Airflow Obstruction Attributable to Work in Industry and Occupation Among U.S. Race/Ethnic Groups: A Study of NHANES III Data

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Objectives *To estimate the fraction of airflow obstruction attributable to workplace exposure by U.S. race/ethnic group.*
Methods *U.S. population-based third National Health and Nutrition Examination Survey (NHANES III) data on 4,086 Caucasians, 2,774 African-Americans, and 2,568 Mexican-Americans, aged 30–75, were studied. Airflow obstruction was defined as FEV1/FVC<75% and FEV1<80% predicted. Weighted prevalence, and prevalence odds ratios (OR) adjusted for the effect of age, smoking status, pack-years, body mass index, education, and socio-economic status were estimated using SUDAAN software.*
Results *Industries with the most cases of airflow obstruction attributable to workplace exposure include: armed forces; rubber, plastics, and leather manufacturing; utilities; textile mill manufacturing; health care; food products manufacturing; sales; construction; and agriculture. The fraction of cases with airflow obstruction associated with work in industry varied by race/ethnic group and was estimated as 22.2% (95% CI 9.1–33.4) among Caucasians, 23.4% (95% CI 2.2–40.0) among African-Americans, and 49.6% (32.1–62.6) among Mexican-Americans.*
Conclusions *This study found differences in the fraction of airflow obstruction cases associated with employment pattern among major U.S. race/ethnic population groups.* Am. J. Ind. Med. 46:126–135, 2004. *Published 2004 Wiley-Liss, Inc.*†

KEY WORDS: chronic obstructive pulmonary disease; prevalence; attributable fraction; employment; racial/ethnic differences

INTRODUCTION

Many studies have demonstrated that occupational exposures can either cause chronic obstructive pulmonary disease (COPD) or contribute to its development [Becklake, 1989; Oxman et al., 1993; Hendrick, 1996]. Recently, the annual cost of occupational COPD in the U.S. population was estimated as $5 billion, based on an assumed attributable fraction for COPD deaths due to occupational exposure of 15% [Leigh et al., 2002]. Very few studies, however, have actually estimated attributable fractions for occupation and COPD in the general U.S. population. A telephone-survey of U.S. adults aged 55–75 estimated that exposure to vapors, gas, dust, or fumes is associated with a 2.0-fold (95% CI 1.6–2.5) increase in the risk of COPD and that the fraction of COPD cases attributable to workplace exposures is around 25% [Blanc et al., 2002]. In our previous study of the Third National Health and Nutrition Examination Survey (NHANES III) data [Hnizdo et al., 2002], we identified U.S. industries and occupations associated with increased risk of COPD (defined as FEV_1<80% predicted and FEV_1/FVC<70%), and estimated that in the U.S. population aged 30–75, 19% (95% CI 7–28%) of cases with COPD are

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associated with work in industry. Among never smokers, the attributable fraction was estimated as 31% (95% CI 1–47%). Although many studies have documented racial/ethnic differences in exposure to occupational respiratory hazards, to our knowledge, the contribution of occupational exposure to the burden of chronic obstructive lung disease among U.S. race/ethnic population groups has not yet been quantified in the literature.

This study estimates the fraction of cases with airflow obstruction associated with work in industry and occupation among three racial/ethnic groups represented in the NHANES III study (i.e., Caucasians, African-Americans, and Mexican-Americans). The aim is to evaluate differences in the work-related respiratory health effects and work-related contributions to health disparities among U.S. race/ethnic groups.

MATERIALS AND METHODS

The detailed methods used in the present study are similar to those used in the previous publication [Hnizdo et al., 2002], thus only methods relevant to this study are described here.

Study Subjects

NHANES III was conducted from 1988 to 1994 by the National Center for Health Statistics (NCHS) to assess the health and nutritional status of the U.S. population. NHANES III used a multi-stage stratified probability sampling to select a representative sample of the U.S. adult population age 17–90 [National Center for Health Statistics (NCHS), 1994; National Center for Health Statistics (NCHS), 1996]. African-Americans, Mexican-Americans, and those age 60 and older were oversampled. The resulting total sample of 20,050 subjects included 47% females and 53% males; 42.3% were Caucasian, 27.4% African-American, and 26.5% Mexican-American. The health examination included lung function testing and questions on employment.

For the present study, we included subjects 30–75 years of age (n = 11,447). Further, we excluded 1,009 subjects because of lung function testing problems: missing tests (826), unreliable flow volume curve (97), only one reliable maneuver (86) [Hankinson et al., 1999]. Subjects with doctor-diagnosed current asthma (506), subjects with missing occupational codes (109), and subjects of an unspecified racial/ethnic background (395) were excluded, leaving 9,428 subjects for the data analysis.

Definition of Airflow Obstruction

Airflow obstruction was defined as FEV1/FVC<75% and FEV1<80% predicted. The FEV1/FVC<75% cutoff point was previously used in a large international study of COPD and occupation [Fishwick et al., 1997], and we used it to increase sample size for race-specific analysis. The FEV_1 % predicted values were calculated using sex-specific reference equations for Caucasians, African-Americans, and Mexican-Americans, estimated on asymptomatic non-smokers from the NHANES III study [Hankinson et al., 1999]. Lung function testing methods for NHANES III conformed to the 1987 ATS criteria [American Thoracic Society (ATS), 1987].

Cigarette Smoking

NHANES III included questions on current smoking status, number of cigarettes smoked, and age when a study subject started and stopped smoking. Two smoking variables were created: smoking status and pack-years. For smoking status, subjects were categorized into never smokers, ex-smokers, and current smokers. Never smokers were respondents who indicated that they never smoked or smoked less than 100 cigarettes in their lifetime.

Occupational Coding

Occupational coding was based on two questions in the NHANES III Adult Survey Questionnaire. Study subjects were asked to identify: (1) the kind of work they did the longest (occupation), and (2) for this occupation, what kind of business or industry they worked in the longest (industry). Occupation in the NHANES III data set was coded to the 1990 Occupational Classification System used in the 1990 U.S. Census [US Department of Commerce (USDC), 1992]. These codes were derived from the 1980 Standard Occupational Classification Manual (SOCM) [1980]. Industry was coded to the 1990 Industrial Classification System, a modification of the Standard Industrial Classification Manual (SICM) [1987]. However, these detailed industry and occupation codes are collapsed in the NHANES III public use data set.

Industry Categories Used in the Analysis

The NHANES III data set contains 44 industry codes that include workers with a varied potential for exposure to respiratory hazards. A priori, we grouped industries with potential for exposure to respiratory hazards as follows. We kept the original industry categories, but subjects with office work occupations were excluded from the industrial sectors in order to focus analysis on production workers within each manufacturing industry. Office workers from all industry sectors were combined into a single category which was used as a comparison group. This ‘‘office workers’’ category included managers, secretaries and typists, clerks, administrative workers, as well as teachers, writers and artists, professionals, and workers from such non-manufacturing sectors as banking, insurance, communications, education, social service, and public administration. We moved laborers, cleaners, material handlers, and maintenance workers from the banking, insurance, communications, education, social service, and public administration sectors into a new industry category called "office building services." Similarly, we moved construction, horticultural, medical, food preparation, and transportation workers from the above non-manufacturing sectors to the appropriate industry category with similar potential for exposure to respiratory hazards. The recoding described above resulted in 26 industry categories. To obtain a more parsimonious model, we combined categories where odds ratios (OR) for airflow obstruction were not increased into one "other industries" category in final analysis. Final models for the race/ethnic-specific analysis presented here used 17 industry categories. Industries that were combined into "other" industries included: apparel and finished textile products; paper products, printing, and publishing; lumber and wood products, furniture; mining; metal industries; machinery except electrical; electrical machinery, equipment, supplies; miscellaneous and not specified manufacturing; communications; eating and drinking places; lodging places; entertainment and recreation services; educational services; justice, public order, and safety; other professional and related services.

Occupation Categories Used in the Analysis

The NHANES III data set contains 40 occupation codes combined across all industries. A priori, we collapsed these into 25 occupation categories believed to have similar potential for exposure to respiratory hazards, and sufficient numbers for analysis. To obtain a more parsimonious model, we combined categories where OR for airflow obstruction were not increased into one "other occupations" category, resulting in 17 occupation categories in final models discussed below.

Statistical Data Analysis

We used SUDAAN software [Shah et al., 1996] to estimate the weighted race/ethnic-specific population size, prevalence and prevalence OR for airflow obstruction by industry and occupation. Race/ethnic-specific logistic models were fitted to estimate weighted OR adjusted for the effect of age, sex, body mass index, smoking status, pack-years of cigarettes smoking, education, and socio-economic status. Socio-economic status was adjusted using the poverty income ratio from the NHANES III data. Industry (or occupation) was included in the models as a set of 0 or 1 dummy variables representing each industry or occupation. The race/ethnic-specific population attributable fractions, AF_p [i.e., the fraction of cases associated with work in industry (or occupation)] were calculated according to a formula [Miettinen, 1974; Bruzzi et al., 1985]:

$$AF_p = \sum_{i=1}^{k} P_{ci}(\mathrm{OR}_i - 1)/\mathrm{OR}_i \qquad (1)$$

where k = number of exposure levels (i.e., the number of industries or occupations), $P_{ci} = \mathrm{Cases}_i$ /Total Cases, where Cases_i represents the estimated number of cases with airflow obstruction at the ith exposure level, and total Cases represents the total cases summed across all exposure levels. OR_i is the adjusted odds ratio for airflow obstruction estimated for the ith exposure level. No cases were attributed to exposure levels with $\mathrm{OR}_i \leq 1.0$.

Using Equation 1 we calculated two estimates of attributable fractions. The first estimate, AF_{p1}, was based on individual industry categories. For the second estimate, AF_{p2}, we combined cases from all industries with OR>1 into one category and calculated the attributable fraction on the summary data. AF_{p2} was calculated in order to estimate 95% confidence intervals (CI) for the attributable fraction based on the standard formula [Rothman and Greenland, 1998]. Both estimates assumed that industries with increased OR can potentially contribute attributable cases of airflow obstruction. Many of the industries have been found in other studies to be associated with increased risk of COPD (see below). Estimates of attributable fractions were also calculated for occupational categories.

RESULTS

The U.S. race/ethnic-specific statistics were estimated on a sample of 4,086 Caucasians of mean age 52.7 (SD, 13.8) years, 2,774 African-Americans of mean age 47.5 (SD, 13.1) years, and 2,568 Mexican-Americans of mean age 47.8 (SD, 13.3) years. Table I shows race/ethnic-specific estimates of population size and prevalence of airflow obstruction for industries that have been identified to have increased OR for COPD [Hnizdo et al., 2002].

Association Between Airflow Obstruction and Work by Industry

Table II shows race/ethnic-specific adjusted OR and 95% CI for airflow obstruction by industry, and the sample sizes on which estimation was based.

While Caucasians had the highest prevalence of airflow obstruction (Table I), the adjusted OR for airflow obstruction were generally highest among Mexican-Americans. For some industries (armed forces; rubber, plastics, leather manufacture), adjusted OR increased in all three racial/ethnic groups. However, for other industries (sales; metal and automobile manufacturing) the increase was observed mainly in one or two race/ethnic groups.

TABLE I. Race/Ethnic-Specific Estimates of Number of U.S. Workers (N) in 100,000 and Percent Prevalence (P) of Airflow Obstruction, by Industry

	Caucasian		African-American		Mexican-American	
Industry	**n**	**P ± SEM (%)**	**n**	**P ± SEM (%)**	**n**	**P ± SEM(%)**
Armed forces	10.0	25.9 ± 9.1	1.8	10.8 ± 3.5	0.2	8.6 ± 5.4
Rubber, plastics, leather manufacturing	7.3	22.4 ± 6.1	0.5	9.0 ± 9.0	0.6	4.6 ± 4.4
Utilities	10.3	21.6 ± 6.1	1.1	18.1 ± 6.1	—	—
Textile mill products manufacturing	12.0	20.7 ± 7.6	2.7	5.2 ± 1.9	0.3	12.5 ± 9.7
Repair service, gas station	22.4	18.0 ± 5.3	1.9	15.9 ± 4.4	1.4	3.1 ± 2.9
Food products manufacturing	15.0	17.7 ± 4.5	3.2	15.0 ± 4.7	2.3	3.9 ± 1.9
Transportation & trucking	27.0	16.4 ± 3.7	5.2	8.9 ± 1.9	1.2	6.2 ± 3.2
Office building services	2.5	16.4 ± 13.6	2.0	14.7 ± 4.9	0.5	4.6 ± 3.0
Chemicals, petroleum, coal manufacturing	10.1	16.0 ± 5.9	1.0	6.3 ± 4.4	0.6	4.5 ± 4.3
Agriculture	26.3	14.2 ± 2.9	2.4	19.1 ± 4.8	7.0	6.5 ± 1.1
Construction	42.9	13.4 ± 2.7	5.4	12.2 ± 2.8	2.7	8.8 ± 2.0
Sales	115.9	12.7 ± 1.6	8.9	5.9 ± 1.4	4.4	2.1 ± 1.0
Personal services	23.4	12.5 ± 3.0	8.8	8.9 ± 2.4	2.4	8.5 ± 3.0
Metal, automobile, ship, railroad manufact.	38.4	10.3 ± 2.7	6.9	11.0 ± 2.5	2.3	0.6 ± 0.4
Health care	56.3	9.7 ± 2.5	12.2	4.9 ± 1.1	2.3	4.6 ± 2.5
Other industries[a]	112.8	9.1 ± 1.5	17.1	6.0 ± 1.2	9.6	2.2 ± 0.6
Office workers	334.6	7.1 ± 0.7	30.0	4.6 ± 0.8	8.1	1.5 ± 0.6
Total working population	867.1	10.7 ± 0.6	111.1	7.5 ± 0.5	46.0	3.9 ± 0.5

NHANES III study subjects 30–75 years of age.
[a]"Other industries" includes industries for which adjusted odds ratios for COPD were not increased.

Table II shows the estimated number of attributable cases of airflow obstruction (in thousands). The race/ethnic-specific attributable fractions were calculated according to Equation 1, using data from Table I and II. For Caucasians, the overall attributable fraction for airflow obstruction was estimated as $AF_{p1} = 21.5\%$. Thus of the 9,266,000 estimated total cases with airflow obstruction in the U.S. Caucasian working population (calculated from data presented in Table I by multiplying the population prevalence by the estimated number of Caucasian workers; the difference is due to rounding off), 1,988,000 cases were attributable to work in industry. The attributable fraction estimated from combining all industries with $OR_i > 1$ into one category was $AF_{p2} = 22.2\%$ (95% CI 9.1–33.4).

For African-Americans, the overall attributable fraction for airflow obstruction was estimated as $AF_{p1} = 25.4\%$. The total number of cases of airflow obstruction in the U.S. African-American working population was estimated as 835,000 and of these 212,000 were attributable to work in industry. The attributable fractions estimated from combining all industries with $OR_i > 1$ into one category was $AF_{p2} = 23.4\%$ (95% CI 2.2–40.0).

For Mexican-Americans, the overall attributable fraction for airflow obstruction was estimated as $AF_{p1} = 55.7\%$. The total number of cases of airflow obstruction in the U.S. Mexican-American working population was estimated as 178,000 and of these 97,000 were attributable to work in industry. The attributable fractions estimated from combining all industries with $OR_i > 1$ into one category was $AF_{p2} = 49.6\%$ (95% CI 32.1–62.6).

Association Between Airflow Obstruction and Work by Occupation

Table III presents race/ethnic-specific adjusted OR for airflow obstruction by occupation. Some occupational categories closely corresponded with the industry (the armed forces, health services, sales, personal services, agriculture, and construction). For these categories, the occupations and industry coding were either similar (and we were not able to obtain more detailed occupation categories), or division into more detailed categories was not justified on the basis of sample size. However, the OR for these industries and occupations are not always exactly the same because of some differences in coding.

Occupations with a consistent increase in OR among all race/ethnic groups included armed forces, freight/stock/material handlers, vehicle mechanics, non-textile machine operators, and construction. For other occupations the increase was less consistent.

The race/ethnic-specific attributable fractions were estimated according to Equation 1, using data from Table III

TABLE II. Race/Ethnic-Specific Sample Size (n), Number of Cases (AO), and Adjusted Odds Ratios (OR) for Airflow Obstruction, and Estimated Number of Attributable Cases (AC) in Thousands, by Industry

	Caucasian					African-American					Mexican-American				
Industry	**n**	**AO**	**OR**	**95% CI**	**AC[a]**	**n**	**AO**	**OR**	**95% CI**	**AC[a]**	**n**	**AO**	**OR**	**95% CI**	**AC[a]**
Armed forces	53	10	2.8	0.8–9.3	167	43	6	2.4	1.1–5.5	11	13	3	5.6	0.6–54.3	1
Rubber, plastics, leather manuf.	30	10	2.5	1.3–5.1	98	11	1	2.3	0.2–24.4	3	27	1	4.7	0.4–50.3	2
Utilities	46	10	2.2	0.8–6.0	121	28	5	3.2	0.9–10.8	14	—	—	—	—	—
Textile mill products manuf.	64	16	2.0	1.0–3.9	124	80	5	1.2	0.5–3.1	2	17	3	7.2	1.3–40.1	3
Health care	237	27	1.7	0.9–3.2	225	285	15	1.0	0.5–1.8	0	118	4	3.3	1.2–9.2	7
Transportation and trucking	121	24	1.7	0.9–3.1	182	126	13	1.5	0.9–2.7	15	66	8	2.8	0.6–13.1	5
Food products manufacturing	70	14	1.6	0.8–3.1	100	78	13	2.6	1.1–6.4	30	115	9	1.8	0.5–6.7	4
Personal services	119	20	1.6	0.9–2.8	110	233	23	1.2	0.5–2.8	13	161	19	4.8	2.2–10.5	16
Sales	532	92	1.5	1.1–2.2	491	201	15	0.9	0.5–1.8	0	238	10	1.0	0.2–4.2	0
Repair service, gas station	114	22	1.6	0.7–3.6	151	49	9	2.7	1.2–6.1	19	78	2	1.3	0.2–11.0	1
Construction	175	28	1.3	0.8–2.3	133	140	19	1.9	1.0–3.6	31	160	15	4.0	1.0–15.8	18
Office building services	10	2	1.3	0.2–7.7	10	48	9	3.3	1.2–9.6	21	24	4	2.4	0.5–11.0	1
Agriculture	165	27	1.2	0.6–2.3	62	76	17	2.0	1.0–4.4	23	339	29	3.1	1.4–6.9	31
Chemical, petroleum, coal manuf.	45	10	1.1	0.4–3.3	15	27	2	1.0	0.2–4.3	0	27	1	3.3	0.5–20.3	2
Metal and automobile manuf.	193	27	0.8	0.4–1.6	0	173	21	1.7	1.0–3.1	30	120	3	0.4	0.1–2.1	0
Other industries[b]	566	66	0.8	0.6–1.2	0	454	32	0.9	0.6–1.6	0	525	18	1.3	0.5–3.9	5
Office workers (baseline)	1,472	130	1.0	—	—	658	35	1.0	—	—	402	7	1.0	—	
Total working sample/cases	4,012[c]	535			1,988[d]	2,710[c]	240			212	2,430[c]	136			97

NHANES III study subjects 30–75 years of age.
[a]AC, attributable cases in thousands.
[b]"Other industries" for which adjusted odds ratios for COPD were not increased.
[c]Excluded were subjects who never worked: 74 Caucasians, 64 African-Americans, and 138 Mexican-Americans.
[d]Column total not exact due to rounding.

TABLE III. Race/Ethnic-Specific Sample Size (n), Number of Cases With Airflow Obstruction (AO), Adjusted Odds Ratios (OR) for Airflow Obstruction, and Estimated Number of Attributable Cases (AC) in Thousands, by Occupation

	Caucasian					African-American					Mexican-American				
Occupation	**n**	**AO**	**OR**	**95% CI**	**AC[a]**	**n**	**AO**	**OR**	**95% CI**	**AC[a]**	**n**	**AO**	**OR**	**95% CI**	**AC[a]**
Armed forces	53	10	3.2	0.9–11.8	178	42	6	2.0	0.9–4.6	10	12	3	6.7	0.7–68.7	2
Freight/stock/material handler	22	5	2.2	1.0–4.9	38	41	10	3.2	1.5–7.0	20	23	2	6.5	1.7–24.8	4
Record proc, matl rec, scheduler	180	34	2.1	1.2–3.8	317	102	4	0.5	0.2–1.7	0	73	1	0.6	0.1–7.2	0
Vehicle mechanic	66	11	1.8	0.6–5.2	112	25	4	2.8	0.7–11.2	8	46	2	2.0	0.3–12.9	2
Health service, diagnosis, treatment	225	25	1.7	0.9–3.5	213	239	9	0.6	0.3–1.3	0	82	2	2.1	0.7–6.3	4
Transportation, matl moving equip	44	10	1.6	0.7–3.7	78	55	11	2.8	1.1–6.8	26	44	1	0.2	0.03–1.6	0
Sales	468	75	1.5	1.0–2.2	422	114	5	0.6	0.3–1.5	0	126	7	1.2	0.3–5.3	1
Motor vehicle operators	113	26	1.5	0.8–3.0	149	138	13	1.0	0.4–2.4	0	89	6	1.5	0.4–5.5	1
Personal services	77	13	1.4	0.6–3.5	51	82	6	1.0	0.3–3.5	0	51	4	7.5	2.4–23.9	9
Machine operators, assorted matl	178	33	1.4	0.7–3.1	163	148	22	1.6	0.8–3.2	27	223	9	1.4	0.5–4.1	3
Construction trades or laborer	164	24	1.4	0.8–2.5	127	122	16	1.5	0.7–3.1	18	151	15	4.7	1.3–17.8	17
Textile, apparel, furnishing mach	103	22	1.2	0.7–2.1	53	119	5	0.6	0.3–1.4	0	85	8	5.3	1.7–16.1	8
Agriculture	162	26	1.1	0.5–2.2	33	92	19	2.1	0.9–4.9	28	321	27	3.2	1.5–6.9	27
Waiter/waitress	58	10	1.1	0.4–2.9	14	11	1	1.2	0.2–6.8	1	31	3	4.2	1.0–18.1	3
Other occupations[b]	740	93	0.9	0.6–1.2	0	551	44	1.1	0.7–1.6	14	529	15	0.9	0.3–2.6	0
Cleaner (equipment, building, household)	82	8	0.7	0.3–1.7	0	255	31	1.5	0.8–3.0	40	188	22	3.2	1.2–8.9	13
Office workers (baseline)	1267	110	1.0	—	—	565	32	1.0	—	—	343	6	1.0	—	—
Total working sample/cases	4,002[c]	535			1,947	2,701[c]	238			191[d]	2,417[c]	133			94

NHANES III study subjects 30–75 years of age.
[a]AC, attributable cases in thousands.
[b]"Other occupations" for which adjusted odds ratios for COPD were not increased.
[c]Excluded were subjects who never worked or who did not have an occupational code: 84 among Caucasians, 73 among African-Americans, and 151 among Mexican-Americans.
[d]Column total not exact due to rounding.

and estimated number of prevalent cases (Table I). For Caucasians, $AF_{p1} = 21.0\%$, thus of the 9,274,000 total cases with airflow obstruction, 1,947,000 cases were attributable to work. For African-Americans, $AF_{p1} = 23.0\%$, thus of the 830,000 total cases with airflow obstruction, 191,000 cases were attributable to work. For Mexican-Americans, $AF_{p1} = 54.4\%$, thus of the total 173,000 cases with airflow obstruction, 94,000 cases were attributable to work. These estimates were similar to those obtained from the industry analysis.

DISCUSSION

In the previously reported study of the NHANES III data [Hnizdo et al., 2002], we have identified the U.S. industries and occupations potentially associated with an increased risk of COPD. In the present study, we investigate whether U.S. race/ethnic groups represented in the NHANES III survey differ with respect to the fraction of airflow obstruction associated with work in these industries and occupations. The fraction of cases of airflow obstruction that can potentially be associated with work in industries was estimated as 22.2% (9.1–33.4) among Caucasians, 23.4% (2.2–40.0) among African-Americans, and 49.6% (32.1–62.6) among Mexican-Americans. The respective estimates obtained for work by occupation were similar.

Table III shows that 25.7% of attributable cases among Caucasians came from industries with $OR \geq 2.0$ (armed forces, rubber, plastics and leather manufacturing, utilities, and textile mill products manufacturing). The largest percentage of attributable cases came from sales (24.7%). Although the OR for sales workers was comparatively low (OR 1.5; 95% CI 1.1–2.2), a large part of the U.S. workforce was employed in sales.

Among African-Americans, the largest percentages of attributable cases came from construction (14.6%); metal and automobile (including ships, railroad cars, and trucks) manufacturing (14.2%); food products manufacturing (14.2%); and agriculture (10.8%). These industries accounted for 13.7% of all airflow obstruction in all working African-Americans.

Among Mexican-Americans, the largest percentage of attributable cases came from agriculture (32.0%), construction (18.6%), and personal services (16.5%). These three industries together accounted for 36.5% of all airflow obstruction among working Mexican-Americans.

Generally, Mexican-Americans had the highest industry/occupation-specific adjusted OR for airflow obstruction and the highest attributable fractions based on industry and occupation estimates. This may be because of: exposure to the highest levels of respiratory hazards either in the U.S. or Mexican industries; lower pack-years of cigarette smoking among Mexican-Americans resulting in a lower baseline frequency of airflow obstruction and better detection of the effect of industrial exposure on airflow obstruction; under-reporting of cigarette smoking which could result in a biased increase in OR for industry; or unstable estimates caused by the small number of Mexican-American office workers in the baseline comparison group. Investigating the issue of under-reporting of smoking, we found the following: (i) a similar exposure-response trend for airflow obstruction with increasing pack-years of smoking among all three racial groups; (ii) the mean cotinine values obtained from the NHANES III data for a subset of Caucasian, African-American, and Mexican-American males were 14.4, 21.3, and 3.2, respectively, among never smokers; 37.3, 49.8, and 6.8, respectively, among ex-smokers; and 268.9, 291.6, and 141.4, respectively, among current smokers; and (iii) the respective correlation coefficients between the current number of cigarettes smoked per day and cotinine measurements were 0.33, 0.30, and 0.49. These results for cotinine are in agreement with another study [Caraballo et al., 2001], support the finding that Mexican-Americans had the lowest tobacco consumption, and suggest that their reporting of smoking was most reliable. Thus, the observed increased risk of airflow obstruction among Mexican-Americans is unlikely to be due to residual confounding from under-reported smoking. Addressing the small number of Mexican-American office workers in the comparison group, in a separate analysis we combined ‘‘other industries’’ and office workers into one baseline category (in order to obtain a larger comparison group) and obtained adjusted OR estimates similar to those reported.

Racial and ethnic disparities in the exposure to occupational hazards have been documented in the U.S. workforce [Murray, 2003]. Minority groups have traditionally been overexposed in hazardous industries such as textile, demolition, and manufacturing [National Institute for Occupational Safety and Health (NIOSH), 2002]. Scientific literature documents work-related racial and ethnic health disparities in several other areas [Ruser, 1996]. African-American workers were found to have a significantly higher rate of fatal injury at work ($RR = 1.4$, 95% CI 1.2–1.5) and the data supported the hypothesis that African-American men were employed in more hazardous jobs [Loomis and Richardson et al., 1998]. Likewise, in California, the relative risk of exposure to all occupational hazards was increased for Hispanics ($RR = 1.33$; 95% CI 1.22, 1.45) in comparison to Caucasians [Robinson, 1989].

Increased risk of COPD has been reported for some of the industries and occupations observed in the present study. A large international study of subjects 20–44 years of age [Fishwick et al., 1997] found associations between airflow obstruction ($FEV_1/FVC < 75\%$) and working as a cleaner, baker, spray painter, laboratory technician, plastics and rubber worker, and in construction and mining. Shortness of breath was reported more often by hairdressers and chemical processors. Chronic bronchitis was reported more frequently in food processors, chemical processors, spray painters, and in construction and mining. Self-reported occupational exposure to vapors, gas, dust, or fumes was associated with chronic bronchitis in agricultural, textile, paper, wood, chemical, and food processing workers [Zock et al., 2001]. Increased risk of non-specific lung disease was reported among textile workers and tailors (RR = 2.4), construction and cement workers (RR = 2.3), transportation workers (RR = 2.1), furnace workers, wood and paper workers, and farmers (RR = 1.6) [Heederik et al., 1990]. Industry-based studies of COPD have found increased risk in textile mills, the rubber industry, mining, construction, chemical production, food products manufacturing, agriculture, welders, shipfitters, and other metal trades workers [Burge, 1994; Hendrick, 1996; Newman Taylor, 1996]. Industries identified by the U.S. Work-Related Lung Disease Surveillance Report to have elevated proportional mortality ratios (PMR) for COPD include trucking services, taxicab services, automotive and miscellaneous repair services, construction, gasoline service stations, and the military [National Institute for Occupational Safety and Health (NIOSH), 1999].

This study found increased risk of COPD in sales and health care industries, especially among Caucasians. Health care workers are known to be exposed to respiratory sensitizers such as latex [Vandenplas et al., 1995], glutaraldehyde [Di Stefano et al., 1999], psyllium [Malo et al., 1990], and irritants. Latex allergy has been associated with rhinitis, occupational asthma, bronchial hyperreactivity [Vandenplas et al., 1995], and work-related changes in peak expiratory flow (PEFR) and FEV_1/FVC ratio [Hack, 2001]. Also, health care workers have been noted to have a high incidence of inhalation accidents [Ross et al., 1998]. However, occupational exposure has not been reported to be associated with chronic pulmonary function loss in health care workers. For sales, primarily Caucasian female workers, including never smokers, had increased risk of airflow obstruction (data not shown). Exposure to passive smoking was found to be associated with decreased lung function among non-smoking females and females with asthma in the NHANES III data [Eisner, 2002]. Increased risk of COPD was also observed among waitresses [Hnizdo et al., 2002] who may be exposed to high levels of tobacco smoke (e.g., in bars). A recent NHANES III based study has shown that environmental tobacco smoke at work, assessed among never smokers without environmental smoking exposure at home, was increased among sales, waiters and waitresses, and other industries [Wortley et al., 2002]. Thus, females workers, occupationally exposed to high levels of tobacco smoke, may be at an increased risk of developing airflow obstruction. However, we did not find passive smoking to be a significant predictor in the models we have fitted.

Personal services include occupations such as hairdressers who are known to have an increased risk of occupational asthma and some studies have reported increased breathlessness and lower pulmonary function [Slater et al., 2000; Hollund et al., 2001]. Record processing clerks include mail handlers who have been reported to have an increased risk of respiratory symptoms possibly associated with paper dust or microbial contaminants [Hewett and Gomberg, 2000].

An NHANES III-based study has shown that some of the industries found in our study to have an increased risk of airflow obstruction, had high prevalence of current cigarette smoking (e.g., construction, repair services, utilities), but others did not (e.g., textile mill products; chemical, petroleum, and coal products; agriculture production) [Bang and Kim, 2001]. Interaction between workplace respiratory hazards and tobacco smoking has been found to be an important contributor to COPD in silica dust exposed workers [Hnizdo, 1990; Hnizdo et al., 1990]. Thus smoking may have caused increased adjusted OR for airflow obstruction through its interaction with occupational exposure. However, since 31% of COPD cases among never smokers from the U.S. population are associated with work in industry [Hnizdo et al., 2002], occupational risks likely play a role on their own.

The strengths of the present study include reliable lung function data, varied industrial and occupational exposure, and a large sample size that allowed for unbiased estimation of the effect of the confounding factors. Weighted race/ethnic-specific estimates of the OR were similar to those from the unweighted analyses. The study had the following limitations: (i) NHANES III was not designed to be representative of the U.S. employment pattern, thus potentially obscuring the importance of some high risk work (e.g., mining); (ii) small sample sizes in some occupation categories may have resulted in imprecise estimates; (iii) the method of NHANES III sampling by which large counties with predominantly African-Americans or Mexican-Americans were selected may account for some of the race-specific differences. To investigate the race/ethnic differences, we used less stringent criteria for the definition of airflow obstruction (i.e., FEV1/FVC<75% and FEV1<80%) than we used to study COPD in the whole U.S. population (i.e., FEV1/FVC<70% and FEV1<80%) [Hnizdo et al., 2002]. This was done to increase the sample size in each race/ethnic subgroup, and thus achieve more stable estimates and narrower 95% CI. Despite this, the adjusted OR for airflow limitation for Caucasians were similar to those published for the whole U.S. population for COPD. This is expected as Caucasians formed a predominant sub-sample of the NHANES sample, but it also shows that the results for the less stringent definition are also valid.

In conclusion, the results suggest that there are differences among the U.S. race/ethnic population groups with regards to estimated fractions of cases associated with work in industry and occupation. While Caucasians had the highest prevalence of airflow obstruction across all industries and occupations, African-Americans and Mexican-Americans generally had higher OR and attributable fractions for work by industry and occupation. Differences in smoking patterns and age may explain the differences in prevalence, but disparities in exposure levels are likely explanations for the differences in adjusted OR and attributable fractions for industry and occupation. These results suggest that race/ethnic-specific differences in exposure pattern should be taken into account when conducting research and implementing prevention programs for occupational COPD.

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