Occupational Lung Cancer in US Women, 1984–1998

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Background *Lung cancer is the leading cause of cancer death in US women, accounting for 72,130 deaths in 2006. In addition to smoking cessation, further reduction of the burden of lung cancer mortality can be made by preventing exposure to occupational lung carcinogens. Data for occupational exposures and health outcomes of US working women are limited.*

Methods *Population-based mortality data for 4,570,711 women who died between 1984 and 1998 in 27 US States were used to evaluate lung cancer proportionate mortality over time by the usual occupation and industry reported on death certificates. Lung cancer proportionate mortality ratios were adjusted for smoking, using data from the National Health Interview Survey (NHIS) and the American Cancer Society's Cancer Prevention Study II.*

Results *Analyses revealed that 194,382 white, 18,225 Black and 1,515 Hispanic women died 1984–1998 with lung cancer reported as the underlying cause of death. Following adjustment for smoking, significant excess proportionate lung cancer mortality was observed among US women working in the US manufacturing; transportation; retail trade; agriculture, forestry, and fishing; and nursing/personal care industries. Women employed in precision production, technical, managerial, professional specialty, and administrative occupations experienced some of the highest significantly excess proportionate lung cancer mortality during 1984–1998.*

Conclusions *The results of our study point to significantly elevated risks for lung cancer after adjustment for smoking among women in several occupations and industries. Because 6–17% of lung cancer in US males is attributable to known exposures to occupational carcinogens, and since synergistic interactions between cigarette smoke and other occupational lung carcinogens have been noted, it is important to continue research into the effects of occupational exposures on working men and women.* Am. J. Ind. Med. 54:102–117, 2011. *© 2010 Wiley-Liss, Inc.*

KEY WORDS: lung cancer mortality trends; female lung cancer mortality; occupation and industry; employed US women; transportation industry; health care industry; service industry; blue collar occupations; white collar occupations; administrative; clerical; technical; managerial occupations

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INTRODUCTION

Since 1987, more US women have died each year from lung cancer than from breast cancer, making lung cancer the most common cancer-related cause of death in women. In 2006, the American Cancer Society (ACS) reported 72,130 lung cancer deaths among US women, accounting for about 29% of all female cancer deaths [ACS, 2006; Espey et al.,

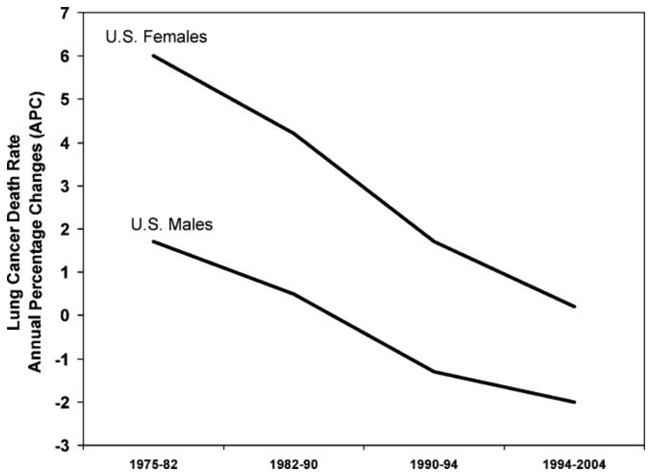

FIGURE 1. Trends in US death rates for lung cancer for 1975–2004 by gender, All races. From Espey et al. [2007]. Annual report to the nation on the status of cancer, 1975–2004, Featuring Cancer in American Indians and Alaska Natives. Mortality trends were evaluated using annual percent change. A percent change >0 indicates the mortality rate is rising; the mortality rate is decreasing when the annual percent change is negative, that is, <0. While male mortality has been decreasing since the 1980s, female mortality, as measured by the annual percent change (APC) statistic, has not decreased. On the contrary, it has increased at least until 2004.

2007]. Mortality trend analysis using annual percent change (APC) statistics show that the lung cancer death rate of males has decreased since the 1980s, while the lung cancer death rate in females has not decreased. On the contrary, this rate increased at least until 2004 (Fig. 1). Hispanic groups have the lowest lung cancer death rates [Espey et al., 2007]. National trends in smoking for the period 1965–2005 for US women based on data from the National Health Interview Survey (NHIS) reveal that white females in 2005 had the highest smoking rate, followed by Black females; Hispanic women reported the lowest rate (Fig. 2). NHIS smoking data for occupational groups suggest that between 1978 and 1997 the largest decline in smoking prevalence was among women in white collar occupations (Fig. 3). Serum cotinine levels dropped in nonsmoking white collar workers between 1988 and 1994, reflecting US legislation prohibiting smoking in public places [Wortley et al., 2002].

Lung cancer is the most problematic of the work-related cancers. Workplace exposures to suspect and known lung carcinogens such as (1) particles and fibers (asbestos, silica, wood dust, paper dust); (2) metals (chromium, arsenic, nickel, cadmium, lead); (3) polycyclic aromatic hydrocarbons (diesel exhaust, cooking oils, cigarette smoke, welding fumes, other combustion processes); (4) radiation (radon gas, ionizing radiation); and (5) solvents have been linked to lung cancer [International Agency for Research on Cancer (IARC), 1987; Coultas and Samet, 1992; Nurminen and Karjalainen, 2001; Alberg and Samet, 2003; Steenland et al., 2003; Alberg et al., 2005; Spitz et al., 2006]. Epidemiologic research on occupational cancer has rarely included women. If women are included in the cohort, they are often excluded from analysis or the presentation of results due to small numbers. Some have suggested that studies that include women tend to use weaker methodologies than studies based on men [Hatch and Moline, 1997]. Although Doll and Peto [1981] estimated that five percent of lung cancer in US women was attributable to occupation, Steenland et al. [1996] estimated the fraction of lung cancer deaths in the US attributable to occupational exposure at two percent in women based on only a few published epidemiologic studies. The estimated attributable fraction was between 6.1% and 17.3% in men. In a later report, others estimated that the number of lung cancer deaths due to occupation ranged from 9,677 to 19,901 for males and females combined [Steenland et al., 2003]. The male/female incidence ratio for lung cancer dropped from 3.56 in 1975 to 1.56 in 1999 [Fu et al., 2005]. An analysis of 1975–1999 National Surveillance, Epidemiology, and End Results (SEER) data found that women accounted for 40.9% of cases less than 50 years of age at diagnosis, although 35.8% of all incident lung cancer cases were women [Fu et al., 2005].

Treatment of lung cancer in the US continues to have a low impact on patient survival. The 5-year survival rate for US women is only 15% [U.S. Surgeon General, 2001]. Further evaluation of lung cancer etiologies could lead to a reduction of the burden of lung cancer, through the prevention of occupational exposure to lung carcinogens. It is important to increase our understanding of all risk factors, including potential work-related exposures and to continue to decrease cigarette smoking rates in order to achieve a more effective, science-driven prevention strategy for women.

US Studies

The results of an analysis of lung cancer in women based on the SEER database characterized the effects of gender on

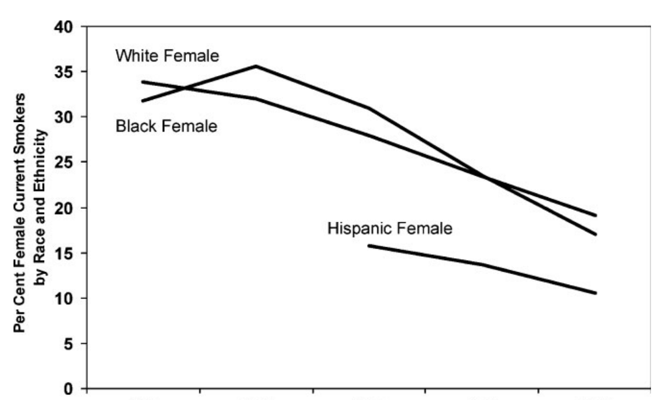

FIGURE 2. Percent cigarette smokers over time among US adult females by race, and Hispanic origin. From Health US [2007]. Data Source: National Center for Health Statistics, National Health Interview Surveys (NHIS). Website: www.cdc.gov/NCHS/hus.htm.

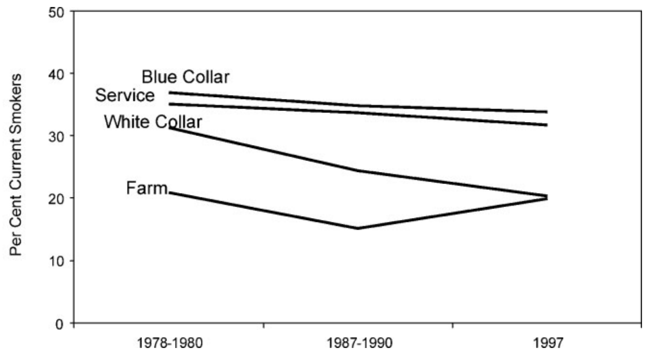

FIGURE 3. Prevalence of smoking among US employed women age 18+ by occupational group and year of survey. From Giovino et al. [2002]. Based on the National Health Interview Survey data. These rates show that the largest decrease in smoking prevalence (1978–1997) occurred among women in white collar occupations.

clinicopathologic features and incidence trends 1975 to 1999 [Fu et al., 2005]. A study of non-small cell lung cancer in Maryland women concluded that lung cancer risk differed in women and men even if they held jobs in the same category; with women, and particularly Black women, being the most susceptible even after adjusting for smoking and other contributing factors including second hand smoke [Amr et al., 2008]. Because new cases of lung cancer in never smoking women are being diagnosed, other causes should be explored such as environmental tobacco smoke (ETS), residential or indoor radon, and occupational exposures to carcinogens. Amr et al. [2008] reported their strongest significantly elevated lung cancer odds ratios in Black females employed in clerical-sales and service occupations, and in white females employed in transportation and material handling occupations. After linking 1987–1994 NHIS smoking data with death records to study lung cancer mortality in 100 of the largest occupational groups, Lee et al. [2004, 2007] reported that female managers (except public administrators); financial records processing occupations; freight, stock, and materials moving and equipment operatives; and heating/refrigeration mechanics have significantly higher hazard ratios for age- and smoking-adjusted lung cancer mortality.

US industries and occupations where female workers experienced excess lung cancer have been identified by State population-based mortality studies that used death certificates [Burnett et al., 1997; Milham, 1997]. Burnett studied 515,579 working women who died in 24 US States 1984–1988 and reported finding significantly elevated lung cancer in white waitresses, and Black women working in the radio, TV, and communication equipment manufacturing industry. A study of deaths occurring 1970–1989 in Washington State reported that elevated proportionate mortality due to lung cancer was experienced by women usually employed as electrical and electronic technicians; florists, bookkeepers, cashiers and payroll clerks; sales clerks; managers, officials and proprietresses not elsewhere classified (NEC); real estate agents, brokers, developers and appraisers; insurance agents, brokers, underwriters, and appraisers; paper and pulp workers; fabric workers; bartenders; bar owners, operators, managers and workers; restaurant owners, managers, and workers; hotel/motel owners, managers; cooks, candy makers, and chefs; and waitresses [Milham, 1997]. Elevated SMRs for lung cancer were reported for women in a small cohort of New York workers employed as professional, clerical, or service workers [Vena and Petralia, 1995]. Robinson et al. [1995] reported that white women employed as construction workers experienced significantly elevated proportionate lung cancer mortality 1979–1990 in 28 US States.

Reports From Europe and the United Kingdom

A chapter in the Registrar General's report described the occupational mortality risks of women in the United Kingdom (UK) [Inskip et al., 1995]. Simpson et al. [1999] evaluated 381,915 cancer registrations of women residing in England and Wales over the 20-year period 1971–1990 and reported a significant association between lung cancer and the "smoky work environments" of publicans and innkeepers, restaurateurs, and bar staff. The authors suggested that other occupational exposures might have contributed to the excess mortality observed in fitters and maintenance engineers, machine tool operators, painters and decorators, construction workers, and press workers and stampers. Carpenter and Roman [1999] reported excess lung cancer in female construction workers, sales representatives, bar staff, plastics workers, and metal polishers in the UK.

Other population-based studies evaluating lung cancer morbidity in Scandinavian, German, Italian, and Central and Eastern European women have found significant associations with the working environment [Andersen et al., 1999; Jahn et al., 1999; Simonato et al., 2001]. A case–control study of occupational risk factors in German women found significantly elevated smoking-adjusted risk in the chemical, oil, pottery, glass, engine, vehicle building, paper, wood, print, cleaning service, hairdressing, housekeeping, and waste disposal industries, as well as in unskilled metal workers, assemblers, stock clerks, restaurant owners, hoteliers, waitresses, and travel attendants [Jahn et al., 1999]. A population-based case–control study in Italy reported significantly elevated smoking-adjusted lung cancer odds ratios for exposure to known (List A) or suspected (List B) lung carcinogens [Ahrens and Merletti, 1998] for female glass workers, laundry/dry cleaners and rubber industry workers. It is unclear whether white collar occupations were evaluated [Richiardi et al., 2004]. A census-based (1970) study of work-related incident cancer cases in Norway, Sweden, Denmark, and Finland reported significantly elevated lung cancer standardized risk ratios that were unadjusted for smoking among female chemical, physical, and biological technical occupations; journalists; administrators and managers; clerical workers; sales agents; shop managers and assistants; transport workers; smelters and foundry workers; mechanics (iron and metal), electrical and wood workers; painters and paperhangers; other construction workers; printers; chemical process and food manufacturing workers [Andersen et al., 1999]. A social gradient in smoking behavior was noted with hourly workers and salaried employees having the highest tobacco consumption in Denmark, and housewives and agricultural workers having the lowest tobacco consumption in Norway, Sweden, and Finland [Andersen et al., 1999].

Conclusions from a meta analysis of European incident lung cancer cases indicated that residential radon acts as a cause of lung cancer in the general population [Darby et al., 2006]. After controlling for tobacco pack years, Bardin-Mikolajczak et al. [2007] reported elevated lung cancer odds ratios among women employed as medical, dental, or veterinary doctors or as librarians and curators in six Central and Eastern European countries.

Most previous epidemiologic studies that evaluated the effects of occupation on lung cancer among women have been conducted in Europe or the United Kingdom. Many of the studies of female lung cancer conducted in the United States have been temporally limited, studied only a small number of occupations, or failed to take into account the effects of smoking. The availability by time, age, and gender of 1984–1998 death certificates from 27 US States that were coded by usual or lifetime occupation and industry led to the present analysis. These data permit a broad evaluation of lung cancer mortality for women employed in smaller occupations and industries that previously have not been studied or reported. We also reviewed published reports on lung cancer and smoking prevalence trends for US women in industrial and occupational settings in the context of our study results. Our goals were to provide estimates of the work-related and smoking-adjusted lung cancer mortality experience of US women and to identify new associations for use as hypotheses for future research and prevention.

METHODS

We analyzed occupation- and industry-coded death certificate data from 27 reporting US States for the years 1984–1998. US death certificates contain information on the usual occupation of the decedent that is provided by the survivors, where usual occupation is defined as the longest or lifetime occupation. These data were contributed to the National Occupational Mortality Surveillance (NOMS) System maintained by the National Institute for Occupational Safety and Health (NIOSH). The States, together with NIOSH, the National Cancer Institute (NCI) and the National Center for Health Statistics (NCHS), have shared the added costs of coding occupation and industry. The reporting States were Alaska, Colorado, Georgia, Idaho, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Utah, Vermont, Washington, West Virginia, and Wisconsin (Fig. 4).

Death certificates for 4,570,711 female decedents, age 15–90 who both resided and died in one of the 27 States were

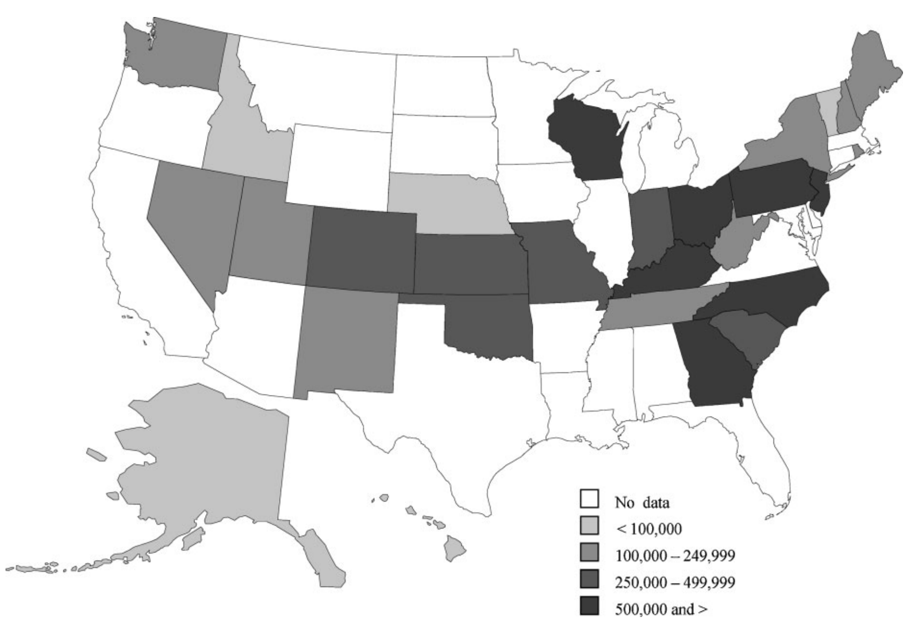

FIGURE 4. Number of NOMS deaths with usual industry and occupation coded for 27 US states, 1984–1998.

TABLE I. Age Distribution of US Female Deaths From Lung Cancer and All Causes in 27 US States, 1984–1998, by Race and Ethnicity

Race and ethnicity	Number of lung cancer deaths	Number of all cause deaths
Age group		
White females		
15–39	1,462	103,278
40–64	64,937	589,576
65+	130,900	3,378,998
Total	197,299	4,071,852
Black females		
15–39	283	36,370
40–64	7,996	128,039
65+	10,209	334,450
Total	18,488	498,859
Hispanic females[a]		
15–39	26	4,650
40–64	515	11,729
65+	1,013	33,489
Total	1,554	49,868

*Includes all deaths age 15–120. Deaths >90 were truncated for the analysis.
[a]Hispanic ethnicity included Mexican, Puerto Rican, Cuban, Central or South American, and other ethnic groups indicated on the death certificate. Race and ethnicity are two separate categories as coded on the US death certificate, they are not mutually exclusive.

the source of study data. The underlying causes of death were coded by State nosologists according to the International Classification of Diseases, Ninth Revision (ICD-9) [WHO, 1978]. Coded demographic cause of death, and occupation and industry data on 4,570,711 death certificates (4,071,852 white women; 498,859 Black women; 49,868 Hispanic women) were provided to NIOSH by the States and NCHS (Table I). Coding of usual occupation and industry provided by next-of-kin was done by specialists trained in procedures developed by the Bureau of the Census (BOC) for NIOSH and NCHS [U.S. BOC, 1982; NCHS, 1987]. Quality control for industry and occupation coding was provided by NIOSH and NCHS.

Identification of Female Deaths

Women aged 15–90 years who died from lung cancer (ICD-9 code 162) and resided in one of the 27 States were identified and used to create analysis files that included age, gender, race, ethnicity, underlying cause of death, and usual occupation and industry.

National death data are reported by the NCHS by age, race, gender, Hispanic origin (ethnicity), cause of death and other variables. NCHS uses race and ethnic categories consistent with the changes to the 1977 Office of Management and Budget (OMB) standards [U.S. OMB, 1997]. Because Hispanic decedents may also indicate race, there may be overlap of ethnicity and race. We chose to report totals for white and Black populations and for Hispanic ethnicity separately. Readers should keep in mind that the Hispanic ethnicity category overlaps the Black/white race categories. Hispanic totals always refer to the total number of Blacks and white Hispanics. Hispanic is the largest ethnic group; the number of deaths for other ethnic groups was insufficient for analysis. Because of the very large size of the data set, it was possible to evaluate proportionate mortality ratios for many of the difficult to study, smaller industries, and occupations that employ women.

Proportionate Mortality Ratio Analysis

Proportionate mortality ratio (PMR) analysis based on the underlying cause of death was used to evaluate the mortality patterns of lung cancer in women by occupation and industry. Race- and ethnicity-specific age-adjusted PMRs were calculated for white, Black, and Hispanic women using a computer program developed at NIOSH [Dubrow et al., 1987; Dubrow and Spaeth, 1993]. This program was designed to calculate PMRs by occupation or industry specifically for population-based data. It calculates PMRs by comparing the proportion of deaths from a specified cause within a specified occupation or industry group with the proportion of deaths due to that cause among all other decedents, and age-adjusts after stratification on race (white, Black) or ethnicity (Hispanic). A PMR above 100 is considered elevated over the average for all occupations. Ninety-five percent confidence intervals (95% CI) for the observed PMRs were calculated. If the observed number of lung cancer deaths was 1,000 or less, the 95% CI was computed based on the Poisson distribution [Bailar and Ederer, 1964]; otherwise, test-based CIs were calculated using the Mantel and Haenszel [1959] χ^2 test. Statistical significance ($P < 0.05$ for a two-sided test) and 95% CIs should be evaluated in the context of hypothesis generation because multiple comparisons were made [Rothman, 1986].

PMRs are often computed when data for the population at risk are not available and rates of death or standardized mortality ratios (SMR) cannot be calculated. The population at risk for this study includes all women ages 15–90 who were at risk of dying at any time between January 1, 1984 to December 31, 1998. Because data by occupation and industry were not available for the entire population of women at risk of death in the occupations and industries reported on the death certificates, we evaluated proportionate mortality based on cumulative deaths over a 15-year period. The PMRs indicate whether the proportion of deaths due to a specific cause appears to be high or low for a particular occupation. The unemployed, part-time workers, those in unknown occupations or industries (about 3%), homemakers and housewives were excluded from the analysis.

Adjustment for Smoking

In this study, lung cancer PMRs were adjusted for smoking using data from the National Health Interview Survey (NHIS) and the American Cancer Society's Cancer Prevention Study II [Thun et al., 2000]. Industry and occupation were categorized into broader groups and a bias factor was calculated for each industry or occupation group based on differences between the smoking prevalence of the industry or occupation group and the overall population under study, as well as the effects of smoking on lung cancer. The smoking-adjusted PMR was then calculated by dividing the unadjusted PMR by the bias factor. We will briefly describe the method here. For details, please see Rothman et al. [2008] and Steenland and Greenland [2004].

Let $P_{current}$, P_{former}, and P_{never} be the proportions in the general population who are current, former, and never smokers respectively; and let $P_{current|exp}$, $P_{former|exp}$, and $P_{never|exp}$ be proportions among workers of a given industry/occupation who are current, former, and never smokers respectively. Let I_0 be the incidence rate of lung cancer for people who never smoked, let $RR_{current}$ and RR_{former} lung cancer indicate risk ratios of current and former smokers versus never smokers respectively, then $RR_{current} \times I_0$ and $RR_{former} \times I_0$ will be incidence rates for current and former smokers respectively. The smoking-weighted incidence rate of lung cancer for the general population can then be calculated as $I_{nonexp} = P_{current} \times RR_{current} \times I_0 + P_{former} \times RR_{former} \times I_0 + P_{never} \times I_0$, and similarly the smoking-weighted incidence rate of lung cancer for workers in the given industry or occupation is $I_{exp} = P_{current|exp} \times RR_{current} \times I_0 + P_{former|exp} \times RR_{former} \times I_0 + P_{never|exp} \times I_0$. The bias factor is defined as the ratio I_{exp}/I_{nonexp}. The smoking adjusted PMR can be calculated as $PMR_{adj} = PMR_{unadj}$/bias factor.

The smoking effects on lung cancer were obtained from a large cohort study, the American Cancer Society's Cancer Prevention Study II [Thun et al., 2000]. The reported risk ratios for current and former smokers versus never smokers were 12.5 and 4.8 respectively among women. Proportions of former, current, and never smokers among female workers were estimated from NHIS 1985 to 1994 data. NHIS codes industry and occupation to the detailed Census codes, providing a major and minor group recode for both industry and occupation. The major group recode has 13 categories and the minor group recode has 41 categories. In this study, industry- or occupation-specific smoking proportions for white female workers and Black female workers were estimated for both the major and minor group recodes. For some minor industry or occupation groups where sample sizes were too small to produce reliable smoking proportions, estimates from the major groups were used. Smoking proportions for Hispanic female workers were estimated for the major group recodes only because of small sample size.

RESULTS

The characteristics of US women who died during the period 1984–1998 in the 27 US reporting States are summarized in Tables I and II. The smoking-adjusted significantly elevated proportionate mortality and 95% confidence intervals for women who died of lung cancer between 1984 and 1998 are displayed by industry and occupation in Tables III and IV. These tables also display stratified PMRs in three 5-year intervals (1984–1988, 1989–1993, and 1994–1998). Because the purpose of this analysis was to identify associations between significantly increased lung cancer mortality and usual occupation and industry, only statistically significant elevated overall PMRs greater than 120 for specific occupations or industries with more than 15 deaths 1984–1998 are shown in the Tables III and IV, although these criteria were not applied to stratified PMRs that were calculated if the number of deaths were >4. PMRs for all occupations and industries analyzed could not be listed due to space limitations but are available on request to the corresponding author or may be viewed at http://www.cdc.gov/niosh/topics/surveillance/NOMS/default.html.

Characteristics of All US Female Deaths and Lung Cancer Deaths 1984–1998

Table I describes the age distribution by race and Hispanic ethnicity for female lung cancer deaths compared with that for all female NOMS deaths coded for usual occupation and industry. Table II provides the number of all deaths by race and Hispanic ethnicity for the major occupation and industry categories. The most often reported major industries were the service industry for white and Black women and the transportation and manufacturing industries for Hispanic women. The 2,181,339 women whose industry was not reported were excluded from analysis. The major occupation categories that most women's death certificates reported (after housewives and homemakers were excluded) were technical, sales and administrative for white women, and service for Black and Hispanic women (Table II).

Lung Cancer PMRs by Occupation

The highest significantly elevated smoking-adjusted lung cancer PMRs observed for a variety of usual or lifetime occupations are summarized in Table III. Among women who were usually employed in blue collar occupations, white sheet metal workers (PMR = 160, CI: 120,213), Black metalworking and plastic machine operators (PMR = 149, CI: 101,202), Black mechanics and repairers (PMR = 148, CI: 101,217), and Black electrical and electronic equipment

TABLE II. Female Deaths by Industry, Occupation, Race, and Ethnicity for 1984–1998 in 27 US States

	White females	Black females	Hispanic[b]
Industry (CIC)[a]			
Service (700–802, 841–860, 872–932)	710,046	159,426	2,143
Health care (812–840, 861–871)	251,177	47,910	1,449
Manufacturing (100–392)	446,581	37,421	17,376
Trade (500–691)	371,832	24,120	4,693
Transportation (400–472)	77,664	6,005	17,795
Agriculture (10–31)	18,567	10,943	71
Construction (60)	12,372	725	0
Mining (40–50)	2,274	52	743
Industry not reported and other[a] (990)	2,181,339	212,257	5,598
Total	4,071,852	498,859	49,868
Occupation (COC)[c]			
Managerial, professional (003–199)	498,769	41,646	3,177
Technical, sales, administrative (203–389)	655,998	35,858	1,872
Farming, forestry, fishery (473–499)	14,575	10,749	239
Operators, fabricators, laborers (703–899)	336,826	45,543	3,012
Service (403–469)	319,250	148,237	5,964
Precision production/craft/repair (503–699)	63,037	6,952	696
Homemaker/housewife (914)	2,082,939	181,704	30,835
Occupation not reported and other codes (999)[d]	100,458	28,170	4,073
Total	4,071,852	498,859	49,868

[a]CIC-US Census industry code [U.S. BOC, 1982].
[b]Hispanic includes Mexican, Puerto Rican, Cuban, Central or South American, and other ethnic groups indicated on the death certificate. Race and ethnicity are two separate categories as coded on the US death certificate. They are not mutually exclusive.
[c]COC-US Census occupation code [U.S. BOC, 1982].
[d]Includes occupations such as military, retired, student, volunteer, homemaker/housewife, disabled, or left blank.

assemblers (PMR = 143, CI: 101,203) experienced the highest PMRs. White women who were usually employed during their lifetime in agricultural occupations such as farm managers (PMR = 163, CI: 112,237), or forestry and fishing (PMR = 183, CI: 116,289), experienced significant excess proportionate mortality (Table III). White electrical and electronic technicians had significantly elevated proportionate mortality (PMR = 151, CI: 126,181), although white radiologic technicians, Black and white health technologists and technicians, and white engineering and chemical technicians all experienced significantly elevated mortality. Black women in administrative support occupations such as computer equipment operators (PMR = 160, CI: 125,204), communications equipment operators (PMR = 150, CI: 113,200), receptionists (PMR = 182, CI: 138,240), and cashiers (PMR = 161, CI: 131,196) also experienced excess proportionate lung cancer mortality. Executive, administrative, and managerial occupations including Black and white legislators and public administrators (PMRs = 145, CI: 110,193) (PMR = 130, CI: 120,141) respectively and Black and white financial officers (PMR = 166, CI: 129,214) (PMR = 132, CI: 127,138) experienced significantly elevated PMRs and accounted for over 1,700 deaths. The large occupational groups of white real estate saleswomen (PMR = 143, CI: 134,152) and hairdressers and cosmetologists (PMR = 122, CI: 117,127) accounted for almost 2,000 deaths 1984–1998 (Table III). White female attendants in amusement/recreation facilities (PMR = 141, CI: 116,171) also had significantly elevated excess proportionate mortality.

Women employed during their lifetimes in 15 different professional specialty occupations experienced significantly elevated lung cancer proportionate mortality (Table III). The professional occupations that were associated with the highest PMRs were industrial engineers (PMR = 168, CI: 103,220) and statisticians and mathematicians (PMRs = 169, CI: 126,226) (Table III).

Lung Cancer PMRs by Industry

The highest significantly elevated smoking-adjusted lung cancer mortality was observed among Black women employed in the radio, TV, and communications equipment manufacturing industry (PMR = 230, CI: 172,305) and in the trucking services industry (PMR = 261, CI: 177,385), as displayed in Table IV. Significantly elevated PMRs occurred

TABLE III. Smoking-Adjusted Lung Cancer* Mortality by Occupation Among US** Women by Race/Ethnicity*** 1984–1998

		1984–1998			1984–1988		1989–1993		1994–1998	
Occupation (BOC code)[a]	**Race, ethnicity*** **	**PMR[b]**	**95% CI**	**No. deaths**	**PMR**	**No. deaths**	**PMR**	**No. deaths**	**PMR**	**No. deaths**
Agriculture										
Farm Managers exc Hort (475)	White	163	112,237	30	174	8	192	14	122	8
Related agricultural occupations (485–489)	White	131	108,160	105	126	19	131	45	124	41
Forestry, fishing, hunting (494–499)	White	183	116,289	21	—	3	172	8	205	10
Precision production										
Mechanics and repairers (503–549)	Black	148	101,217	29	168	7	196	13	101	9
Sheet metal workers (653–654)	White	160	120,213	50	133	10	202	25	124	15
Electrical and electronic equipment assemblers (683)	Black	143	101,203	35	143	6	165	14	126	15
Inspectors, testers, and graders (689)	White	132	111,157	133	133	36	130	48	126	49
Metal working and plastic machine op. (703–725)	Black	149	101,202	35	242	15	108	10	123	10
Punching and stamping machine operators (706)	White	123	106,142	192	114	49	133	84	112	59
Technicians										
Radiologic technicians (206)	White	132	109,161	104	134	25	136	41	122	38
Health technologists and technicians NEC (208)	Black	140	105,187	50	236	14	150	19	101	17
	White	122	106,140	212	169	51	103	60	108	101
Electrical and electronic technicians (213)	White	151	126,181	125	165	31	150	45	132	49
Engineering technicians (216)	White	131	107,197	164	100	28	109	52	156	84
Chemical technicians (224)	White	145	107,197	45	154	11	179	21	99	13
Technical, sales, administrative support										
Computer programmers (229)	White	131	105,164	80	131	15	108	25	141	40
Legal assistants (234)	White	130	109,155	130	133	23	121	48	129	59
Real estate sales (254)	White	143	134,152	931	156	239	138	348	131	344
Salesperson, other commodities (274)	Black	125	104,150	117	126	29	139	49	111	39
Cashiers (276)	Black	161	131,196	100	151	22	176	39	151	39
Service										
Child care workers, private household (406)	Black	165	115,236	32	165	8	170	10	161	14
Hairdressers and cosmetologists (458)	White	122	117,127	1,979	120	521	124	782	119	676
Attendants, amusement/recreation facilities (459)	White	141	116,171	110	119	17	148	38	133	55
Executives, administrators, managers										
Legislators and public administrators (003–005)	Black	145	110,193	52	160	14	94	12	183	26
	White	130	120,141	622	135	164	133	232	122	226
Financial officers (023–025)	Black	166	129,214	64	185	15	157	21	165	28
	White	132	127,138	1,695	132	424	125	590	132	681
Purchasing agents, buyers (028–033)	White	139	126,152	465	143	129	133	171	141	165
Professional specialties										
Engineers (044–062)	White	153	126,185	112	177	26	150	42	133	44
Industrial engineers (056)	White	168	103,220	29	189	6	162	11	153	12
Computer and systems analysts (064–065)	White	144	120,172	122	160	22	135	40	136	60
Statisticians and mathematicians (066–068)	White	169	126,226	49	173	15	196	20	140	14
Natural scientists (069–083)	White	136	111,166	103	113	17	165	46	112	40
Physicians (084)	White	143	111,184	66	138	18	179	29	116	19
Nurses (095)	Black	124	112,136	411	134	120	117	144	124	147
Counselors, educational/vocational (163)	White	136	110,169	90	133	22	152	39	116	29
Librarians, archivists, curators (164, 165)	Black	159	107,236	27	183	7	169	10	137	10
	White	135	122,148	458	124	112	130	167	147	179
Social workers (174)	Black	132	112,155	150	128	32	141	57	127	61
Designers (185)	White	127	116,139	510	104	109	123	186	143	215

TABLE III. (*Continued*)

Occupation (BOC code)[a]	Race, ethnicity***	1984–1998 PMR[b]	1984–1998 95% CI	1984–1998 No. deaths	1984–1988 PMR	1984–1988 No. deaths	1989–1993 PMR	1989–1993 No. deaths	1994–1998 PMR	1994–1998 No. deaths
Painters, sculptors, craft artists, print-makers (188)	White	131	117,147	319	117	64	131	121	134	134
Photographers (189)	White	136	106,174	65	159	18	153	29	100	18
Editors, reporters (195)	White	127	111,145	228	135	68	135	91	113	69
Public relations specialists (197)	White	132	102,173	58	140	17	148	23	110	18
Administrative support										
Computer equipment operators (304, 308, 309, 385)	Black	160	125,204	69	258	25	143	24	115	20
Communications equipm. operators (306, 348–353)	Black	150	113,200	50	157	11	179	20	127	19
Secretaries (313)	Black	129	113,148	224	162	68	110	66	125	90
	Hispanic	144	101,204	34	299	7	135	13	119	14
Receptionists (319)	Black	182	138,240	54	181	11	203	23	163	20
Records processing (exc financial) (325–336)	Black	152	113,206	46	130	9	148	15	166	22
Material recording, sched., distrib. clerks (359–374)	Black	138	111,172	85	131	18	153	38	128	29
General office clerks (379)	Black	145	128,165	244	162	82	137	91	123	71

*Lung Cancer ICD-9 162.
**States that contributed data for 1984–1998 were: Alaska, Colorado, Georgia, Idaho, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Utah, Vermont, Washington, West Virginia, and Wisconsin.
***Race and ethnicity are two separate categories as coded on the US death certificate, they are not mutually exclusive.
[a]US Bureau of the Census (BOC). 1982. 1980 Census of Population and Housing. Alphabetical index of industries and occupations. PH C80-R3, US Department of Commerce, US GPO, Washington, DC.
[b]Table includes occupations with a statistically significant >20% PMR elevation, and 15 or more deaths in occupation/race category over the 15-year period 1984–1998.

among Hispanics employed in nursing and personal care facilities (PMR = 172, CI: 108,273) and Black women employed in retail department stores (PMR = 163, CI: 137,193). Black women usually employed during their lifetime in bus service and urban transit (PMR = 144, CI: 105,196), white women usually employed in the fishing, hunting, or trapping industries (PMR = 163, CI: 109,244), and Black and Hispanic women employed in public administration experienced significantly elevated disproportionate mortality (PMR = 132, CI: 123,142) (PMR = 162, CI: 124,213) (Table IV).

PMRs by Occupation and Industry Over Time

Stratified PMRs were evaluated over three 5-year intervals during the study period: 1984–1988, 1989–1993, and 1994–1998 (Tables III and IV). The trucking services industry; and the radio, TV, and communications equipment manufacturing industries continued to experience PMRs that were highly elevated in the most recent stratum (1994–1998). PMRs for blue collar or precision production occupations and white collar occupations such as computer programmers, service, financial officers, librarians, receptionists, and records processing occupations remained elevated in the most recent stratum (1994–1998).

DISCUSSION

Our population-based study is the broadest analysis of occupation, industry, and lung cancer among US women to date, and it was conducted to allow the evaluation of mortality for women employed in smaller occupations and industries that previously have not been studied or reported. The study includes many women over a wide geographic area (27 US States over 15 years of mortality 1984–1998) and overcomes some of the limitations of other US studies of women that are temporally limited or do not adjust for smoking prevalence. The purpose of the study is to generate hypotheses about occupational exposures that may cause lung cancer. In our study, we found that women employed during their lifetime in industrial/blue collar and agriculture, including forestry and fishing, occupations were more likely to have died from lung cancer after adjusting for smoking. In addition, we found that technical, professional, administrative support, and managerial occupations were associated with increased proportionate lung cancer mortality in women.

Blue Collar Workers

Women working in blue collar occupations experienced significantly elevated PMRs for lung cancer after adjustment

TABLE IV. Smoking-Adjusted Lung Cancer* Mortality by Industry Among US Women** by Race/Ethnicity*** 1984–1998

		1984–1998			1984–1988		1989–1993		1994–1998	
Industry (BOC code)[a]	**Race/ ethnicity*** **	**PMR[b]**	**95% CI**	**No. deaths**	**PMR**	**No. deaths**	**PMR**	**No. deaths**	**PMR**	**No. deaths**
Agriculture										
Horticultural services (021)	White	130	109,156	52	213	19	124	19	86	14
Fishing, hunting, trapping (031)	White	163	109,244	26	114	4	202	15	140	7
Manufacturing										
Printing, publishing, allied ind (172)	Black	146	107,200	43	130	8	189	21	114	14
Industrial and misc. chemicals (192)	White	123	111,136	383	123	94	135	163	111	126
Radio, TV communication equip (341)	Black	230	172,305	50	262	12	212	19	230	19
Electrical machinery, equip., and supp. (342)	Black	136	106,174	66	150	15	114	23	153	28
Not specified manufacturing (392)	Black	129	114,146	247	144	63	109	77	138	107
Transportation										
Bus services and urban transit (401)	Black	144	105,196	42	192	11	111	11	145	20
Trucking/services (410)	Black	261	177,385	28	—	3	321	11	259	14
Services incidental to transport (432)	White	126	110,143	238	156	61	111	76	123	101
Communications and utilities										
Telephone, wire, and radio (341)	Black	133	108,163	96	154	23	128	32	127	41
Electric and gas and other combinations (462)	White	129	100,167	63	142	19	113	23	140	21
Trade										
Machinery, equip, supplies whsl (530)	White	124	110,140	279	131	92	130	124	107	63
Department stores (ret) (591)	Black	163	137,193	138	184	43	163	53	147	42
Apparel and shoe stores (630, 631)	Black	142	109,184	61	123	13	135	23	161	25
Fuel and ice dealers (ret) (672)	White	129	105,157	100	157	31	85	24	152	45
Misc. retail stores (682)	White	127	118,136	809	141	235	119	278	124	296
Finance, insurance, real estate (700–712)	Hispanic	150	102,219	29	206	4	160	14	126	11
Banking (700)	Black	163	130,206	77	226	25	163	27	127	25
Real estate incl insurance-law offices (712)	White	125	121,130	1862	131	469	125	691	121	702
Business services NEC (742)	Black	153	119,198	63	266	16	134	24	135	23
Service										
Nursing and personal care (832)	Hispanic	172	108,273	20	—	1	207	9	194	10
Engineering, architectural, survey (882)	White	136	117,157	187	151	45	136	74	127	68
Membership organizations (881)	Black	163	118,225	40	181	11	141	14	176	15
	White	138	126,152	446	127	128	142	177	147	141
Accounting, audit and bookkeeping (890)	White	125	117,134	788	129	182	128	305	120	301
Public administration										
Public administration (900–932)	Black	132	123,142	718	143	200	124	250	132	268
	Hispanic	162	124,213	56	169	7	126	15	184	34
General government NEC (901)	Black	130	117,148	319	156	98	128	118	115	103
Just ice, public order and safety (910)	Black	129	106,158	101	130	24	103	29	152	48
Administ. of human resources (922)	Black	128	104,159	90	138	27	113	27	134	36
Administ. of environmental quality (930)	Black	173	103,292	16	—	3	189	5	256	8

*Lung Cancer ICD 162.
**States that contributed data for 1984–1998 were: Alaska, Colorado, Georgia, Idaho, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Utah, Vermont, Washington, West Virginia, and Wisconsin.
***Race and ethnicity are two separate categories as coded on the US death certificate, they are not mutually exclusive.
[a]BOC—Bureau of the Census. US 1980.
[b]Table includes industries with a statistically significant >20% PMR elevation, and 15 or more deaths in industry/race category over the 15-year period 1984–1998.

for smoking, including mechanics and repairers; sheet metal workers; electrical and electronic equipment assemblers; inspectors, testers and graders; punching and stamping press operators; and metal working and plastic machine operators (Table III). Women working in several manufacturing industries (radio, television, and communication equipment manufacturing; printing, publishing and allied; industrial and miscellaneous chemicals; electrical machinery, equipment, and supplies; and product not specified) experienced excess lung cancer mortality (Table IV). Most of these blue collar occupations associated with elevated risk for women have been reported in previous studies of men that did not include or report female mortality. Similarly, Jahn et al. [1999] reported significantly elevated smoking-adjusted risk for lung cancer among European women employed in metal assembly, precision production occupations, printing operators, and motor vehicle manufacturing and related jobs. Also, Lee et al. [2006] reported elevated smoking-adjusted mortality for precision production occupations and machine operators, noting that some of the occupations had concurrent exposure to asbestos and other lung carcinogens in addition to having higher prevalences of cigarette smoking than the US population 1987–2004.

The lack of a decline in US female lung cancer mortality rates (Fig. 1) does not appear to reflect the decline in the smoking prevalences of employed women (Fig. 2), even after accounting for 20-year lung cancer latency. Several occupational exposures that are known or suspected lung carcinogens may act independently or together with benzo [a] pyrene in cigarette smoke to increase lung cancer risk. These exposures are asbestos, arsenic, bis(chloromethyl) ether, chromium VI, nickel, nickel compounds, PAHs, radon, vinyl chloride, acrylonitrile, beryllium, cadmium, formaldehyde, acetaldehyde, silica, coal tar, coke oven emissions, and synthetic vitreous fibers [Dement, 2002]. The consistently elevated PMRs we observed for some occupations and industries over the 15-year interval 1984–1998 suggest that there may be carcinogenic exposures associated with the workplace. Other etiologic exposures might include indoor radon or passive smoking, which our study did not directly evaluate. Elevated PMRs among women employed in the manufacturing sector or the blue collar occupations may reflect risk from smoking, other occupational exposures, or a synergistic interaction of cigarette smoke with exposure to occupational lung carcinogens.

Transportation Sector

New observations of significantly increased smoking-adjusted female lung cancer mortality were found in the US transportation sector among Black women who worked in trucking service (PMR = 261, CI: 177,385) and in the bus services and urban transit industry (PMR = 144, CI: 105,196) (Table IV). Employment in the US transportation sector is expected to increase 10% by 2016 [US Bureau of Labor (BLS), 2008]. Excess mortality or morbidity among US women who worked in the trucking service industry has not been previously reported. The tasks of US trucking service workers may include hauling or drive away transport, cargo carriers, commercial truck driving, local and long distance hauling, auto freight, and trucking terminal, pier, or teaming [U.S. BOC, 1992]. Trucking service PMRs remained elevated when stratified over the 15-year period 1984–1998 (Table IV). The excess mortality we observed for women corresponds to elevated risk previously reported for male drivers that has been associated with exposure to diesel exhaust (a known lung carcinogen) and likely is confounded by passive exposures to cigarette smoke in truck cabs, enclosed terminals, cabs, and truck stops [Steenland et al., 1998; Boffetta et al., 2001]. In addition to PAHs from diesel engine exhaust fumes, truck drivers may have potential exposure to other lung carcinogens such as asbestos in brake linings [Steenland et al., 1998; Robinson and Burnett, 2005]. Lung cancer mortality for Black women in bus service and urban transport in our study was increased by 45% (PMR = 145) for the most recent time interval (1994–1998). Andersen et al. [1999] reported significant elevated risk (not adjusted for smoking) for female Scandinavian transport workers (but his category did not include drivers); transport workers were defined as railway, bus and train staff (except drivers and operators), aircraft (pilots, traffic supervisors, and other). Neither Jahn et al. [1999], nor Lee et al. [2006], found elevated risk for women in transportation, but they studied somewhat smaller numbers of women. Lung cancer and other mortality among US women in trucking service jobs, where exposures to diesel and side stream smoke may be higher within truck terminals, docks or nearby offices, has not been adequately studied.

Managerial, Professional, Technical, and Administrative Support Occupations

Significant excess lung cancer mortality compared to other female workers was noted for legislators and public administrators; computer equipment operators; financial officers, secretaries, librarians, records processing, and many other white collar occupations and professional specialties (Table III). All PMRs when stratified remained elevated in the last 5-year interval (1994–1998) of the 15-year time period (Table III). Workers in white collar occupations tend to have less passive exposure to cigarette smoke, as measured by serum cotinine levels among non-smokers [Wortley et al., 2002], as well as lower reported prevalence of smoking 1978–1997 than blue collar workers [Lee et al., 2007] (Fig. 3). Office workers may be exposed to known or potential carcinogens—that is, polycyclic aromatic hydrocarbons (PAHs) such as petroleum distillates and carbon black [Sorahan et al., 2001], dust from coated paper, glues, and other emissions from office supplies or equipment—or, may work in areas adjacent to production areas where exposure to industrial carcinogens could occur [NIOSH, 1989]. A recent report based on NHIS mortality data 1987, 1988, and 1990–1994 noted significantly increased female lung cancer mortality for some of the same occupations we report: financial records processing; managers, administrators, except public administration; officials and administrators, public administration; and computer equipment operators [Lee et al., 2006]. The consistency of findings and the persistent elevations in selected PMRs in 1984–1998, despite a 10% or greater decrease in smoking rates among female white collar workers by 1997 (Fig. 3) [Giovino et al., 2002], suggest that a re-evaluation of risk to both women and men in office environments should be conducted in the next decade.

Amr et al. [2008] observed that clerical-sales jobs were associated with excess lung cancer in women regardless of their smoking status. These jobs as well as jobs in the Service sector are performed primarily indoors where there may be exposure to potential hazards including environmental tobacco smoke (ETS) (an established risk factor for lung cancer in non-smokers [IARC, 2004]) and radon (a radioactive gas found in some homes and the second major cause of lung cancer [Darby et al., 2006]). These potential exposures may help explain the elevated lung cancer mortality in women working in indoor occupations, for whom smoking rates have declined. The increasing lung cancer incidence among younger women reported by Fu et al. [2005], despite decreased smoking rates over the last 30 years, is disturbing and suggests that studies of the relationship between lung cancer and occupation for women should be a priority.

Health Care Sector

We observed significant excess proportionate lung cancer mortality among Black nurses (PMR 124, CI 112,136), white female physicians (PMR 143, CI 111,184), white radiologic technicians (PMR 132, CI 109,161), Black and white health technologists and technicians (PMR 140, CI 105,187) (PMR 122, CI 106,140) and among women of Hispanic ethnicity who worked in nursing and personal care facilities (PMR = 172, CI: 108,273). Significantly elevated lung cancer among Hispanic women worked in nursing and personal care facilities has not been previously reported and represents a new finding that should be investigated. The health care sector and Hispanic women have had the lowest rates of smoking over the last 6 decades (the last two decades for Hispanic women) (Fig. 2) [Brackbill et al., 1988; U.S. Surgeon General, 2001; Lee et al., 2007; Kung et al., 2008]. Because Hispanics may be coded as white or Black, race-based analyses may miss increased proportionate mortality in occupations tending to have large Hispanic subpopulations.

Trade, Sales and Real Estate Occupations

Large numbers of women working in sales (retail department stores; real estate; wholesale machinery equipment and supplies; fuel and ice dealers; and apparel and shoe stores) experienced significantly increased mortality from lung cancer (Table IV). Hnizdo et al. [2004] reported increased risk of chronic obstructive pulmonary disease (COPD) among wholesale and retail sales workers. Prior respiratory disease, including COPD, has been reported to be a risk factor for lung cancer after control for smoking and in non-smokers [Alavanja et al., 1992; Brenner et al., 2001; Koshiol et al., 2009; Liang et al., 2009; Schwartz et al., 2009]. Particularly in the wholesale sectors, increased lung cancer mortality may be hypothesized to result from exposures to lung carcinogens such as silica and particulate dust. Materials being sold may contain lung carcinogens, for example, asbestos in building materials or textile dusts and fibers. Exposures to carcinogenic diesel fumes or cigarette smoke might occur in warehouses where wholesale goods are stored and loaded. Increased lung cancer risk has previously been reported for the retail and sales occupations for males [Lee et al., 2006] and females [Amr et al., 2008].

During the past 35 years there have been significant regulatory efforts intended to reduce the exposure of workers to known lung carcinogens and to monitor the exposure of workers to some carcinogens [Russi, 2004]. Shopland et al. [2001, 2004] reported that 70% of the US workforce worked under a smoke-free policy by 1999. Other studies reported smoking rates had decreased by only three percent or less among female workers in blue collar, service, or farm-related occupations—from 37% in 1978–1980 to 34% in 1997—however rates for white collar workers dropped 10% [Giovino et al., 2002] (Fig. 3). We provide new evidence based on smoking-adjusted US proportionate mortality that women in several occupational and industry groups that have not been adequately studied are at increased risk of lung cancer mortality. Because 6–17% of lung cancer in US males is attributable to exposures to known occupational carcinogens [Steenland et al., 1996], and since synergistic interactions between these exposures and cigarette smoke have been noted [Dement, 2002], it is important to continue research into the effects of both occupational and smoking exposures on working men and women.

Advantages and Limitations

Limitations in the PMR method may bias risk estimates toward the null. For example, if the overall mortality rate of the working population is higher than that of the comparison population, the PMR as an estimator of the SMR or death rate will be artificially decreased [DeCoufle et al., 1980]. More recent studies suggest that PMR analysis, when used for population-based studies of workers, may be less biased than SMR analysis. This is because comparison with other workers limits the impact of the healthy worker effect—that is, all causes mortality in workers is low during the working years compared to the general population due to selection processes in employment [Park et al., 1991; Checkoway et al., 2004].

Misclassification may be a source of bias due to inaccurate reporting of usual occupation and industry, the underlying cause of death, and the lack of data on occupational exposures. Usual occupation and industry on death certificates are identified by informants, not the deceased worker, and could have been inaccurate in some cases, resulting in some misclassification. Four case–control studies of long-term white workers across all occupations [Peterson and Milham, 1974; Wegman and Peterson, 1978; Steenland and Beaumont, 1984; Milham, 1997] have reported 75–80% agreement between occupations as listed on the death certificate and those determined by interviewing next-of-kin. For most States, there is no information on specific occupational exposures on death certificates, nor for confounding factors such as cigarette smoking. However, because of the higher smoking prevalence among the unemployed, restricting the comparison population to employed US women with usual occupation and/or industry reported has slightly reduced the negative bias that would arise from including a comparison population more heavily exposed to cigarette smoke. Finally, while the degree of misclassification of cause of death varies by disease, fatal chronic disease such as lung cancer is much more accurately classified than many other causes of death [Kircher et al., 1985]. Both cause of death and smoking misclassification would tend to lower PMRs toward the null. While some believe that adjustment for multiple comparisons is unnecessary in hypothesis-generating analyses, other statisticians disagree. Rather than adjust for the large number of statistical comparisons, we chose to draw on other criteria, such as statistical precision, previously published reports, and biologic plausibility in emphasizing associations [Hill, 1971; Wegman, 1992].

Although usual occupation and industry listed on the death certificate are reasonably accurate for the usual or longest occupation, they do not provide a complete description of occupational exposure for the workers in this study. This is particularly true for mobile or unskilled workers who may change jobs many times. The impact of many job changes on the risk of lung cancer by occupation or industry, although not assessed, may confound some associations. For example, many workers with office or administration as usual occupations may have had prior periods of work in blue collar occupations or industries with exposure to lung carcinogens. This issue cannot be directly addressed in this study with the available data but should be considered when interpreting the results.

Nevertheless, these findings were based on the analysis of a very large population-based data set obtained from 27 US States over a 15-year time period. The large number of deaths and geographic distribution of the States make these data valuable for evaluating mortality in women, and in the smaller under-studied occupations in sectors such as service, wholesale/retail, and professional/technical, as well as occupations and sectors that employ minority or unskilled workers. Although the analysis is based on selected States, it permits stable estimates of risk for smaller occupational and race-sex minority groups; such estimates are needed for the over-arching goal of Healthy People 2010/2020 to reduce health disparities in the US population [US DHHS Healthy People 2006].

CONCLUSIONS

Occupational lung carcinogens have been well documented; epidemiologic studies have mostly studied men but not women. Using a very large group of decedents that is representative of the US population, we evaluated the associations of usual lifetime occupation and industry with death due to lung cancer in US women. The size of our study allowed the estimation of associations between specific occupations and industries and subsequent lung cancer mortality among women, and the generation of hypotheses that can be useful as starting points for future studies. The results of our study point to significantly elevated risks for lung cancer after adjustment for smoking among women in several occupations and industries. We provide new evidence based on smoking-adjusted proportionate US mortality data stratified by gender, race/ethnicity, and 5-year time periods that women in several occupational groups (precision production, agricultural, technical, professional, health care, management, and administrative support) and industrial groups (transportation, manufacturing, and retail trade) are at significant increased risk for lung cancer mortality. In addition, we report increased significant excess mortality among women in many of these occupations and industries that remained consistently elevated over the 15-year interval 1984–1998, and that have not been adequately studied. Carcinogenic occupational and environmental exposures in these industries and occupational groups, including side stream smoke and indoor radon, should be investigated more carefully over the next decade. Identification and reduction of occupational risk factors for lung cancer in epidemiologic studies of women and men in working populations should be vigorously pursued.

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