



# occupational and environmental health

## Costs of Occupational COPD and Asthma\*

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**Objective:** To estimate the number of annual deaths, as well as the direct and indirect costs of occupational COPD and asthma, in the United States in 1996.

**Design:** Aggregation and analysis of national data sets collected by the National Center for Health Statistics, the Health Care Financing Administration, and other government bureaus and private firms. To assess mortality, we reviewed data from national surveys and applied a population attributable risk (PAR) of 15% for both asthma and COPD. We use a lower age limit of 35 years for occupational COPD and 20 years for occupational asthma. To calculate costs, we use the human capital method that decomposes costs into direct categories, such as medical expenses, as well as indirect categories, such as lost earnings and lost home production. We calculated proportionately adjusted costs for other plausible PARs.

**Results:** The 15% PARs result in costs of \$5.0 billion for COPD and \$1.6 billion for asthma. For COPD, 56% of costs were direct and 44% were indirect; for asthma, 74% were direct and 26% indirect. These estimates are conservative since we ignored costs associated with pain and suffering as well as the value of care rendered by family members. The proportionately adjusted costs for 10 to 20% PARs are \$3.3 to \$6.6 billion for COPD and \$1.1 to \$2.1 billion for asthma.

**Conclusions:** The estimated \$6.6 billion cost of occupational COPD and asthma in 1996 is likely to rise with the increasing prevalence of these diseases and warrants preventive intervention.

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**Key words:** asthma; COPD; economics; jobs; occupational respiratory diseases

**Abbreviations:** ICD9-CM = *International Classification of Diseases, Ninth Edition, Clinical Modification*; PAR = population attributable risk

All obstructive lung diseases—COPD and asthma (*International Classification of Diseases, Ninth Edition, Clinical Modification* [ICD9-CM] codes 490 through 496)—represent the fourth-leading cause of death in the United States. They were

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responsible for 106,027 deaths in 1996.<sup>1</sup> Moreover, from 1979 to 1996, the age-adjusted death rate for all obstructive lung diseases increased 44%. By contrast, the age-adjusted death rates for diseases of the heart, cancer, cerebrovascular diseases, and injury/accidents decreased by 33%, 2%, 37%, and 29%, respectively.<sup>1</sup> The obstructive lung disease death rate in women has shown an especially great increase, nearly doubling from 1980 to 1994. Although this increase in women is commonly attributed to increased smoking,<sup>2</sup> it could also be due, in part, to the rapid increase of women in the workforce. The number of employed women grew > 30% from 1980 to 1994, and the female employment-to-population ratio grew from 47 to 54%.<sup>3</sup>

The National Heart, Lung, and Blood Institute<sup>4</sup> estimated the cost of COPD to be \$26 billion in

1998. Estimated direct costs accounted for \$13.6 billion (52%) and indirect costs for \$12.4 billion (48%). Asthma was estimated to cost \$11.3 billion, with \$7.5 billion in direct costs (66%) and \$3.8 billion in indirect costs (34%).<sup>4</sup> Earlier studies put the cost of asthma at \$6.2 billion in 1990 dollars<sup>5</sup> and \$5.8 billion in 1994 dollars.<sup>6</sup> COPD generates higher indirect costs than asthma because COPD causes more deaths than asthma.

Unfortunately, few estimates of the numbers of deaths and costs of occupational obstructive lung diseases are available.<sup>7–10</sup> Costs can be used to assess the magnitude of the burden and to rank public-health initiatives in order of economic importance. Our purpose in this study is to generate estimates of deaths and costs that incorporate the best methods from prior studies. We use standard methods with some simple improvements, such as adjusting for the mix of costs between inpatient and outpatient care. As a result, our estimates may be compared to published estimates for other diseases (whether or not job related). We will also discuss how society at-large is likely to pay for a significant portion of these costs.

## MATERIALS AND METHODS

### *Epidemiology*

Workplace exposures to coal mine dust, cotton dust, silica, and grain dust are known causes of occupational COPD.<sup>11–15</sup> Exposure to isocyanates, natural rubber latex, animal danders, platinum salts, and a host of other occupational agents have been shown to initiate or aggravate asthma.<sup>16–20</sup> Environmental tobacco smoke also makes a substantial contribution to both COPD and asthma. Asthma caused by massive exposure to irritants—reactive airways dysfunction syndrome—is clinically recognized as occupational asthma.<sup>20</sup> Finally, irritants and cold temperature may exacerbate asthma.

There are two methods of considering disease rates: incidence and prevalence. Since forecasting the future costs of incident cases requires heroic assumptions, we use the prevalence method to estimate annual deaths and costs of prevalent cases of COPD and asthma occurring in 1996. The prevalence method has been used in other published estimates of the cost of obstructive lung disease<sup>21</sup> and measures the current economic impact of all prevalent cases.

There are no data available that unambiguously count the number of either occupational COPD or occupational asthma deaths. Although as many as 80 to 90% of COPD cases in the United States are frequently attributed to direct smoking,<sup>22</sup> the etiologies of both asthma and COPD are multifactorial. Prior studies<sup>11–20</sup> have attempted to determine the percentage of obstructive pulmonary disease deaths attributable to occupational hazards—the population attributable risk (PAR)—by estimating epidemiologic associations based on job exposures or occupations, or by identifying self-reported or physician-diagnosed cases of occupational lung disease. We assume, as prior authors<sup>11–20</sup> have, that the prevalence of obstructive lung disease would drop by the PAR if occupational exposures were removed, recognizing

that this assumption may be invalid due to biases, competing hazards, and the difficulty of assigning one cause in a multifactorial disease.

There is no consensus in the epidemiologic literature regarding the correct PAR for occupational factors that contribute to asthma and COPD. Becklake<sup>11</sup> and Becklake and Ernst<sup>12</sup> have published the most comprehensive review of studies on the PAR of occupational factors in COPD, selecting five population-based studies adjusted for age and smoking. These studies reported PARs of 2% (Norway), 14% (six US cities), 28% (male patients in Tucson, AZ), 14% (chronic bronchitis in Italy), and 16 to 18% (chronic bronchitis in France). We have selected a PAR of 15% for the United States, given this range, heavily influenced by the study by Korn et al<sup>23</sup> of > 8,500 men and women in six US cities. We use linear (proportional) estimating techniques for deaths, hospital days, and costs so that the cost associated with any attributable fraction can be easily calculated.

Authors of *Healthy People 2010*<sup>24</sup> suggest that “occupational factors cause or trigger asthma episodes in 5 to 30% of adults with this disease.” Blanc and Toren<sup>25</sup> published a comprehensive review of 43 attributable risk estimates for occupationally associated asthma from 19 countries. The median PAR value for the 23 published estimates was 9% (range, 2 to 33%; interquartile range, 6 to 18%), whereas the median value for the eight PARs that Blanc and Toren<sup>25</sup> derived from published data was 25% (range, 15 to 45%). The 12 studies extrapolating PARs from incidence data generated significantly lower estimates, with a median value of 5% (range, 1 to 17%). The 12 most methodologically sound studies, based on the number of subjects with asthma, the source of asthma diagnosis, determination of work-relatedness, study design and sampling method, adjustment for smoking, age at onset, and publication type, had a 15% median PAR estimate, which was also the median in the 10 studies that estimated the PAR from population-based samples. From these ranges, we have selected a 15% PAR for occupational asthma (in accord with a draft statement prepared by an ad hoc committee of the American Thoracic Society on PARs for both asthma and COPD) [John Balmes, MD; personal communication; December 2000].

An age restriction is necessary because children do not hold jobs and teenagers typically work part-time, if at all. We assume that no job-related COPD deaths or hospitalizations occur in persons < 35 years of age. More than 99% of COPD deaths and roughly 98% of hospitalizations occur in persons at least 35 years of age. For asthma, we do not count any deaths, hospitalizations, or costs in patients < 20 years of age. We use a younger age limit for asthma than for COPD because there is some evidence for job-related asthma even in teenagers.<sup>26</sup> Given that (1) the great majority of teenagers do not work full-time, (2) many do not work outside the home at all, and (3) job turnover among teenagers is the highest of all age groups,<sup>27</sup> we did not deem it appropriate to apply our PAR estimates to teenagers. We estimate that 5% of asthma deaths (298 of 5,667 deaths) and roughly 35% of all asthma-related hospital days are excluded by our age restriction.

We defined COPD based on a first-listed diagnosis of ICD9-CM codes 490 (bronchitis, “not otherwise specified”), 491 (chronic bronchitis), 492 (emphysema), 494 (bronchiectasis), or 496 (chronic airway obstruction, “not elsewhere classified”), using data from the National Hospital Discharge Survey and the Healthcare Cost and Utilization Project Nationwide Inpatient Sample. The definition of “other COPD and allied conditions” in the National Ambulatory Medical Care Survey and the National Hospital Ambulatory Medical Care Survey also includes 495 (extrinsic allergic alveolitis), so we were unable to exclude this condition from our estimate of outpatient costs. Fortunately, this code has “virtually no effect on the size and trend of the morbidity and mortality statistics for COPD.”<sup>28</sup> In accord with all

prior studies using data from the federal government, we aggregated emphysema and chronic bronchitis, because these conditions often coexist, have similar causes, and are treated in very similar ways.<sup>29</sup> In fact, official coding guidelines published by the American Hospital Association state that “since patients rarely fall neatly into a single category, and bronchitis and emphysema frequently coexist, the diagnosis of COPD, 496, is often used . . . the coder is warned not to attempt a more specific identification.”<sup>30</sup> Because we lack confidence in our ability to distinguish these conditions using administrative data, we applied the same job-related PAR to each subtype of obstructive pulmonary disease: chronic bronchitis, emphysema, and all other types of COPD.

### Economics

Costs are estimated using the human capital method, whereby two broad categories are constructed: direct and indirect costs. Within the direct category, there are medical expenses and administrative expenses. Medical costs include payments to hospitals, physicians, pharmaceutical companies, nursing homes, and vendors of medical supplies, including oxygen. Insurance administration includes the cost of processing claims, managing financial accounts, paying bills, advertising, sales commissions, rate credits, prosecuting fraud, dividends, and profits or losses. The administrative expenses are in turn split into administration for medical and administration for indemnity insurance.

Indirect costs include lost wages, lost fringe benefits, and lost home production. Lost wages are meant to capture not just the hardship for the person and family without the wages, but also the cost to the economy in terms of lost output. Lost fringe benefits are included for the same reason. Home production includes the time costs of child care, making home repairs, preparing meals, and so on. General discussions of the advantages and disadvantages of the human capital method are available.<sup>7</sup>

*Direct Costs:* Our “top-down” approach to estimating direct costs is similar to that of Rice et al.<sup>21,31</sup> Our estimates rely on ratios involving hospital days multiplied by national estimates of medical spending (see equation 1 following). These hospital-day ratios act as anchors in the estimation of all direct costs. Hospitalizations are the most expensive broad category of medical care, responsible for 40% of medical costs in 1996. Doctors’ services are second at 22%.<sup>32</sup> Most other cost studies assume that spending on all other direct costs is proportional to hospital spending.<sup>21</sup> This assumption is controversial, especially for COPD and asthma. COPD frequently results in death, whereas asthma does not. Asthma typically requires considerable outpatient care, but hospitalization rates may be relatively low. We adjust for the inpatient/outpatient mix of costs, which represents an improvement over prior cost studies.<sup>7,21,31</sup>

Our top-down approach begins with an estimate of national expenditures on medical care: \$1,035 billion or 13.6% of the gross domestic product in 1996.<sup>32</sup> Medicare and Medicaid (including Medi-Cal) contributed 20.0% and 14.7%, respectively; other third-party government spending contributed 11.4%; direct out-of-pocket expenditures contributed 17.6%. The remainder, 36.3%, was contributed by private health insurance and health maintenance organizations. These \$1,035 billion in health-care expenditures included payments for hospitalizations, physician visits, nursing home care, medications, medical supplies, and dental services, among other services. Although the estimate of \$1,035 billion by Levit et al.<sup>32</sup> includes \$60.9 billion for the cost of program administration and the net cost of health insurance, we believe that this estimate (6.3% of total health expenditures) is too low. Studies have shown that administrative costs can add up to 45% of the total cost of medical care.<sup>33–36</sup> Danzon<sup>34</sup> has been especially critical of the low estimates for Medicare and Medic-

aid. For example, private insurance companies require buffer funds that are captured in premiums, but may not be paid out as benefits during a given year. These buffer funds are sometimes viewed as wasteful administration, but they are not. Governments do not require buffer funds, because they can raise taxes to shore up public insurance programs, such as the Medicare Hospital Insurance trust fund.<sup>35</sup> The 1994 estimate by Cutler<sup>36</sup> of 15% appears to be reliable and widely used in previous analyses.<sup>7,10</sup> As a result, we exclude the \$60.9 billion estimate of Levit et al.,<sup>32</sup> but add a 15% administrative expense to our calculations. We also exclude dental services (\$47.6 billion), reasoning that neither asthma nor COPD should influence dental costs.

Using the National Hospital Discharge Survey,<sup>37</sup> we then calculated the total number of days spent in the hospital by patients with a principal diagnosis of COPD or asthma. To illustrate, suppose we consider only COPD:

$$\text{Med\$COPD} = (\$926.6 \text{ billion} \times [\text{COPDDays/TotalDays}] \\ \times 0.15) + \text{inpatient adjustment} + \text{outpatient adjustment}$$

where Med\$COPD is our estimate of the dollars spent on medical care for occupational COPD; COPDDays is the number of hospital days attributed to COPD; TotalDays is the total number of hospital days attributed to all diseases and injuries in the United States; \$926.6 billion is the estimate of total US health-care spending (Levit et al.<sup>32</sup>), not including the costs of dental and administrative services; and 0.15 is the PAR.

The inpatient and outpatient adjustments are unique to this study. The hospital-days ratio in equation 1 assumes that all hospital days have equal costs, regardless of the disease. It also assumes that all nonhospital (outpatient) costs are proportional to hospital days, for all conditions.<sup>10,21,31</sup> In fact, mean daily charges (and presumably costs) are about 16% lower for COPD hospitalizations, and 17% lower for asthma hospitalizations, than for the average US hospitalization.<sup>38</sup> Furthermore, asthma is responsible for a relatively large share of outpatient care (eg, 1.33% of all physician visits in 1996 vs 1.07% of all hospital days), whereas COPD is responsible for a relatively small share (eg, 1.83% of all physician visits, vs 2.06% of all hospital days).<sup>39,40</sup> Therefore, we adjust for these important differences using data on hospital days and physician visits from the National Center for Health Statistics,<sup>39,40</sup> and data on hospital daily charges from the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality.<sup>38</sup>

The equation estimates do not account for administrative costs. To obtain administrative costs, we assume that (1) insurance companies and governments spent \$803 billion on health care in 1996 (subtracting \$171.2 billion in out-of-pocket expenditures from \$974.2 billion in total nonadministrative expenditures); and (2) the average of private and public insurance administrative costs is 15%.<sup>36</sup> We further assume that similar administrative costs apply to indemnity insurance (disability, Workers’ Compensation) administration, and that these indemnity payments average about 50% of a worker’s prior wages. Detailed calculations are available from the first author.

*Indirect Costs:* Indirect mortality costs were estimated using a standard present value equation.<sup>10</sup> The present value equation used age-specific, sex-specific, life-table estimates and disease-specific mortality data from the National Center for Health Statistics, Vital Statistics Division,<sup>41–43</sup> as well as earnings and labor force participation data from the Bureau of Labor Statistics.<sup>44</sup>

Finally, we calculated national disease-specific ratios for morbidity costs to direct costs from Rice et al.<sup>21</sup> to estimate the morbidity costs of occupational COPD and asthma. These estimates were, in turn, adjusted to reflect the fact that asthma causes many hospitalizations but few deaths. Whereas asthma

accounts for roughly 25% of hospital days for all obstructive pulmonary diseases, it accounts for only 5% of deaths for all obstructive pulmonary diseases.

Indirect mortality costs capture wages, fringe benefits, and home production for years of life lost due to early death. Indirect morbidity costs capture the same three categories for persons who have not died, but are at least partially disabled due to obstructive pulmonary disease.

## RESULTS

### Epidemiology

**Deaths:** Assuming a 15% PAR, we estimated 15,032 occupational COPD deaths and 805 occupational asthma deaths in 1996, for a total of 15,837 deaths due to occupational obstructive pulmonary disease. Assuming a 10% PAR would yield estimates two-thirds these in size; assuming a 20% PAR would yield estimates one-third above these in size.

**Prevalence:** The National Center for Health Statistics provides estimates of prevalence of obstructive disease.<sup>43</sup> In 1996, 14,150,000 persons were estimated to have chronic bronchitis, 1,821,000 to have emphysema, and 14,596,000 to have asthma. If we assume that 15% of chronic bronchitis and emphysema cases are due to occupational factors, then our prevalence estimate is 2,395,650 for chronic bronchitis and emphysema combined (COPD). Although this estimate ignores age, > 99% of COPD deaths occur in persons aged  $\geq 35$  years. Whereas ignoring age may be inconsequential for chronic bronchitis and emphysema, it is problematic for asthma because 35% of asthma hospital days are among persons < 20 years of age. Adams et al<sup>45</sup> estimate 9,712,000 asthma cases among persons  $\geq 20$  years of age. Fifteen percent of this total is 1,456,800. As more solid estimates of PAR are developed, revised estimates of prevalence can be calculated by multiplying the above-mentioned estimates by the ratio of

the revised estimate to our 15% estimate. These prevalence estimates are not used to estimate costs; hospital days are used instead.

### Costs

Table 1 presents our estimates of the direct costs of COPD. Table 2 presents our estimates of the direct costs of asthma. Table 3 presents estimates of the indirect costs of COPD and asthma. Table 4 combines the more important estimates from Tables 1 through 3, with the total of direct plus indirect costs. Our estimates of total costs, given a 15% PAR, were \$5.0 billion for COPD, \$1.6 billion for asthma, and \$6.6 billion for all obstructive pulmonary diseases combined. For the 10 to 20% PAR range, the COPD costs ranged from \$3.3 to \$6.6 billion; the asthma costs ranged from \$1.1 to \$2.1 billion.

The ratio of direct to indirect costs for asthma (74%/26%) was larger than the ratio for COPD (56%/44%). Asthma accounted for a much higher percentage of hospital days (25%), which drives direct costs, than deaths (5%), which is the major factor driving indirect costs, among all patients with obstructive pulmonary diseases.

## DISCUSSION

### Other Studies

The estimate by Weiss et al<sup>5</sup> on the cost of asthma in 1985, for persons aged  $\geq 18$  years, was \$1.2 billion for direct costs and \$1.3 billion for indirect costs. To compare these estimates to ours, we must make several adjustments. First, the prevalence of asthma has more than doubled among persons aged 18 to 44 years, and among persons  $\geq 65$  years of age.<sup>2</sup> It has increased nearly 50% among persons aged 45 to 65 years.<sup>2</sup> These increases reflect a higher incidence of disease, as well as a larger population at risk. Assum-

**Table 1—Direct Costs for COPD and Occupational COPD, 1996, Derivation of Estimates**

Definition/Category	Number/Estimate
COPD hospital days for persons aged $\geq 35$ yr (ICD9-CM 490 through 496, excluding 493)	3,215,000
Total US hospital days, all diseases, injuries, and conditions	159,883,000
Ratio of COPD days (aged $\geq 35$ yr) to total US days	0.02011
Total cost of health care in the United States, excluding "program administration" and dental services	\$926.6 billion
Total cost of health care for COPD, before adjustment and excluding program administration	\$18.6339 billion
Our PAR of COPD hospital days	15% due to job exposures
Total cost of health care for occupational COPD, before adjustment and excluding program administration	\$2.7951 billion
Hospital, inpatient adjustment	– \$0.2102 billion
Physician visits, outpatient adjustment	– \$0.1599 billion
Total cost of health care for occupational COPD, after adjustment but excluding program administration	\$2.4250 billion
Medical insurance administration (15% of medical costs except those for out-of-pocket expenses)	\$0.2998 billion
Indemnity insurance administration (15% on one half of lost earnings)	\$0.1175 billion
Total direct cost of occupational COPD	\$2.8423 billion

**Table 2—Direct Costs for Asthma and Occupational Asthma, 1996, Derivation of Estimates**

Definition/Category	Number/Estimate
Asthma hospital days for persons aged $\geq 20$ yr (ICD9-CM 493)	1,121,115
Total US hospital days, all diseases, injuries, and conditions	159,883,000
Ratio of asthma days (aged $\geq 20$ yr) to total US days	0.007012
Total cost of health care in the United States, excluding "program administration" and dental care	\$926.6 billion
Total cost of health care for asthma, before adjustment and excluding program administration	\$6.4973 billion
Our PAR of asthma hospital days due to job exposures	15%
Total cost of health care for occupational asthma, before adjustment and excluding program administration	\$0.9746 billion
Hospital inpatient adjustment	– \$0.07801
Physician visits, outpatient adjustment	\$0.1272
Total cost of health care for occupational asthma, after adjustment but excluding program administration	\$1.0238
Medical insurance administration 15% of medical costs except those for out-of-pocket expenses	\$0.1266
Indemnity insurance administration 15% on one half of lost earnings	\$0.0222
Total direct cost of occupational asthma	\$1.1726 billion

ing an 80% increase in prevalence, averaging across all age groups results in a corresponding 80% increase in costs from 1985 to 1996. Second, we must account for inflation. The consumer price index for medical care, which applies to direct costs, increased 105.3% from 1985 to 1996.<sup>46</sup> The employer cost index, which applies to indirect costs, increased 42.7% from 1985 to 1996. Thirdly, the estimate of Weiss et al<sup>5</sup> for persons aged  $\geq 18$  years included only hospital and physician costs. These costs constitute roughly 67% of nonadministrative medical expenditures.<sup>32</sup> Incorporating all three of these adjustments, the adjusted estimate of Weiss et al<sup>5</sup> of the total cost of asthma in 1996 would be \$9.9 billion (\$6.6 billion for direct costs, \$3.3 billion for indirect costs).

If we assume that our 15% PAR (\$1.6 billion) can be multiplied by 6.67 to generate an estimate for all asthma, whether or not job related, then our 1996 cost estimate would be \$10.5 billion. Given that our estimate includes a higher insurance administration expense than Weiss et al,<sup>5</sup> and a slightly narrower age spectrum (eg,  $\geq 20$  years vs  $\geq 18$  years), our total estimates are remarkably similar. With these adjustments, the estimate by Weiss et al<sup>5</sup> of the ratio of direct to indirect costs, 67 to 33%, is also comparable to our estimate of 74 to 26%.

Similar comparisons can be made with Smith et al,<sup>6</sup> who estimated \$2.9 billion of direct costs and \$0.5 billion of indirect costs for asthma in 1987, across all ages. If we assume that the division of direct costs between adults and persons  $< 18$  years of age (Weiss et al<sup>5</sup>) also applies to Smith et al,<sup>6</sup> then the estimate by Smith et al of the direct cost of asthma among adults in 1987 would be \$2.1 billion. We do not use the 1994 estimate of Smith et al,<sup>6</sup> since it did not allow for increased disease prevalence from 1987 to 1994. If we assume a 70% increase in prevalence from 1987 to 1996 and a 78%

inflation rate for medical care, then the direct cost estimate in 1996 by Smith et al<sup>6</sup> would be \$6.4 billion. This estimate is similar to the equivalent estimate of \$6.1 billion by Weiss et al,<sup>5</sup> as well as our direct cost estimate that excludes administrative costs (\$6.8 billion =  $\$1.0238 \times 6.67$ ).

The estimate of indirect costs by Smith et al,<sup>6</sup> even with adjustments for increasing prevalence and inflation, is considerably less than ours and that of Weiss et al.<sup>5</sup> Their relatively low indirect cost estimate is likely a result of their decision to exclude mortality costs and put a lower price on homemaker services than Weiss et al.<sup>5</sup>

### Implications

The morbidity and mortality burden of occupational obstructive lung disease is significant, with an

**Table 3—Indirect Costs of Job-Related Obstructive Pulmonary Diseases, 1996, in Billions of Dollars**

Variables	All Obstructive Diseases	COPD 1996	Asthma 1996
Lost earnings			
Mortality	0.6773	0.6429	0.0344
Morbidity	1.1851	0.9241	0.2610
Total (vertical sum)	1.8624	1.5670	0.2954
Fringe benefits			
Mortality	0.1573	0.1493	0.0080
Morbidity	0.2721	0.2114	0.0607
Total (vertical sum)	0.4294	0.3607	0.0687
Home production			
Mortality	0.0918	0.0871	0.0047
Morbidity	0.1605	0.1252	0.0353
Total (vertical sum)	0.2523	0.2123	0.0400
Total indirect costs			
Mortality	0.9264	0.8793	0.0471
Morbidity	1.6177	1.2607	0.3570
Total (vertical sum)	2.5441	2.1400	0.4041

**Table 4—Total Costs, Billions of 1996 Dollars, Assuming a 15% PAR**

Categories	COPD Only*	Asthma Only†
Direct	\$2.8423 (56% of total)	\$1.1726 (74% of total)
Medical only	\$2.4250	\$1.0238
Administration for medical insurance	\$0.2998	\$0.1266
Administration for indemnity insurance	\$0.1175	\$0.0222
Indirect	\$2.1400 (44% of total)	\$0.4041 (26% of total)
Earnings	\$1.5670	\$0.2954
Fringe benefits	\$0.3607	\$0.0687
Home production	\$0.2123	\$0.0400
Total	\$4.9823 billion‡	\$1.5767 billion‡
Grand total (COPD plus asthma, assuming PAR = 15%)		\$6.5590 billion‡

\*Assumes 15,032 COPD deaths among persons aged  $\geq 35$  yr within ICD-9CM codes 490 through 496, excluding 493. This number should be adjusted proportionally upward or downward for a larger or smaller PAR.

†Assumes 805 asthma deaths among persons aged  $\geq 20$  yr within ICD9-CM code 493. This number should be adjusted proportionately upward or downward for a larger or smaller PAR.

‡A 10% PAR would correspond to two thirds of, and a 20% PAR would correspond to one third more than, the figures shown here. For example, a 10% PAR for asthma would lead to total costs of \$1.0 billion.

estimated 15,837 deaths in 1996. By comparison, 31,130 Americans died of AIDS; 20,971 were murdered; and 20,340 died of leukemia.<sup>1</sup> The magnitude of occupationally related asthma and COPD dwarfs statistics for coal workers' pneumoconiosis mortality (1,417 deaths), asbestosis (1,176 deaths), and mesothelioma (510 deaths).<sup>47</sup>

Second, the cost of job-related obstructive lung disease is significant: \$6.6 billion in 1996 assuming a 15% PAR. This represents an important burden on the health-care system and a drain on the economy. Costs have become a critical factor in the national debate on the allocation of medical spending. Rarely, however, has that debate addressed job-related COPD and asthma.<sup>48</sup>

Thirdly, whereas some portion of the \$1.6 billion cost of occupational asthma is likely paid by employer's contributions to Workers' Compensation premiums, the "lion's share" of the \$5.0 billion cost for COPD is paid by workers, their families, and taxpayers. Only infrequently do Workers' Compensation systems pay for COPD, because the disease manifests itself commonly after retirement and is multifactorial in etiology. It is difficult to prove that the condition in an individual was caused by job factors. Most of the costs of medical care for COPD are likely to be borne by Medicare, *ie*, by taxpayers. A significant portion of the lost wages is likely to be paid for by the Social Security Administration, either through survivors' benefits or disability benefits. Most economic studies of the Social Security payroll tax and the Medicare tax indicate that workers pay these employer taxes indirectly, in the form of lower wages.<sup>7</sup>

In summary, workers and taxpayers, not employers, bear the brunt of the costs of occupational

COPD. In the language of economics, a negative externality exists. Employers are not paying for the true costs of production. They are shifting the costs to workers and taxpayers. Simple economic analysis<sup>49</sup> shows that under these conditions, too much of the "negative externality" (*ie*, job-related COPD and asthma) will be produced by employers.

#### Limitations

There are a number of limitations to our study. First, deaths and hospital days were counted as occurring in 1996. However, the exposures leading to these deaths and hospitalizations could have occurred 20 or 30 years earlier. Death rates due to obstructive lung disease have been increasing for 20 years. Moreover, the labor force grows virtually every year. These limitations suggest that the true cost of occupational obstructive lung disease may grow in the future. However, we have little information regarding whether workplace exposures associated with COPD and asthma have changed over the last 20 years; any changes could affect the future burden of chronic obstructive lung disease. The methods and estimates for the 1996 burden of occupational COPD and asthma will likely prove useful to future researchers.

Another limitation of this study is that ICD9-CM codes cannot effectively distinguish between different subtypes of COPD, such as chronic bronchitis and emphysema. Following the methodology of earlier "cost of illness" studies,<sup>21</sup> we relied on ICD-9-CM codes to define illness. We therefore included code 492 (emphysema) with codes 490 and 491 (chronic bronchitis), as well as codes 494 through 496 (other COPDs). Unfortunately, the estimates for

specific subtypes are unreliable. For example, among deaths, chronic bronchitis contributed 3%, emphysema contributed 17%, and all other COPDs contributed 80%. For days of hospitalization, chronic bronchitis contributed 70%, emphysema contributed 7%, and all other COPDs contributed 23%.

If one subtype is more strongly associated with occupational factors than any other, and this subtype is also more or less costly than average, then our estimates of the cost of occupational COPD may be biased. However, there is no empirical evidence that any single subtype of COPD is more strongly associated with occupational exposures than any other. For example, Becklake<sup>11</sup> reported odds ratios of 1.0 to 2.1 for chronic bronchitis (across five studies) and odds ratios of 1.4 to 2.3 for COPD (across four of the same studies). Therefore, this limitation is unlikely to be a major source of bias.

Our cost estimates depend on the assumed PAR. There is controversy surrounding which PAR is most relevant to the US population, which we have partially addressed by restricting attention to persons aged  $\geq 20$  years for asthma, and aged  $\geq 35$  years for COPD. We used linear estimating techniques so that alternative PARs can be applied, if future evidence suggests that a higher or lower PAR is more accurate.

If we assume that the PAR for smoking is 80%,<sup>22</sup> then a 15% PAR for occupational factors suggests that occupational exposures account for 75% of all COPD not caused by smoking. PARs for different factors are likely to sum to  $> 100\%$  because of synergistic effects. In our case, for some people, both occupational dust exposure and smoking would be required to cause COPD. If either one were eliminated, some persons would not develop COPD.<sup>50,51</sup> Synergistic effects on lung cancer are well documented for asbestos and smoking.<sup>52</sup> The presence of synergistic effects would imply that  $> 20\%$  could be allocated to nonsmoking causes, assuming an 80% PAR for smoking.

Finally, our PAR estimates for both COPD and asthma ignore the possible impact of occupation on smoking patterns and quitting rates. But social and psychological pressures within certain occupations may discourage people from quitting. Among women, waitresses, bus drivers, assemblers, and laborers historically have been heavy smokers.<sup>53</sup> Among men, meat cutters, auto mechanics, truck drivers, police officers, and laborers historically have been heavy smokers.<sup>53</sup> Attributable risk proportions that ignore these psychosocial patterns likely underestimate the deaths and costs associated with job-related COPD and asthma.

There are additional limitations. We did not adjust for current employment status in the present value of earnings tables. We merely adjusted for the labor

force participation rate. In doing so, we modestly undervalued the earnings of those currently employed, because those currently employed are not a random sample of all persons in the labor market. In fact, currently employed persons probably have better lifetime employment prospects than the average of all persons in the labor force, because the latter group includes unemployed persons. This limitation suggests that we underestimated indirect costs.

We ignored costs due to pain, suffering, and impaired quality of life, because it is so difficult to estimate these costs. Lawsuits involving nonfatal injuries almost always involve some payment for pain and suffering. A "rule of thumb" frequently cited in the courts is that the value of pain and suffering equals three to four times the sum of medical expenses and lost wages.<sup>54</sup> A variety of willingness-to-pay methods have been developed to estimate the costs of pain and suffering, but there is no consensus regarding the best method to use for occupational illnesses. Although some economists have argued that workers in dangerous occupations receive a wage premium that reflects their willingness to pay to avoid the associated risks, the size of this wage premium may not reflect the actual level of risk.<sup>7</sup> This limitation suggests that we significantly underestimated true costs.

We did not include the costs of family caregivers' time, nor the costs of health problems that occur among caregivers. These costs are undoubtedly large, but are difficult to estimate. Covinsky et al<sup>55</sup> documented the deleterious physiologic, psychological, and economic consequences on spouses who provide care. One highly regarded study<sup>56</sup> estimated that family ("informal") caregiving comprises 20% of direct costs. This figure would add \$0.8 billion to our combined estimate for asthma and COPD, using a 15% attributable risk. We also excluded indirect costs to employers for hiring and training new workers to replace those who die or experience long absences.

Despite these limitations, there are unique merits to our approach. With the exceptions noted below, we used standard cost-of-illness techniques. Consequently, our estimates can be compared to other cost-of-illness estimates for COPD, asthma, and all other diseases and injuries. Some of our methods improve on prior estimates, by excluding dental services, adjusting for the relative mix of inpatient and outpatient care, which varies across conditions, and adjusting for the varying resource intensity of hospital care across conditions. Because these characteristics are likely to differ for other diseases, we recommend that this method be used in other studies of the cost of illness. Finally, we did not rely on the National Center for Health Statistics<sup>32</sup> esti-

mates for program administration, which have been sharply criticized by economists<sup>34,36</sup> and ignore the cost of insurance administration for indemnity benefits.

## CONCLUSION

The costs due to job-related COPD and asthma are estimated to be \$6.6 billion in 1996. The costs are borne by diseased workers and their families, by all workers through lower wages, and by taxpayers and businesses. The magnitude of these costs justifies more attention to prevention of obstructive lung disease associated with workplace exposures in parallel with efforts to reduce smoking-related morbidity and mortality.

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