences suffered in a given time frame (regardless of when the injury actually occurred). The costs are typically calculated for the same period of time used to define prevalence. These two approaches can lead to very different numbers. Their choice should be dictated by the application at hand, although, in general, cost figures derived to identify burden of injury and plan preventive strategies should use an incidence-based approach, whereas cost figures needed for health services planning should be prevalence based. (This incidence vs. prevalence consideration is relevant to all measurements of the impact of injury; however, it becomes more relevant as long-term assessments are conducted.)

Developing cost estimates by using either approach is a labor-intensive economic exercise that involves combining epidemiologic data on the number of “units” (i.e., injuries or injured persons) with economic data on the cost per unit. Development of the cost per unit involves many considerations. The first relates to the conceptual framework used to quantify these costs, that is, whether to use a human capital or a contingent valuation approach. The human capital approach entails accounting for resources lost because of the injuries and assigning a monetary value to these losses. This monetary value is most commonly derived from market prices. Some of these lost resources are commonly referred to as “direct costs” because they relate to resources spent and include, for example, provision of emergency medical services, emergency department care, hospital admission and other institutionalizations, fees to physicians and other health professionals, and administrative costs related to processing insurance claims. (Some researchers also include property losses related to the injurious event.) In contrast, other resources are “lost” because they cannot be produced because of the injuries. These resources are known as “indirect costs” and primarily relate to productivity losses. Indirect costs commonly are substantially larger than direct costs (46, 47), a reflection of the value placed on foregone productivity. Since the human capital approach accounts for resources spent and lost, whose resources are being considered is crucial to interpreting the results. This issue is known as the “perspective” of the analysis, and, even though governments, insurers, or employers, among others, could be perfectly legitimate perspectives to use, it has been suggested that the “societal” perspective always be included

to provide a common framework from which to compare separate analyses (48). This perspective accounts for all (net) resources lost, regardless of whose they are, and does not include resources transferred across society members (such as, for example, a disability pension).

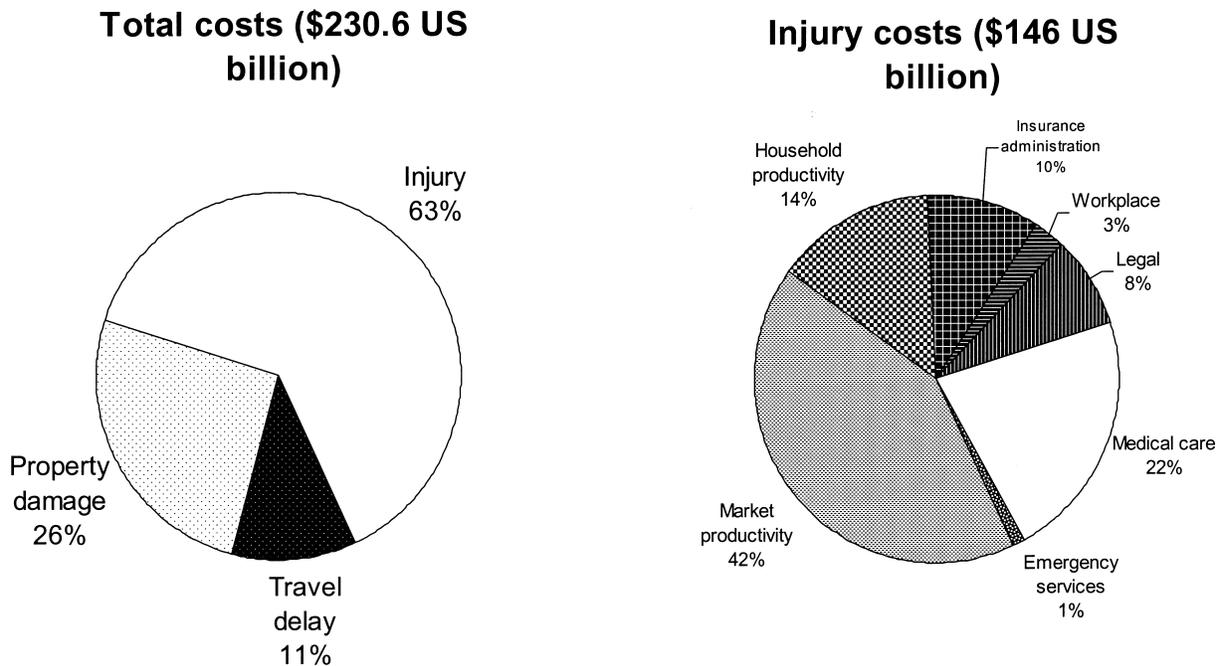
A limitation of the human capital approach is its inability to quantify in monetary units the costs related to the pain, suffering, and loss of quality of life, the so-called intangible consequences of the injuries. This limitation is overcome by the alternative “unit” cost approach, contingent valuation. With this method, instead of identifying and quantifying all spent and lost resources, a single cost figure is produced that represents how much money society is willing to pay to avoid a particular injury. The method most frequently used is called willingness to pay (49). This cost figure is elicited by either surveying persons (and thus collecting their “stated” preferences) or observing what people actually pay to reduce their probability of being injured (and thus collecting their “revealed” preferences), for example, by observing how much they pay for a vehicle with extra safety measures.

Interestingly, most examples of the application of this approach are from countries other than the United States. For example, a 1998 survey of Swedes indicated that the median willingness to pay was \$72 for a 30 percent risk reduction in a baseline risk of 69 in 100,000 for a temporary injury; for a 30 percent risk reduction of being killed in a road crash, the median willingness to pay was \$120 (50). In another 1998 survey of Swiss citizens, the maximum willingness to pay was \$98 for hip protectors that eliminate hip fractures (51).

In two variations of the contingent valuation method, one may investigate instead how much money society is accepting at the expense of incurring larger risks (the method is known as willingness to accept) (52) or how much society is willing to give to someone who suffered the injuries (willingness to award) (53). In a willingness to accept exercise, the researcher would, for example, document the higher salary that workers accept when working in a high-risk environment; in a willingness to award framework, the researcher would identify how much a jury awards after evaluating damages to an injured worker. Conceptually, the figures produced by using any of these three contingent valuation methods integrate all injury consequences that matter to society, whether direct, indirect, or quality-of-life related, an “inclusive” or “comprehensive” characteristic often mentioned when these costs are presented. A review of the literature regarding the value of life using contingent valuation suggests that the value per fatality averted ranges from \$2 million to \$7 million (26).

The difficulty with contingent valuation relates to the validity of the figures produced, that is, whether persons truly reflect the value of safety in their answers or actions. For example, in the first Swedish survey mentioned above, subjects reported a similar willingness to pay for fatality risk reductions of 10 percent, 30 percent, and 50 percent (50).

To date, the most comprehensive known work on the cost of injuries is the *1989 Cost of Injury in the United States* (46). In this report, incidence-based epidemiologic data were used in combination with human-capital-based cost data in a societal-perspective analysis to estimate the lifetime direct and indirect costs of injuries that occurred in 1985. The total



**FIGURE 5.** Total and injury costs (percentage distribution) of motor vehicle crashes in the United States, 2000. Adapted from Blincoe et al. (26).

was estimated at \$182 billion in 1988 dollars (or \$264 billion in 2002 dollars). Interestingly, the percentage of such costs spent during the first year after the injury occurred ranged from 55 percent for fall victims to 98 percent for drowning and near-drowning victims, with motor-vehicle victims spending 72 percent of their lifetime costs during this time. Overall, injuries occurring to persons aged 25–44 years were responsible for 42 percent of the total costs, coinciding with the age group for which costs per injured person (overall and for males) were highest. Although deaths represented less than 1 percent of all injuries, they contributed to nearly one third of the total economic costs (largely because of the lost productivity accrued among persons dying at young ages). Direct costs constituted 29 percent of the total costs. Of these direct costs, hospital services contributed about 55 percent to the total, and nonmedical direct costs (e.g., home modification, vocational rehabilitation, health insurance) contributed an additional 14 percent. Note that 41 percent of the total lifetime cost was associated with lost productivity resulting from short- and long-term disability. Therefore, if we are to have a significant impact on the overall burden of injury, it will be important to develop a better understanding of the factors that contribute to high productivity losses among survivors.

The methodological choices selected for that report (46) have been echoed in most US-based cost studies published since then, as suggested by the preliminary findings of a review of approximately 100 papers or reports that document original cost calculations (work in progress). Among these more recent cost works, we highlight those by Miller et al. (47), who first built on the 1989 report while investigating in

more detail the costs of nonfatal injuries. In their 1995 book, they reported overall costs of \$963 billion (in 1989 dollars), and they derived this figure by combining the human capital approach for direct costs and productivity losses with willingness to award and other data for quality-of-life-related costs (as initially explored in the report) while using prevalence-based injury counts (in contrast with the report). More recently, the same team has been involved in two other reports: the Consumer Product Safety Commission's *Revised Injury Cost Model* (53) and the National Highway Traffic Safety Administration's *The Economic Impact of Motor Vehicle Crashes 2000* (26). The lifetime direct and indirect costs of consumer-product-related injuries that occurred in 2000 amounted to \$315 billion; if quality-of-life losses are included, the cost of these injuries increases to \$405 billion (53). The lifetime direct and indirect injury costs of motor vehicle crashes occurring in 2000 were \$146 billion (in 2000 dollars). If property loss and travel delay costs are added, the figure rises to \$230.6 billion. Adding quality-of-life costs instead raises the figure to \$368.6 billion (26). Figure 5 presents the distribution, by cost category, of the \$230.6 billion and \$146 billion figures.

Because of all the methodological variations outlined so far and a few more beyond the scope of this paper (such as the choice of discount rate), the reader is cautioned against comparing costs figures from different papers without understanding their methodological differences. (For additional readings on costs issues, refer to Drummond et al. (54) and Gold et al. (48)). The Centers for Disease Control and Prevention is currently undertaking a major update to the 1989 *Cost of Injury in the United States* (46) that should

provide new estimates for all injuries in the United States (R. J. Waxweiler, Centers for Disease Control and Prevention National Center for Injury Prevention and Control, personal communication, 2002).

### MEASURES OF HEALTHY LIFE EXPECTANCY

Although we have already stressed the importance of developing single metrics that integrate changes in longevity with changes in disability, functionality, pain, and emotional distress, the previous section discussed the challenges of using costs as such metrics, particularly in regard to the costing of pain, suffering, and quality of life. Over the past decade, new and exciting approaches have been developed to quantify the burden of illness in nonmonetary units. These approaches combine information on life expectancy with any of a variety of indices or metrics that define “health,” resulting in what are generically referred to as measures of health-related quality of life, healthy life expectancy, or quality adjusted life years, although some confusion exists regarding the generic term that best describes them. The choice of the metric used to define health defines the major differences among the approaches, and this choice is also related to the specific name given to the measure.

In the following paragraphs, we discuss specific metrics in chronologic order and review them in light of their use in measuring the burden of injuries. However, before we do that, we should first discuss an aspect that characterizes many of them: being *preference based*. Compared with the *psychometric-based metrics* (described in a previous section), *preference-based measures* of health status and health-related quality of life are fewer in number, and even fewer of them have been applied to measuring the burden of injury. More important than their difference in number is that preference-based metrics are based on decision theory and economic principles, and they synthesize the effect of disease or injury across different health domains by indicating the overall preference for, value of, or “utility” of living in such a condition. Because of this characteristic, they can combine the effect of death and nonfatal consequences into a summary measure that typically ranges from 0 (representing death) to 1 (representing optimal health or function) and where any number in between reflects the relative preference for particular health states. That the metrics are preference based is a requirement so they apply in the context of decision analyses or economic evaluations such as cost-utility analyses.

Because these measures involve eliciting preferences over health states, whose preferences are elicited and how those preferences are elicited are crucial to the validity of the measure. Some of the metrics presented herein use preference values derived from representative samples from specific geographic areas, whereas others used convenience samples in their development. Population-based preferences are more appropriate for population-level assessments of burden. Some of the metrics are based on elicitation methods grounded in utility theory (i.e., the so-called standard gamble method), whereas others use transformations to approach this method or simpler methods altogether (i.e., the visual analog scale). Scales that use standard gamble or approxima-

tions to this method are preferable to the ones that use less-refined methods.

The quality of well-being (QWB), formerly known as the health status indicator or the index of well-being, was one of the first preference-based health status metrics to be developed and has been validated across a wide range of conditions. It combines patient-reported symptoms or problem complexes (as many as 27) and function (measured across three domains of mobility, physical activity, and social activity) into a single index that provides an expression of well-being that ranges from 0 for death to 1 for asymptomatic full functioning (55). The QWB is frequently used in both clinical and population-based settings. Limited norms for the general population exist, and, when combined with life expectancy data, this metric produces a quality-adjusted-life-years metric known as Well Years (56). The best example of the application of this metric to a trauma population is the work of Holbrook et al. (57, 58), who assessed outcomes following multiple trauma (excluding patients with major head trauma) up to 18 months postinjury. In their study, mean QWB scores were 0.40 at hospital discharge, 0.63 at 6 months postinjury, 0.67 at 12 months postinjury, and 0.68 at 18 months postinjury. At 18 months postinjury, only 18 percent of the patients achieved scores typical of the general population, 0.80.

Although the QWB is a potentially useful measure for quantifying the burden of injury, and it is one of the few preference-based measures applied to this purpose, it has some limitations that should be kept in mind. First, the QWB has been criticized for its emphasis on physical health and is generally viewed as underrepresenting the domain of mental health. In addition, the QWB assesses cognitive function by using one symptom only: “trouble learning, remembering, or thinking clearly”; thus, caution should be exercised in applying it to populations in which head injuries are common. Finally, because the QWB includes a large number of symptoms, it is particularly sensitive to minor deviations from complete, asymptomatic well-being, which could lead to overestimating the true impact of injuries (35).

In contrast to the detail contained in the QWB, the European quality of life (EuroQoL) is a briefer preference-based metric that produces single scores (59). The metric has evolved over the years, but, since 1991, the version in use is the simpler five-dimensional EQ-5D. The scale incorporates the dimensions of mobility, self-care, usual activities, pain and discomfort, and anxiety and depression. Limitations within each dimension are described by using three levels of severity (60). The brevity of the scale is an advantage in some instances, although this characteristic may also limit its ability to discriminate well among health states. Similar to the QWB, the fact that it does not directly assess cognitive limitations could also be problematic if brain injury is a topic of concern; some researchers have overcome this problem by adding this dimension when applying the metric (61). Preference scores used to derive the EuroQol were obtained by using a representative sample of United Kingdom citizens. EuroQol scores range from 0 for death to 1 for optimal health, and the resulting scores can be combined with life expectancy data to generate quality adjusted life years. Despite its wide application at clinical and population levels

to other health issues, the EuroQol has been applied somewhat less frequently to injury, except for a few studies evaluating the cost-effectiveness of trauma care or preventive interventions (62). The only injury-related population-based application that we are aware of is that on a 2-, 5-, and 9-month follow-up study of all injured patients aged 15 years or older visited in one of the emergency departments that belong to the Dutch Injury Surveillance system and that report average scores of 0.62 and 0.74 at 2 and 5 months postinjury, respectively, and no further changes at 9 months (63). All postinjury scores were below the age-adjusted population EQ-5D score of 0.825 reported for the United Kingdom population (64).

The Health Utilities Index is another well-validated, preference-based metric that has gained wide acceptance and is used in both clinical and population settings. This index provides both profiles and interval-scale single scores that summarize the value of health states and that range between 0 (death) and 1 (normal health) (65). Similar to the QWB and the EuroQol, the Health Utilities Index can be combined with life expectancy data to produce quality adjusted life years scores to use in cost-utility analysis. The metric has evolved over the past 20 years (66, 67); the current version, Health Utilities Index:3, was developed for inclusion in the Statistics Canada Ontario Health Survey, a survey similar to the US National Health Interview Survey. Health Utilities Index:3 measures functional capacity across eight dimensions: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain. Preference weights (i.e., the "values") for the health states defined by different levels of function across domains were derived by using a representative sample of Ontario (Canada) residents. Even though, in clinical settings, the Health Utilities Index:3 has been applied to brain and spinal injury victims (D. Feeny, Center for Health Economics and Policy Analysis, University of McMaster, personal communication, October 31, 2000), we are not aware of any published report focusing on the burden of injuries as measured by Health Utilities Index:3. However, it is a particularly appealing measure for use in injury studies because it explicitly incorporates domains of cognitive and sensory functioning and should therefore be particularly sensitive to differences in outcomes among persons with varying severities of brain injury. However, the one known "indirect" application of the Health Utilities Index to the injury field has been by Miller et al. (47), who, since the mid-1990s, have used preference values from the Health Utilities Index to calibrate (and validate) some cost estimates of quality of life lost due to more severe injuries (AIS 2–5).

The Health and Activity Limitation Measure was developed by the US National Center for Health Statistics (Bethesda, Maryland) to monitor annual progress toward the objective of Healthy People 2000 using the information collected in the National Health Interview core survey (68). The Health and Activity Limitation Measure uses information on ADL, limitations in usual major activity (work, school, household maintenance), and limitations in other activities to develop a hierarchical six-level variable that classifies people into the following categories: dependent in ADLs, dependent in IADLs, unable to perform one's usual

major activity, limited in one's usual major activity, limited in other activities, and not limited. This information is then combined with self-perceived health to yield a matrix of health states. Preference-based values derived from the Health Utilities Index:3 were used to derive preferences for each of the states described in the matrix. This matrix can be combined with life expectancy data to derive quality adjusted life years scores sometimes referred to as Years of Healthy Life. The Health and Activity Limitation Measure was designed for population applications only, and it belongs to the same type of health-adjusted life expectancy metrics used by the World Health Organization (and formerly known as Disability Adjusted Life Expectancy) in their assessment of the average level of population health among member states. Even though there are publications reporting applications of Years of Healthy Life (68), we could not find any published example of the application of the Health and Activity Limitation Measure or Years of Healthy Life to injury despite the fact that reports on the impact of injuries on ADL and IADLs are numerous. One appealing attribute of this measure is that it incorporates perceived health status along with limitations in activity and participation. Thus, the overall score for persons who have a disability and score low on role limitation may be compensated for by their perception of their own health. The resulting score may better represent health-related quality of life for these persons.

The Functional Capacity Index (FCI) is a multiattribute, preference-based, functional limitations measure created to measure functional status among injured persons and populations (69). The scale measures function across 10 domains: eating, excretory function, sexual function, ambulation, bending and lifting, hand and arm movement, visual function, auditory function, speech, and cognitive function; for each domain, several levels of functioning are possible. The resulting health profiles can be transformed into a preference-based single score that ranges from 0 (representing death) to 1 (representing no limitations). Preference scores were derived from a convenience sample of US residents; as with the QWB and EQ-5D, whether the preference scores have interval scale properties is arguable because of the specific elicitation method used in deriving these preferences: the visual analog scale (in contrast to the Health Utilities Index and Health and Activity Limitation Measure, where standard gamble is the underlying elicitation method).

An assessment of the actual self-reported functional limitations of 1,240 motor-vehicle-related trauma patients aged 18–59 years who were discharged from the 12 trauma centers that participate in the Pennsylvania statewide trauma registry indicated that, 1 year after the crash, less than 21 percent of them had no functional limitations (FCI scores of 1). Of the patients with some limitations, 14 percent had scores of 0.81–0.99, some 22 percent had scores of 0.61–0.8, and the remaining 45 percent had scores of less than 0.6 (including 9 percent whose scores were below 0.2) (42).

Although the FCI can be applied at the individual and population levels directly, its use in population settings is further facilitated by mapping AIS injury descriptors into FCI profiles and scores. The resulting AIS-F12 measure provides a prediction of the functional limitations still

present 1 year after injury. This mapping can be used to derive estimates of FCI scores from any population database that contains either AIS data, such as the National Automotive Sampling System Crashworthiness Data System crash-related database (described earlier in this paper) or population-based trauma registries; or *International Classification of Diseases*, Ninth Revision, Clinical Modification, coded data, such as hospital discharge databases. As an example of population-level applications, an analysis of 1996 National Automotive Sampling System Crashworthiness Data System data predicted that approximately 7 percent of all motor vehicle crash victims in the United States sustained functional limitations 1 year after the crash (i.e., AIS-F12 score of less than 1) (70).

Developed about the same time as the FCI, the Injury Impairment Scale is a health status scale developed to predict impairment in patients injured in motor vehicle crashes; the scale explores functional losses over time across seven areas: mobility; cognitive function; ADL related to bending, grasping, and lifting; sensory; cosmetic; pain; and the probability of permanent work-related disability (71). Resulting profiles can be translated into single scores, although the values used for this translation are not preference based but a mix of health professionals' judgment and information derived from the Health Utilities Index and QWB. Even though, to our knowledge, this scale has not been applied to any population-based data set, and several studies have raised concerns about its validity (72–74), it permeates several of the US-based costs analyses that quantify in monetary units the pain, suffering, or quality-of-life consequences, including the *1989 Cost of Injury in the United States* (46) that used a very coarse version of this scale. Like the Health Utilities Index, the Injury Impairment Scale has been used to calibrate some cost estimates (46, 47).

Although all metrics described so far in this section were developed with individual and population applications in mind, disability adjusted life years (DALYs) were developed for population-level applications only and, more specifically, for the World Health Organization's effort to define the global burden of disease (75). DALYs are the result of adding life expectancy data to another preference-based metric that combines values for seven disability categories that encompass 22 health-state indicators. In contrast to the QWB, EuroQoL, Health Utilities Index, or the FCI, which are based on patient self-reported data on health status, DALYs rely on epidemiologic data regarding the incidence or prevalence of disease and injury and their expected disability levels in different regions of the world. The predicted disabilities related to those conditions and the values (or preferences) for these disabilities are then combined with life expectancy data. As with previous metrics in this section, the preferences range from 0 (no disability) to 1 (perfect health). An example of the application of DALYs to the injury problem is the widely quoted finding that motor vehicle injuries will result in the sixth leading cause of DALYs in 2020 around the world (76).

Because DALYs are the healthy life metric sponsored by the World Health Organization, this metric quickly permeated the teaching and research environments, although it also has resulted in severe criticism related to the methodologies

used during its development (77). These criticisms primarily concern the fact that both predicted disability and preference scores were based on expert judgment. Partly because of these criticisms, the metric recently underwent some modifications, particularly regarding elicitation of preferences; now these values are derived from representative population surveys, and it is expected that, in the near future, the elicitation method will be that of standard gamble (78). A recent application of the revised metric to estimate the burden of injury worldwide reports 182,555 DALYs lost to intentional and unintentional injuries in 2000, or 12.4 percent of all DALYs lost because of all causes (79).

The Centers for Disease Control and Prevention also created two measures with a population-level application in mind: healthy days and healthy expectancy. Healthy days is a non-preference-based, single-score metric developed to monitor progress toward specific Healthy People 2010 goals such as those related to increasing the quality and Years of Healthy Life and to eliminating health disparities (80). In particular, unintentional injury and violence are among the leading health indicators that the Centers for Disease Control and Prevention will monitor by using this metric. The healthy days measure uses information from the US Behavioral Risk Factors Surveillance System and the US National Health and Nutrition Examination Survey. Healthy days measures what proportion of the population spent the 30 days prior to the interview cognitively healthy, with usual activity not limited, in good physical and mental health, and very healthy and energetic (the so-called four core questions), although it can be refined further by incorporating 10 additional health-related questions also available in those national surveys. Because the resulting metric is a single score, healthy days can be combined with life-expectancy data to create another healthy-life-expectancy type of measure. When the four core questions have been used, it has been reported that, nationwide, US adults have an average of 24.7 healthy days per month, more than the 18.9 healthy days reported by the 1.7 percent of the population with activity limitations due to a fracture or to a bone or joint injury; interestingly, subjects reporting fractures or bone and joint injuries have these limitations for an average of 5.9 years (80).

Similar to healthy days, healthy expectancy (81) was created to monitor progress toward Healthy People 2010 goals, although here the concern was to develop a scale that could be used with data from the US National Health Interview Survey and that was conceptually simpler than the Years of Healthy Life metric introduced in 1995 (44). Healthy expectancy is another non-preference-based metric that uses data on the proportion of the population that perceives their health as less than good (i.e., after dichotomizing whether subjects report having excellent, very good, or good health or whether they are in fair or poor health) with life expectancy data. The resulting scores range from 0 (if persons are in fair or poor health and regardless of their life expectancy) to however many years of remaining life expectancy they have. We are not aware of any example of applying healthy expectancy to measure the burden of injuries, most probably because of its recent development.

Healthy expectancy also provides a crude, non-preference-based simple metric that, although appealing in simplicity, cannot be used in decision analysis or economic evaluation applications. In contrast to the QWB, EuroQoL, Health Utilities Index, Years of Healthy Life, or FCI, both healthy expectancy and healthy days seem to emerge not from the conceptualization of what framework best describes the burden of disease or injury but from the need to obtain some information on this burden from existing population-level databases. They also seem to represent preliminary steps toward developing measures that mimic efforts to measure the burden of other conditions (e.g., cardiac disease) and that transform well-known and widely available non-preference-based descriptive measures of health status into probabilities that a person will be “healthy” in the future, hence creating so-called probability of healthy future scores that incorporate death as an endpoint and can be combined with life expectancy data to develop estimates of Years of Healthy Life lost (82, 83). These probability of healthy future measures have been developed only for older adult populations by using a limited set of health statuses (e.g., ADL, IADL, SF-36), and we are not aware of any injury application.

A similar need prompted the recent release of the Short-Form 6-Dimensions, a preference-based metric that transforms SF-36 data into a score that can be combined with life expectancy to compute quality adjusted life years (84). The objective was to transform *psychometric-based* profiles gathered with the SF-36 (and widely used to date) into *preference-based* scores than can be used in a wider array of applications, including economic evaluations. A computerized mapping algorithm transfers the information reported for each of the eight domains included in the SF-36 into a new six-dimension profile to which preference scores are applied. These preference scores were derived from a survey of a representative sample of the United Kingdom population by using the same elicitation methods as for the preference values obtained for the QWB, EuroQoL, or the FCI. The resulting scores range from death (a score of 0) to optimal health (a score of 1). Although this metric was developed too recently for any injury-specific findings to be available yet, we anticipate numerous references to the burden of injuries with this metric in coming years because of widespread use of the SF-36. In fact, several ongoing studies include the SF-36 in their follow-up surveys, and it is likely that estimates of the population burden of injuries using the Short-Form 6-Dimensions will appear soon in the literature (S. Ameratunga, Division of Community Health, University of Auckland, personal communication, 2002). However, any application of this metric will be hampered by the same limitations presented above regarding our discussion of the SF-36. Furthermore, because the Short-Form 6-Dimensions adopted the health status framework from the SF-36, whether this framework is fully valid for a measure of healthy life requires further study.

## CONCLUSIONS AND IMPLICATIONS

Identifying and positioning injuries as a major public health problem is unarguably one of the major achievements of injury professionals over the past 25 years and one that

has made the broader health community aware of the need for further research in this area. In large measure, this recognition is due to data gathered by using traditional public health metrics, such as death counts, death rates, and YPLL, which helped characterize injuries as one of the leading causes of death, especially among children and young adults. The importance of data on fatalities cannot be underestimated; even today, information on the demographic, environmental, and injury characteristics most frequently associated with premature death is greatly needed to identify priorities for intervention.

However, documenting the burden of injury must go beyond counting deaths to recognizing the impact of nonfatal injuries. Early use of health-services-related databases and application of short-term severity metrics facilitated an accounting of these nonfatal injuries in terms of overall numbers and rates of occurrence. For example, we now can report that, for every injury death, there are at least 10 hospital discharges and 190 injury-related visits to the emergency department. Although many nonfatal injuries are minor and result in only 1 or 2 days of restricted activity, a large proportion result in fractures, amputations, brain injuries, major burns, or other significant injuries that often have far-reaching consequences for the person, the family, the health care system, and society at large.

Initial approaches to measuring these nonfatal consequences included some of the most original work in the field and provided us with an understanding of the economic impact of injury. Early estimates of the costs of injury in the United States have been used to characterize the problem as consuming 3.5 percent of the gross domestic product. More recent estimates suggest that this impact has grown, because even the most conservative calculations indicate that, in the United States, the combined costs of consumer-product-related and motor-vehicle-related injuries in 2000 amounted to 4.7 percent of the US gross domestic product for that year (i.e., counting direct and indirect costs only, no pain or quality of life, no property damage). The information we gleaned by using these metrics only helped confirm our suspicion that, while injury deaths account for a disproportionate share of the overall economic cost of injury, two thirds of these costs are associated with use of health services and productivity losses accrued by persons who survive their injuries.

Yet, measures of the economic costs of injuries fall short in assessing the impact of injury on functioning and quality of life. Over the last few decades, significant advances have been made in conceptualizing the dimensions or domains that define health status and the aspects that contribute to the “burden” of a condition. Significant progress has also been made in developing metrics to assess health status and health-related quality of life regarding both morbidity per se and integration of mortality, morbidity, and quality-of-life consequences. These advances have resulted in development of generic metrics that can be applied across a wide variety of conditions and that have been evaluated in regard to technical properties such as reliability and validity (2). However, only recently have these metrics been applied in assessing the impact of injury at the population level. These metrics are the focus of a substantial portion of this paper.

A review of English-language-based papers published up to mid-1999 regarding injured persons and their health state, as measured by health-state metrics, found 238 such papers (E. J. MacKenzie, unpublished data). Of the scales used, the ADL, the Functional Independence Measure (85), and the Sickness Impact Profile (86) were used most frequently, whereas the SF-36, QWB, and EuroQol were far less common. A broader review of health-status metrics and their use in the medical and epidemiologic literature (87) ranked the SF-36, Sickness Impact Profile, and Nottingham Health Profile (88) as the three scales used most frequently and found the EuroQol in sixth place, the QWB in ninth place, and the Health Utilities Index in 11th place. However, to our knowledge, the Functional Independence Measure, the Sickness Impact Profile, and the Nottingham Health Profile have not been used in population-level assessments of the burden of injury, probably because of their length and complexity, the need for original data collection (they are not currently included in any population-level data set), and their psychometric-based nature. In addition, none of them seems likely to be used for that purpose in the near future, thus their exclusion from this paper.

Of the scales that have been used to assess the burden of injuries at the population level, we have highlighted those that can be used to integrate mortality and morbidity into a single score using preference-based methods, including the QWB, EuroQoL, Health Utilities Index, Health and Activity Limitation Measure, FCI, DALYs, Short-Form 6-Dimensions, and scales that integrate these aspects by using other approaches, such as the Injury Impairment Scale, healthy days, and healthy expectancy. Over the past years, measures that integrate mortality and morbidity seem to be making their way into more and more studies, and rightly so, as highlighted by the examples from recent publications reviewed for this paper.

The fact that there are several of these scales should be interpreted as indicating that, at the present time, none seems to contain all of the ideal attributes that one would like to include, probably because we, as a field, might not have properly invested the time and effort to define the ideal attributes of “burden” when assessing the public health impact of these injuries. In our view, the ideal measure to quantify the burden of injuries at the population level should have a solid framework in which to define “burden,” it should identify all dimensions deemed relevant to that definition, and it should be preference based—not only to produce a joint estimate of the impacts of mortality and morbidity but also to produce a single score that can more efficiently be used in epidemiologic, health services research, and decision analysis investigations. (The ideal metric should also be reliable and be responsive to changes over time.) To enhance the feasibility of this measurement (which includes resulting in a reasonable cost), the measure should also be either incorporated into already existing population-level databases or easily derived from data already existing in these databases.

Currently, however, the choice of metric depends on several factors, including the appropriateness of the measure’s content to the research question or application, its evidence of reliability, its validity, the level of aggregation

of the measure (with practical analytical implications), and the availability of population norms. Because so many of these scales have been developed since 1996, it is too early for a final judgment on most of them. Future work should confirm their value in injury research and evaluation. For the time being, we will concede that, of the metrics we have reviewed, the Health Utilities Index, the Health and Activity Limitation Measure, and the FCI seem to be closer to the ideal metric presented above. Even then, the Health and Activity Limitation Measure lacks grounding on a conceptual framework of burden (the other two concentrate on functional capacity or limitations as their measure of burden), while there are no population norms for the FCI yet. None of the other scales reviewed seems to align itself very well with any existing disability framework, whether the pathology-impairment, functional-limitation, disability framework presented by Nagi in 1975 (89); the World Health Organization revised definition of its International Classification of Functioning, Disability and Health, which defines health in the context of body functions and structures, activities and participation, and environmental and personal factors (90); or the comprehensive US Institute of Medicine framework that expands the Nagi model to incorporate quality of life as a domain concurring with the disablement process (91). At this time, we worry that the three latest metrics developed (i.e., SF-6D, healthy days, and healthy expectancy) seem to derive more from the desire to use existing data in simpler forms than from the decision that none of the already existing ones was good enough. As a field, we should decide what we need and then work to incorporate it into the data sources we have, not the other way around.

Finally, the fact that this paper presents many more examples of the knowledge regarding the burden of injuries at the population level from the United States than from other settings reflects the fact that most of the evidence presented in the English-language literature has been generated in the United States. We suspect that the burden of injuries in other societies is not any lower than the one identified in the United States. For example, in developing countries, initial DALY estimates seem to suggest that it may not only be already larger than that in developed countries but also growing at a faster rate. Nevertheless, and before metrics to measure burden are transported from one setting to another, it is important to evaluate whether the aspects of “burden” captured by the measure are relevant across cultures and whether preference values derived from specific populations can be adopted by others. We look forward to future research investigating all of these aspects.

## ACKNOWLEDGMENTS

Support for this project was provided from a Centers for Disease Control and Prevention National Center for Injury Prevention and Control grant to the Johns Hopkins Center for Injury Research and Policy (R49-CCR 302486-14).

The authors thank Lois Fingerhut, Margaret Warner, Robert Anderson, Susan and Timothy Baker, Elyce Biddle,

and Maria Bulzacchelli for their assistance in writing this manuscript. They also thank Rhonda McCray for her administrative support in preparing the paper for publication.

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