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A novel method for estimating the effects of job conditions on asthma and chronic lung disease*

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Abstract

Objective: This study uses 32 years of longitudinal job history to analyze the long-term effect of exposure to specific workplace conditions on the risk of contracting asthma or chronic lung disease later in life. Our approach allows for the estimation of occupational respiratory risks even in the absence of direct environmental monitoring. *Methods:* We employ a novel methodology utilizing data from the National Longitudinal Survey of Youth 1979 (NLSY79), and ratings of job exposures from the Occupational Information Network (O*NET), which are based on 70 years of empirical data compiled by the U.S. Department of Labor. A series of multivariable logistic regression analyses are performed to determine how long-term exposure to a particular occupational O*NET indicator (e.g., working in an extremely hot or cold environment) is related to asthma and COPD risk. *Results:* The risk of contracting COPD was significantly associated with long-term work in very hot or cold temperatures (OR = 1.50, CI: 1.07–2.10), performing physically demanding activities (OR = 1.65, CI:1.20–2.28), working outdoors exposed to weather (OR = 1.45, CI:1.06–1.99), and workplace exposure to contaminants (OR = 1.42, CI:1.05–1.96). In general, the effects of exposure were greater for COPD than for asthma. With respect to contracting asthma, only exposure to work in very hot or cold temperatures (OR = 1.35, CI:1.08–1.70) and performing physically demanding activities (OR = 1.23, CI:1.00–1.52) were statistically significant. *Conclusions:* Use of O*NET job descriptors as surrogate measures of workplace exposures can provide a useful way of analyzing the risk of occupationally-related respiratory disease in situations where direct exposure measurement is not feasible.

Keywords

Environmental development, epidemiology, exercise induced, mechanisms, prevention

History

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Introduction

Evidence indicates that many cases of asthma and chronic lung disease are induced or aggravated by workplace exposures. It is estimated that approximately 16–17% of the adult-onset asthma [1] and 15% of chronic obstructive pulmonary disease (COPD) [2] is attributable to occupational exposures. These work-related respiratory disorders create a significant economic burden for employers and employees, estimated (as of 2002) to represent an annual cost in the U.S. of $1.6 billion for asthma and $5.0 billion for COPD [3,4]. As a result, efforts have been made to identify specific risk factors in the workplace that contribute to the onset of those disorders, so that effective prevention and mitigation efforts can be established.

There is a wide variety of known and suspected causes of occupational asthma including workplace exposure to isocyanates, flour and grain dust, animals and insects, enzymes, and an assortment of other allergens, dusts, fumes, vapors, and chemical agents [5–7]. In some cases, a clear causal relationship between exposure to a particular noxious substance in the workplace and asthma can be established with some confidence. But in other cases, the relationship might be difficult to verify. The potential combinatory effect of exposure to multiple hazards in a work environment further complicates the assessment of occupational causation for asthma.

Many of the same workplace respiratory hazards that are thought to induce asthma are also suspected of causing or aggravating COPD. That list includes a variety of mineral dusts, metal dusts and fumes, organic dusts, irritant gases or

*For purposes of this article, we shall use ''chronic lung disease'' and COPD interchangeably, even though in some contexts there may be slight differences in the definition of those terms.

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vapors, diesel exhaust, sensitizers and organic solvents [8,9]. Additionally, long-term exposure to tobacco smoke is known to be strongly associated with the etiology of COPD.

Workplace prevention efforts for these respiratory hazards include process changes or substitution to minimize exposure, surveillance, environmental monitoring, ventilation, housekeeping, personal protective equipment, administrative controls (e.g. job rotation), and targeted employee and supervisory training. Performing regular risk-assessment and exposure measurement are important tools for identifying and controlling the hazards. However, from a practical standpoint, there are many potential obstacles to undertaking those preventive measures.

For example, it may be difficult for many employers to conduct long-term monitoring and exposure assessment because of the costs and technical complexities involved. Records may not be available to document prior exposure levels, especially if testing had not been performed previously in a thorough and consistent way. Because of staff turnover and retirement, and a long latency of such diseases, some cases of work-related asthma or COPD may go unrecognized. Additionally, long-term exposure assessment is particularly challenging when considering a broad environmental exposure (e.g. ''exposure to metal dusts'') rather than a specific agent such as toluene diisocyanate (TDI).

The study reported in this article employs a novel approach to addressing these limitations, so that the relationship between job exposures and the long-term risk of contracting asthma and/or COPD can be assessed. The process we developed utilizes thirty-two years (1978 through 2009) of occupational history data from the National Longitudinal Survey of Youth, 1979 (NLSY1979), along with quantified estimates of environmental exposures in specific job categories from the Occupational Information Network (O*NET). These data enable us to analyze the relationship between long-term exposure to selected workplace factors and the prevalence of asthma (and COPD). The standardized approach we have developed permits estimation of these risks even in situations where conventional exposure monitoring has not been performed. By extension, this methodology can be applied to other types of exposures and chronic diseases.

Methods

Data sources

This study utilized data from two publicly available federal sources: O*NET, sponsored by the U.S. Bureau of Labor Statistics (BLS) and administered by the U.S. Department of Labor/Employment and Training Administration (DOL/ETA); and the National Longitudinal Survey of Youth, 1979 (NLSY1979), sponsored by the BLS and administered by the Ohio State University Center for Human Resource Research.

O*NET is a comprehensive database of worker attributes and job characteristics, containing continually updated information on the skill requirements and job characteristics of 974 occupational classifications [10]. Occupational classifications were coded using the 2010 Standard Occupational Classification (SOC) coding system of the U.S. Census Bureau. Within O*NET, each occupation is characterized by a standardized, measurable set of 277 variables called ''descriptors'' that describe and rate job requirements, worker activities, workplace conditions, and worker perspectives. Ratings are assigned to each descriptor (on a scale of 0 to 100) within a particular occupational classification. The ratings are based on accumulated empirical data collected and analyzed by DOL/ETA, and its predecessor, the Dictionary of Occupational Titles, since 1939 [10]. Ratings of occupational characteristics were previously performed by DOL raters and extensive on-site job analysis by industrial/organizational psychology and human resource management specialists. However, O*NET has now transitioned to basing its rating of descriptor variables principally on surveys of employers and employees conducted by the BLS [11]. The most current version (18.0) of the updated O*NET database was released in July of 2013.

Several studies have been performed in which O*NET descriptor ratings are used as surrogate measures of occupational hazard levels, especially when other measures of workplace exposure are not available. Cifuentes et al. recently (2010) summarized 28 studies in which O*NET estimates of job exposures were used as exposure estimates in analyses of health and safety outcomes [12].

The NLSY79 cohort is comprised of 12 686 men and women who were 14 to 22 years of age when first surveyed in 1979. Follow-up interviews with NLSY79 respondents have been conducted annually from 1979 to 1994, and biannually since 1996. The latest year of complete data for this study was drawn from the 2010 survey when cohort members were 45 to 53 years old. As of 2010, there were 7565 survey respondents, approximately 75.9% of the remaining 9964 cohort members [13].

The NLSY79 collects information on respondents' sociodemographic characteristics, household composition, education, training, detailed work histories, job and employer characteristics, income and assets, health insurance status, incidence of work related injuries and illnesses, episodes of work disability, and respondents' social and domestic functioning. The survey's sampling strategy is designed to be representative of the non-institutionalized civilian segment of young people living in the United States in 1979 and born between 1 January 1957 and 31 December 1964. Additionally, NLSY79 over-sampled civilian Hispanic, black, and economically disadvantaged white youth to help detect variations in employment and health conditions according to respondents' race, ethnicity, and socioeconomic status. NLSY79 provides sampling weights for each response to reflect the national distribution of Americans in this age range.

Beginning in 1998, as cohort members were entering their 40 s, a module to the NLSY79 survey questionnaire was added to assess health status and prevalence of chronic conditions among those who were at least 40 years old. A similar health module for cohort members at least 50 years old was added in 2008. In both of the 40+ and 50+ modules, respondents were asked whether a doctor had ever diagnosed them with one of several chronic conditions including asthma, hypertension, diabetes, heart disease, non-skin cancer, chronic lung disease, arthritis or rheumatism and emotional problems (emotional, nervous, or psychiatric problems).

Research Design

The aim of this study is to demonstrate the utility of using the O*NET job descriptor ratings as indicators of long-term exposure to various types of occupational environments and conditions, so that the association between those indicators and disease prevalence (asthma or chronic lung disease) can be assessed even if direct exposure measurement has not been performed. To accomplish this, we used NLSY79 data to create job histories over a 32-year period (1978 through 2009) for the 12 686 men and women in the NLSY79 cohort. We then cross-linked those job histories with the O*NET ratings of work exposures (i.e. the O*NET job descriptors) for each job held by every cohort member during the study period. Logistic regression analyses were then performed to measure the association between the O*NET exposure ratings and the diagnosis of a particular chronic disease (either asthma, or chronic lung disease) as reported in NLSY79.

Ascertainment of Outcome

The presence of asthma was determined in two different ways:

(1) Asthma prevalence was first assessed in 1998 as part of the 40+ health module. The questionnaire asked the respondent ''Do you have any of the following health problems?'' to which ''asthma'' was one of the possible responses. A similar question was asked as part of the 50+ module first administered in 2008. Neither of the 40+ module or 50+ modules provided information on whether the condition was diagnosed by a health professional or the date of diagnosis.

(2) Beginning in 2004, a series of questions about asthma were added to the questionnaire. Respondents were asked ''Has a doctor, nurse or other health professional ever told you that you have asthma?'' A follow-up question asked the respondents with asthma to report the age when asthma was first diagnosed. Because this study concerns adult asthma (potentially work-induced) rather than childhood asthma, we excluded 330 respondents who reported being diagnosed with asthma before the beginning of the study period (i.e. in 1979) from the 7565 people remaining in the NLSY79 cohort as of 2010. Our final sample for asthma included 658 respondents with a diagnosis of asthma among the 7235 people who did not report being diagnosed with asthma prior to the beginning of the study period (1979).

The presence of chronic lung disease was determined by a positive response to the following question on the NLSY79 40+ and 50+ modules: ''Not including asthma, has a doctor ever told you that you have chronic lung disease such as chronic bronchitis or emphysema?'' NLSY79 did not include information about the date of diagnosis. Given the etiology of chronic lung disease, however, it is unlikely there were any cases of COPD occurring before the beginning of the study period. The final sample for chronic lung disease included 324 respondents with a diagnosis of chronic lung disease among the 7565 people remaining in the NLSY79 cohort as of 2010.

Ascertainment of exposure

We selected seven O*NET job descriptors as the work exposures most relevant to the development of asthma and chronic lung disease: (1) exposure to contaminants, such as pollutants, gases, dust or odors; (2) working indoors, in non-controlled environmental conditions, (e.g. a warehouse without heat); (3) working outdoors, exposed to weather conditions; (4) working in very hot (above 90 F degrees) or cold (below 32 F degrees) temperatures; (5) working in an enclosed vehicle or equipment; (6) performing general physical activities (such as climbing, lifting, balancing, walking, stooping, and handling of materials); and (7) working under time pressure. Available research literature described below had indicated support for each of these as a possible risk factor for asthma or COPD.

For example, previous research studies consistently have found that certain airborne pollutants and indoor air contaminants increase the risk of developing asthma and chronic lung disease [14–16]. Studies have also linked exposure to extreme temperature variations with these disorders [17–18]. Exposure to both indoor environments without sufficient ventilation and working outdoors, exposed to ambient weather conditions, have been associated with asthma and COPD risk [19–20]. Working in an enclosed vehicle or equipment may also elevate workers' exposure to air pollutants, such as diesel exhaust emissions [21]. Also, it has been suggested that intensive physical activity might also increase the risk of asthma [22–23]. For that reason, we included the O*NET job descriptor of ''performing intensive physical activities'' at work as one of the occupational risk factors. Likewise, stress has been linked to adult-onset asthma [24], so we included ''time pressure'' as one of the seven O*NET job descriptors to be included in this analysis.

For each individual in the cohort, a ''mean intensity level'' (MIL) for each of the seven O*NET job descriptors was calculated by averaging the O*NET intensity level for every week that the cohort member worked on a full-time basis in a job during the 32-year-study period. Working full-time during a week was defined as working at least 30 hours in that week. If an individual worked in two or more different jobs in a week and the total work-hours were at least 30 hours (e.g. ten hours at one job and 20 at another job), that week was also considered to be working on a full-time basis. Weeks in which the cohort member did not work or worked part-time (less than 30 hours per week) did not contribute to the average weekly MIL.

Statistical analysis

Multiple logistic regression analyses were performed using each of the seven O*NET job descriptors as the independent variable and one of the diseases (either asthma or COPD) as the outcome variable. The value of the independent variable was the mean MIL level of the O*NET descriptor under study (e.g. performing intensive physical activities) in a specific occupational classification based upon O*NET's scale. The analysis compared the occurrence of disease among individuals with an average weekly MIL above the median for the entire cohort (''high'') to individuals with an average weekly MIL below the cohort median (''low'').

We controlled for important demographic and socio-economic characteristics in the analysis, including age (as of 2010), gender and education level. We also controlled for whether or not subjects had any of seven co-occurring chronic health conditions: chronic heart disease, non-skin cancer, diabetes, affective and mental disorders, hypertension and either asthma or chronic lung disease (i.e. the disease not being analyzed). We also included the cohort member's smoking status in the regression (ever smoked or never smoked), because smoking is a potential risk factor for both asthma and chronic lung disease [25,26].

Respondents completed the 40+ module as they turned 40 and completed the 50+ module after they turned 50, so people over 50 had two opportunities to report asthma and chronic lung disease, and those under 50 only had one opportunity. We therefore controlled for whether individuals were aged 50 and over as of 2010 (who had two reporting opportunities) or aged 45–49 (who had one reporting opportunity).

Results of each of the fourteen logistic regressions (seven job descriptors and two disease outcomes) were reported as adjusted odds ratios with a 95% confidence interval. Additional analyses were conducted to test whether there was a dose-response relationship between exposure (MIL) and disease outcome. Odds ratios were calculated for each MIL quartile (each quartile contained 25% of the study population), using the lowest MIL quartile as the referent category. Then, the odds ratios for the 2nd, 3rd, and 4th quartiles were compared to the 1st to determine whether a trend was apparent. A linear trend analysis was also performed using MIL as a continuous variable rather than a categorical variable.

SAS Statistical Software, Version 9.2 (Cary, NC) was used to perform the multivariable logistic regression analyses and calculate a point estimate of the mean odds ratio, along with 95% confidence intervals and associated p values. The level of statistical significance was set at $p < 0.05$. Final regression results were weighted by applying individuals' survey weights from the 2010 NLSY79 dataset.

Results

Table 1 summarizes demographic characteristics of the sample for asthma and self-reported asthma prevalence. As of the 2010 NLSY79 survey, 9.1% of the cohort reported having asthma. Individuals with asthma were slightly older (49.6 years vs. 49.3 years), much more likely to be female (70.8% vs. 47.1%), and more likely to have lower educational attainment (52.9% vs. 49.0% having a high-school education or less) than those without asthma. Prevalence of asthma varied by respondents' occupational classification (assessed as of 2010), with service-sector workers having the highest prevalence (12.7%) and transportation/material moving workers having the lowest prevalence (6.0%). A majority of respondents with asthma had at least one other chronic condition (69.8%) compared to 42.9% among respondents without asthma.

Table 2 summarizes demographic characteristics of the sample for chronic lung disease and the prevalence of doctor-diagnosed chronic lung disease. The prevalence of doctor-diagnosed chronic lung disease was 4.3% among this cohort. Demographic characteristics for cohort members with chronic lung disease were quite similar to those having asthma. Respondents with chronic lung disease were slightly older (50.2 years vs. 49.3 years), more likely to be female (64.3% vs. 48.4%), and more likely to have lower educational attainment (66.2% vs. 48.5% having a high school education or less) than respondents without chronic lung disease. Service-sector workers had the highest prevalence (6.8%) and professional workers had the lowest prevalence (1.9%). Almost all the cohort members with chronic lung disease had more than one other chronic condition (94.8%) compared to 47.7% among workers without chronic lung disease.

Table 3 presents a descriptive statistical summary of the MIL levels for each of the seven O*NET job descriptors for the analysis involving asthma. The mean MIL levels varied across the seven O*NET descriptors with a high of 68.24 for

Table 1. Demographic characteristics of respondents and prevalence of asthma.

	Total $n = 7235$	With asthma $n = 658$	Weighted %	Without asthma $n = 6577$	Weighted %	p Value	% Prevalence of asthma 9.09
Mean age in years (as of 2010)	49.37	49.63		49.34		0.03	–
Gender							
Male	3509	184	29.2	3325	52.9	<0.01	5.24
Female	3726	474	70.8	3252	47.1		12.72
Education							
High school or less	3834	361	52.9	3473	49.0	0.11	9.42
College	2643	237	35.4	2406	37.9	0.28	8.97
Graduate school	758	60	11.7	698	13.1	0.43	7.92
Occupation							
Management	962	66	11.4	896	16.5	<0.01	6.86
Professional	1070	97	16.6	973	16.9	0.90	9.07
Service	1384	176	23.4	1208	15.6	<0.01	12.72
Sales	367	29	5.0	338	6.1	0.36	7.90
Office	1183	125	18.7	1058	15.3	0.05	10.57
Farming/Fishing/Forestry	68	5	0.6	63	0.8	0.65	7.35
Construction	369	27	5.3	342	5.5	0.84	7.32
Installing/Maintenance/Repair	264	17	2.3	247	4.3	0.04	6.44
Production	1038	83	12.3	955	13.2	0.62	8.00
Transportation/Material Moving	467	28	4.3	439	5.8	0.21	6.00
≥1 Co-occurring health conditions	3237	457	69.8	2780	42.9	<0.01	–

Table 2. Demographic characteristics of respondents and prevalence of chronic lung disease.

	Total $n = 7565$	With chronic lung disease $n = 324$	Weighted %	Without chronic lung disease $n = 7241$	Weighted %	p Value	% Prevalence of COPD 4.28
Mean age in years (as of 2010)	49.37	50.21		49.33		<0.01	–
Gender							
Male	3669	107	35.7	3562	51.6	<0.01	2.92
Female	3896	217	64.3	3679	48.4		5.57
Education							
High School or Less	4009	214	66.2	3795	48.5	<0.01	5.34
College	2759	94	27.8	2665	38.1	<0.01	3.41
Graduate School	797	16	6.1	781	13.4	<0.01	2.01
Occupation							
Management	1008	27	9.4	981	16.6	<0.01	2.68
Professional	1110	21	7.6	1089	17.1	<0.01	1.89
Service	1455	99	27.4	1356	15.9	<0.01	6.80
Sales	388	17	6.1	371	6.0	0.96	4.38
Office	1243	56	18.2	1187	15.5	0.27	4.51
Farming/Fishing/Forestry	69	2	0.6	67	0.8	0.77	2.90
Construction	384	17	6.8	367	5.4	0.37	4.43
Installing/Maintenance/Repair	279	8	2.1	271	4.2	0.12	2.87
Production	1076	52	16.4	1024	12.9	0.11	4.83
Transportation/Material Moving	482	21	5.3	461	5.6	0.82	4.36
≥1 Co-occurring health conditions	3752	308	94.8	3444	47.7	<0.01	–

Table 3. Mean intensity level (MIL) values for asthma.

	O*NET job descriptor variables.						
MIL	Exposed to contaminants	Indoors, not environmentally controlled	Outdoors, exposed to weather	Very hot or cold temperatures	In an enclosed vehicle or equipment	Performing general physical activities	Time pressure
Mean (Std. Dev.)	46.59 (20.25)	31.46 (16.61)	31.83 (19.32)	33.84 (18.33)	28.49 (16.12)	41.97 (14.41)	68.24 (11.38)
25% Percentile	29.45	18.59	17.89	19.10	16.64	31.01	65.55
50% Percentile (Median)	44.76	27.69	27.20	30.14	25.43	42.36	71.14
75% Percentile	64.92	45.25	43.49	48.84	37.06	53.70	74.55
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	92.27	91.00	99.33	83.28	97.18	78.37	93.64

''time pressure'' and a low of 28.49 for ''in an enclosed vehicle or equipment'' (on O*NET's 0–100 scale). Maximum values of MILs ranged from a high of 99.33 for ''working outdoors, exposed to weather'' to a low of 78.37 for ''performing general physical activities.'' The minimum MIL was 0.00 for all the seven descriptors, reflecting that some cohort members never worked full-time during the 32-year-study period. Additionally, a few respondents worked only in an occupation that had an O*NET intensity rating of zero. The descriptive statistics of MILs in the chronic lung disease study population are almost the same as those of the asthma study population (Table 4).

Results of regression analyses using asthma as the outcome variable are summarized in Table 5, and results using chronic lung disease as the outcome variable are summarized in Table 6. In general, the level of association between the O*NET job descriptors and COPD was found to be stronger than the association between the O*NET job descriptors and asthma.

For the asthma analysis (Table 5), exposure to ''very hot or cold temperatures'' (OR = 1.35, $p < 0.01$) and ''performing general physical activities'' (OR = 1.23, $p < 0.05$) were found to be associated with increased asthma prevalence. Additionally, when considering MIL as a continuous variable, there was evidence of a linear dose-response trend for the ''exposure to contaminants,'' ''working outdoors, exposed to weather,'' ''working in very hot or cold temperatures,'' and ''performing general physical activities'' job descriptor categories.

For the COPD analysis (Table 6), ''exposure to contaminants,'' ''working outdoors, exposed to weather,'' ''working in very hot or cold temperatures,'' and ''performing general physical activities'' were all found to be significantly associated with increased COPD prevalence. As in the asthma analysis, when considering MIL as a continuous variable, a statistically significant dose-response trend was found for the ''exposure to contaminants,'' ''working in very hot or cold temperatures,'' and ''performing general physical activities'' job descriptor categories.

Discussion

There is a substantial amount of existing research literature concerning occupational risk factors for asthma and chronic lung disease. This study, however, is distinctive in several important ways.

First, we used the intensity levels of O*NET job descriptors to estimate exposure levels. This represents a relatively

Table 4. Mean intensity level (MIL) values for chronic lung disease.

	O*NET job descriptor variables.						
MIL	Exposed to contaminants	Indoors, not environmentally controlled	Outdoors, exposed to weather	Very hot or cold temperatures	In an enclosed vehicle or equipment	Performing general physical activities	Time pressure
Mean (Std. Dev.)	46.55 (20.27)	31.39 (16.59)	31.78 (18.31)	33.78 (18.31)	28.47 (16.10)	41.92 (14.45)	68.16 (11.57)
25% Percentile	29.48	18.58	17.92	19.14	16.63	30.99	65.50
50% Percentile (Median)	44.68	27.64	27.16	29.99	25.47	42.38	71.14
75% Percentile	64.84	45.16	43.40	48.82	37.03	53.64	74.54
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	92.27	91.00	99.33	83.28	97.18	78.37	93.64

Table 5. Odds ratios and 95% confidence intervals with asthma as the primary outcome variable.

	O*NET job descriptor variables.						
MIL	Exposed to contaminants	Indoors, not environmentally controlled	Outdoors, exposed to weather	Very hot or cold temperatures	In an enclosed vehicle or equipment	Performing general physical activities	Time pressure
High vs. low	1.22 (0.98, 1.50)	1.09 (0.86, 1.39)	1.19 (0.96, 1.49)	1.35** (1.08, 1.70)	0.89 (0.71, 1.13)	1.23* (1.00, 1.52)	0.81* (0.66, 0.99)
Continuous per 10 MIL points	1.07* (1.01, 1.14)	1.04 (0.97, 1.13)	1.08* (1.01, 1.15)	1.08* (1.01, 1.16)	0.99 (0.92, 1.07)	1.10* (1.01, 1.19)	0.97 (0.90, 1.04)
1st quartile (referent)	1.00	1.00	1.00	1.00	1,00	1.00	1.00
2nd quartile	1.04 (0.79, 1.37)	1.24 (0.96, 1.60)	1.33* (1.02, 1.73)	1.03 (0.79, 1.35)	1.02 (0.79, 1.30)	1.08 (0.82, 1.43)	0.99 (0.77, 1.28)
3rd quartile	1.17 (0.88, 1.56)	1.20 (0.89, 1.63)	1.30 (0.98, 1.72)	1.37* (1.03, 1.81)	0.95 (0.71, 1.26)	1.28 (0.97, 1.68)	0.83 (0.63, 1.09)
4th quartile	1.38* (1.00, 1.91)	1.29 (0.90, 1.83)	1.60** (1.15, 2.24)	1.39 (0.98, 1.96)	0.82 (0.58, 1.17)	1.29 (0.93, 1.79)	0.78 (0.58, 1.04)

*$p<0.05$, **$p<0.01$, ***$p<0.001$.

Table 6. Odds ratios and 95% confidence intervals with chronic lung disease as the primary outcome variable.

	O*NET job descriptor variables.						
MIL	Exposed to contaminants	Indoors, not environmentally controlled	Outdoors, exposed to weather	Very hot or cold temperatures	In an enclosed vehicle or equipment	Performing general physical activities	Time pressure
High vs. low	1.42* (1.03, 1.96)	1.19 (0.84, 1.68)	1.45* (1.06, 1.99)	1.50* (1.07, 2.10)	0.86 (0.63, 1.19)	1.65** (1.20, 2.28)	0.84 (0.62, 1.12)
Continuous per 10 MIL points	1.13** (1.03, 1.23)	1.12 (0.99, 1.25)	1.06 (0.97, 1.15)	1.15* (1.03, 1.28)	0.98 (0.89, 1.07)	1.15* (1.01, 1.30)	0.96 (0.87, 1.05)
1st quartile (referent)	1.00	1.00	1.00	1.00	1,00	1.00	1.00
2nd quartile	1.36 (0.89, 2.10)	1.14 (0.78, 1.67)	1.29 (0.86, 1.92)	1.45 (0.96, 2.21)	1.32 (0.93, 1.88)	0.82 (0.52, 1.28)	1.07 (0.75, 1.53)
3rd quartile	1.57* (1.02, 2.43)	1.25 (0.82, 1.92)	1.67* (1.11, 2.51)	1.75* (1.14, 2.70)	1.00 (0.66, 1.51)	1.44 (0.95, 2.18)	1.06 (0.72, 1.54)
4th quartile	1.95** (1.20, 3.15)	1.32 (0.80, 2.18)	1.72* (1.07, 2.77)	2.11** (1.26, 3.52)	1.03 (0.65, 1.64)	1.59 (0.98, 2.58)	0.65 (0.42, 1.00)

*$p<0.05$, ** $p<0.01$, ***$p<0.001$.

novel approach to studying the potential influence of workplace environments and job activities on chronic disease occurrence. Many workplaces, especially in smaller establishments, do not perform monitoring or assessments of exposure conditions, and thus are unable to assess the effects of those exposures on disease risk. Using the O*NET intensity ratings, developed through 70 years of empirical study by DOL, as an indicator of workplace exposure allows for an indirect estimation of respiratory disease risk even when direct exposure measurement has not been conducted.

Second, using 32 years of longitudinal data from the NLSY79 allows for considering the long-term effects of exposure to occupational hazards and conditions over a working lifetime. This provides perspectives on the relationship between long-term employment in various jobs and the risk of chronic disease occurrence.

Third, most previous epidemiological studies of the risk factors for asthma and chronic lung disease have examined the putative causal role of a specific chemical, organic, or physical agent, such as TDI, cleaning solvents, wood dusts, etc. The seven exposures used in this study do not focus on a particular agent but rather describe important general characteristics of employees' working environments and their job activities.

Fourth, the individual-level data from the NLSY79 allows us to control for demographics and smoking status of the cohort members, which increases the accuracy of estimates on the relationship between occupational exposures and the risk of chronic disease occurrence.

Finally, using a common methodology and a uniform set of exposure indicators, we are able to assess similarities and differences in disease risk between asthma and chronic lung

disease. The NLSY79 data contains chronic disease assessment for both asthma and for COPD, thus enabling comparisons between the exposure indicators and those two respiratory conditions. Relatively few comparative analyses have been undertaken to identify differences in respiratory disease outcomes (asthma, COPD) among workers with the same set of exposure conditions.

In that regard, this study detected a generally stronger association between the O*NET exposure indicators and COPD than between those same indicators and asthma. This finding is consistent with evidence from some other comparative studies analyzing occupational exposures for both asthma and COPD. For example, a Chinese study of occupational exposure to dusts (cotton, wood, metal, minerals, and/or asbestos) found a statistically elevated risk of chronic bronchitis (OR = 1.26) compared to adult-onset asthma (OR = 1.14) [27]. Similarly, a Swedish study of exposure to traffic-related air pollution found a greater risk of contracting COPD (OR = 1.64) than contracting asthma (OR = 1.40) among people living in close proximity to a major highway [28]. However, other studies [29] have found mixed results with regard to the relative risks for asthma and COPD among workers exposed to a common set of job-related environmental exposures.

The existing research evidence is insufficient to determine why the risk of contracting COPD appears to be somewhat greater than the risk of contracting asthma, given exposure to the same set of O*NET indicators. It may be that inherently different physiological processes or inflammatory responses mediate the linkage between the occupational exposures and disease onset. It is also possible that similar exposure (e.g. working in cold temperatures) has markedly different effects among workers with asthma and COPD. For example, results from a recent European health survey found that 35.3% of respondents with asthma were concerned with seasonal exacerbation of their symptoms during the cold weather season compared to 54.4% of respondents suffering from COPD [30]. The exposure period needed prior to disease onset may also influence the differences observed in risk of disease occurrence. Additional investigation would be needed to identify the factors most responsible for the differences observed between results for cohort members with asthma and those with COPD.

In both the asthma and COPD analyses, the greatest disease risk was related to working in very cold or hot temperatures and/or performing general physical activities. According to the O*NET documentation, general physical activities involve ''performing physical activities that require considerable use of your arms and legs and moving your whole body, such as climbing, lifting, balancing, walking, stooping and handling of materials.'' This finding is consistent with other studies suggesting that workplace exertion might be related to the onset of occupational asthma. For example, physical activity on the job can increase ventilation, and thus exposure to airborne contaminants [31]. Additionally, workers performing physically demanding activities in cold environments may induce exercise bronchospasm [23].

We included ''time pressure'' as an exposure variable in our analysis based on a few studies showing a relationship between perceived stress and respiratory symptomology [32,33]. However, we did not find any significant relationship between time pressure and chronic lung disease, and, contrary to our expectations, observed a small but significant protective effect for asthma (OR = 0.81). The available O*NET descriptor mentioned only ''time pressure,'' rather than other forms of psychological stress. Additionally, we were not able to control for individuals' stress outside work, which is also part of their overall stress. Thus, it is difficult to interpret this finding and account for the unexpected result, which varied in direction from findings among the other O*NET exposure variables.

A methodological strength of our study is that we conducted the analysis on a general population sample, rather than a workforce-based population sample, so the results are less sensitive to a healthy worker effect. The healthy worker effect can create bias in occupational health research through two complementary mechanisms: first, less healthy people are less likely to select high-exposure jobs or be hired by employers for those jobs (healthy worker hire effect); and less healthy workers are also more likely to leave high-exposure jobs (healthy worker survivor effect) [34]. Using 32 years of work history data, our study was able to assess the influences of work exposures not only for the current job, but also for previous jobs, thus reducing the healthy worker survivor effect. In the asthma studies, we excluded youths with early-onset asthma diagnosed before the beginning of the study period, and thus reduced the healthy worker hire effect. There might still be some remaining healthy worker effect, however, because we do not have full information available on date of diagnosis of asthma or COPD. Thus, it is likely that some cohort members left the workforce or switched to low-exposure jobs after the development of asthma or chronic lung disease, on average to reduce their calculated exposure level. However, any residual healthy worker effect would tend to bias the study findings toward the null hypothesis.

The indicators we applied in this study were the most relevant available exposure categories in the O*NET database. Utilizing those O*NET indicators as measures of exposure provides a different, but complementary and potentially informative, framework for investigating potential predictors of asthma and COPD. The primary advantage of using O*NET is its ability to provide a general approach for estimating risk, even in the absence of direct measurements. Because resources are scarce, extensive on-site exposure assessment may not always be feasible. The approach we describe here, based on O*NET, can provide a relatively easy and accessible screening device to help identify general patterns of respiratory risk and indicate whether more in-depth assessment appears to be warranted.

Limitations

While we consider the use of O*NET descriptors to provide a novel approach to estimating workplace exposure levels for asthma and COPD, we acknowledge that the exposure ratings will essentially not be as precise or useful as would direct exposure assessment. The O*NET exposure estimates only reflect general characteristics of an occupational category,

and thus fail to capture many important site-specific exposures and job conditions that could be measured more precisely if the appropriate measurement methods were available. Nonetheless, these deficiencies are counterbalanced, to some extent, by the expanded ability to estimate exposures in many environments and among diverse populations that would otherwise not be amenable to analysis.

In this study, outcomes determination depended on self-reported responses to the NLSY79. As with any self-reported survey, information provided by the respondent might not be entirely accurate. However, there is no particular reason to suspect that the responses are biased.

Another limitation resulted from how the NLSY79 collected information on chronic diseases. The cohort members were asked to report chronic health conditions only when they turned 40 and 50 years old (in the 40+ and 50+ modules). Thus, if a cohort member was diagnosed with a disease after turning 40 years old, but had not yet turned 50 years old as of 2010 (the last date of data collection), or was diagnosed positive after turning 50 years old, the reported status would be inaccurate. The NLSY79 reporting method thus could be misclassified with respect to the disease status (i.e. a false negative finding). That misclassification would tend to bias the study results towards the null.

The NLSY79 distinguished between ''full-time workers'' (employees working at least 30 hours per week) from ''part-time workers'' (<30 hours per week). To achieve a more uniform comparison of work intensity levels, we decided only to consider weeks of full-time work in our analysis. However, even though these part-time hours represented only a small proportion (<10%) of all hours, it is possible that the hours contributed by part-time workers created additional job exposures that might have affected the development of asthma and chronic lung disease. We tested whether this method affected our results by performing an analysis including all hours (part-time and full-time work history) into the calculation of MIL. Sensitivity analyses found that whether or not part-time work history was included in the analysis had negligible impact on the final results.

Analytically, we tested the association between the mean intensity level of a particular job descriptor and a specific disease outcome (e.g. asthma), for each of seven relevant O*NET job descriptors. The influence of each of those seven exposure variables was considered independently. However, it is quite possible that those risk factors actually affect the disease outcomes jointly rather than separately. Furthermore, there are likely many other job factors that affect that relationship other than the ones already identified (for example, the effect of exposure to second-hand tobacco usage in some workplaces). Additional research is needed to test the combinatorial and interaction effects between these variables to determine their combined influence on disease outcomes. Our study focused on individual analyses of particular O*NET variables that had not previously been tested in other research studies, to identify relevant new risk factors for asthma and COPD. These results thus help to build a foundation for future inquiry into the role of work environment factors in the progression of respiratory disease.

Declaration of interest

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