Occupation and Lung Cancer Mortality in a Nationally Representative U.S. Cohort: The National Health Interview Survey (NHIS)

David J. Lee, PhD
Lora E. Fleming, MD, PhD
William G. LeBlanc, PhD
Kristopher L. Arheart, EdD
Katherine Chung-Bridges, MD, MPH
Sharon L. Christ, MS
Alberto J. Caban, MPH
Terry Pitman, BS

Objective: *The objective of this study was to assess the risk of lung cancer mortality in a nationally representative sample of U.S. workers by occupation.* ***Methods:*** *National Death Index linkage identified 1812 lung cancer deaths among 143,863 workers who participated in the 1987, 1988, and 1990–1994 National Health Interview Surveys.* ***Results:*** *Current and former smoking status was predictive of lung cancer mortality (hazard ratio [HR] = 15.1 and 3.8, respectively). Occupations with significantly higher risk for age- and smoking-adjusted lung cancer mortality included heating/air/refrigeration mechanics (HR = 3.0); not specified mechanics and repairers (HR = 2.8); financial records processing occupations (HR = 1.8); freight, stock, and materials handlers (HR = 1.5); and precision production occupations (HR = 1.4).* ***Conclusion:*** *Although tobacco use continues to be the single most important risk factor for lung cancer mortality, occupational exposure to lung carcinogens should be targeted as well to further reduce the burden of lung cancer.* (J Occup Environ Med. *2006;48:823–832*)

From the Sylvester Comprehensive Cancer Center (Dr Lee, Dr Fleming), the Department of Epidemiology & Public Health (Dr Lee, Dr Fleming, Dr LeBlanc, Dr Arheart, Mr Caban, Mr Pitman), the Department of Family Medicine (Dr Chung-Bridges), and the Odum Institute for Research in Social Science (Ms Christ), University of Miami, Miller School of Medicine, Miami, Florida.

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Address correspondence to: David J. Lee, PhD, Department of Epidemiology & Public Health, University of Miami Miller School of Medicine, P.O. Box 016069 (R-699), Miami, FL 33101; E-mail: dlee@med.miami.edu.

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Despite reductions in male mortality rates and a recent stabilization of female incidence rates, lung cancer remains the leading cause of cancer death in the United States.[1,2] Tobacco use remains the single most preventable cause of lung cancer.[2] However, approximately 3% to 17% of U.S. lung cancer is attributable to known and probable occupational carcinogen exposures, including asbestos, arsenic, chloromethyl esters, chromium, crystalline silica, nickel, polycyclic aromatic hydrocarbons, radon, beryllium, cadmium, manmade vitreous fibers (eg, rock wool, slag wool, glass/ceramic fibers), diesel exhaust, air pollution, and secondhand tobacco smoke.[3–8] Synergistic interactions between smoking and occupational exposures such as asbestos have also been noted.[9]

To date, there have been a limited number of occupational studies that have examined lung cancer risk in nationally representative U.S. samples from 1950 to 1970.[10,11] Since these earlier studies, the epidemic of lung cancer in the general population peaked in the early 1990s for males with rising rates in females starting to stabilize later in the decade.[1] These lower lung cancer rates were preceded by reductions in smoking rates, which peaked in the 1940s to 1950s in males, and in the 1960s in females, and are thought to be largely responsible for the ebbing of the epidemic.[12] During the past 50 years, there have also been significant advances in the reduction of the number of workers exposed to

known carcinogens (such as asbestos) as well as the establishment of mandatory medical monitoring for workers exposed to selected carcinogens.[6] A national assessment of lung cancer mortality risk in occupational groups is therefore needed to indirectly evaluate the efficacy of the reduction of carcinogenic workplace exposures and to aid in the identification of new worker groups who may still be in need of targeted interventions to further reduce carcinogen exposure.

The National Health Interview Survey (NHIS) is a multipurpose household survey of the U.S. civilian noninstitutionalized population conducted yearly since 1957 by the National Center for Health Statistics (NCHS). The 1986–1994 NHIS collected information on job and occupational characteristics on all adult household members. From 1986–1994, over 450,000 U.S. workers, age 18 years and older, participated in the NHIS; individual smoking status was available for over 143,000 adults who participated in the NHIS supplements in 1987, 1988, and 1990–1994. The NCHS has recently completed a new mortality linkage with the National Death Index that identified 1812 lung cancer deaths through 2002 among these NHIS workers with available smoking status information.

Materials and Methods

In the survey period 1986–1994, each week, all adults in a probability sample of households were interviewed by trained personnel to obtain information about the characteristics of each member of the household.[13] In the majority of cases (63%), the participants themselves answered all the questions; for the remaining participants, the responses were obtained from their relatives or other proxies. For simplicity, in the present study, both self-reported and proxy-reported data are referred to as "reported." In the period 1986–1994, annual NHIS household survey response rates ranged from 94% to 97%.[14–22]

Occupational Classification

Information on employment during the 2 weeks before the interview was collected for all persons aged 18 years or older to determine the person's current employment status. Although labeled "SOC" codes in their documentation,[23] the NHIS actually uses the U.S. Census Occupational Codes to classify workers. In 1992, the NHIS began using the 1990 version of the U.S. Census Occupational Codes.[24] Before 1992, the 1980 U.S. Census codes were used. There were differences in 26 of the occupational categories between the 1980 version and the 1990 version; these categories were programmatically recoded in the 1986–1991 data sets to categories compatible with the 1990 version (see www.rsmas.miami.edu/groups/niehs/niosh/ for details on these recodes).

The NCHS did not routinely collect information on longest held job, which would have permitted a more accurate assessment of potential exposure to occupational carcinogens. However, two occupational health-related supplements were administered to NHIS participants, one in 1986 and the second in 1988.[25,26] We used previously published Kappa[27] values from these two supplements to estimate the extent to which "current job" reflected "longest held job" within each occupational category.[28]

Smoking Status

The 1986–1994 NHIS did not include questions about tobacco use in its core household interview. However, each year, the NCHS randomly administered supplemental surveys within the households selected to participate in the NHIS. Supplement topics varied from year to year (eg, health promotion and disease prevention, cancer control). Some supplemental surveys contained varying numbers of questions on tobacco use; with the exception of 1989, in the years 1987–1994, at least some adult respondents or their designated proxy informants were asked "Have you or other family members smoked at least 100 cigarettes in their lifetime?" Additional smoking questions were then asked among those responding "yes" to this question. There were slight differences in the wording of these subsequent questions. For example, some supplements used the following question: "Do you smoke cigarettes now?," whereas other supplements asked: "Do you now smoke cigarettes everyday, some days, or not at all?" Responses from these questions were used to construct a smoking variable representing lifetime smoking history (ie, current, former, never). A small percentage of participants who responded "yes" to the first question on smoking at least 100 cigarettes did not have valid data on the subsequent question inquiring about current cigarette use (0.55%) and were excluded from further analyses. Complete smoking data were available for 143,863 participants of the 1987, 1988, and the 1990–1994 NHIS.

National Health Interview Survey Multiple Cause of Death Linkage

NHIS participants who were 18 years or older at the time of their 1986–1994 interview were included in the National Death Index (NDI) mortality linkage, which is complete through December 31, 2002. The weighted matching methodology used in linking the NHIS data files and the NDI permits the classification of potential death certificate matches into one of five mutually exclusive classes on the basis of personal identifiers and the number of sociodemographic items matched (eg, name, Social Security Number, birthday, state of birth, state of residence).[29] All of the matches fulfilling the class 1 criteria were considered to be true matches, whereas those in class 5 were false matches. The remaining

three classes designated matches with varying degrees of probability. We used NCHS-recommended cutoff scores for classifying class 2, 3, and 4 matches as true or false (variable MORTSTAT).[29] NCHS cause of death coding for all U.S. deaths used the 10th revision of the International Statistical Classification of Diseases, Injuries, and Cause of Death (ICD-10) starting in 1999; provided in the linkage are comparable ICD-10 recodes for deaths occurred from 1986–1998 and which were previously classified under ICD-9 criteria.[30] Lung cancer mortality included ICD-10 codes C33–C34.

Statistical Analysis

Because of the multistage sampling design, all analyses were performed with adjustment for sample weights and design effects using the Software for Survey Data Analysis (SUDAAN) statistical package.[31] The sample weights used were those required for the analysis of NHIS data from combined survey years and were calculated as specified by Botman and Jack.[32] Cox regression analyses were completed using the SUDAAN (version 8.0.2; Research Triangle Park, NC) survival procedure. Overall and sex-specific age and smoking-adjusted hazard ratio estimates and corresponding 95% confidence intervals (CIs) are reported for a 41-category occupational grouping. Smoking status was coded using two dummy variables contrasting former and current smokers with never smokers. In each model, lung cancer mortality risk was compared between workers in a particular occupational category versus all other workers and included adjustment for age and smoking status. Using the more detailed COC codes, we also calculated hazard ratio (HR) models for all worker groups that had at least five lung cancer deaths. A series of models including and not including interaction between occupation and smoking status were considered. Analyses of HR models stratified by smoking status were undertaken when occupation by smoking status interactions were present.

Results

There were a total of 143,863 persons aged 18 years and older who reported working within the 2 weeks before their participation in the 1986–1994 NHIS surveys and who had information on smoking status and sufficient information for inclusion in the mortality linkage. The prevalence of current and former smokers was 28% and 22%, respectively, in this occupational cohort.

Table 1 presents the age- and smoking-adjusted and occupation-specific lung cancer mortality hazard ratios for all workers and separately for females and males in 41 occupational groups. Presented data are ranked according to the hazard ratio for the 41 occupational categories and include sample size, the estimated number of U.S. workers in each category, the kappa value assessing concordance between current and longest held job, occupation title, the number of lung cancer deaths, and the age- and smoking-adjusted hazard ratios with corresponding 95% confidence intervals (CIs) comparing lung cancer mortality risk for each occupational group. Hazard ratios with significant interactions between occupation and smoking status are noted when present and hazard ratios stratified by smoking status were completed.

In each occupational comparison, the age-adjusted hazard ratios among former and current smokers were 3.8 (2.9–5.0) and 15.1 (11.5–19.7), respectively. Sex-specific age-adjusted former and current smoking hazard ratios were 4.0 (2.7–5.8) and 15.5 (10.9–22.0) for male and 3.5 (2.3–5.5) and 14.8 (10.0–21.7) for female workers.

For female and male workers combined, those employed in the financial records processing occupations had the highest statistically significant age- and smoking-adjusted lung cancer mortality risk (HR = 1.76; 95% CI = 1.25–2.50). Other worker groups with statistically significant elevations in lung cancer risk included freight, stock, and materials handlers (1.53; 1.09–2.14) and those employed in the precision production occupations (1.39; 1.01–1.91). Occupations with statistically significant lower mortality risk relative to all workers included writers, artists, entertainers, and athletes (0.33; 0.14–0.79);mail and message distributing (0.38; 0.15–0.99); engineers (0.41; 0.18–0.90); and sales representatives, commodities, and finance (0.65; 0.44–0.97).

Lung cancer risk was significantly elevated among female workers employed as material moving equipment operators, although the HR was based only on two deaths with a wide 95% CI (6.17; 1.40–27.29). Significantly elevated risks in female workers were also noted for financial records processing occupations (1.72; 1.17–2.53) and managers administrators, except public administration (1.52; 1.05–2.20). Male workers employed as freight, stock, and material handlers had significantly elevated lung cancer mortality risk (1.60; 1.07–2.39), whereas significantly lower risks were found for writers, artists, entertainers, and athletes (0.24; 0.07–0.79) and engineers (0.33; 0.13–0.81).

Interactions between smoking and occupation were noted for male financial records processing occupations ($P = 0.04$) and male farm operators and managers ($P = 0.04$). No attempt was made to compare lung cancer rates in the former occupational group stratified by smoking status because there were only four deaths. Smoking-stratified, age-adjusted results for male farm operators and managers were: never smokers HR = 2.41 (2.27–2.56), former smokers 0.46 (0.43–0.48), and current smokers 1.22 (1.17–1.27).

Table 2 presents selected age-adjusted and occupation-specific lung cancer mortality hazard ratios using the more detailed 206 occu-

TABLE 1
Age- and Smoking-Adjusted Lung Cancer Mortality Risk in Selected Worker Groups: The 1987, 1988, and 1990–1994 National Health Interview Supplement Surveys

Ranking*	Sample Size	Estimated US Workforce†	Concordance With Longest Held Job‡	Occupation	No. of Lung Cancer Deaths	Occupational Hazard Ratio§	95% Confidence Interval
All workers							
1	3159	2,245,512	48.4	Financial records processing occupations	31	1.76	1.25–2.50
2	169	176,360	54.1	Other transportation, except motor vehicles	2	1.70	0.40–7.27
3	3854	3,410,507	31.3	Freight, stock, material handlers	33	1.53	1.09–2.14
4	194	199,857	47.2	Forestry and fishing occupations	3	1.44	0.50–4.14
5	965	793,111	35.2	Other protective service occupations	20	1.41	0.84–2.37
6	4420	3,766,588	46.0	Precision production occupations	43	1.39	1.01–1.91
7	6439	5,221,401	54.8	Machine operators/tenderers, except precision	48	1.29	0.94–1.76
8	4531	4,203,192	58.1	Mechanics and repairers	38	1.26	0.90–1.76
9	12,320	9,296,535	43.4	Other administrative support	69	1.24	0.93–1.67
10	880	670,109	36.4	Computer equipment operators	3	1.24	0.48–3.25
11	7252	5,892,896	43.0	Other sales	48	1.23	0.90–1.67
12	3860	3,529,824	63.5	Motor vehicle operators	41	1.22	0.87–1.70
13	5782	4,570,186	56.3	Food service	34	1.21	0.83–1.78
14	1828	1,616,443	40.2	Farm workers and other agricultural workers	16	1.19	0.74–1.89
15	3804	2,836,111	48.3	Cleaning and building service	42	1.12	0.79–1.58
16	1928	1,357,639	60.0	Health technologists/technicians	5	1.11	0.61–2.02
17	1237	1,094,233	51.0	Material moving equipment operators	11	1.10	0.61–1.98
18	662	697,191	25.6	Construction laborers	5	1.02	0.37–2.86
19	5200	4,960,923	60.3	Construction and extractive trades	35	0.98	0.69–1.38
20	14,058	1,337,987	38.8	Managers administrators, except public administration	84	0.96	0.74–1.24
21	3056	2,566,964	47.9	Fabricators, assemblers, inspectors, samplers	15	0.89	0.50–1.60
22	1280	761,954	50.6	Private household occupations	8	0.89	0.40–1.97
23	3319	2,356,169	52.1	Personal service	17	0.88	0.54–1.45
24	743	542,174	33.7	Officials and administrators public administration	6	0.88	0.38–2.04
25	1712	1,399,369	59.8	Farm operators and managers	18	0.83	0.51–1.35
26	3412	2,658,590	47.7	Technologists, technicians, except health	10	0.79	0.40–1.57
27	3070	2,227,360	64.7	Other professional specialty occupations	13	0.79	0.42–1.48
28	4175	3,596,023	36.8	Supervisors and proprietors	19	0.76	0.47–1.23
29	5303	3,975,190	49.9	Management-related occupations	21	0.73	0.44–1.21
30	3645	2,482,299	74.9	Health assessment/treating occupations	11	0.71	0.36–1.43
31	3037	1,986,806	55.4	Health service	11	0.71	0.41–1.21
32	7454	5,231,152	72.9	Teachers, librarians, counselors	19	0.69	0.43–1.11
33	5970	4,413,986	63.6	Secretaries, stenographers, and typists	17	0.68	0.41–1.13
34	1331	1,157,796	63.5	Police and firefighters	4	0.66	0.24–1.86
35	4428	3,603,720	50.6	Sales representatives, commodities and finance	21	0.65	0.44–0.97
36	1767	1,330,325	50.2	Natural mathematical/computer scientists	3	0.51	0.18–1.42
37	955	829,443	85.6	Health-diagnosing occupations	3	0.43	0.12–1.53
38	2468	2,009,300	66.4	Engineers	6	0.41	0.18–0.90
39	1186	914,844	56.0	Mail and message distributing	3	0.38	0.15–0.99
40	2756	1,971,725	58.1	Writers, artists, entertainers, athletes	6	0.33	0.14–0.79
41	254	201,731	61.6	Architects and surveyors	0	—	—
Female workers							
1	94	58,299	27.7	Material moving, equipment operators	2	6.17	1.40–27.29
2	249	160,767	46.5	Engineers	1	3.60	0.59–21.99
3	231	165,622	27.0	Mechanics and repairers	2	3.08	0.73–13.00

(Continued)

TABLE 1
Continued

Ranking*	Sample Size	Estimated US Workforce†	Concordance With Longest Held Job‡	Occupation	No. of Lung Cancer Deaths	Occupational Hazard Ratio§	95% Confidence Interval
4	162	108,553	19.1	Construction and extractive trades	2	2.98	0.72–12.39
5	2900	2,024,900	50.3	Financial records processing occupations	27	1.72	1.17–2.53
6	234	154,696	36.5	Other protective service occupations	2	1.62	0.40–6.49
7	6004	4,077,780	36.4	Managers administrators, except public administration	38	1.52	1.05–2.20
8	346	226,264	35.6	Officials and administrators, public administration	3	1.40	0.40–4.92
9	603	430,315	35.5	Computer equipment operators	2	1.34	0.42–4.30
10	1253	871,854	36.8	Precision production occupations	8	1.30	0.50–3.38
11	1129	783,489	27.5	Freight, stock, material handlers	6	1.29	0.58–2.85
12	1226	828,348	44.5	Technologists, technicians, except health	3	1.24	0.37–4.13
13	2945	2,087,003	57.2	Machine operators/tenderers, except precision	15	1.18	0.73–1.93
14	416	293,592	40.5	Farm workers and other agricultural workers	2	1.14	0.28–4.71
15	5145	3,876,373	47.4	Other sales	25	1.10	0.72–1.67
16	1729	1,280,203	35.1	Supervisors and proprietors	8	1.09	0.56–2.13
17	9454	6,704,416	44.2	Other administrative support	41	1.09	0.76–1.56
18	1440	894,969	51.8	Other professional specialty occupations	3	1.09	0.59–2.03
19	3949	2,836,105	56.7	Food service	21	0.98	0.60–1.59
20	1237	725,924	51.2	Private household occupations	8	0.96	0.45–2.06
21	3027	2,065,347	46.2	Management-related occupations	9	0.89	0.44–1.77
22	561	382,126	59.0	Motor vehicle operators	2	0.87	0.19–3.95
23	2769	1,929,380	52.3	Personal service	12	0.86	0.48–1.55
24	621	422,502	43.4	Natural mathematical/computer scientists	1	0.83	0.10–6.83
25	1667	1,110,015	61.2	Health technologists/technicians	4	0.81	0.29–2.24
26	1813	1,169,530	51.8	Cleaning and building service	8	0.73	0.34–1.58
27	5851	4,331,594	62.1	Secretaries, stenographers, and typists	17	0.72	0.44–1.19
28	3234	2,165,864	74.4	Health assessment/treating occupations	9	0.65	0.34–1.27
29	2786	1,779,022	55.8	Health service	9	0.60	0.34–1.07
30	5333	3,589,125	73.3	Teachers, librarians, counselors	10	0.58	0.31–1.08
31	496	331,625	51.3	Mail and message distributing	1	0.57	0.08–4.13
32	1433	946,492	57.3	Writers, artists, entertainers, athletes	3	0.55	0.18–1.74
33	1731	1,208,194	47.3	Sales representatives, commodities and finance	4	0.54	0.21–1.39
34	1390	985,638	46.3	Fabricators, assemblers, inspectors, samplers	3	0.46	0.13–1.66
35	5	5625	50.0	Other transportation, except motor vehicles	0	—	—
36	31	20,877	16.0	Construction laborers	0	—	—
37	9	24,647	69.6	Architects and surveyors	0	—	—
38	36	8315	0.0	Forestry and fishing occupations	0	—	—
39	248	161,301	66.1	Health-diagnosing occupations	0	—	—
40	209	136,365	47.3	Police and firefighters	0	—	—
41	335	230,968	49.3	Farm operators and managers	0	—	—
Male workers							
1	261	247,624	51.0	Health technologists/technicians	1	2.29	0.34–15.67
2	259	220,612	25.7	Financial records processing occupations‖	4	2.12	0.79–5.67
3	251	207,785	41.7	Health service	2	1.84	0.46–7.34
4	1833	1,734,081	54.1	Food service	13	1.75	0.98–3.13
5	164	170,736	54.2	Other transportation, except motor vehicles	2	1.70	0.41–7.05
6	2725	2,627,018	32.5	Freight, stock, material handlers	27	1.60	1.07–2.39

(Continued)

TABLE 1
Continued

Ranking*	Sample Size	Estimated US Workforce†	Concordance With Longest Held Job‡	Occupation	No. of Lung Cancer Deaths	Occupational Hazard Ratio§	95% Confidence Interval
7	2866	2,592,119	35.9	Other administrative support	28	1.50	0.98–2.30
8	185	191,542	48.2	Forestry and fishing occupations	3	1.47	0.46–4.71
9	2107	2,016,522	32.5	Other sales	23	1.41	0.91–2.20
10	3167	2,894,734	48.8	Precision production occupations	35	1.41	1.00–1.99
11	731	638,415	34.6	Other protective service occupations	18	1.39	0.79–2.45
12	3494	3,134,398	52.7	Machine operators/tenderers, except precision	33	1.35	0.90–2.01
13	1991	1,666,580	45.4	Cleaning and building service	34	1.28	0.84–1.96
14	3299	3,147,698	63.3	Motor vehicle operators	39	1.24	0.89–1.73
15	4300	4,037,571	58.5	Mechanics and repairers	36	1.22	0.87–1.70
16	1412	1,322,851	39.8	Farm workers and other agricultural workers‖	14	1.20	0.63–2.29
17	1666	1,581,326	49.2	Fabricators, assemblers, inspectors, samplers	12	1.15	0.59–2.24
18	411	316,435	74.6	Health assessment/treating occupations	2	1.12	0.27–4.60
19	277	239,795	38.1	Computer equipment operators	1	1.08	0.16–7.18
20	631	676,315	25.6	Construction laborers	5	1.04	0.40–2.67
21	550	426,790	48.2	Personal service	5	0.94	0.37–2.38
22	1143	1,035,934	52.5	Material moving equipment operators	9	0.94	0.47–1.88
23	5038	4,852,370	59.8	Construction and extractive trades	33	0.93	0.64–1.33
24	1377	1,168,400	61.7	Farm operators and managers	18	0.92	0.59–1.44
25	2121	1,642,027	71.2	Teachers, librarians, counselors	9	0.84	0.39–1.81
26	8054	7,260,207	39.8	Managers administrators, except public administration	46	0.74	0.53–1.02
27	1122	1,021,431	65.1	Police and firefighters	4	0.72	0.26–2.02
28	1630	1,332,391	73.3	Other professional specialty occupations	10	0.68	0.32–1.44
29	2697	2,395,527	52.0	Sales representatives, commodities and finance	17	0.68	0.41–1.11
30	2186	1,830,242	49.0	Technologists, technicians, except health	7	0.67	0.30–1.53
31	397	315,909	32.3	Officials and administrators public administration	3	0.66	0.21–2.09
32	2276	1,909,843	53.5	Management-related occupations	12	0.63	0.34–1.16
33	2446	2,315,820	37.5	Supervisors and proprietors	11	0.62	0.31–1.25
34	707	668,142	90.7	Health-diagnosing occupations	3	0.48	0.15–1.50
35	1146	907,823	53.5	Natural mathematical/computer scientists	2	0.43	0.11–1.73
36	690	583,219	58.7	Mail and message distributing	2	0.34	0.08–1.34
37	2219	1,848,533	67.7	Engineers	5	0.33	0.13–0.81
38	1323	1,025,232	58.9	Writers, artists, entertainers, athletes	3	0.24	0.07–0.79
39	43	36,030	20.6	Private household occupations	0	—	—
40	218	177,084	60.3	Architects and surveyors	0	—	—
41	119	82,392	36.9	Secretaries, stenographers, and typists	0	—	—

* Based on hazard ratio for occupation.
† Calculated from total employment estimates derived from annual NHIS sampling.
‡ Based on the kappa statistic.
§ All other workers is the referent.
‖ There is an interaction between occupation and smoking status (see "Results" section).

pational codes representing occupations with at least 100,000 U.S. workers. Presented results are limited to occupations with at least five lung cancer deaths. Worker groups with significantly elevated hazard ratios included heating, air conditioning, and refrigeration mechanics (2.96; 1.21–7.20) and not specified mechanics and repairers (2.83; 1.33–6.01). Managers and administrators had a significantly lower risk of lung cancer (0.69; 0.51–0.93).

Discussion

The NHIS database represents a probability sample of the entire U.S.

TABLE 2
Age- and Smoking-Adjusted Lung Cancer Mortality Risk in Worker Groups Classified by Census Occupational Codes With Five or More Lung Cancer Deaths: The 1987, 1988, and 1990–1994 National Health Interview Supplement Surveys

Ranking*	Sample Size	Estimated US Work-force†	Concordance With Longest Held Job‡	Occupation (Census occupational code)	No. of Lung Cancer Deaths	Occupational Hazard Ratio§	95% Confi-dence Interval
1	234	225,091	36.7	Heating air conditioning, and refrigeration mechanics (534)	5	2.96	1.21–7.20
2	250	254,196	11.1	Not specified mechanics and repairers (549)	7	2.83	1.33–6.01
3	446	344,383	40.8	Bartenders (434)	8	1.80	0.88–3.71
4	216	159,703	13.5	Supervisors, cleaning, and building service workers (448)	5	1.62	0.69–3.80
5	451	423,173	32.2	Industrial machinery repairers (518)	6	1.42	0.63–3.16
6	646	626,998	62.3	Electricians (575)	6	1.38	0.59–3.22
7	2598	1,817,127	49.3	Bookkeepers, accounting, and auditing clerks (337)	27	1.36	0.92–2.02
8	1268	1,092,668	36.6	Supervisors, production occupations (628)	14	1.35	0.79–2.30
9	998	747,566	36.0	Receptionists (319)	6	1.28	0.45–3.59
10	638	501,893	36.6	Miscellaneous food preparation occupations (444)	6	1.26	0.56–2.84
11	2627	2,118,672	28.2	Sales workers, other commodities (274)	25	1.23	0.80–1.89
12	705	585,833	28.4	Stock and inventory clerks (365)	6	1.21	0.51–2.91
13	593	531,212	43.8	Traffic, shipping, and receiving clerks (364)	5	1.20	0.49–2.93
14	588	437,321	64.9	Bus drivers (808)	8	1.16	0.57–2.37
15	740	650,044	20.7	Stock handlers and baggers (877)	5	1.08	0.42–2.79
16	705	571,665	45.0	Production inspectors, checkers, and examiners (796)	7	1.06	0.42–2.67
17	2756	2,640,585	62.5	Truck drivers (804)	32	1.01	0.68–1.50
18	1951	1,587,227	52.2	Cooks (436)	11	0.95	0.49–1.82
19	779	650,456	31.1	Guards and police, except public service (426)	15	0.93	0.51–1.69
20	813	686,987	35.1	Farm workers (479)	10	0.91	0.46–1.78
21	992	727,887	41.5	Other financial officers (25)	6	0.88	0.35–2.19
22	1106	912,207	37.0	Miscellaneous machine operators (777)	8	0.87	0.42–1.80
23	826	637,557	26.0	Managers/marketing/advertising/public relations (13)	5	0.86	0.33–2.24
24	811	551,376	48.3	Maids and housemen (449)	6	0.81	0.33–1.99
25	2702	2,067,101	41.9	Janitors and cleaners (453)	31	0.78	0.50–1.20
26	977	717,172	21.4	Administrative support occupations (389)	6	0.77	0.34–1.75
27	10,496	8,609,388	34.4	Managers and administrators (22)	67	0.69	0.51–0.93

* Based on hazard ratio for occupation.
† Calculated from total employment estimates derived from annual NHIS sampling.
‡ Based on the kappa statistic.
§ All other workers is the referent.

population with the ability to compare mortality among U.S. workers. Furthermore, as noted by NIOSH[33] and the British Registrar General's decennial reports,[34] databases such as the NHIS surveys can be used not only to target studies of work-related conditions and to add to the body of evidence generated from epidemiologic studies, but also to provide surveillance data for tracking progress toward the elimination of preventable diseases. Previous research examining occupational lung cancer risk has often focused on worker groups with known exposures to potent lung cancer carcinogens, including asbestos and radon.[6,35,36] The NHIS is not particularly well suited for the study of these high-risk occupations given the relatively small proportion of workers employed in the United States (eg, mining, steel production). However, the NHIS does provide the opportunity to examine lung cancer risk in representative and larger worker groups while controlling for age and smoking status.

Several occupational groups identified at increased risk of lung cancer mortality in the present analysis likely experienced occupational exposures to asbestos and other lung cancer carcinogens (including heating, air conditioning, and refrigeration mechanics [HR = 3.0]), not specified mechanics and repairers (HR = 2.8), and precision production operations (HR = 1.4). For other identified high-risk occupations, the likely presence of lung cancer carcinogens in the workplace

is less clear. For example, freight, stock, and material handlers had a significantly increased risk of lung cancer mortality (HR = 1.5). Aside from silica and unspecified dusts, there have been no other apparent lung carcinogen exposures in this occupational group; furthermore, occupational exposure to secondhand smoke is similar to the U.S. average for all worker groups.[37,38] Female managers and administrators, except public administration, were also at increased risk of lung cancer mortality (HR = 1.5); workers in this occupational group can be exposed to polycyclic aromatic hydrocarbons (such as petroleum distillates and carbon black), but tend to be less exposed to workplace secondhand smoke relative to other worker groups.[37,38] Excess lung cancer mortality risk was also noted for female financial records processing occupations (HR = 1.7). Aside from carbon black, it is unclear if workers in this occupation are exposed to known lung cancer carcinogens.[37]

There were a number of occupational groups with significantly lower risk of lung cancer even after adjustment for age and smoking status, including writers, artists, entertainers, and athletes (HR = 0.3); engineers (HR = 0.4); mail and message distributing (HR = 0.4); and sales representatives, commodities, and finance (HR = 0.7). The reasons for these lower risks are not clear, although other researchers have also found lower smoking-adjusted lung cancer risk in selected occupations (eg, public administrators).[39] Several of these occupations require at least some college-level education, which has been shown to be inversely related to cancer risk.[40] Possible mechanisms for this reduced risk include not only lower pack-year smoking levels, but also better access and utilization of preventive cancer-related healthcare services,[41] lower exposure to air pollutants (both occupational and environmental), including secondhand smoke and radon,[42,43] and higher consumption of antioxidants through fruit and vegetable intake, which may be protective not only for the general population, but also among smokers.[44,45]

Another strength of the present analysis was the examination of lung cancer risk in female workers, which have often been excluded in other occupational studies due, in part, to the relatively low employment rates in occupations traditionally at high risk for lung cancer such as metals manufacturing and mining. Excess smoking-adjusted lung cancer risk in female workers employed in the chemical and oil, pottery and glass, engine and vehicle building, and the paper wood and print industries has been reported in other studies.[46] Analysis of lung cancer risk in female workers is essential given that it is now the leading cause of cancer death in this gender group in the United States; additionally, there is some evidence that sex-based genetic differences may make female lungs more susceptible to carcinogens relative to males.[47] Although most HRs were not significant due to small worker sample size and/or a small number of lung cancer deaths, Table 1 indicates that 12 occupations with at least one female worker death had a HR which ranged from 1.24 to 6.17, indicating that additional research in lung cancer risk in female workers is warranted. The role that occupational and home secondhand smoke exposure may play in lung cancer risk in women is another important area of research given that female never-smokers are more likely to develop this cancer relative to male never-smokers.[47]

Limitations

Detailed smoking histories were not uniformly available in the NHIS; therefore, it was not possible to control for pack-years of exposure, which would have reduced the possibility of residual confounding in our analysis.[48,49] Furthermore, the accuracy of self-reported smoking status may have differed across occupation raising the possibility that residual confounding levels may have varied by occupation.[50] The influence of occupation and lung cancer mortality risk varies considerably as a function of the duration and intensity of carcinogen exposure.[51,52] Occupational exposure assessment using detailed interviews enables the construction of a job-exposure matrix. This approach generally leads to stronger associations between high-risk occupations and lung cancer risk than when job title is used as a surrogate for job exposure as was the case in the present study.[35] Furthermore, we used "current," as opposed to "longest held job" to classify workers, because the latter was not routinely assessed in the NHIS. Current and longest held job tend to correlate, although the strength of the associations varies according to job.[28] As can be seen in Tables 1 and 2, kappa scores the association between longest held and current jobs for workers ranged from 85.6 in those employed in the health-diagnosing professions to 11.1 in not specified mechanics and repairers. Variability in kappa scores indicates that exposure misclassification in the present study likely differed across occupation. Although the effects of misclassification can inflate and reduce the hazard ratio estimates, the extent to which random misclassification is present will generally bias estimates toward the null.[53] Finally, we lack data on occupational and other secondhand smoke exposures, which also vary across worker groups.[38]

Conclusions

Historically declining exposures to occupational carcinogens have likely pushed the percentage of occupationally implicated cancer deaths to the lower bound of the previously published attributable risk estimates of 3% to 17%.[3–5] Peto[54] has recently estimated that the removal of known occupational carcinogens would result in only a 0.4% reduction in cancer mortality in the United States. This is in sharp contrast to the 60%

mortality reduction that would occur if current U.S. smokers quit. Although continued efforts to reduce worksite exposure to carcinogens are needed, occupational interventions focusing on smoking cessation are the single most important approach to lowering cancer risk in worker groups. Smoking rates in worker groups vary considerably, with high rates in many blue collar groups.[55] Targeted worksite smoking cessation interventions should be a national priority in occupational groups with large proportions of smokers.[56,57] Additionally, lung cancer relative risk estimates for occupational secondhand smoke exposure in never smoking workers are 1.19 (1.09–1.30) for women and 1.12 (0.80–1.56) for men.[58] Reduction in worksite exposure to secondhand smoke may also play a key role in further reductions in worksite carcinogen exposure burden for the U.S. worker population.[59–61] Finally, this study identified for the first time several worker groups at significantly increased risk of lung cancer mortality even after adjustment for smoking status (eg, financial records processing occupations). If confirmed in other studies, additional targeted research using case–control study designs will be necessary to identify occupational and nonoccupational exposures responsible for this increased risk.

Main Messages

1. Smoking is the most important modifiable risk factor for lung cancer in U.S. worker groups.
2. Worker groups at increased risk of lung cancer mortality after adjustment for age and smoking include: 1) heating, air conditioning, and refrigeration mechanics; 2) not specified mechanics and repairers; 3) financial records processing occupations; 4) freight, stock, and materials handlers; and 5) precision production occupations.

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