Occupational Injury and Illness in the United States

Estimates of Costs, Morbidity, and Mortality

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Objective: To estimate the annual incidence, the mortality, and the direct and indirect costs associated with occupational injuries and illnesses in the United States in 1992.

Design: Aggregation and analysis of national and large regional data sets collected by the Bureau of Labor Statistics, the National Council on Compensation Insurance, the National Center for Health Statistics, the Health Care Financing Administration, and other governmental bureaus and private firms.

Methods: To assess incidence of and mortality from occupational injuries and illnesses, we reviewed data from national surveys and applied an attributable risk proportion method. To assess costs, we used the human capital method that decomposes costs into direct categories such as medical and insurance administration expenses as well as indirect categories such as lost earnings, lost home production, and lost fringe benefits. Some cost estimates were drawn from the literature while others were generated within this study. Total costs were calculated by multiplying average costs by the number of injuries and illnesses in each diagnostic category.

Results: Approximately 6500 job-related deaths from injury, 13.2 million nonfatal injuries, 60300 deaths from disease, and 862200 illnesses are estimated to occur annually in the civilian American workforce. The total direct ($65 billion) plus indirect ($106 billion) costs were estimated to be $171 billion. Injuries cost $145 billion and illnesses $26 billion. These estimates are likely to be low, because they ignore costs associated with pain and suffering as well as those of within-home care provided by family members, and because the numbers of occupational injuries and illnesses are likely to be undercounted.

Conclusions: The costs of occupational injuries and illnesses are high, in sharp contrast to the limited public attention and societal resources devoted to their prevention and amelioration. Occupational injuries and illnesses are an insufficiently appreciated contributor to the total burden of health care costs in the United States.

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Most people between the ages of 22 and 65 years spend roughly 40% of their waking hours at work. Some risk of injury or illness attends virtually every job held by the 120 million Americans who work. Yet few studies have assessed or estimated the national incidence or prevalence of occupational injuries or illnesses. Even fewer studies have attempted to calculate the costs of either these injuries or illnesses. This is unfortunate, especially since costs have become a critical measure in the health care debate. Knowing costs is important, because it allows comparisons with such disparate health care conditions as acquired immunodeficiency syndrome, Alzheimer disease, circulatory diseases, cancer, and musculoskeletal conditions.

We report estimates of the numbers and direct and indirect costs of job-related injuries and illnesses in the United States in 1992. We summarize a recent report to the National Institute for Occupational Safety and Health on costs of occupational injuries and illnesses. Standard epidemiological, economic, and accounting techniques were applied to national sources of data to estimate incidence and costs of injuries and illnesses incurred at work.

This study appears to be unique in the literature. To our knowledge, no prior study uses national data to generate estimates of the burden and costs of occupational injuries and illnesses in the United States. Only 1 previously published study has attempted to estimate these combined costs of occupational injury and illness, but it was limited to Pennsylvania.
METHODS

INCIDENCE OF OCCUPATIONAL INJURIES, 1992

Deaths

Several primary and secondary sources of data were used to construct our estimate of deaths from injury. Primary sources included the Census of Fatal Occupational Injuries (Census), the Annual Survey of Occupational Injuries and Illnesses (Annual Survey), and the Supplementary Data System of the U.S. Bureau of Labor Statistics, the National Traumatic Occupational Fatality Study (National Traumatic Study) of the National Institute for Occupational Safety and Health; and the workers' compensation data of the National Council on Compensation Insurance (National Council). Secondary sources included the National Safety Council's Accident Facts and reports by Miller and Marquis.

The Census is regarded as the most reliable primary data source since it uniquely requires confirmation of a work-related death by 2 separate sources. However, like the National Traumatic Study, the Census depends largely on death certificates, which are known to undercount work-related deaths by 10% to 40%.

The Census and the National Traumatic Study provided the best data on civilian deaths and weighted them more heavily than all the other estimates in calculating our estimate. To obtain a summary estimate of the number of traumatic deaths in the United States in 1992, we adjusted all the death estimates from the literature except for the one derived from the Census. The unadjusted (listed first) and adjusted (listed second) estimates were the following: the Census (6063, 6063); National Traumatic Study (3714, 6346); Annual Survey (2800, 5384); National Council (3300, 8306); Supplementary Data System (3601, 6994); National Safety Council (8500, 10,000); Miller (11,900, 9678). The adjustments reflected deficiencies such as relying only on workers' compensation data, ignoring murders, ignoring deaths in small firms, and among the self-employed, ignoring data from California, New York, and other states, and for our purpose, not reporting data for 1992.

Apart from this last point about 1992, the authors of these studies acknowledge these deficiencies. To calculate our global estimates, we assigned different weights to the individual estimates as follows: Census (6.8); National Traumatic Study (0.2); and all others (0.04). We developed an econometric forecasting model to update all estimates in the published literature to 1992.

Nonfatal Injuries

For nonfatal injuries we analyzed 3 primary sources—the Annual Survey, the National Council ultimate reports, and the National Health Interview Survey—the same secondary sources identified above as well as studies by Miller and Marquis. Each of the primary sources suffered from serious undercounts, especially the Annual Survey—the primary data source most frequently cited in the literature.

The 1992 Annual Survey reflects questionnaire data reported by employers from a stratified sample of approximately 250,000 private-sector firms. The Annual Survey does not cover government workers, the self-employed, and farms with fewer than 11 employees. Moreover, the Annual Survey is collected from private firms that face an economic incentive to underreport. All these deficiencies lead to underestimates that range from just less than 50% to more than 70%. For example, the Census shows an undercount of deaths in 1992: 0.3 million. 13.99 million, and 0.4 National Institute for Occupational Safety and Health, 4.7 million. 17.21 million, and 0.15; National Health Interview Survey, 8.7 million. 11 million, and 0.15; Marquis, 7 million, 13.2 million, and 0.15; and Miller, 11 million, 10.8 million, and 0.15. Again, each of these studies suffers deficiencies that the authors acknowledge. For example, the National Health Interview Survey likely misses a high percentage of assaults. Our adjustments attempted to account for each of these deficiencies.

We categorized injuries as traumatic deaths, disabling injuries, and nondisabling injuries. Disabling means that the injury resulted in at least 1 day of work loss. While nondisabling means no loss of a full workday. Within the disabling category, there are 3 workers' compensation categories: permanent total, permanent partial, and temporary total and partial. Although there are a few legal exceptions, permanent total generally means the person will never work again at any job. Permanent partial is the next most severe category. It means that the person will probably never work again at the preinjury job, but, with training, may find a different job. Temporary total and partial means temporarily out of work or working at diminished capacity but fully anticipating returning to the preinjury job. Injuries were split into these workers' compensation categories so that they could be matched to reliable workers' compensation cost data. We did not categorize injuries by type, i.e., head injury, amputation of fingers, and so on. Injuries categorized this way were not uniform, i.e., they originate with studies using varied assumptions. Moreover, an accident could have resulted in more than 1 injury and classified by body part, e.g., a car crash could cause a concussion and a finger amputation. The source estimates, the Annual Survey, through Miller and Galbraith, were used to generate one global estimate of all disabling and nondisabling injuries. The global estimate was then decomposed into workers' compensation categories based on percentages drawn from National Council reports.
INCIDENCE OF OCCUPATIONAL ILLNESS

Deaths

An estimate of annual deaths attributable to occupational diseases was obtained by combining 2 approaches. The numbers of deaths attributable to occupation-specific causes in 1992 are recorded in the mortality statistics gathered by the National Center for Health Statistics. These occupation-specific causes include mesothelioma and the pneumoconioses, for which all, or virtually all, cases can be attributed to occupational exposures.

Since few diseases are caused solely by occupational exposures, a second approach was used—an attributable risk proportion model. In this method, percentages of deaths in major disease categories are attributed to occupational exposures. Given the uncertainty in knowledge of the exact proportions of deaths attributable to occupation, ranges and point estimates of proportions of deaths were used, including 6% to 10% of cancer, 3% to 10% of cardiovascular and cerebrovascular disease, 10% of chronic respiratory disease, 100% of pneumoconioses, and 1% to 3% of nervous system disorders and renal diseases. In estimating these deaths, we ignored decedents aged 24 years or younger for all categories of deaths, and for circulatory diseases we also excluded decedents older than 65 years.

Rationale for Attributable Risk Proportion Model

Selection of these ranges of attributable proportions is based on literature in occupational medicine and related disciplines. The estimate of 6% to 10% of all cancer attributable to occupational exposures is grounded in part on specific studies of selected cancers and in part on general trends in human and animal cancer research. At least a dozen case-control studies, after controlling for cigarette smoking, collectively show that 10% to 33% of all types of lung cancer in men are attributable to occupational exposures. Applying a narrower range of point estimates, 15% to 20%, to the 91,405 deaths from lung cancer among men in the United States in 1992 yields a total of 13,711 to 18,281 deaths in men from lung cancer caused by occupational agents. These deaths from lung cancer represent 2.7% to 3.5% of all deaths from cancer in the United States in 1992. A similar analysis of deaths from another well-documented occupational cancer, bladder cancer, provides an estimate that 21% to 27% of deaths from bladder cancer for men are attributable to occupation in the United States. Since there were 7,123 deaths caused by bladder cancer among US men in 1992, 1,496 to 1,923 deaths caused by bladder cancer, or approximately 0.3% of all deaths caused by cancer, were attributable to occupational agents. Together bladder cancer and lung cancer among men alone accounted for approximately 3% to 4% of all deaths caused by cancer in the United States in 1992.

Four sets of research findings in occupational cancer in the last 10 to 15 years support the proposition that the percentage of cancer caused by occupation is significantly higher than the 3% to 4% specifically caused by cancer of the lung and bladder. First, recent studies have increased the likelihood that a number of well-known toxins or exposures are human carcinogens. Included in this category are silica and fiberglass and lung cancer; electromagnetic radiation and vinyl chloride and brain cancer; and orthotoluidine and bladder cancer. For other common agents, limited evidence has accumulated to support a causative role in cancer. Among these agents are formaldehyde, 1,3 butadiene, and perchloroethylene.

Second, a number of studies demonstrate increased risks of cancer for specific occupations without clear identification of the suspect agents. Examples include farmers with lymphoma and firefighters with brain cancer. Third, toxicologic assays in animals completed in the last 2 decades show that a significant number of chemicals tested to date show evidence of carcinogenicity. More than 600 chemical agents have been shown to be carcinogenic in at least 1 rodent species. Among the most important agents that showed evidence of carcinogenicity in experiments conducted by the National Toxicology program are methylene chloride, tetrachloroethylene, and propylene oxide. While there is considerable disagreement about the significance of the results of animal testing for human cancer, demonstration of carcinogenicity in animals is still considered evidence of likely carcinogenicity in humans. Collectively, these studies suggest that the problem of occupational cancer may be larger than is recognized when only established human carcinogens are considered.

Fourth, side smoke from cigarettes is a likely carcinogen in some jobs. Clear patterns exist in occupations concerning cigarette use. Waitresses, bartenders, laborers, auto mechanics, welders, and kitchen workers, among others, report high cigarette use in recent surveys and in surveys from 20 years ago. On the other hand, teachers, physicians, nurses, dentists, clergy, and librarians, among others, report low cigarette use in the same surveys.

The estimate of 5% to 10% of cardiovascular and cerebrovascular disease is based on a number of studies showing that job strain or psychosocial stress causes excess morbidity and mortality and that selected common chemical exposures, such as lead, carbon monoxide, and solvents, adversely affect the heart. We restrict our estimates of occupational cardiovascular and cerebrovascular disease to people aged 64 years and younger, because the long-term effects of cardiotoxic exposures are not well studied. Our 5% to 10% range for ages 25 through 64 years corresponds to a 0.6% to 1.2% range for all deaths from circulatory disease for all ages.

A number of large, well-performed, population-based studies consistently show that exposure to occupational dusts and, to a lesser extent, gases and fumes is associated with a 30% to 50% increase in symptoms and pulmonary function deficits characteristic of chronic obstructive pulmonary disease (COPD). Other studies relate specific occupational exposures, principally coal, silica, grain dust, and cadmium, and specific occupations to excess mortality from COPD. To recognize the likelihood that occupational exposures play a limited but definite role in death caused by COPD, we assign an estimate of 10% mortality caused by COPD to occupational exposures.

Renal toxic effects have been associated with occupational exposure to lead and mercury, glycol ethers, and other organic solvents. Neurological disorders stemming from the workplace exposures have been caused by pesticides, heavy metals, many organic solvents, and other organic agents.

The quantitative burden of renal and neurological disease that these exposures impose is not known. We therefore assign a conservative range of 1% to 3%.
Morbidity

To estimate the number of acute and relatively well-recognized chronic occupational diseases (e.g., dermatitis, repetitive strain injuries), the following data sources were used: the Annual Survey, the public-sector employee health and safety programs, the National Hospital Discharge Survey, and R. Sligher (US Dept of Labor, oral communication, September 1994).

The limitations of the Annual Survey are well recognized and are believed to produce a significant underestimate of occupational diseases. The Annual Survey counts illnesses of current employees. Retired persons are ignored. Yet many cancers, respiratory diseases, cases of pneumoconiosis, and so on do not manifest themselves until retirement. For example, we estimated 150,000 new job-related cases of COPD, and the Annual Survey counted 717 cases in 1992.

The Adult Blood Lead Epidemiology and Surveillance program, maintained by the National Institute for Occupational Safety and Health since 1992, collects adult blood lead data (blood lead level, \( \geq 12.0 \) \( \mu g/dL \) \( \geq 25 \mu g/ 

The number of cases of lead poisoning recorded in the Adult Blood Lead Epidemiology and Surveillance program is adjusted upward by one third to allow a national estimate.

To obtain an estimate of the number of new cases of major chronic diseases, including cancer, chronic respiratory disease, and cardiovascular and cerebrovascular disease, we applied the same percentages to morbidity estimates as we did to mortality estimates as noted in the previous section. Numbers of new cases of these diseases in the general population were obtained from established data sources and from the American Cancer Society (S. Montgomery, written communication, March 1, 1995). Again, we also restricted analyses to persons aged 35 years and older, and in the case of cardiovascular and cerebrovascular diseases, to persons younger than 65 years.

COSTS

Theory

We adopted the direct and indirect or human capital method for calculating costs. The direct and indirect method is the most widely used method in the medical and legal literature in large part because estimates are available and reliable.

Direct costs represent actual dollars spent or anticipated to be spent on providing medical care to an injured or ill person as well as on property damage, police and fire services, and administrative costs for delivering indemnity benefits. Medical costs include physicians' and nurses' services, hospital charges, drug costs, rehabilitation services, ambulance fees, payments for medical equipment, and supplies. Indemnity benefit costs do not include the benefits themselves, rather they include the administration costs associated with providing workers' compensation indemnity or Social Security disability payments to injured or sick workers and their families. Property damage includes costs of damage to vehicles, machine, buildings, and so on directly associated with the injuries and illnesses.

The largest indirect costs include the injured or sick workers' lost earnings, fringe benefits, and home production. Other indirect costs include employer costs associated with retraining and restaffing, worker costs of lost productivity, and wage delays.

Two approaches can be used in estimating the costs of injury or illness by the direct and indirect method: prevalence and incidence techniques. Prevalence-based costs provide an estimate of the burden in a base year as a result of the prevalence of injury or disease. Included are the injury or illness costs during the base year whether they had their onset in the base year or any time prior to the base year. Incidence-based costs represent the lifetime costs resulting from a new injury or illness originating in the base year. In the aggregate, incidence costs in a given base year reflect the likely course of an injury or a disease and its duration, including survival rates, medical care that will be used, and costs for the duration of the injury or disease.

We used the incidence method for all injuries and morbidity estimates of reported incident disease. We used the prevalence method for the estimates of deaths caused by diseases and morbidity obtained by the proportionate attributable risk calculations described earlier.

Direct and Indirect Cost Application: Injuries

Estimation of the costs of injuries required multiplying the number of injuries in each category by the average costs of such injuries. Direct average costs for medical care were drawn from the National Council ultimate reports. Lifetime medical costs (1992 dollars) for deaths were valued at $20,120, for permanent total at $132,419, for permanent partial at $17,920, for temporary total and partial at $32,250, and for no work loss at $275. The medical expenses were drawn from workers' compensation accounts and did not require adjustment since workers' compensation paid virtually 100% of medical bills in 1992. I.e., no co-payments or deductibles were charged to clients.

The calculation of the indirect costs was based on a variety of sources, including National Council indemnity data and federal government data on employment, earnings, and mortality. Home production, as well as hiring, training, and workplace disruption, costs were priced in accord with estimates in the literature. Indirect costs for fatalities required a present value calculation. We assumed that persons who died would have earned what others of the same age and gender earned.

The estimate was drawn from a range of 6603 to 10,000, which was determined by adjustments to totals of deaths caused by injury estimated by the Census, National Safety Council, Supplementary Data System and Bureau of Labor Statistics, National Traumatic Study, National Council, and the National Health Interview Survey.

RESULTS

BURDEN OF OCCUPATIONAL INJURIES

We estimated that 6529 workers died from workplace-related injuries in the United States in 1992. This point

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The distribution of deaths by age and sex were estimated with information from the Census. These age and sex data were combined with information of wages, probabilities of survival to age 75 years, as well as the employment within those categories. The present value formula we used was similar to the one used by Rice et al. 41

\[ PV_{death} = \sum \frac{P_{i,sex} \times \left( M_{i,sex} + H_{i,sex} \times F_{i,sex} \right) \times LFPR_{i,sex} \times (1 - g)^{t - r}}{(1 + r)^t}, \]

where \( PV_{death} \) represents the present discounted value of losses because of death in injury-per person, \( F_{i,sex} \), probability that a person of a certain sex and age will survive to a certain age, \( y \), age at which the person was injured, \( s \), sex of person, \( n \), age of person, \( m \), mean annual earnings of employed persons of a certain sex and age, \( H_{i,sex} \), annual value of household production for persons of sex and age; and \( LFPR_{i,sex} \), labor force participation rate proportion of the population by sex and age that are employed in the labor market. The LFPR of 1 was for injured (not ill) persons who were working and older than 65 years, \( F_{i,sex} \), fringe benefits by sex and age; \( g \), rate of increase in labor productivity assumed to be 1%, and \( r \), real discount rate assumed to be 4%.

The LFPR requires comment. Most people retire at or before the age of 65 years. We assumed that persons who died before the age of 65 years would have an LFPR of typical persons now older than 65 years, eg, 0.161 for men and 0.803 for women. However, a few of our injury decedents, before death, were older than 65 years and working. For these people we assumed an LFPR of 1.0, i.e., we assumed that they would have continued working until the age of 75 years. We assumed no one would work beyond the age of 75 years. \( M \) represents average annual earnings for full-time and part-time employees. \( H \) represents the annual value of household production. Home production included changing diapers, reading to children, home repairs, building cabinets, plumbing repairs, and so on. Estimates on home production were drawn from Douglas et al 38 and updated to 1992 using an inflation index. A rate of fringe benefits of 22% for men and 16% for women was used. The disparity reflects the greater likelihood that men were employed full-time.

The National Council 13 figures also provided indemnity benefits that were used to estimate wage losses. The indemnity benefits themselves were not added to wage losses. The indemnity benefits were adjusted assuming workers' compensation paid to clients for the following rates: 40% of pretax wages for permanent total conditions, 50% for permanent partial conditions, and 60% for temporary total and partial conditions. 41 Fringe benefits were assumed to be 21% of the pretax wage for men and women combined.

Insurance administrative costs were assumed to range between 10% and 31% of medical expenses depending on the type of insurance. Private workers' compensation was assumed to have the highest 40 and Medicare was assumed to have the least. 40 Estimates on the cost of property damage, time delays, and police and fire services were drawn from Blincoe and Faigin. 40

Direct and Indirect Cost Application: Disease

There are no national studies, to our knowledge, that describe the amount of hospital, physician, nursing, or other medical care required to treat patients with disease attributable to occupational risk factors. We therefore constructed our estimates, using available national expenditure data, and assuming disease-specific treatment patterns similar to the general population.

Using the National Hospital Discharge Survey, 92 we calculated the total number of days spent in the hospital by patients with a primary diagnosis for disease cost for disease categories included in the attributable risk calculations of occupational diseases. Total days of hospitalization by disease group were transformed to obtain standardized proportions of national hospital utilization attributable to each occupational disease. We applied these disease-specific proportions to the national health expenditure accounts (minus nursing home costs, estimated by disease category by the Health Care Financing Administration, 92 to obtain an estimate of medical direct costs. The direct costs of nursing home care for occupationally related disease were estimated using the National Nursing Home Survey. 93 These cost estimates, using diagnosis-specific nursing home length-of-stay data, were added to the medical expenditure estimates.

Indirect costs were estimated using age-specific and sex-specific mortality data from the same sources identified above in the discussion of indirect costs of deaths caused by injury. By applying the occupational attributable proportions for deaths caused by disease, the present value of the indirect costs of premature mortality attributable to occupational disease was estimated for the base year 1992. Finally, we projected national disease-specific trends over time in the ratios of morbidity costs to direct costs and mortality costs to mortality costs 90,10 to obtain an estimate of the morbidity costs for the occupational disease. All indirect costs estimates are presented in 1992 dollars and apply the same assumptions regarding age-specific LFPRs, discount rates, and administrative costs used to estimate the economic costs of occupational injury with one exception: we did not allow an LFPR of 1.0 for persons older than 65 years for our disease estimates. Instead, we applied national averages for sex-specific rates for persons older than 65 years with occupational disease. The 1.0 rate was used only for deaths caused by injury to those who before death were older than 65 years and working.

In addition to estimating the economic costs associated with the occupational diseases responsible for major causes of death in the United States, we investigated the costs of specific nonfatal occupational diseases, including skin disease, carpal tunnel syndrome, and others, as reported to the Bureau of Labor Statistics. 95 Industry-specific wage rates were applied to lost work time to obtain an estimate of indirect costs. Direct costs were based on estimates obtained from published data from the National Council. 13

estimate was closer to the lower bound, reflecting increased emphasis on the Census, which provided the lower-bound estimate.

A disproportionate share of injuries, especially deaths resulting from injury (40%), were caused by transportation accidents, including aircraft crashes, boat and rail accidents, and most important, vehicle collisions. Other causes of deaths were assaults and violent acts (20%), falls (10%), electrocutions (5%), and fires and explosions (3%).

We estimated 13,247 million nonfatal injuries. Disabling injuries accounted for 6.09 million and nondisabling accounted for 7.15 million injuries. The follow-
Table 1. Estimated Occupational Disease Mortality Attributed to Selected Causes, United States, 1992

<table>
<thead>
<tr>
<th>Causes of Death</th>
<th>No. of Deaths, Ages &lt;25, United States, 1992</th>
<th>Estimated Percentage Attributed to Occupation</th>
<th>No. of Deaths Attributed to Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer</td>
<td>517,000</td>
<td>6-10</td>
<td>31,025-51,708</td>
</tr>
<tr>
<td>Cardiovascular and cerebrovascular disease</td>
<td>104,846</td>
<td>5-10+</td>
<td>50,922-10,185</td>
</tr>
<tr>
<td>Chronic respiratory disease</td>
<td>91,541</td>
<td>10</td>
<td>9,154</td>
</tr>
<tr>
<td>Pneumonoces</td>
<td>1,136</td>
<td>100</td>
<td>1,136</td>
</tr>
<tr>
<td>Nervous system disorders</td>
<td>26,936</td>
<td>1-3</td>
<td>269-808</td>
</tr>
<tr>
<td>Renal disorders</td>
<td>22,957</td>
<td>1-3</td>
<td>2,233-689</td>
</tr>
<tr>
<td>Total</td>
<td>761,006</td>
<td></td>
<td>46,092-73,600</td>
</tr>
</tbody>
</table>

*Adapted from Kochanek and Hudson,* and the National Center for Health Statistics.†

† Only includes deaths between the ages of 25 and 64 years. Our 5% to 10% range corresponds to a 0.8% to 1.2% range for all ages.

Table 2. Estimated Occupational Disease Morbidity, United States, 1992

<table>
<thead>
<tr>
<th>Attributable Proportion-Based Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Annual No. of New Cases in United States Percentage Attributed to Occupation</td>
</tr>
<tr>
<td>Estimated No. of Occupational Illnesses Attributed to Occupation</td>
</tr>
<tr>
<td>Cancer</td>
</tr>
<tr>
<td>Coronary heart disease</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>Subtotal</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*Data adapted from the Annual Survey of Occupational Injuries and Illnesses (Annual Survey)*, American Cancer Society*, Kannel and Thorn*, American Heart Association*, and Farer and Schieffelin.†

† Ages 25 to 64 years inclusive.

‡ Total excludes estimated overlap among data sources. This includes 1485 cases of cancer, heart disease, stroke, and chronic obstructive pulmonary disease that were recorded in the 1992 Annual Survey and an estimated 3500 cases of elevated blood lead levels that are included in the 1992 Annual Survey.

BURDEN OF OCCUPATIONAL DISEASE

We estimated that 817,000 to 907,400 new cases of occupational illnesses and 46,900 to 73,700 deaths resulted from occupational diseases in the United States in 1992 (Table 1 and Table 2). The midpoints for these estimates were 862,200 new cases of illness and 60,300 deaths.

Table 1 provides the results of applying the attributable occupational proportions ascribed to major categories of disease and pneumonoces. Cancer dominated these estimates because of its high overall incidence and because of the restriction of occupationally associated cardiovascular and cerebrovascular deaths to persons younger than 65 years.

Table 2 presents data on occupational morbidity. In the top of the table, established data sources provided estimates of readily recognized occupational diseases, including the Annual Survey (457,400 occupational illnesses), the Adult Blood Lead Surveillance program of the National Institute for Occupational Safety and Health (1,250 workers with elevated blood lead levels), and public-sector employees (92,010 occupational illnesses). The numbers of cases of occupational disease among federal and nonfederal government workers were obtained by applying an occupational illness rate of 50 per 10,000 full-time workers to the 18,640,000 federal and state and local workers employed in 1992. This rate was derived from federal and state data and R. Slighter (oral communication, September 1994).

In the bottom of Table 2 estimates are presented based on the proportion model. Assuming that 6% to 10% of cancers in adults aged 25 years and older estimated by the American Cancer Society are occupational in origin, then 66,700 to 171,310 new cases of cancer were caused by workplace factors in 1992.

Data for the national incidence for coronary heart disease are less than optimal, since they are extrapolated from the Framingham Heart disease sample of approximately 5000 people. Nonetheless, these data have been used to determine that there are approximately 1.25 million new or recurrent myocardial infarctions each year in the United States, including 53,000 myocardial infarctions among individuals between the ages of 25 and 64 years, inclusive. Approximately 78,000 of these half million myocardial infarctions are fatal. The Framingham database has also allowed an estimation of approximately 200,000 new cases of uncomplicated angina pectoris each year in the United States among people younger than 65 years.

Applying the population 5% to 10% range cited above, we estimated 36,500 to 73,000 new or recurrent cases of coronary heart disease (including new or recurrent myocardial infarctions and new cases of uncomplicated angina) each year in the United States attributable to occupational risk factors.

Applying similar Framingham statistics, we estimate that 5,050 to 14,400 strokes and transient ischemic attacks among people older than 24 years but younger than 65 years are associated with occupational exposures.

National data on the incidence of COPD are virtually nonexistent. The one estimate we found was 1.5 million new cases of COPD in 1984. Given the rise of COPD mortality from 27,7 per 100,000 in the United States in 1984 to 54.1 per 100,000 in 1992, the estimate of 1.5 million is likely to be an underestimate of the annual num.
Lack of data on the numbers of new cases of renal and neurological disease that occur in the United States each year preclude application of the occupational attributable proportion approach to obtain estimates of occupational renal and neurological morbidity.

Table 3. Total Direct and Indirect Costs for Injuries, United States, 1992

<table>
<thead>
<tr>
<th>Type of Costs</th>
<th>Costs, $ in Billions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>145.37</td>
</tr>
<tr>
<td>Direct</td>
<td>49.17</td>
</tr>
<tr>
<td>Medical</td>
<td>25.07</td>
</tr>
<tr>
<td>Administrative costs on workers' compensation (31%), private insurance, Medicaid, welfare, Medicare (16%)</td>
<td>5.70</td>
</tr>
<tr>
<td>Indemnity administration costs for workers' compensation (31%), Social Security, and private insurance (10%)</td>
<td>8.96</td>
</tr>
<tr>
<td>Property damage</td>
<td>8.75</td>
</tr>
<tr>
<td>Police and fire services</td>
<td>0.78</td>
</tr>
<tr>
<td>Indirect</td>
<td>96.20</td>
</tr>
<tr>
<td>Lost earnings</td>
<td>68.16</td>
</tr>
<tr>
<td>Fatalities</td>
<td>2.55</td>
</tr>
<tr>
<td>Nontalities</td>
<td>65.61</td>
</tr>
<tr>
<td>Fringe benefits</td>
<td>14.33</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.56</td>
</tr>
<tr>
<td>Nontalities</td>
<td>13.78</td>
</tr>
<tr>
<td>Home production</td>
<td>8.21</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.31</td>
</tr>
<tr>
<td>Nontalities</td>
<td>7.90</td>
</tr>
<tr>
<td>Workplace training, restaffing, and disruption</td>
<td>5.20</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.04</td>
</tr>
<tr>
<td>Nontalities</td>
<td>5.16</td>
</tr>
<tr>
<td>Time delays</td>
<td>0.31</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.01</td>
</tr>
<tr>
<td>Nontalities</td>
<td>0.30</td>
</tr>
</tbody>
</table>

* The primary data sources were from the following: Census of Fatal Occupational Injuries; Supplementary Data System and Annual Survey; National Traumatic Occupational Fatalities; National Council on Compensation Insurance; and National Health Interview Survey.

In 1992, injuries in the workplace generated a total of direct and indirect costs of $145.37 billion (Table 3). Direct costs of fatal and nonfatal injuries were $49.17 billion. While these costs were clearly substantial, they represented only 34% of total costs, with indirect costs contributing 66%. Costs can be further described within the broad direct and indirect categories as shown in Table 3. Of the $49 billion in direct costs, $25.1 billion was spent on physicians, hospitals, drugs, nursing homes, and rehabilitation providers; $5.7 and $8.9 billion covered medical and indemnity insurance administration expenses; $8.7 billion covered property damage; and $0.8 billion paid for police and fire services. The $96.2 billion of indirect costs can also be disaggregated (Table 3): $68 billion in wage losses, $14 billion in fringe benefits, $8 billion in home production losses, $5.2 billion for workplace training, and $0.3 for time delays.

Table 4. Number and Costs of Injuries and Illnesses, United States, 1992

<table>
<thead>
<tr>
<th>Category</th>
<th>No.</th>
<th>Direct</th>
<th>Indirect</th>
<th>Total1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injuries</td>
<td>13,253,529</td>
<td>49.17</td>
<td>96.20</td>
<td>145.37</td>
</tr>
<tr>
<td>Deaths</td>
<td>6,529</td>
<td>23</td>
<td>3.46</td>
<td>3.69</td>
</tr>
<tr>
<td>Nontalities</td>
<td>13,247,000</td>
<td>48.94</td>
<td>92.73</td>
<td>141.67</td>
</tr>
<tr>
<td>Illnesses</td>
<td>16,07</td>
<td>9.07</td>
<td>25.54</td>
<td>34.61</td>
</tr>
<tr>
<td>Deaths</td>
<td>60,283</td>
<td>10.70</td>
<td>9.00</td>
<td>19.70</td>
</tr>
<tr>
<td>Mortality</td>
<td>850,165</td>
<td>5.37</td>
<td>0.47</td>
<td>5.84</td>
</tr>
</tbody>
</table>

* The primary data sources were the following: Census of Fatal Occupational Injuries; Annual Survey; Supplementary Data System; National Traumatic Occupational Fatalities; National Council on Compensation Insurance; National Health Interview Survey; Kochanek and Hudson; National Center for Health Statistics; American Cancer Society; Kannel and Thom; American Heart Association; and Fetter and Schiefeleben.
† May not sum because of rounding off.
‡ The number of deaths and illnesses cannot be summed.
SUMMARY OF COST

Table 5 summarizes the total costs associated with occupational injuries and illnesses in the United States in 1992. The estimated 6,500 deaths from injury, 13.2 million nonfatal injuries, 60,300 deaths caused by disease, and 857,500 illnesses resulted in estimated costs of $170.9 billion in 1992, roughly 3% of the gross domestic product.

SENSITIVITY ANALYSIS

Our sensitivity analysis is captured by the ranges of our estimates. These ranges relied on the lower and upper bounds for the number of injuries and illnesses as well as alternative ratio estimates for the costs of illnesses. Lower bounds involved exclusive reliance on the 3 most widely cited surveys: the Census, the National Health Interview Survey, and the National Center for Health Statistics; the estimates for each are 6,063 deaths and 6.3 million and 8.7 million nonfatal injuries. At a lower bound minimum, the per million rate of 8.8 per 100 employees to the number of full-time employees employed persons, we estimated 8.8 million injuries. Lower-bound estimates for deaths was 6,063 and lower-bound estimate for nonfatal injuries was 8.75 million (8.75 was the average of 8.8 and 8.7). Now 6,063 was 7% less than our preferred estimate of 6,529 deaths and 8.75 million is 3% less than our preferred estimate of 13.25 million nonfatal injuries conservatively assuming that 3% is the relevant statistic, our lower-bound cost estimate would be $96.6 billion.

Upper bounds rely on the National Safety Council's estimate for deaths adjusted for murders: 10,000; the annual survey, assuming the same percentage undercount of deaths in the Census applies to nonfatal cases: 19.8 million injuries; and assuming that the percentage difference between the upper-bound nonfatal cases and preferred estimate applies to costs. $217 billion.

Ranges for occupational diseases were already estimated with the proportion model mentioned above.

46,899 to 73,681 deaths and 817,015 to 907,285 for new cases of illnesses. To assess the reliability of our disease cost estimates, we (1) estimated morbidity costs using a second technique in which our estimates were based on ratios of morbidity costs to direct costs and (2) applied average cost figures to the ranges of disease estimates. We estimated our ratio as a linear function of the 1986 and 1989 ratios calculated by Rice and colleagues. Our lower and upper bounds for costs were $18.8 and $30 billion. The lower-bound estimate is $6.7 billion less than our point estimate of $25.3 for diseases. This $6.7 billion represents 3.9% of our point estimate for diseases and injuries. That is, if we assume the smallest percentages apply in the proportion attributable risk model (eg, 6% for cancer and 3% for circulatory disease) and if we apply the lower average cost estimate, our total costs for both diseases and injuries would decrease by only 3.9% to $164.2 billion.

The ranges of all estimates are summarized in Table 3. Total costs for both deaths and injuries range from $11.3 to $24.7 billion.

The sensitivity analysis did not adjust for varying discount rates for the simple reason that the varying discount rates would not greatly alter the findings. The discount rates used only influenced mortality costs. Our preferred estimates of the costs of deaths caused by injury and illness—roughly $27 billion—represents roughly 15% of total costs. Moreover, the bulk of these $27 billion—$19.7 billion—was attributed to illness. Deaths caused by illness tend to occur later (eg, 65 years of age) than deaths from injury (eg, 25 years of age). This is important because varying discount rates will result in much greater variation in costs when dollars lost 30 or 40 years from now are compared with 5 to 10 years from now. In our estimates, much greater cost variation was dictated by variation in the number and kinds of injuries and illnesses than with variation in discount rates.

COMMENT

Identifying the costs of occupational injury and disease in the United States has been an elusive goal. Our study represents, to our knowledge, the first attempt to estimate the national cost of occupational injury and illness using national data. Recent improvements in national data systems such as the Census and the National Health Interview Survey provide increasing confidence that the overall magnitude of the problem can be approximated. Proper interpretation of national surveys, recognition of the deficiency of workers' compensation reports, and prudence in application of an attributable proportion model to major causes of diseases provided the foundation for our study of the civilian workforce in 1992. Any single source of data, such as the Annual Survey, National Institute for Occupational Safety and Health, workers' compensation, or National Health Interview Survey, underestimated the number of injuries and illnesses. Multiple data sources must be combined to provide comprehensive and reasonably accurate national estimates. In all, we considered 14 primary sources and more than 200 secondary sources, each of which had limitations. Indeed, in the medical...
An advantage of our study is that we implicitly accounted for the severity of injuries by estimating the number of permanent total and permanent partial injuries as defined by workers' compensation authorities. Injuries resulting in permanent impairments are expensive. Future researchers will have even better estimates of severity since the Annual Survey now gathers and publishes data on fatalities absent of particular injuries and illnesses.

Because of the incomplete data, these estimates have important caveats. They tend to produce an underestimation of burden costs of occupational illnesses and injuries. Our counts of the numbers of occupational injuries and illnesses tend to be low because they exclude injuries and illnesses among military personnel, use a conservative estimate (55%) of the degree to which workers' compensation undercounts occupational fatalities, restrict occupational cardiovascular and cerebrovascular morbidity and mortality to events among people younger than 65 years, and use data from a year of high unemployment (1992). Costs are concomitantly lowered, since their estimation relies on the counts of injuries and illnesses. In addition, costs tend to be underestimated because they omitted the wages lost and suffering. Used average medical cost data from the National Council database that excluded 2 high-cost states (California and New York), failed to include home care costs provided by the family, ignored the deleterious effect on children of having a disabled or absent parent, and did not include the wage losses suffered by disabled workers hired into new, less lucrative jobs. Other important sources of underestimation are failure to include lost workdays in years other than the one in which the occupational illness occurred, a well-described limitation of the Annual Survey, and exclusion of costs to innocent bystanders, e.g., airline crash. Finally, we did not allow for recurring injuries. For example, once the knee has been injured, it is easier to injure it again. If the second injury occurs at home, no percentage of the second one is assumed to be job related.

In calculating our medical expenses for injuries, we relied heavily on cost data from workers' compensation because they were readily available and complete (i.e., workers' compensation pays virtually 100% of medical bills). Baker and Krueger have argued that workers' compensation payments to physicians exaggerate true medical costs associated with an injury or illness. Yet the study by Baker and Krueger found that hospital costs (the bulk of all medical costs) were less for workers' compensation than for nonworkers' compensation insurance and did not account for the cost of litigation and paperwork surrounding workers' compensation claims.

While the use of proportions of major categories of disease attributable to occupational exposures may be controversial, we attempted to use ranges that are plausible and consistent with present knowledge. Ranges of estimates of similar magnitudes have been used by occupational health researchers, including ourselves, in studying occupational disease in diverse geographical regions, including New York, Connecticut, Texas, New Jersey, Pennsylvania, and Canada.

Our study methods and results are consonant with the relatively few studies of occupational injury and illness costs that have been conducted to date. Hoskin et al. applied an incidence-based approach to National Safety Council data and estimated the total cost for job-related injuries to be $115.9 billion in 1992. The discrepancy with our estimate ($143 billion) is largely the result of 2 factors: (1) the National Safety Council explicitly ignored violent incidents (assault, murder, and suicide), and more important, (2) the National Safety Council relied on the National Health Interview Survey estimate of nonfatal work injuries, which only captures roughly 60% of all nonfatal injuries. Interestingly, the relative proportions of the estimates of direct and indirect costs were similar in our study and the study by Hoskin et al.

ੰ costs tend to be underestimated because they omitted the costs of pain and suffering

Miller and Galbraith combined occupational injury statistics from 1989 with the National Council medical cost data to obtain an estimate of 11 million occupational injuries (disabling and nondisabling) in 1989. These injuries were associated with costs of $96.6 billion in 1990 dollars. Adjusting for the inflation rate between 1990 and 1992, their estimate was within 10% of the estimate derived from Hoskin et al. Although many of our methods were similar to Miller and Galbraith, our cost estimates were higher in part because our estimate of injuries, 13.25 million, was higher. In addition, we included occupational diseases, and we also assumed higher administrative costs.

Neumark et al. estimated the incidence cost of occupational injuries and diseases in Pennsylvania in 1987 through 1989. They extrapolated to the United States and found a mean estimate of $5.5 billion for illnesses and injuries. This estimate appears to be too low. Their total cost estimate for injuries alone—$17 billion for the late 1980s—was less than half the national costs of injury of workers' compensation in the same year.

Marquis estimated that 7 million Americans suffered injuries on the job in 1989, and another 4 million had persistent disability in 1989 as a result of an injury that occurred prior to 1989. She estimated a total cost of $83 billion in 1989, including 40% for direct (medical) costs and 60% for cost of work loss. The study by Marquis has important limitations. It excluded fatalities, a considerable number of violent incidents, and minor injuries (involving 1-3 days of work loss). Minorities and the poor were also underrepresented—groups that are more likely than other groups to experience injuries on and off the job.

Finally, Webster and Snook estimated that the total workers' compensation costs of back injury and pain in the United States was $11.1 billion in 1986. If we assume (1) workers' compensation only captures 45% of all cases, (2) administrative costs add an additional 21%
for medical (our average of workers' compensation and nonworkers' compensation) and 16% for indemnity (our average of workers' compensation and nonworkers' compensation). (3) Related direct and indirect costs (home production and workplace disruption, fringe benefits, and so on) were 27% (our average), and (4) an average medical and wage inflation of 35% from 1986 to 1992, then beginning with Webster and Snook's $11.1 billion, the adjusted 1992 estimate costs of back pain attributable to job-related factors would be $49.2 billion. This $49.2 represents 34% of our total $145.37 billion. This compares favorably with the National Safety Council estimate of back pain contributing 31%. The close proximity of these 2 estimates provides support for the consistency of our estimates, since we applied our assumptions and results to obtain this $49.2 billion estimate from Webster and Snook.

The costs of occupational injuries and illnesses are large compared with other diseases. The direct and indirect costs of acquired immunodeficiency syndrome were estimated to be roughly $30.0 billion in 1992, excluding insurance administration costs. Our costs, also excluding administration, were roughly $15.5 billion.

Alzheimer disease was recently estimated to cost $20.6 billion in direct costs and $46.7 billion in indirect costs, including administration.

Cardiovascular and cerebrovascular disease are common and costly. The most reliable estimate of the costs of all coronary disease dates to 1980. Rice et al estimated $32.5 billion in direct costs and $47.1 billion in indirect costs in 1980. To bring these 1980 estimates up to 1992 requires several assumptions, involving inflation and secular trends in the rates of these categories of disease as well as administration costs. With these assumptions, we calculated that the total costs for all circulatory diseases would be $164.3 billion in 1992. Similar calculations can be carried out for the costs of cancer.

We estimated a $170.7 billion cost for cancer in 1992. The direct and indirect costs, including administration, of all musculoskeletal conditions was estimated to be $149 billion in 1992.

In summary, the medical costs of occupational injuries and illnesses appear to be much larger than those for acquired immunodeficiency syndrome. The total costs of occupational injuries and illnesses appears to be considerably larger than those for Alzheimer disease and are of the same magnitude as those of cancer, of all circulatory disease, and of all musculoskeletal conditions. These costs are high in part because so many people are at risk: 120 million people held jobs in the United States in 1992.

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REFERENCES


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