

Prevalence of Asthma by Industry and Occupation in the U.S. Working Population

Michelle K. McHugh, MS, PhD,^{1†} Elaine Symanski, PhD,^{2*‡}
Lisa A. Pompeii, PhD,^{2§} and George L. Delclos, MD, MPH, PhD^{1¶}

Background Workers are potentially exposed to asthmagens daily. Our study was conducted to estimate the prevalence of asthma among working adults in the U.S. by industry and occupation.

Methods Using data from the National Health and Nutrition Examination Survey (2001–2004), multiple logistic regression was used to investigate associations between industry and occupation and current asthma as defined by positive responses to “Has a doctor or other health professional ever told you that you have asthma?” and “Do you still have asthma?”

Results Workers in mining (17.0%), health-related industries (12.5%), teaching (13.1%), or in health-related occupations (12.6%) had the highest prevalence of asthma. As compared to construction industry workers, workers in mining ($aOR = 5.2$, 95% CI: 1.1–24.2) or health-related ($aOR = 2.3$, 95% CI: 1.1–4.8) industries had significantly higher odds of asthma.

Conclusion Our study adds to the increasing evidence that miners, healthcare workers and teachers remain high-risk working populations and appropriate evaluation and control measures are needed to protect these workers. *Am. J. Ind. Med.*

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KEY WORDS: asthma; adult asthma; epidemiology; prevalence; NHANES; occupation; industry

INTRODUCTION

Asthma, a chronic lung disease, is a serious and continuing health problem that affects millions of Americans.

Not only has the incidence [King et al., 2004] and prevalence [Mannino et al., 1998] of asthma been increasing over the last three decades in the general population, it is the most common reported occupationally induced lung disease in developed countries [Pepys and Bernstein, 2006]. More than 300 natural and synthetic chemicals agents, known as asthmagens, have been reported to induce asthma in the work environment [Mapp et al., 2005; Becklake et al., 2006].

In a systematic review of 43 studies conducted between 1966 and 1999 to determine the burden of asthma that may be attributed to the workplace, Blanc and Torén [1999] reported attributable risk estimates that ranged from 5% to 18% with a median value of 9%, while findings from the European Community Respiratory Health Survey (ECRHS) attributed 5–10% of asthma to occupational exposures [Kogevinas et al., 1999]. The most recent analysis by Torén and Blanc [2009], which included studies published from 1999 to 2007 and 10 former studies from their original 1999 review, indicated 15–20% may represent a more accurate range.

¹Division of Environmental and Occupational Health Sciences, The University of Texas School of Public Health, Houston, Texas

²Division of Epidemiology and Disease Control, The University of Texas School of Public Health, Houston, Texas

[†]Postdoctoral Fellow.

[‡]Associate Professor.

[§]Assistant Professor.

[¶]Professor.

Contract grant sponsor: NIOSH Southwest Center for Occupational & Environmental Health Training; Contract grant number: T42CCT610417.

*Correspondence to: Elaine Symanski, Division of Epidemiology and Disease Control, The University of Texas School of Public Health, 1200 Herman Pressler Drive, E643, Houston, TX 77030. E-mail: elaine.symanski@uth.tmc.edu

Accepted 28 November 2009

DOI 10.1002/ajim.20800. Published online in Wiley InterScience (www.interscience.wiley.com)

A significant number of population-based studies have reported the prevalence of asthma among workers in and outside of the United States (U.S.) [Kogevinas et al., 1999, 2007; Torén et al., 1999; Le Moual et al., 2004; Zock et al., 2004; Mirabelli et al., 2007]. However, population-based studies using nationally representative samples among workers in the U.S. are limited [Arif et al., 2002, 2003b; Bang et al., 2005]. Using data from National Health and Nutrition Examination Survey (NHANES) III (1988–1994) for longest held occupations in U.S. adults, Arif et al. [2003b] found approximately a tenfold difference in the odds of work-related asthma among equipment cleaners and protective service occupations as compared to administrative and clerical workers. Three- to fourfold differences were also detected for individuals working in entertainment, agriculture, or textiles, or as motor vehicle operators. In stratified analyses of data from the 2001 National Health Interview Survey (NHIS) for current industry with office workers as the referent group, White males in printing, publishing, and allied industries had a 2.4 increased odds of having asthma and White females in health care had a 1.3 increased odds of having asthma [Bang et al., 2005]. Four- to fivefold differences in the odds of asthma were detected for Black females in entertainment and recreation industries; and furniture, lumber, and wood trades, respectively. Based on results from the most recently completed round of the ECRHS-II (1998–2003), nurses and cleaners had the highest relative risk for new-onset asthma compared to workers employed in professional, clerical, and administrative jobs [Kogevinas et al., 2007]. One recent study found that female non-domestic cleaners have more asthma symptoms at work than non-cleaning staff (e.g., individuals who worked in the building as clerical, maintenance, and security personnel) [Obadia et al., 2009].

Using data from NHANES 2001–2004, this study describes demographic characteristics among working adults aged 20 to 59 years in the U.S., makes prevalence comparisons for current asthma and employment by industry sectors and occupational categories for this sub-population, and identifies industries and occupations with a high prevalence for asthma.

MATERIALS AND METHODS

Our data came from two cycles (2001–2002 and 2003–2004) of the NHANES. The NHANES is a cross-sectional, multi-stage probability sample representative of the U.S. civilian, non-institutionalized population conducted by the Centers for Disease Control and Prevention (CDC). To ensure adequate sample size, the NHANES over-sampled African Americans, Mexican Americans, individuals 60 years of age and over, and low-income Whites. Industry and occupation groups were coded by trained nosologists according to the National Center for Health Statistics

(NCHS) Industry and Occupation Classification Source Codes and closely follow the patterns established by NHANES III [U.S. Department of Health and Human Services (CDC), 2008]. The original sample for 2001–2004 included 6,391 adults, ages 20–59 years. We excluded 6 participants who were missing data for questions concerning healthcare professional-diagnosed asthma and another 1,798 participants who were not working at a job or business at the time of the interview and/or were missing occupation or industry data. Our final sample included a total of 4,585 eligible working adults: 2,413 males and 2,172 females.

Definition of Asthma

Current asthma was ascertained by the following questions: “Has a doctor or other health professional ever told you that you have asthma?” and “Do you still have asthma?” Participants who had a positive response to both questions were considered to have current asthma [U.S. Department of Health and Human Services (CDC), 2008].

Definition of Industry and Occupation Categories

NHANES ascertained data on participants’ current occupation, longest held occupation, and current industry of employment. The question “What kind of work were you doing?” was used to classify the occupational group for current occupation and “Thinking of all the paid jobs or businesses you ever had, what kind of work were you doing the longest?” was used to classify longest held occupation. However, nearly two-thirds of the participants were missing data on longest held occupation and thus we conducted analyses on current occupation only. For those participants who answered “yes” to “Do you usually work 35 or more hours per week?” information on the industrial classification of a participant’s current job was taken from the question “What kind of business or industry is this?” [U.S. Department of Health and Human Services (CDC), 2008].

Due to small sample sizes within some of the original industry and occupation groups coded by NHANES, our study collapsed many of these smaller groups to form new larger industry and occupation groups based on their potential for similar exposures to asthmagens [Bang et al., 2005; Mapp et al., 2005; Malo and Chan-Yeung, 2009]. For example, the “Agriculture production” and “Agricultural services, forestry, and fishing” industries were combined to form “Agriculture, forestry, and fishing”; “Offices of health practitioners,” “Hospitals,” and “Health services, n.e.c. (‘not elsewhere classified’)” were created to form “Health-related industries”; and a new “Retail” group was formed by combining all retail trades (i.e., “Retail-department stores”; “Retail-food stores”; “Retail-vehicle dealers, supply and

service stores”; “Retail-apparel and accessory stores”; and “Other retail trade”). Examples of occupational groups that were collapsed include: “Engineers, architects, and scientists” joined with “Other professional specialty occupations” to form “Engineers and scientists”; “Vehicle and mobile equipment mechanics and repairers” combined with “Other mechanics and repairers” to form “Mechanics”; and “Cooks” and “Miscellaneous food preparation and service occupations” to form “Cooks and food preparation.” In total, industry groups were collapsed from 44 to 26 categories (Appendix A) and occupational groups were collapsed from 40 to 22 categories (Appendix B).

Demographic Characteristics

For covariates of interest in this study, we used information on participants about their gender, years of age, smoking status, and race/ethnicity (non-Hispanic Whites, non-Hispanic Blacks, Mexican Americans, other Hispanics, and other-mixed races). Smoking status was categorized as current smokers; former smokers (having previously smoked at least 100 cigarettes and/or a pipe or cigar 20 times in their lifetime, but who did not smoke cigarettes, pipes, or cigars at the time of the interview); and individuals who never smoked. Height and weight measurements for participants were taken at the mobile examination centers (MEC) following standardized protocols with calibrated equipment during the medical exam [U.S. Department of Health and Human Services (CDC), 2008]. These measures were used to calculate body mass index (BMI) based upon weight in kilograms divided by the square of height in meters. Standard BMI definitions were used to classify normal weight ($18.5 < 25.0 \text{ kg/m}^2$), overweight ($25.0 < 30.0 \text{ kg/m}^2$), obese ($30.0 < 40.0 \text{ kg/m}^2$), and extremely obese ($\geq 40.0 \text{ kg/m}^2$) individuals [U.S. Department of Health and Human Services (NHLBI), 1998].

We used education level (less than high school; high school graduate (including GED), more than high school) and the poverty income ratio (PIR) as measures of socioeconomic status. NHANES calculates the PIR based upon the official poverty measure of the U.S. Census Bureau that represents a family or person’s income divided by 1 of 48 possible poverty thresholds [U.S. Department of Health and Human Services (CDC), 2008]. Poverty thresholds vary by family size and age of family members and are updated annually for inflation using the Consumer Price Index (CPI-U). Federally established PIR cut-points were used to define values less than 1.00 as indicative of below the poverty level and values greater than or equal to 1.00 as representative of incomes above the poverty level [U.S. Census Bureau, 2008].

Analyses

SAS (Version 9.1.3, SAS Institute, Inc., Cary, NC) was used for database management. SAS-callable SUDAAN

(SUDAAN Version 9.0.1, Research Triangle Institute, Research Triangle Park, NC) was used to address the complex multi-stage survey design of NHANES [Research Triangle Institute, 2004]. All analyses were conducted using the appropriate 4-year weight variable and variances were estimated by the Taylor series linearization method [U.S. Department of Health and Human Services (CDC), 2008].

The prevalence of asthma was estimated for working adults by current employment, based on classifications of industry and occupation as described above. To examine the association between employment (industry and occupation) and asthma, logistic regression models were used to calculate crude (ORs) and adjusted (aOR) prevalence odds ratios with 95% confidence intervals (95% CIs). In our analyses, construction workers were used as the referent group because they had a relatively low prevalence of asthma and were a large enough group to enhance precision of the results [Kleinbaum et al., 1982]. Potential risk factors evaluated as confounders included gender, age, race/ethnicity, BMI, education level, smoking history, and PIR. Confounding was assessed by a 10% difference between the crude and adjusted point estimates for any level of the industrial or occupational groups.

RESULTS

Over 71% of study participants were non-Hispanic Whites and nearly 54% were males (Table I). Almost half of the participants (48.2%) had never smoked and 28% were current smokers. More than 90% of the subjects lived above the poverty line and at least 62% of the participants had some education greater than high school.

Demographic Characteristics by Industry Group

Males dominated 17 of the 26 industries with the highest percentages in construction (91.3%), mining (91.7%), utilities (89.0%), and repair services (99.4%) (Table II). Females worked in higher proportions in the textile manufacturing (60.5%); private household, lodging and personal services (73.5%); health-related (78.9%); and educational services (70.7%) industries. In terms of race/ethnicity, non-Hispanic White workers were represented in the highest proportion for all 26 industries followed by non-Hispanic Blacks and Mexican Americans. The highest percentage of workers who fell under the official poverty threshold came from agriculture, forestry, and fishing (22.3%); eating and drinking establishments (24.1%); and private household, lodging, and personal services (19.1%). The majority of the industries employed those with a high school degree or higher, although the construction industry (27.9%); eating and drinking establishments (30.2%);

TABLE I. Demographic Characteristics in U.S. Working Adults Aged 20–59 Years, National Health and Nutrition Examination Survey (NHANES), 2001–2004

NHANES (2001–2004)	N	Weighted %^a	Population size^b
Gender	4,585		
Males	2,413	53.67	128,833,658
Females	2,172	46.33	111,227,886
Race/ethnicity	4,585		
Mexican American	985	8.41	20,192,701
Other Hispanics	189	4.94	11,862,175
Non-Hispanic White	2,299	71.04	170,539,819
Non-Hispanic Black	912	10.46	25,114,735
Mixed race—other	200	5.15	12,352,114
Body mass index (BMI)	4,472		
Normal weight (BMI 18.5–<25.0 kg/m ²)	1,482	34.97	82,109,536
Overweight (BMI 25.0–<30.0 kg/m ²)	1,592	34.68	81,492,240
Obesity (BMI 30.0–<40.0 kg/m ²)	1,170	25.71	60,364,497
Extreme obesity (BMI ≥40.0 kg/m ²)	228	4.64	10,907,853
Age (years)	4,585		
20–29	1,254	23.90	57,364,380
30–39	1,224	26.22	62,939,917
40–49	1,266	30.02	72,080,096
50–59	841	19.86	47,677,152
Education	4,583		
<High school	935	12.97	31,121,233
High school graduate	1,112	24.85	59,634,290
>High school	2,536	62.18	149,193,170
Smoking history ^c	4,582		
Never	2,338	48.19	115,603,142
Former	1,004	23.87	57,256,447
Current	1,240	27.94	67,011,187
Poverty income ratio (PIR) ^d	4,340		
≥1.00	3,796	91.05	207,021,218
<1.00	544	8.95	20,349,585

^aPercentages are weighted to correspond to population estimates of the U.S. Census Bureau.

^bCorresponding U.S. population estimates.

^cSmoking history: current smokers; former smokers have smoked at least 100 cigarettes and/or a pipe 20 times and/or smoked cigars 20 times in their lifetime but did not smoke cigarettes, pipes, or cigars at the time of the interview; and individuals who never smoked.

^dPoverty income ratio (PIR): The U.S. Census Bureau calculates the ratio of income to a family's appropriate poverty threshold. PIR values below 1.00 are considered below the official poverty threshold and values greater than 1.00 indicate income above the poverty threshold.

agriculture, fishing, and forestry (35.1%); and the textile manufacturing industry (45.8%) employed a moderately high number of individuals with less than a high school diploma or equivalent. Industries that employed the highest number of current smokers included: construction (42.6%); private household, lodging, and personal services (43.7%); rubber manufacturing (43.8%); eating and drinking establishments (46.8%); and the construction trades (42.6%).

Demographic Characteristics by Occupation Group

Non-Hispanic Whites had the highest proportion of workers in all occupational groups followed by Non-Hispanic Blacks and Mexican Americans (Table III). Males dominated the workforce in the following groups: construction (96%); mechanics (99.2%); extractive and precision products (96.0%); and motor vehicle operators

TABLE II. Demographic Characteristics by Current Industry in U.S. Working Adults Aged 20–59 Years, National Health and Nutrition Examination Survey (NHANES), 2001–2004

Current industry	Gender		Race				Age (years)		PIR ^b		Education	Smoking	Status	
	% ^a Males	% Non-Hispanic White	% Non-Hispanic Black	% Mexican American	% Other Hispanic	% Mixed/ other	Median	% <1.0	% <1.0	school	% Never	% Former	% Current	
Construction	91.3	69.2	5.4	16.5	5.7	3.3	36.9	12.6	27.9	29.5	27.9	42.6		
Administration and finance	42.3	76.8	12.3	3.5	2.6	4.8	40.5	4.5	5.5	54.9	26.3	18.7		
Agriculture, forestry, and fishing	70.9	61.2	3.8	31.2	1.0	2.7	35.3	22.3	35.1	55.3	18.1	26.5		
Mining	91.7	78.7	1.1	16.4	0.0	3.8	40.4	8.3	19.1	20.8	30.6	48.6		
Mfg.—Food and kindred	60.9	52.1	10.4	12.3	12.3	13.0	33.6	8.7	22.6	41.7	22.0	36.2		
Mfg.—Textile	39.5	26.4	17.5	18.9	8.9	28.3	42.8	10.5	45.8	52.1	26.4	21.5		
Mfg.—Paper	61.2	80.0	7.3	8.1	2.5	2.1	37.5	3.7	10.8	41.2	29.6	29.2		
Mfg.—Chemical	72.8	72.0	8.6	6.9	9.1	3.4	41.7	3.5	12.9	60.8	29.2	10.1		
Mfg.—Rubber	73.6	59.9	15.3	14.7	10.2	0.0	35.2	13.4	23.1	45.0	11.2	43.8		
Mfg.—Lumber	79.3	72.7	11.6	10.6	0.0	5.1	37.2	13.0	22.9	36.0	29.0	35.0		
Mfg.—Metal	74.9	74.7	8.7	7.9	3.7	5.1	39.5	7.3	15.3	35.2	34.4	30.4		
Mfg.—Electrical	76.5	67.4	6.3	14.4	3.7	8.2	39.6	5.5	13.6	55.7	22.1	22.2		
Mfg.—Transportation equipment	72.3	75.3	10.4	9.3	1.8	3.1	41.3	4.1	10.3	39.4	31.4	29.2		
Trucking services	73.4	68.4	14.2	7.2	6.3	3.9	41.9	5.5	13.6	35.5	28.4	36.2		
Communications	53.6	71.3	16.4	4.8	5.3	2.3	36.7	4.4	7.1	45.7	24.0	30.4		
Utilities	89.0	81.9	9.4	4.7	1.4	2.6	43.4	3.8	3.4	40.8	25.7	33.5		
Wholesale (durable, non-durable)	68.3	74.7	4.0	9.3	7.4	4.7	40.8	5.4	12.1	34.7	30.5	34.9		
Retail	51.7	71.3	9.1	8.4	4.8	6.5	36.5	15.6	14.4	51.5	16.9	31.6		
Eating and drinking establishments	48.4	59.8	12.6	14.2	5.2	8.3	29.4	24.1	30.2	37.7	15.5	46.8		
Business services	55.2	72.7	10.8	6.3	3.7	6.6	40.4	5.2	7.8	52.9	25.1	22.0		
Repair services	99.4	73.2	10.7	10.6	4.3	1.2	40.7	3.2	21.5	34.4	21.9	43.7		
Private household, lodging, and personal services	26.5	58.7	9.5	11.0	13.0	7.9	39.4	19.1	21.7	54.2	17.1	28.8		
Entertainment—recreation services	72.1	69.6	11.6	8.6	4.3	6.0	33.7	15.7	13.1	45.0	35.0	20.0		
Health-related	21.1	69.3	15.2	4.2	6.6	4.7	40.0	5.6	13.1	52.8	22.7	24.5		
Educational services	29.3	77.6	9.8	4.1	4.8	3.8	40.6	5.8	7.1	65.1	21.8	13.1		
Justice, public order, and safety	61.2	79.5	11.4	3.9	2.8	2.5	43.0	2.7	1.5	51.6	25.3	23.1		

Mfg, manufacturing.

^aPercentages are weighted based upon population estimates of the U.S. Census Bureau to produce unbiased national estimates.

^bPoverty income ratio (PIR): The U.S. Census Bureau calculates the ratio of income to a family's appropriate poverty threshold. PIR values below 1.0 are considered below the official poverty threshold and values greater than 1.0 indicate income above the poverty threshold.

TABLE III. Demographic Characteristics by Current Occupation in U.S. Working Adults Aged 20—59 Years, National Health and Nutrition Examination Survey (NHANES), 2001—2004

Current occupation	Gender	Race				Age (years)		PIR ^b	Education	Smoking		Status			
		% Non-Hispanic		% Mexican American	% Other Hispanic	% Mixed/other	Median			% <1.00	% <High school		% Never	% Former	% Current
		White	Black												
Construction	Males	% ^a	68.7	6.1	17.4	5.3	36.3	2.6	13.4	30.7	29.5	25.3	45.2		
Management-related and clerical			75.5	9.6	5.4	4.5	41.0	5.0	4.3	6.3	51.8	24.3	23.9		
Engineers and scientists			81.6	6.8	3.1	2.7	40.2	5.8	1.4	0.8	55.1	30.0	15.0		
Health-related			68.0	15.7	3.8	7.6	37.1	4.9	7.1	6.3	57.3	21.7	21.0		
Teachers			77.6	10.8	3.1	2.4	39.4	6.1	4.4	0.6	71.0	19.0	10.1		
Writers, artists, athletes, and entertainment			84.5	5.8	2.4	2.8	40.1	4.5	6.7	0.0	39.6	49.4	11.0		
Technicians			78.8	8.3	2.7	4.7	38.3	5.6	5.4	0.9	53.4	24.7	21.9		
Supervisors, sales, and proprietors			76.7	8.5	4.5	5.0	37.2	5.4	10.4	10.3	50.7	21.3	28.0		
Private house-holds and personal services			59.8	11.5	8.9	13.8	40.2	6.0	19.0	14.7	57.7	18.6	23.7		
Protective services			63.8	21.7	2.7	7.1	35.0	4.7	5.9	4.1	43.4	28.6	28.0		
Waiters and waitresses			80.7	5.8	6.4	3.3	26.7	3.9	24.6	21.2	42.2	15.1	42.8		
Cooks and food preparation			50.5	18.2	17.8	5.1	35.3	8.4	27.5	35.4	42.2	19.7	38.2		
Cleaning and building services			49.3	20.4	17.8	6.7	37.8	5.8	14.2	33.5	45.2	22.8	32.1		
Agriculture, forestry, and fishing			56.8	4.8	33.1	1.0	37.4	4.3	24.2	37.5	45.8	23.5	30.7		
Mechanics			73.6	7.3	11.3	3.6	40.9	4.3	4.0	12.5	22.1	31.2	46.7		
Extracative and precision products			67.0	6.9	14.3	5.7	40.1	6.1	3.8	20.7	34.3	24.6	41.1		
Machine operators			58.1	13.7	20.6	5.8	37.4	1.8	14.1	30.8	48.5	18.5	33.0		
Fabricators			62.1	16.8	16.3	2.7	36.2	2.1	19.1	26.1	47.7	22.9	29.4		
Motor vehicle operators—transportation			66.4	14.7	8.7	4.9	39.9	5.2	10.3	19.7	31.1	24.4	44.5		
Laborers (except construction)			51.3	8.2	27.3	3.7	26.9	9.5	33.3	25.0	47.6	12.2	40.3		
Freight, stock, and material handlers			53.9	20.0	8.6	7.8	35.6	9.6	13.8	28.7	50.4	11.2	38.5		
Equipment cleaners			43.5	14.9	21.9	9.4	35.4	10.5	30.7	47.1	53.9	12.6	33.5		

^aPercentages are weighted based upon population estimates of the U.S. Census Bureau to produce unbiased national estimates.

^bPoverty income ratio (PIR): The U.S. Census Bureau calculates the ratio of income to a family's appropriate poverty threshold. PIR values below 1.00 are considered below the official poverty threshold and values greater than 1.00 indicate income above the poverty threshold.

and transportation (94%). Female workers were highly represented in health-related occupations (78.3%); teaching occupations (71.3%); and the private household, lodging, and personal service occupations (84.9%). Seventeen of the 22 occupational groups had 80% or more of their workers above the poverty threshold level. The six occupations that fell below the official poverty threshold level included: waiters and waitresses (24.6%); cooks and food preparation (27.5%); agricultural, forestry, and fishing (24.2%); machine operators (19.1%); laborers (except construction) (33.3%); and equipment cleaners (30.7%). In terms of education level, occupations which employed 30% or more of their workers with less than a high school diploma or equivalent included: construction (30.7%); machine operators (30.8%); cleaning and building services (33.5%); cooks and food preparation (35.4%); and agriculture, fishing, and forestry (37.5%). Current smokers were employed in higher numbers in the following occupations: laborers (except construction) (40.3%); extractive and precision products (41.1%); waiters

and waitresses (42.8%); motor vehicle operators and transportation (44.5%); and construction workers (45.2%).

Asthma Prevalence by Industry Group

The prevalence of current asthma by industry group ranged from 1.7% to 17.0% (Table IV). Individuals working in mining (17.0%) or health-related industries (12.5%) had the highest prevalence of asthma, while persons working in the paper manufacturing (3.3%); repair services (3.0%); textile manufacturing (2.1%); agriculture, forestry, and fishing (1.8%) industries; and transportation equipment manufacturing (1.7%) experienced the lowest.

Individuals employed in the mining (aOR = 5.2, 95% CI: 1.1–24.2) or health-related (aOR = 2.3, 95% CI: 1.1–4.8) industries experienced elevated odds of current asthma, while those employed in the agriculture, forestry, and fishing industry had significantly lower odds of asthma (aOR = 0.1, 95% CI: 0.0–0.7) compared to those employed

TABLE IV. Prevalence of Current Asthma and Odds Ratios by Current Industry in U.S. Working Adults Aged 20–59 Years, National Health and Nutrition Examination Survey (NHANES), 2001–2004

Current industry	N	No. reporting asthma	% Prevalence (weighted) ^a (95% CI)	Adjusted ^b OR (95% CI)
Construction	379	12	3.8 (1.9–7.6)	Referent
Administration and finance	518	42	7.9 (5.9–10.5)	1.7 (0.8–3.7)
Agriculture, forestry, fishing	144	2	1.8 (0.4–9.1)	0.1 (0.0–0.7)
Mining	36	5	17.0 (6.1–39.0)	5.2 (1.1–24.2)
Mfg.—Food and kindred	74	3	4.1 (1.3–12.1)	1.0 (0.3–3.7)
Mfg.—Textile	33	1	2.1 (0.3–14.1)	0.4 (0.5–3.1)
Mfg.—Paper	65	3	3.3 (0.8–12.5)	0.8 (0.2–3.7)
Mfg.—Chemical	40	1	4.3 (0.5–27.5)	1.1 (0.1–11.2)
Mfg.—Rubber	34	2	7.5 (1.5–29.4)	1.8 (0.4–7.7)
Mfg.—Lumber	48	3	9.2 (2.5–28.6)	2.2 (0.4–11.3)
Mfg.—Metal	112	7	6.4 (2.5–15.3)	1.5 (0.4–5.3)
Mfg.—Electrical	93	1	1.7 (0.2–11.1)	0.4 (0.0–3.1)
Mfg.—Transportation equipment	73	2	4.5 (0.8–21.8)	1.0 (0.2–7.3)
Trucking services	203	15	8.8 (4.5–16.3)	2.2 (0.8–6.4)
Communications	77	5	7.0 (2.5–17.7)	1.8 (0.5–6.8)
Utilities	57	0	NA	NA
Wholesale (durable, non-durable)	121	6	3.2 (1.1–9.2)	0.7 (0.2–2.9)
Retail	454	27	6.0 (3.8–9.2)	1.4 (0.6–3.4)
Eating and drinking establishments	267	11	5.1 (3.3–7.9)	1.0 (0.4–2.3)
Business services	443	29	6.9 (4.8–9.8)	1.6 (0.7–3.8)
Repair services	62	1	3.0 (0.4–17.6)	0.8 (0.1–6.5)
Private household—lodging—personal services	173	6	5.0 (2.1–11.7)	0.9 (0.3–3.5)
Entertainment—recreation services	74	5	7.3 (2.8–17.7)	1.6 (0.4–6.2)
Health-related	505	51	12.5 (8.4–18.3)	2.3 (1.1–4.8)
Educational services	397	38	9.0 (6.3–12.8)	1.7 (0.6–4.6)
Justice, public order, and safety	91	10	9.7 (4.1–21.3)	2.4 (0.8–7.4)

OR, odds ratio; CI, confidence interval; Mfg., manufacturing.

^aPrevalence % is weighted based upon population estimates of the U.S. Census Bureau to produce unbiased national estimates.

^bAdjusted for gender, BMI, and PIR (age and smoking history were excluded from the model as they did not act as confounders).

in the construction trades. However, the finding for agriculture, forestry, and fishing were based upon a very small sample size for current asthma (Table IV). All models were adjusted for gender, BMI, and PIR, and although examined, years of age and smoking history were not found to function as confounders in these models and were subsequently removed.

Asthma Prevalence by Occupational Group

For occupational groups, teachers (13.1%) and health-related occupations (12.6%) had the highest prevalence of current asthma while those employed in agriculture, forestry, and fishing occupations (1.8%); and as freight, stock, and material handlers (1.0%) had the lowest prevalence of current asthma (Table V).

In our adjusted logistic regression models, adults working in management-related and clerical occupations (aOR = 1.8, 95% CI: 0.8–4.1); engineers and scientists (aOR = 1.9, 95% CI: 0.8–4.6); those in health-related occupations (aOR = 2.4, 95% CI: 0.9–6.5); and

teaching occupations (aOR = 2.6, 95% CI: 0.8–9.0) had an increased odds of current asthma; however, the results were not statistically significant. Similar to our findings by industry (and also based upon a relatively small sample of asthmatics), those employed in agriculture, forestry, and fishing occupations experienced considerably lower odds of asthma (aOR = 0.01, 95% CI: 0.0–0.6) compared to those in the construction trades (Table V).

DISCUSSION

Based on our findings, 7% percent of working adults currently have asthma, representing approximately 16.7 million U.S. workers. This number is lower than the nearly 10% prevalence of current asthma we found in adults aged 20–85 years [McHugh et al., 2009]. We also identified several industries and occupations where the prevalence of current asthma is high, including workers in the mining and health-related industries, as well as those employed in health-related occupations and teaching occupations. Our prevalence estimate for health-related industries (12.5%) is higher than that previously reported for U.S. workers in Bang

TABLE V. Prevalence of Current Asthma and Odds Ratios by Current Occupation in U.S. Working Adults Aged 20–59 Years, National Health and Nutrition Examination Survey (NHANES), 2001–2004

Current occupation	N	No. reporting asthma	%Prevalence (weighted) ^a (95% CI)	Adjusted ^b OR (95% CI)
Construction	313	8	3.8 (1.7–8.4)	Referent
Management-related and clerical	1,158	92	7.9 (6.4–9.7)	1.8 (0.8–4.1)
Engineers and scientists	264	20	7.2 (4.8–10.6)	1.9 (0.8–4.6)
Health-related	298	35	12.6 (8.6–18.1)	2.4 (0.9–6.5)
Teachers	217	25	13.1 (7.8–21.2)	2.6 (0.8–9.0)
Writers, artists, athletes, and entertainers	77	5	8.5 (3.5–19.3)	2.3 (0.7–8.1)
Technicians	145	12	9.2 (4.7–17.1)	1.9 (0.6–6.3)
Supervisors, sales, and proprietors	423	25	5.6 (3.4–9.1)	1.2 (0.5–3.4)
Private households and personal services	143	6	5.0 (1.8–13.0)	1.1 (0.3–3.8)
Protective services	72	5	4.4 (2.0–9.6)	1.2 (0.3–4.2)
Waiters and waitresses	71	4	7.1 (2.4–19.2)	1.2 (0.3–5.7)
Cooks and food preparation	194	11	7.2 (4.1–12.3)	1.4 (0.5–4.2)
Cleaning and building services	139	5	3.6 (1.3–10.1)	0.8 (0.2–3.2)
Agriculture, forestry, and fishing	153	2	1.8 (0.3–9.2)	0.1 (0.0–0.6)
Mechanics	153	7	6.3 (3.0–12.7)	1.7 (0.5–5.4)
Extractive and precision products	139	8	7.3 (3.7–14.0)	1.8 (0.6–4.8)
Machine operators	145	6	3.9 (1.3–11.4)	0.9 (0.2–3.8)
Fabricators	96	3	5.0 (1.6–14.8)	1.1 (0.3–4.9)
Motor vehicle operators—transportation	221	7	3.6 (1.4–8.5)	0.6 (0.2–2.3)
Laborers (except construction)	21	0	NA	NA
Freight, stock and material handlers	64	1	1.0 (0.1–7.9)	0.3 (0.0–2.9)
Equipment cleaners	64	1	3.1 (0.4–19.0)	0.7 (0.1–6.1)

OR, odds ratio; CI, confidence interval.

^aPrevalence % is weighted based upon population estimates of the U.S. Census Bureau to produce unbiased national estimates.

^bAdjusted for gender, BMI, and PIR (age and smoking history were excluded from the model as they did not act as confounders).

et al. [2005] (8.5%), suggesting the prevalence of asthma among these working adults continues to rise.

Our study found the highest prevalence of asthma in the mining industry. Epidemiologic studies of coal miners in the U.S., Britain, and Italy report associations between respirable coal dust and decreased lung function [Hnizdo et al., 2006]. However, the sample size for this group was relatively small and, of those who reported “current asthma” there is a chance that other respiratory diseases more common to miners, such as chronic obstructive pulmonary disease (COPD) (i.e., chronic bronchitis and emphysema) [Hnizdo et al., 2006], could have confounded these results since they may share similar symptoms with asthma.

In our study, we found that healthcare workers had a high prevalence of asthma, which is consistent with previous findings for selected groups of healthcare workers. In an analysis of the ECHRS-II study, Kogevinas et al. [2007] reported over a twofold increased risk of new-onset asthma in nurses. Following the ECHRS protocol in Canada, Johnson et al. [2000] found nurses were the most commonly reported occupation for those with probable asthma (i.e., employed in a high-risk job at onset of asthma). Potential exposures to asthmagens reported among healthcare workers have included detergents, latex, glutaraldehyde, formaldehyde, general cleaning products, and aerosolized medications [Bang et al., 2005; Mapp et al., 2005; Delclos et al., 2007; Mirabelli et al., 2007; Arif et al., 2009]. In a study focused on the healthcare industry, Delclos et al. [2007] found an increased risk of asthma for workers who were involved in medical instrument cleaning, wore powdered latex gloves between 1992 and 2000, or administered aerosolized medications. In the ECHRS II, Mirabelli et al. [2007] found a nearly fivefold increased risk of asthma among hospital technicians and a twofold increased risk of asthma in those who used ammonia and/or bleach at work. Arif et al. [2009] reported that nursing professionals exposed to general cleaning products and disinfectants and glues and/or solvents used in patient care were associated with new-onset asthma.

Among the 22 occupations we examined, teachers ranked second in asthma prevalence (13.1%). Potential asthmagens for teachers reported in prior studies include: indoor air pollutants, cleaning products, solvents and hydrocarbons, dusts, mold, and miscellaneous chemicals (i.e., photo developing chemicals, fire extinguisher discharge, and other chemicals) [Mazurek et al., 2008]. According to the National Institute for Occupational Safety and Health’s (NIOSH) Sentinel Event Notification System for Occupational Risks (SENSOR) Program from four states in the U.S. (i.e., California, Massachusetts, Michigan, and New Jersey) (1993–1999), educational service workers (229 cases) were the third highest industry to report work-related asthma behind health services (405 cases) and transportation equipment manufacturing (482 cases) [U.S. Department of Health and Human Services (NIOSH), 2002]. Using the same

four states, for the period of January 1, 1993 to December 31, 2000, Mazurek et al. [2008] found teachers and teachers’ aides (54%) were the most likely to report work-related asthma. In a study to characterize work-related asthma in patients presenting in the New York State Occupational Health Network (OCHN), Fletcher et al. [2006] found teachers were the most common occupation to present at the OCHN.

In some cases the classification of workers in NHANES was similar by occupation and industry and in other cases dissimilar, which limited our ability to compare across these two sets of analyses. For example, our study found the highest prevalence of asthma in the mining industry; yet, there was no corresponding occupation group for “miners.” In evaluating which jobs were held by workers in the mining industry, we found that they were employed in diverse occupations including: management-related and clerical engineers and scientists; technicians; supervisors, sales, and proprietors; mechanics; construction; extractive and precision products; machine operators; and motor vehicle operators transportation. In contrast, the industry and occupational classifications were more closely aligned for the health-related industry and the healthcare occupational group and the results did not differ greatly.

While epidemiologic studies of asthma in the work environment have traditionally used administrative workers and/or clerical-related workers as the referent group [Kogevinas et al., 1999, 2007; Arif et al., 2002, 2003b; Le Moual et al., 2004; Bang et al., 2005], we chose the construction trades as the referent group in our analyses based upon the practice of selecting a group that has a low disease prevalence (or risk) with the additional consideration of being large enough to generate stable estimates [Kleinbaum et al., 1982]. The question of the suitability of whether “office workers” are the best referent group has been raised in the literature [Bang et al., 2005]. Studies similar to ours have also reported a higher prevalence of asthma among workers in the office and clerical trades compared to construction workers [Arif et al., 2002, 2003a; Bang et al., 2005]. A possible explanation of an increasing prevalence of asthma among office workers may be due to the preferential migration of asthmatics to this type of work (i.e., the “healthy worker effect”) [Bang et al., 2005] or may be due to exposures in the indoor air environment, as many common indoor air pollutants (e.g., environmental tobacco smoke, particulate matter, nitrogen dioxide, volatile organic compounds, and formaldehyde) are known respiratory irritants [Viegi et al., 2004; Menzies and Kreiss, 2006; Bernstein et al., 2008]. In a population-based incident case-control study of office workers in Finland researchers found over a one and a half-fold to nearly twofold increased risk of adult-onset asthma in office workers due to paper dust and carbonless copy paper, respectively [Jaakkola and Jaakkola, 2007].

The “healthy worker effect” (HWE) may also operate if workers self-select out of occupations that exacerbate their asthma, or avoid employment in certain types of jobs [Punnett, 1996; Pearce et al., 1998; Arif et al., 2003b; Checkoway et al., 2004; Becklake et al., 2006; Le Moual et al., 2008]. In our study we attempted to minimize the HWE by analyzing the longest held occupation (rather than current occupation) and excluding those who were not working at the time of the interview, but data were missing on this variable for 66% of the study population. Due to the cross-sectional nature of the study, we were not able to address the differential selection out of employment on the basis of current or past exposure and subsequently there may be an underestimation of the true magnitude of the health effects associated with occupational exposures [Punnett, 1996].

Defining asthma in population studies continues to generate controversy in the scientific literature [Pearce et al., 1998; Pekkanen and Pearce, 1999; Pekkanen et al., 1999; Peat et al., 2001; Marks, 2005; von Hertzen and Haahtela, 2005]. Pekkanen and Pearce [1999] suggest that there are advantages of using different asthma definitions depending on the purpose of the study (i.e., prevalence vs. etiologic studies). In our parent study [McHugh et al., 2009], from which we drew our worker population, we were unable to develop an alternative definition of asthma based on respiratory symptoms (e.g., “coughing most days over a 3-month period” and “wheezing or whistling in chest in the past year”) due to extensive missing data. Because the second question used in our study to ascertain current asthma (“do you still have asthma”) did not include a time reference (e.g., “in the last month” or “the last 12 months”) our findings for current asthma may also be underestimated. Although NHANES also collects data on the job held when a participant was told he/she had asthma (i.e., those who responded to “Has a doctor or other health professional ever told you that you have asthma” were also asked the “Kind of job held when had asthma”) and 264 (92%) of the 288 asthmatics in our population responded to the latter question, 170 (64%) of these asthmatics were not employed at the time of diagnosis, thus raising the possibility that for some of these workers their asthma may have developed in childhood or adolescence.

In conclusion, our study adds to the increasing evidence that healthcare workers and teachers/educational services remain high-risk working populations, suggesting the need for evaluation and control measures to protect these workers. These occupational groups consist of a higher proportion (>70%) of women thus highlighting the need to explore gender-specific risk factors of asthma in working populations. The increasing prevalence of asthma among office workers also warrants further investigation, especially since they were considered an ideal referent group in prior occupational studies.

ACKNOWLEDGMENTS

This work was funded, in part, by the NIOSH Southwest Center for Occupational & Environmental Health Training Grant #T42CCT610417.

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APPENDIX A: INDUSTRY GROUP CODES BY NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES) 2001–2004 INDUSTRY CLASSIFICATION CODES

Study code	Industry group titles	NHANES code	Industry titles (NCHS Industry Classification Source Codes) ^{a,b}
1	Administration and finance	29	Banking and other finance (700–702, 710)
		30	Insurance and real estate (711, 712)
		41	Social services (861–863, 870, 871)
		44	Public administration, except justice, public order, and safety (900–901, 921, 922, 930–932)
2	Agriculture, forestry, and fishing	1	Agriculture production (10–12)
		2	Agricultural services, forestry, and fishing (20, 30–32)
3	Mining	3	Mining (40–42, 50)
4	Construction	4	Construction (60)
5	Mfg.—Food and kindred	5	Mfg.—Food and kindred products (100–102, 110–112, 120–122, 130)
6	Mfg.—Textile	6	Mfg.—Textile mill products (132, 140–142, 150)
		7	Mfg.—Apparel and other finished textile products (151, 152)
7	Mfg.—Paper	8	Mfg.—Paper products, printing, publishing, and allied industries (160–162, 171, 172)
8	Mfg.—Chemical	9	Mfg.—Chemicals, petroleum, and coal products (180–182, 190–192, 200, 201)
9	Mfg.—Rubber	10	Mfg.—Rubber, plastics, and leather products (210–212, 220–222)
10	Mfg.—Lumber	11	Mfg.—Lumber and wood products, including furniture (230–232, 241, 242)
11	Mfg.—Metal	12	Mfg.—Metal industries (270–272, 280–282, 290–292, 300, 301)
		13	Mfg.—Machinery, except electrical (310–312, 320–322, 331, 332)
12	Mfg.—Electrical	14	Mfg.—Electrical machinery, equipment, and supplies (340–342, 350)
		16	Mfg.—Miscellaneous and not specified manufacturing industries (250–252, 261, 262, 371, 372, 380, 381, 390–392)
13	Mfg.—Transportation equipment	15	Mfg.—Transportation equipment (351, 352, 360–362, 370)
14	Trucking services	17	Trucking service (410)
		18	Transportation, except trucking (400–402, 411, 412, 420–422, 432)
15	Communications	19	Communications (440–442)
16	Utilities	20	Utilities (450–452, 470–472)
17	Wholesale (durable, non-durable)	21	Wholesale trade, durable goods (500–502, 510–512, 521, 530–532)
		22	Wholesale trade, non-durable and not specified goods (540–542, 550–552, 560–562, 571)
18	Retail	23	Retail—Department stores (591)
		24	Retail—Food stores (601, 602, 610, 611)
		25	Retail—Vehicle dealers, supply, and service stores (612, 620–622)
		26	Retail—Apparel and accessory stores (623, 630)
		28	Other retail trade (580–582, 590, 592, 600, 631–633, 640, 642, 650–652)
19	Eating and drinking establishments	27	Retail—Eating and drinking places (641)
20	Business services	31	Business services (721, 722, 731, 740, 741, 742, 750)
		42	Other professional and related services (841, 872, 873, 880–882, 890–893)
21	Repair services	32	Repair services (751, 752, 760)
22	Private household—lodging—personal services	33	Private households (761)
		34	Lodging places (762, 770)
		35	Personal services, except private households and lodging (771, 772, 780–782, 790, 791)
23	Entertainment—recreation services	36	Entertainment and recreation services (800–802, 810)
24	Health-related	37	Offices of health practitioners (812, 820–822, 830)
		38	Hospitals (831)
		39	Health services, n.e.c. (832, 840)
25	Educational services	40	Educational services (842, 850–852, 860)
26	Justice, public order, and safety	43	Justice, public order, and safety (910)

Mfg., manufacturing; n.e.c., not elsewhere classified.

^aDivision of Vital Statistics, National Center for Health Statistics. Instruction Manual Part 19: Industry and Occupation Coding for Death Certificates. U.S. Department of Health & Human Services, Centers for Disease Control & Prevention, National Center for Health Statistics, Hyattsville, Maryland, 1997.

^bDivision of Vital Statistics, National Center for Health Statistics. Instruction Manual Part 19b: Alphabetical Index of Industries and Occupations. U.S. Department of Health & Human Services, Centers for Disease Control & Prevention, National Center for Health Statistics, Hyattsville, Maryland, 1997.

APPENDIX B: OCCUPATION GROUP CODES BY NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES) 2001–2004 OCCUPATION CLASSIFICATION CODES

Study code	Occupation group titles	NHANES code	Occupation titles (NCHS Industry Classification Source Codes) ^{a,b}
1	Management-related and clerical	1	Executive, administrators, and managers (3–9, 13–19, 21, 22)
		2	Management-related occupations (23–29, 33–37)
		12	Secretaries, stenographers, and typists (313–315)
		13	Information clerks (316–319, 323)
		14	Records processing occupations (325–329, 335–339, 343, 344)
		15	Material recording, scheduling, and distribution clerks (359, 363–366, 368, 373, 374)
		16	Miscellaneous administrative support occupations (303–309, 345–348, 353–357, 375–379, 383–387, 389)
2	Engineers and scientists	3	Engineers, architects, and scientists (43–49, 53–59, 63–69, 73–79, 83)
		7	Other professional specialty occupations (163–169, 173–179)
3	Health-related	4	Health diagnosing, assessing and treating occupations (84–89, 95–99, 103–106)
		22	Health service occupations (445–447)
4	Teachers	5	Teachers (113–119, 123–129, 133–139, 143–149, 153–159)
5	Writers, artists, athletes, and entertainment	6	Writers, artists, entertainers, and athletes (183–189, 193–195, 197–199)
6	Technicians	8	Technicians and related support occupations (203–208, 213–218, 223–229, 233–235)
7	Supervisors, sales, and proprietors	9	Supervisors and proprietors, sales occupations (243)
		10	Sales representatives, finance, business and commodities ex. Retail (253–259)
		11	Sales workers, retail and personal services (263–269, 274–278, 283–285)
8	Private households and personal services	17	Private household occupations (403–407, 466)
		24	Personal service occupations (456–459, 461–465, 467–469)
9	Protective services	18	Protective service occupations (413–418, 423–427)
10	Waiters and waitresses	19	Waiters and waitresses (435)
11	Cooks and food preparation	20	Cooks (436)
		21	Miscellaneous food preparation and service occupations (433, 434, 438, 439, 443, 444)
12	Cleaning and building services	23	Cleaning and building service occupations (448, 449, 453–455)
13	Agriculture, forestry, and fishing	25	Farm operators, managers, and supervisors (473–477)
		26	Farm and nursery workers (479, 483, 484)
		27	Related agricultural, forestry, and fishing occupations (485–489, 494–499)
14	Mechanics	28	Vehicle and mobile equipment mechanics and repairers (505–509, 514–517)
		29	Other mechanics and repairers (503, 518, 519, 523, 525–527, 529, 533–536, 538, 539, 543, 544, 547, 549)
15	Construction	30	Construction trades (553–558, 563–567, 569, 573, 575–577, 579, 583–585, 587–589, 593–599)
		37	Construction laborers (869)
16	Extractive and precision products	31	Extractive and precision production occupations (613–617, 628, 634–637, 639, 643–647, 649, 653–659, 666–669, 674–679, 683, 684, 686–689, 693–696, 699)
17	Machine operators	32	Textile, apparel, and furnishings machine operators (738, 739, 743–745, 747–749)
		33	Machine operators, assorted materials (703–709, 713–715, 717, 719, 723–729, 733–737, 753–759, 763–766, 768–769, 773–774, 777, 779)
18	Fabricators	34	Fabricators, assemblers, inspectors, and samplers (783–787, 789, 793, 795–799)
19	Motor vehicle operators—transportation	35	Motor vehicle operators (803, 804, 806, 808, 809, 813, 814)
		36	Other transportation and material moving occupations (823–826, 828, 829, 833, 834, 843–845, 848, 849)
20	Laborers (except construction)	38	Laborers, except construction (889)
21	Freight, stock, and material handlers	39	Freight, stock, and material movers, hand (875–878, 883)
22	Equipment cleaners	40	Other helpers, equipment cleaners, hand packagers, and laborers (864–868, 874, 885, 887, 888)

^aDivision of Vital Statistics, National Center for Health Statistics. Instruction Manual Part 19: Industry and Occupation Coding for Death Certificates. U.S. Department of Health & Human Services, Centers for Disease Control & Prevention, National Center for Health Statistics, Hyattsville, Maryland, 1997.

^bDivision of Vital Statistics, National Center for Health Statistics. Instruction Manual Part 19b: Alphabetical Index of Industries and Occupations. U.S. Department of Health & Human Services, Centers for Disease Control & Prevention, National Center for Health Statistics, Hyattsville, Maryland, 1997.