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April 2014

CPWR Small Study Final Report

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CPWR, the research and training arm of the Building and Construction Trades Dept., AFL-CIO, is uniquely situated to serve construction workers, contractors, practitioners, and the scientific community. This report was prepared by the authors noted. Funding for this research study was made possible by a cooperative agreement with the National Institute for Occupational Safety and Health, NIOSH (OH009762). The contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH or CPWR.

AIRWAYS OBSTRUCTION AMONG SHEET METAL WORKERS PARTICIPATING IN A RESPIRATORY SCREENING PROGRAM

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RUNNING TITLE: COPD among Sheet Metal Workers

GRANT SPONSOR: National Institute for Occupational Safety and Health
GRANT NUMBER: Cooperative Agreement Number (U60 OH009762, CFDA # 93.262)
CPWR SMALL STUDY NUMBER: 13-1-PS

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Draft: April 21, 2014

ABSTRACT

Background: The Sheet Metal Occupational Health Institute Trust (SMOHIT) was formed in 1985 to examine the health hazards of the sheet metal industry in the U.S. and Canada through an asbestos disease-screening program. A study of COPD prevalence among screening program participants was undertaken.

Methods: Participants (N=3944) provided a detailed work and exposure history and underwent a respiratory examination that included a respiratory history, respiratory symptoms, a posterior-anterior (P-A) chest radiograph classified by ILO criteria, and spirometry. COPD cases were defined based on an FEV_1/FVC ratio less than the lower limit of normal using prediction equations based on NHANES data. Logistic regression was used explore COPD risk while controlling for potential confounders including smoking.

Results: The overall prevalence of COPD in this sheet metal worker population was 10.0% (95% CI=9.0-10.9) and ranged from 9.7% for those 40-49 years of age to 12.8% for those over 70. Exposures to man-made mineral fibers (MMMF), cement dusts, drywall dusts, and spraying painting were statistically associated with COPD risk in analyses that considered all exposures collectively. Analyses by individual tasks and material exposures also were suggestive of increased COPD risk and carbon arc welding and exposure to urethane foam insulation

Conclusions: This study found COPD risk to be associated with several construction-related exposures suggested by other published literature. This study provides some additional support for an association between COPD and exposures to MMMF and spray painting.

KEY WORDS: COPD, sheet metal workers, welding, MMMF, spray painting, cement dust, drywall dust, urethane

KEY FINDINGS

- The prevalence of current smokers among workers participating in the Sheet Metal Occupational Health Institute Trust (SMOHIT) medical screening program was considerably less that than reported data for construction-related trades and among all U.S. males.

- The overall prevalence of COPD among medical screening program participants was 10.0% (95% CI=9.0-10.9). Comparisons with NHANES III data for those who never smoked did not show increased COPD prevalence among these workers.

- Exposures to man-made mineral fibers (MMMF), cement dusts, drywall dusts, and spray painting were statistically associated with COPD risk in analyses that considered all exposures collectively.

- Carbon arc welding and exposure to urethane foam insulation were associated with increased risk of COPD in analyses that considered each exposure separately.

- Bystander exposure to spray painting operations was associated with increased COPD risk.

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a heterogeneous disorder that includes chronic bronchitis and emphysema [Pistolesi, 2009] and more than 12 million people in the US have a prevalent diagnosis of COPD [NHLBI, 2009]. Death rates for COPD are rising [NCHS, 2001] and in 2005 COPD ranked as the fourth leading cause of death with 130,993 deaths [EPA, 2009]. COPD is projected to become the third most common cause of death worldwide by 2020 [Chapman et. al., 2006]. In 2007 the annual cost in the US for COPD was estimated to $42.6 billion [Janda et al., 2009].

Tobacco smoking is a major risk factor for COPD with an estimated population attributable fraction (PAR %) of 80 to 90% [ATS, 1995a]. While smoking is the primary cause of COPD, smoking alone does not explain all the variance in the development of COPD. Only 15-20% of smokers develop COPD and 10% of COPD related mortality occurs in persons without a history of smoking [Barr et al., 2002; Mannino, 2002]. Based on NHANES data, Whittemore et al. [1995] found that 4-5% of lifelong non-smokers reported a physician diagnosis of COPD. Fifteen percent of COPD cases overall are estimated to be attributable to occupational exposures and the PAR may be as high as 31% among never smokers [ATS, 2003; Hnizdo et al., 2002]. Smoking is an important factor to consider in occupational studies of COPD as smoking is both a confounder and an effect modifier for some occupational exposures [Rushton, 2007; Hnizdo et al., 2002].

There is growing evidence that occupational exposures to particles and possibly high levels of ambient particulate pollutants are associated with COPD. Experimental evidence suggests that particulates, including air pollution particles, can induce airway wall fibrosis, a process that can lead to COPD [Churg and Wright, 2002]. Increased COPD risk has been observed among workers exposed to ‘vapors, gases, dusts, and fumes’ (VGDF) [Oxman, 1993; Hendrick, 1996; NIOSH, 2002; ATS, 2003; GOLD, 2008; Balmes, 2005; Trupin et al., 2003; Blanc et. al., 2009a; Blanc et. al., 2009b; Weinmann et al., 2008]. Blanc et al. [2009a] observed a highly elevated risk of COPD (Odds-Ratio=14.1, 95% CI=9.33-21.2) among individuals occupationally exposed to VGDF and also smoked.

Increased COPD risk has been found to be associated with some specific occupational exposure agents through prevalence studies, case-control studies, and mortality analyses. These agents include: 1) coal dust [Becklake, 1989; Hendrick, 1996; NIOSH, 1995; Henneberger and Attfield, 1996; Coggon and Newman Taylor, 1998]; 2) asbestos [ATS 2004; Glencross et al., 1997; Dement et al., 2010]; 3) silica [Rushton, 2007; Hnizdo and Vallyathan, 2003; Oliver et al., 2006; Tse et al., 2007; Dement et al., 2010]; 4) welding and cutting gases and fumes [Meldrum et. al., 2004; Balmes, 2005; Mastrangelo et.al., 2003; Hunting and Welch, 1993; Dement et al., 2010]; 5) cement dust [Rushton, 2007; Fell et. al., 2003; Abrons et. al., 1998; Mwaiselage et. al., 2004; Dement et al., 2010]; 6) diesel exhausts [Hart et al., 2006; Hart et al., 2008; Tüchsen and Hannerz, 2000; Ulvestad et al, 2000; Weinmann et al., 2008]; 7) spray painting [Glindmeyer et al., 2004; Mastrangelo et al., 2003; Promk et. al., 2007; Hammond et al., 2005; Hendrick, 2007];

and 8) possibly man made mineral fibers [Hughes et al., 1993; Clausen et al., 1993; Kilburn et al., 1992; Hansen et al., 1999]. The strength and consistency of the association varies with agent and a causal association cannot yet be made for many of the agents listed above. Available data does appear to be sufficient to establish a causal association between coal dust, silica, and possibly welding and COPD given sufficient exposure frequency, intensity, and duration.

Construction workers experience a wide spectrum of exposures, including most of the agents listed above, and often experience mixtures of agents and high dust levels during activities such as building renovation and demolition. Glencross et al. [1997] found that sheet metal workers followed over a 10-year period sustained significantly accelerated loss of FEV1 if they were exposed to asbestos and smoked. Using spirometry data from the NHANES III for 1988-1994, workers in construction trades were observed to be at increased risk of COPD [Hnizdo et al., 2002]. Based on data for 1999 in the NIOSH Work-Related Lung Disease (WoRLD) Surveillance System, construction workers are at significantly increased mortality risk for COPD [NIOSH, 2009b]. Bergdahl et al. [2004] observed increased COPD mortality risk among Swedish construction workers exposed to inorganic dusts (RR=1.10, 95% CI=1.06-1.4) after control for age and smoking. Among construction workers who had never smoked, increased COPD risk was associated with exposures to inorganic dusts (RR=2.30, 95% CI=1.07-4.96), gases and irritants (RR=3.85, 95% CI=2.50-5.94), and fumes (RR=4.44, 95% CI=2.80-7/04). Dement et al. [2003] observed an elevated prevalence of airway obstruction among construction workers employed at US nuclear sites and increased COPD mortality has been observed among workers at some DOE sites [Dement et. al., 2009a]. More detailed analyses of exposures experienced by DOE construction workers found significant associations for COPD and exposures to asbestos, silica, welding, cement dusts, and some tasks associated with exposures to paints, solvents, and removal of paints [Dement et al., 2010].

One of the major barriers in the prevention of work-related COPD is the identification of specific exposure agents or combinations of agents increasing risk. Most studies have assessed exposures only to the broad category of ‘vapors, gases, dusts, and fumes’, which fails to identify specific causal agents. Additional limitations of many studies of work-related COPD include: 1) low statistical power due to small populations with low numbers of COPD cases, 2) differing COPD case definitions ranging from self-reported physician diagnoses or self-reported respiratory symptoms to spirometry, 3) exposure assessments often simply based on job title, occupation, or industry, and 4) limited data on non-occupational risk factors such as cigarette smoking, obesity, medical history, family history, and hobby-related activities [Rushton, 2007].

We report on the prevalence of airways obstruction among a cohort of sheet metal workers participating in a respiratory disease surveillance program. We also report on results of exploratory analyses of exposures associated with COPD risk among these workers.

MATERIALS AND METHODS

Sheet Metal Occupational Health Institute Trust (SMOHIT)

The Sheet Metal Workers International Association and the Sheet Metal and Air Conditioning National Association formed the Sheet Metal Occupational Health Institute Trust (SMOHIT) in 1985 to study respiratory health hazards among sheet metal workers. The Institute invited sheet metal workers employed for at least 20 years in the construction sector of the industry to participate in a survey and a medical examination provided for them at a convenient time and place. Participating medical facilities and physicians were chosen by the Medical Director in consultation with the staff of the SMOHIT, based on each clinic's experience in conducting similar screening programs in the past. Participating physicians agreed to complete standardized reporting forms, to classify the chest x-rays using the ILO classification [ILO, 1980; ILO, 2002], and to follow the ATS standards for conducting pulmonary function testing [ATS, 1995b; ATS, 2005]. A respiratory history and symptom questionnaire adapted from the American Thoracic Society (ATS) DLD-78 questionnaire [Ferris, 1978] is included in the medical history. Workers also are offered a limited clinical chemistry panel (e.g. serum lipids) as part of the examination. Work and medical history questionnaires are self-administered and subsequently reviewed by the clinic staff. Results of the examinations are given to the individuals with a standardized notification letter, and discussed in a meeting held with all participants subsequent to the examinations.

The first phase of this surveillance program for the United States included 10,395 workers and x-ray results have been previously published [Welch et al., 1994]. Overall, 32% of the participants examined between 1988 and 1990 were found to have either pleural or parenchymal abnormalities consistent with pneumoconiosis. The parenchymal changes were primarily in major category 1/0 of the ILO classification; less than 1% of the films were classified as 2/1 or higher, and 2.4% were classified as 1/2. Interviews were conducted with a subset of workers of 407 workers on the basis potential exposures to glass fibers and asbestos in order to obtain a more detailed occupational history [Hunting and Welch, 1993]. Workers with 20 or more years in the trade were found to have a high prevalence of obstructive pulmonary disease among both smokers and non-smokers. Workers with a history of high intensity exposure to glass fibers were found to have more than a doubled risk of chronic bronchitis and welding fume exposure was a positive predictor of obstructive lung disease.

Sheet metal workers are invited to follow-up screenings if: (1) they were not eligible for the prior screening, because they had not yet worked 20 years as a journeyman, (2) they did not participate in the prior screening even if they were eligible, or (3) they participated and were found not to have asbestos related disease. Any sheet metal worker who are found to have asbestos-related disease are not included in subsequent screenings

Occupational and Exposure History Questionnaire

The original SMOHIT occupational history questionnaire lacked sufficient detail concerning specific tasks and exposures to allowed analyses of COPD risks by exposures. We developed and pilot tested an updated occupational and exposure history questionnaire for this project. The questionnaire was designed to obtain an occupational and exposure for each worker until their date of examination by the SMOHIT surveillance program. The following information was included in the questionnaire:

- Jobs held for at least three months and the start and stop dates (month and year).
- A qualitative assessment of exposure frequency (none to daily) for an established list of respiratory hazards (e.g. silica, asbestos, wood dust, cement dusts, paints, glues, acids, etc.) found in construction. The list of materials was based our prior asthma questionnaire, experience with the DOE and SMOHIT surveillance programs, focus group inputs during questionnaire development, and published literature.
- A qualitative assessment of frequency of doing selected construction tasks known to generate respiratory exposures (e.g. cutting concrete, insulation installation, wood sanding, etc.). We also assessed the frequency of working near these tasks while in the vicinity of other construction trades
- A qualitative assessment of home and hobby respiratory exposures (e.g. wood working, photo development, etc.). This included hours per week and number of years of potential exposure.

Pilot testing involved both focus groups with experienced sheet metal workers and a second pilot by mail with an additional group of sheet metal workers. The SMOHIT also reviewed the questionnaire. After appropriate modifications and updates based on the pilots and SMOHIT review, the exposure questionnaire was finalized and incorporated into the overall asbestos worker screening program. The questionnaire was further refined and some questions eliminated or combined in 2011 based on worker feedback and an interim analysis of data for 1967 workers.

Study Population and Prevalence Analyses

Data presented in this report are for 3944 male workers completing examinations through December 31, 2012 and meeting the following criteria: 1) at least 40 years of age at the time of their examination that included spirometry; 2) not missing demographic data (age, race, sex, and height); 3) spirometry meeting our inclusion criteria, and 4) reported having performed at least one of the tasks associated with exposures of interest. Spirometry inclusion criteria included a minimum of three recorded expiratory efforts and reproducibility of FVC and FEV1 of 0.2 liters or less [ATS, 1995]. Females were excluded due to very small numbers (N=22). Figure 1 provides details with regard to workers excluded.

A typical clinical COPD case definition is a FEV1/FVC ratio of less than 0.70 and a FEV1 less than 80 percent of predicted. A number of investigators have shown that use of a fixed FEV1/FVC ratio to define airway obstruction may result in disease misclassification based on studies that show that the FEV1/FVC declines with normal aging; resulting in underreporting of

COPD in young workers and false positive COPD classification for workers older than age 55 years [Hansen et al., 2007; Swanney et al., 2008; Enright et al., 2008; Hnizdo et al., 2006]. In our studies of Department of Energy Workers we found that a COPD case definition based on a FEV1/FVC ratio below the lower limit of normal (LLN) produced stronger exposure-specific associations [Dement et al., 2010], indeed suggesting disease misclassification using the fixed ratio definition. Based on our preliminary results, the published literature, and current recommendations by the ATS/ERS Task Force [ATS/ERS, 2005], our COPD case definition was based on a FEV1/FVC ratio below the lower limit of normal (LLN) using the prediction equations of Hankinson et al. [1999].

Workers with and without COPD were compared for demographic characteristics and prevalence of respiratory symptoms, chest x-ray changes by ILO criteria, smoking history, and other respiratory diagnoses. Descriptive analyses include prevalence values (%) or mean values ± standard errors of the mean (SE) for continuous variables. Continuous variables were compared by Analysis of Variance (ANOVA) procedures using SAS Proc GLM. The Wilcoxon rank-sum test using SAS Proc NPARIWAY was employed for comparing continuous variables that departed significantly from a normal distribution. Dichotomous variables were compared using the chi-square test of general association. Ordinal categorical data were compared using the Cochran-Armitage test for trends or the Spearman correlation test for variables with more than two categories. In all tests p-values <0.05 were considered statistically significant.

Of the 3944 male workers included in these analyses 3823 (96.9%) had a posterior-anterior (P-A) chest radiograph, classified according to ILO criteria For analyses presented in this report, a parenchymal abnormality was defined as a profusion score of 1/0 or greater for any shape or size of small opacity. Pleural abnormalities were defined as presence of any notations of positive findings in sections 3A-D of the NIOSH ILO coding form.

Exposure Assessment

The occupational history questionnaire obtained information concerning performing a specific list of tasks, working near other individuals performing tasks, or having exposures to a defined list of agents. For each task or exposure agent workers provided a qualitative estimate of the frequency of performing the task on an ordinal scale. For each positive response, workers also estimated the total years that they were associated with the task or agent. The ordinal frequency scale was as follows:

- 0 - No reported agent exposure or performance of the task.
- 1 - Exposed to agent or performs the task 1-2 times per month or less.
- 2 - Exposed to agent or performs the task weekly or most weeks.
- 3 - Exposed to agent or performs the task daily or almost every day.

Our qualitative exposure analyses are based on the worker reported frequencies of being exposed to specific agents while performing tasks associated with exposures of interest. Multiple tasks were associated with each exposure of interest. For example, asbestos exposures were associated with multiple tasks such as application or removal of pipe insulation; work with asbestos-cement products, gaskets, packings, etc. Additionally, some tasks such as work with asbestos-cement products (e.g. Transite) were associated with multiple exposures (e.g. asbestos, cement dust, silica).

For each task, weights were first assigned to the ordinal frequency categories to estimate the number of days per month that a worker performed the task in question. Monthly days of exposure assigned to the ordinal task frequency categories were as follows: 0 = 0 days/mo; 1 = 1 day/mo; 2 = 4 days/mo; and 3 = 20 days/mo. The estimated exposure days per month were then multiplied by the worker reported duration in years to arrive at an estimated cumulative exposure index for each task or agent. We then summed the estimated task cumulative exposure indices to form an overall exposure index for each agent. An example of asbestos-associated tasks and overall asbestos exposure index for a worker in our study is given below. In a similar manner, overall exposure indices were generated for each of the agents considered.

Task Description	**Ordinal Task Frequency**	**Exposure Days Per Month**	**Years of Exposure**	**Cumulative Index**
Asbestos Cement (Transite) Work (drill, cut, grind)	3	20	5	100
Scrape or Remove Asbestos Fireproofing from Beams/Decks	2	4	20	80
Sand/Refinish Asbestos Floor Tiles	1	1	10	10
OVERALL ASBESTOS EXPOSURE INDEX				190

Cumulative exposure indices were developed for exposures to asbestos, sand blasting, man-made mineral fibers (MMMF), cement dusts, drywall dusts, welding/cutting dusts and fumes, spray painting, and solvents/detergents.

Given the nature of tasks typically performed by the sheet metal workers, task scores were correlated. For example, workers doing tasks associated with asbestos-containing insulation may perform tasks with MMMF. In order to further examine risks by agents collectively, principal component analysis (PCA) (with VARIMAX rotation) was used to derive exposure scores for the combination of cumulative exposure indices associated with each agent. PCA was used to identify independent factors that explained the maximum amount of mutual correlation of the individual task exposure scores [Burstyn 2004; Vermeulen et al., 2004]. Inputs to the PCA analyses were the log of estimated cumulative exposure indices for each agent (e.g. asbestos, cement dust, etc.). PCA was used to transform a larger number of possibly correlated task exposure scores into a smaller number of uncorrelated variables or principal components. The first principal component accounted for as much of the variability in the data as possible, and each succeeding component accounted for as much of the remaining variability as possible. The output of principal component analyses was a set of weights or 'loadings' that were then multiplied by each worker's exposure index to derive a summary score for each principal component. Principal components with eigenvalues greater than one were selected for additional analyses. For each exposure, we also used scree plots (i.e. principal component number versus eigenvalues) as an additional aid in determining the last principal component that made a significant contribution to explaining the multiple correlations among the exposure indices.

Analyses of Exposures and COPD Risks

In initial analyses, task and material ordinal frequency and exposure duration scores were placed into three relative cumulative exposure categories (none-low, moderate, and high) as follows:

	Task Exposure Duration (Years)		
Task Frequency Category	**<10**	**10-20**	**20+**
None to Monthly	Low	Low	Mod
Weekly	Low	Mod	High
Daily	Mod	High	High

Cumulative exposures were further dichotomized into categories of none to low exposures and COPD risks compared to those with moderate to high cumulative exposures based on the categories above. Following the assessment of dichotomous exposures categorical individual task and material cumulative exposures (none-low, moderate, and high) and their association with COPD were investigated using Cochran-Armitage trend tests.   The Cochran-Armitage trend tests evaluated trends over exposure categories unadjusted for potential confounders. Unconditional logistic regression was used to explore the risk of COPD by the three relative cumulative exposure categories controlling for age category (40-49, 50-59, 60-69, and 70+), race/ethnicity (Caucasian and Other), and cigarette smoking status (never, former, current, and unknown).

We next investigated associations with derived continuous exposure indices and principal components of exposure indices. Exposures were entered into the models as logs of the exposure indices due to the highly skewed distribution of exposure scores. The primary outcome of interest was a statistically significant positive trend in the odds-ratios by log exposure scores. For comparison purposes, odds-ratios and confidence intervals are presented as changes in risk of COPD associated with an increase of one standard deviation in log PCA scores or overall exposure scores.

SAS Version 9.3 [SAS, 2011] was used for all analysis presented in this report.

All study procedures and materials were approved by the Center for Construction Research and Training IRB. All analysis files received at Duke were stripped of personal identifiers under provisions approved by the Duke University Health System IRB.

RESULTS

Descriptive and Stratified Analyses

Information concerning the final analysis cohort section is provided in Figure 1. The overall prevalence of COPD in this sheet metal worker population was 10.0% (95% CI=9.0-10.9) and ranged from 9.7% for those 40-49 years of age to 12.8% for those over 70 (Table I). The COPD prevalence was higher among Caucasians (10.1%) compared to all other races (7.0%); however, prevalence estimates for the all other race category was based on few COPD cases. Age and smoking specific COPD prevalence for males is compared to data from NHANES III [Swanney et al., 2008] in Table II based on the same COPD case definition used in our analyses. The prevalence of COPD among sheet metal workers who never smoked was slightly less than observed among all NHANES III participants without regard to occupational exposures.

COPD cases and non-cases are compared in Table III. Cases and non-cases were not statistically different with regard to race/ethnicity or years of work in the sheet metal trade; however the mean age of COPD cases was slightly higher than that of non-cases (61.5 years versus 60.3 years). As expected, workers with COPD had significantly reduced FVC, FEV_1, and FEV_1/FVC ratios compared to workers without COPD. The prevalence of cough, phlegm, and dyspnea were significantly higher among COPD cases. The overall prevalence of chest x-ray abnormalities among this population was relatively low (Table IV) and an overall test of association with COPD was not statistically significant (p=0.91). COPD was strongly related to cigarette smoking history and COPD cases reported significantly greater history of physician diagnosed asthma, chronic bronchitis, and emphysema.

Results of the dichotomous analyses of individual task and material exposures and their association with COPD are presented in Table V. Significant associations from either the stratified or multivariate analyses are shown. In the adjusted analyses, cutting, applying and removing of MMMF insulation and pouring concrete were significantly associated with COPD risk. The stratified analyses also found carbon arc welding, use of asbestos cloth, aprons, and gloves, exposure to urethane foam insulation, and working near welding and cutting to be associated with COPD

Detailed results of the stratified and logistic regression analyses by task and material cumulative exposure categories (None-Low, Moderate, and High) and tests for association are shown in Appendices I – III. The following tasks or agents were found to be associated with COPD risk based on a Cochran Armitage test of trend in COPD prevalence by cumulative exposure category ($p<0.05$).

- Cut and Apply Man-Made Mineral Fiber Insulation
- Remove Man-Made Mineral Fiber Insulation
- Clean-up Man-Made Fiber Debris by Sweeping or Blowing
- Install Man-Made Fiber Insulation by Pouring or Blowing
- Pour Concrete
- Spray Apply Paints or Finishes
- Carbon Arc Welding (CAW)

- Exposure to Urethane Foam Insulation

In the logistic models, which adjusted for age, race/ethnicity, and smoking, only pouring concrete, carbon arc welding, exposure to urethane foam insulation, and working near spray painting were significantly associated with COPD. Several tasks resulting in exposures to man-made mineral fibers and spray application of paints and finishes were of borderline statistical significance in the adjusted logistic models.

Multivariate Analyses by Combined Indices for Tasks and Materials

Our final analyses investigated associations between COPD risks and cumulative overall summary indices and principal component scores of summary indices. We investigated COPD risks by log total exposures indices (e.g. MMMF, asbestos, cement dust, etc.) and principal components of total exposure in logistic models that adjusted for age category (40-49, 50-59, 60-69, and 70+), race/ethnicity (Caucasian and Other), and cigarette smoking status (never, former, current, and unknown). Results of these analyses are shown in Tables VI and VII. In these analyses, only the cumulative overall exposure indices for spray painting (OR=1.13, 95% CI=1.01-1.25) and working near spray painting (OR=1.12, 95% CI=1.02-1.22) were statistically associated with COPD. The second principal component based on inclusion of all individual agent cumulative exposure indices was significantly associated with risk of COPD. A review of positive loadings for this principal component found the following loadings ordered from the largest to smallest weighting: MMMF Index Cement Index, Drywall Index, and Spray Paint Index.

We conducted additional analyses to evaluate the impact of excluding workers not meeting ATS variability for PFT maneuvers. Inclusion of these workers did not detect any additional significant associations with the study exposure metrics nor alter associations found without inclusion of these workers.

DISCUSSION

The overall prevalence of COPD in our sheet metal worker study population was 10.0% (95% CI=9.0-10.9). Comparisons with NHANES III data for those who never smoked did not show increased COPD prevalence among these workers. It should be noted that the NHANES III comparison is based on all occupations and prevalence in the NHANES III would be lower if based on occupations without significant exposures. For example, in their analyses of COPD risk by occupation using NHANES III data, Hnizdo et al. [2002] used office workers as the reference population for calculation of odds-ratios adjusted for age, sex, race/ethnic group, body mass index, smoking status, pack-years of cigarette smoking, education, and socioeconomic status. The prevalence of COPD in the office worker reference population was 4.7% compared to 8.7% for construction workers.

Cigarette smoking is a major risk factor for COPD and the prevalence of current smoking among

3866 workers with known histories was low (13.5% current smokers, 44.6% past smokers, and 39.9% never smoked). The prevalence of current smokers in our sheet metal worker study population is considerably less than reported by Lee et al. [2004, 2007] among construction-related trades during 1997-2004 (38.8%) and lower than all U.S. males during 1997-2004 (24.5%). Lee et al. reported a smoking prevalence for sheet metal workers for 1987-1994 of 42.4%, much higher than observed in our study population. These data suggest that participants in the SMOHIT screening program may not be representative of sheet metal workers in general with regard to smoking.

Participation in the SMOHIT screening program for asbestos related disease requires membership in the Sheet Metal Workers International Union for 20 years or more. Participants are not representative of the sheet metal trade with regard to smoking patterns and may be healthier. Indeed, our prior analyses of mortality patterns among SMOHIT participants support this conclusion based on a strong healthy worker effect as demonstrated by significantly reduced overall mortality (SMR= 0.83, 95% CI=0.80–0.85) [Dement et al., 2009b]. The SMR for COPD in our sheet metal worker mortality study was 0.92 (95% CI=0.82-1.04). Additionally, the prevalence of COPD among SMOHIT screening program participants is considerably less than observed among sheet metal workers at Department of Energy (DOE) sites using the same case definition (15.3%, 95% CI=11.9-19.1) [Dement et al., 2010]. Participation in the SMOHIIT program requires 20 years of sheet metal work whereas the DOE medical screening programs do not require a fixed employment period.

We explored COPD risk among these sheet metal workers based on self-reported exposures. Multivariate odds ratios by individual task or material categories of cumulative exposure (Appendices I-III) suggested significant associations with exposures to man-made mineral fibers, pouring of concrete, carbon arc welding, spray painting, and exposure to urethane foam insulation. Other published data, as reviewed in the introduction, generally support these associations. Multivariate analyses using principal components in order to consider correlated exposures also suggested a significant association with COPD and exposures to MMMF, cement dusts, drywall dusts, and spray painting.

We did not find an association between COPD and welding/cutting tasks when all tasks were combined to form a welding/cutting cumulative index. Carbon arc welding, when analyzed separately as a specific task, was significantly associated with the risk of COPD. A number of studies have found significantly increased risk of COPD among welders and other workers performing welding tasks [Maldrum et. al., 2004; Balmes, 2005; Mastrangelo et al., 2003; Lillienberg et al., 2008]. COPD also has been associated with exposures to biological dusts in several studies [Matheson et al., 2005; Mastrangelo et al., 2003].

We not find a consistent and significant association between asbestos exposures and COPD in this study; however, an association was observed in our study of DOE workers [Dement et al., 2010] and has been observed by others [Meldrum et al., 2005; Ohar et al., 2004]. While a test of association between COPD and chest x-ray changes was not statistically significant, workers with either parenchymal changes or pleural changes did have a slightly higher prevalence of COPD. In our prior study we observed significantly increased COPD mortality risk among workers having parenchymal profusion scores of 1/0 or greater or asbestos-related pleural changes [Dement et al., 2009b]. Given these results, our lack of a significant association with asbestos exposures in the current study may simply be related to low statistical power in that we had only fourteen COPD cases with parenchymal or pleural x-ray changes.

Our study has a number of limitations that should be considered in interpreting results. The exposure characterizations are based on self-reported frequencies and durations of performing tasks or being exposed to materials. Approximately 21% of tasks with a reported task frequency were missing data on task duration. Analyses presented in this report are based on workers without missing data for the particular task or material being considered. When summary exposure indices were generated or principal components of these indices were formed, workers missing task duration were eliminated, thus substantially reducing statistical power to investigated combined exposures. Furthermore, exposure indices were based on self-reported data and exposure misclassification likely biases our results toward the null. An additional limitation is the nature of the sheet metal cohort. Participation in the screening program requires 20 years of work in the trade; therefore, no sub-cohort with minimal exposure was available for these internal analyses. The lack of exposure contrasts limited our ability to detect occupational exposure signals in the presence of a strong smoking effect. Lastly, our analyses involved multiple statistical comparisons; therefore, some positive associations would be expected due to chance.

CONCLUSIONS

Our study of COPD among SMOHIT screening program participants did not suggest an overall increased risk of COPD among never smoked compared to NHANES III data. The low prevalence of current smokers in our study population coupled with the observation of significantly reduced overall mortality among SMOHIT participants suggests a substantial healthy worker effect. This conclusion is strengthened when COPD risk among SMOHIT participants is compared to COPD risk among sheet metal workers employed at DOE sites.

While SMOHIT screening program participants do not appear to be at an increased risk of COPD overall, some exposures experienced by these workers were found to be associated with increased risk. All of our statistical models found smoking to be a powerful risk factor for COPD. This study provides additional support for the importance of preventing of both smoking and occupational exposures in order to reduce the burden of COPD among construction workers.

ACKNOWLEDGMENTS

The National Institute for Occupational Safety and Health supported this study through a cooperative agreement with the Center for Construction Research and Training and the National Institute for Occupational Safety and Health (Cooperative Agreement Number OH009762). We express our appreciation to the Sheet Metal Workers International Association and the Sheet Metal Occupational Health Institute Trust who provided the data for this project and assisted with development of the exposure assessment questionnaire. Opinions expressed are those of the authors and do not necessarily represent the official views of CPWR or NIOSH

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TABLE I
COPD Prevalence by Age and Race/Ethnicity
Male Sheet Metal Workers

Variable	Number of Workers	COPD Cases and Prevalence (%)
Age Category (Years)		
40-49	565	55 (9.7%)
50-59	1434	124 (8.7%)
60-69	1306	132 (10.1%)
70+	639	82 (12.8%)
Race/Ethnicity		
Caucasian	3743	379 (10.1%)
All Other	201	14 (7.0%)
Crude Overall Prevalence	3944	385 (10.0%)

TABLE II
Age Specific COPD Prevalence by Smoking Category Compared to NHANES III[1]
Male Sheet Metal Workers[3]

Age Category (Years)	Sheet Metal Worker Prevalence N (%)	NHANES III Prevalence (%) Swanney[1]	NHANES III Prevalence (%) Hansen[2]
Never Smoked			
40-49	18 (5.8)	6.6	4.5
50-59	17 (2.8)	6.3	6.7
60-69	17 (3.9)	4.7	5.5
70+	9 (4.3)	9.4	4.6
Past Smoker			
40-49	13 (8.9)		
50-59	55 (9.7)		
60-69	71 (10.5)		
70+	58 (15.9)		
Current Smoker			
40-49	22 (23.2)		10.3
50-59	50 (22.4)		16.4
60-69	41 (24.6)		33.2
70+	14 (28.9)		34.3

[1] NHANES III data published by Swanney et al. (2008) for asymptomatic never smokers
[2] NHANES III data published by Hansen et al. (2007) Lower Limit of Normal case definition.
[3] 78 workers were missing smoking data.

TABLE III
Comparison of Male Workers by COPD Case Status

Parameter[3]	No COPD (N=3551)	COPD[1] (N=393)	P-value
Mean Age (SE)	60.3(0.15)	61.5 (0.49)	0.01
Caucasian Race (%)	3364 (94.7%)	379 (96.4%)	0.15
Years in Trade[2], Mean (SE)	33.3 (0.11)	33.7 (0.37)	0.94
Spirometry Mean (SE)			
% Predicted FVC	99.2 (0.29)	90.7 (0.95)	<0.001
% Predicted FEV_1	102.8 (0.30)	70.9 (0.97)	<0.001
FEV_1/FVC Ratio	0.79 (0.002)	0.58 (0.004)	<0.001
Respiratory Symptom Prevalence (%)[4]			
Cough (N=3471)	651 (20.7%)	149 (45.2%)	<0.001
Phlegm (N=3552)	633 (19.8%)	150 (42.7%)	<0.001
Dyspnea (N=3472)	1143 (36.6%)	205 (58.6%)	<0.001
B-Reader Prevalence (N=3823) (%)[5]			
Pleural Changes Only	26 (0.8%)	3 (0.8%)	0.91
Parenchymal Changes Only	84 (2.4%)	11 (2.9%)	
Both Pleural and Parenchymal	2 (0.1%)	0 (0.0%)	
Cigarette Smoking Prevalence (%)			
Current	407 (11.5%)	127 (32.3%)	<0.001
Former	1560 (43.9%)	197 (50.1%)	
Never Smoked	1514 (42.6%)	61 (15.2%)	
Smoking Unknown	70 (2.0%)	8 (2.0%)	
Cigarette Smoking Pack Years, Mean (SE)	14.1 (0.33)	33.7 (1.37)	<0.001
Physician Diagnosis (Ever) (%)			
Asthma (N=3516)	209 (6.6%)	57 (17.3%)	<0.001
Chronic Bronchitis (N=3481)	125 (4.0%)	45 (13.8%)	<0.001
Emphysema (N=3513)	55 (1.7%)	61 (18.0%)	<0.001
Hypertension Prevalence (N=3938) (%)	1076 (30.3%)	110 (28.1%)	0.35

[1] COPD cases defined based on an FEV_1/FVC ratio less than the lower limit of normal using the Hankinson et al. [1999].
[2] Calculated based on total years in sheet metal trade.
[3] Results are based on workers without missing data. The number of responses available is shown for variables.
[4]**Cough** - "Yes" to "Do you usually have a cough?" and "Yes" to "Do you usually cough like this on most days for 3 consecutive months or more during the year?"
Phlegm - "Yes" to "Do you usually bring up phlegm from your chest?" and "Yes" to "Do you bring up phlegm like this on most days for 3 consecutive months or more during the year?"
Dyspnea - "Yes" to "Do you walk slower than people your age because of breathlessness?" or a positive answer to additional questions showing more severe shortness of breath.
[5] B-reader data were not available for 121 workers.

TABLE IV
Male Worker COPD Prevalence by Chest Radiograph B-Reader Category

Chest X-ray B-Reader Classification[1]	Number Workers with B-Read Results	COPD Cases and Prevalence (%)[2]
Normal	3697	364 (9.9%)
Parenchymal Changes Only	95	11 (11.6%)
Pleural Changes Only	29	3 (10.3%)
Pleural and Parenchymal Changes	2	0 (0.0%)

[1] Parenchymal changes with profusion scores ≥ 1/0. Statistical test of general association between COPD and X-ray category (χ^2 =0.54, , df=3, p=0.91). 121 workers were missing valid B-reader results.

[2] COPD cases defined based on an FEV_1/FVC ratio less than the lower limit of normal using the Hankinson et al. [1999].

TABLE V

Crude and Adjusted Odds-Ratios for Dichotomous Task and Material Exposures[1]

Task or Material	Number Workers	Crude Odds-Ratio (95% CI)	Adjusted Odds-Ratio (95% CI)[2]
Cut and Apply Man-Made Mineral Fiber (MMMF) Insulation	3531	1.21 (0.97-1.51)	1.34 (1.05-1.73)
Remove Man-Made Mineral Fiber Insulation (MMMF)	3498	1.31 (1.04-1.64)	1.39 (1.09-1.79)
Scrape or Remove Man-Made Fiber Fireproofing from Beams or Decks	3542	1.29 (1.03-1.62)	1.23 (0.97-1.57)
Clean-up Man-Made Fiber Debris by Sweeping or Blowing	3511	1.30 (1.03-1.64)	1.24 (0.97-1.59)
Install Man-Made Fiber Insulation by Pouring or Blowing	3546	1.46 (1.04-2.06)	1.41 (0.98-2.03)
Pour Concrete	3634	1.81 (1.26-2.60)	1.84 (1.25-2.72)
Carbon Arc Welding	3586	1.40 (1.08-1.81)	1.29 (0.99-1.70)
Use Asbestos Blankets, Cloth, Aprons, or Gloves	3647	1.48 (1.01-2.18)	1.14 (0.75-1.75)
Work Near Arc Welding or Cutting	3676	1.27 (1.02-1.58)	0.90 (0.71-1.14)
Exposure to Urethane Foam Insulation	3647	1.35 (1.03-1.76)	0.97 (0.58-1.62)

[1] Cumulative exposures dichotomized into categories of none to low exposures compared to those with moderate to high cumulative exposures. Only exposures showing a statistically significant association ($p<0.05$) in the crude or adjusted analyses are shown.
[2] Logistic regression models controlling for age, race, smoking.

TABLE VI
Logistic Regression Models for COPD Prevalence by Cumulative Task Exposure Indices

Exposure Index[1]	Workers Included	Odds Ratio[2]	95% LCL	95% ULC	Logistic Model Type II Effect P-value
Tasks Directly Performed					
MMMF Index	3139	1.07	0.94	1.21	0.32
Cement Index	3220	1.06	0.94	1.19	0.38
Drywall Index	3777	1.04	0.93	1.16	0.50
Spray Paint Index	3820	**1.13**	**1.01**	**1.25**	**0.03**
Welding/Cutting Index	3077	0.96	0.86	1.09	0.55
Plastic Cutting/Welding Index	3851	0.96	0.86	1.08	0.70
Sand Blasting/Cleaning Index	3642	0.89	0.791	1.02	0.09
Molds/Spores Index	3788	1.02	0.91	1.13	0.78
Asbestos Index	3314	1.03	0.91	1.18	0.61
Acid/Caustic Index	3657	1.04	0.93	1.16	0.47
Furnace Boiler Cleaning Index	3751	0.96	0.86	1.07	0.46
Solvent /Detergent Cleaning Index	3718	0.99	0.88	1.10	0.80
Tasks Worked Near					
Working Near MMMF Tasks	3755	1.06	0.96	1.18	0.23
Working Near Cement Tasks	3817	1.08	0.98	1.19	0.12
Working Near Drywall Tasks	3790	1.04	0.94	1.16	0.43
Working Near Painting Tasks	3607	**1.12**	**1.02**	**1.22**	**0.02**
Working Near Welding/Cutting	3489	1.02	0.92	1.14	0.66
Working Near Sand Blasting	3828	0.91	0.76	1.09	0.31
Working Near Solvent/Detergent Cleaning	3821	0.95	0.84	1.08	0.47

[1] All models were adjusted for age, race, and smoking with exposures entered as the log of the cumulative exposure index. Only workers without missing data on frequency and duration for each component of the respective exposure index are included in the analyses.

[2] The odds-ratios represent changes in risk for an increase of one standard deviation in the given log of the exposure parameter. COPD cases defined based on an FEV_1/FVC ratio less than the lower limit of normal using the Hankinson et al. [1999].

TABLE VII
Logistic Regression Models for COPD Prevalence by Cumulative Material Exposure Indices

Material Index[1]	Workers Included	Odds Ratio[2]	95% LCL	95% ULC	Logistic Model Type II Effect P-value
Organic Dusts[3]	3406	0.96	0.86	1.08	0.53
Inorganic Dusts[4]	3430	1.01	0.90	1.12	0.99
Irritant Gases and Vapors[5]	3399	1.00	0.90	1.11	0.70
Cutting Oils	3647	1.03	0.93	1.14	0.70
Pesticides, Insecticides, Herbicides	3707	0.96	0.85	1.09	0.53
Urethane Foam Material	3647	1.08	0.98	1,18	0.11
Tar and Wood Sealers	3547	1.01	0.91	1.13	0.85
Engine Exhausts	3602	1.04	0.94	1.15	0.48

1 All models were adjusted for age, race, and smoking with exposures entered as the log of the cumulative exposure index. Only workers without missing data on frequency and duration for each component of the respective exposure index are included in the analyses.

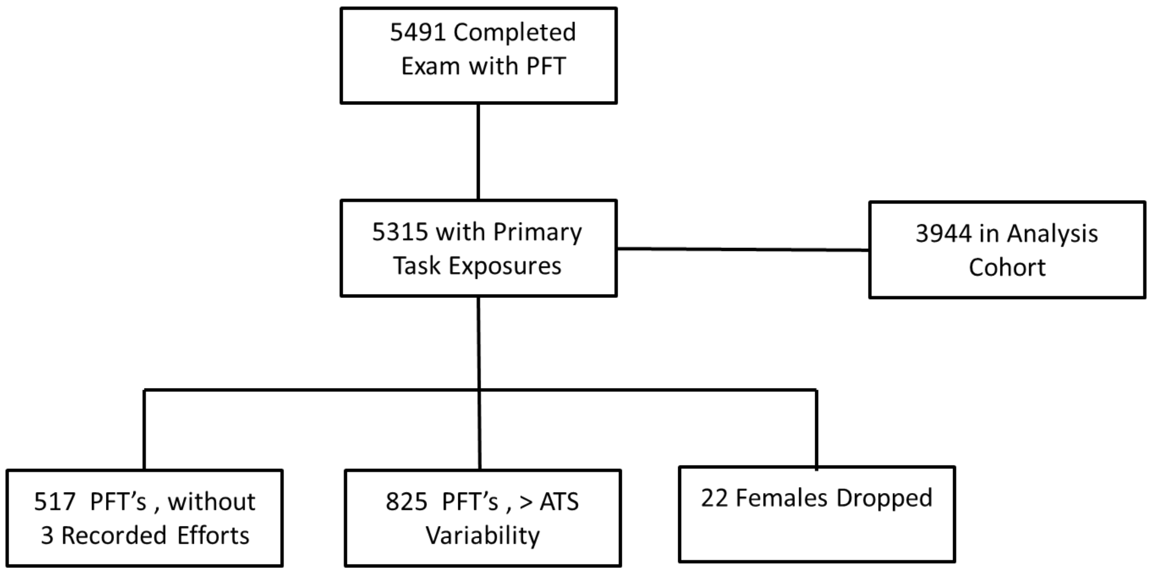
2 The odds-ratios represent changes in risk for an increase of one standard deviation in the given log of the exposure parameter. COPD cases defined based on an FEV_1/FVC ratio less than the lower limit of normal using the Hankinson et al. [1999].

3 Inorganic dusts from materials lists includes lime, vermiculite/zonolite, and demolition dusts.

4 Organic dusts include coal dust, wood dust, particle board dust, plastic dusts, and molds/spores.

5 Irritant gases and vapors include acids, caustics, formaldehyde, sulfur dioxide, ozone, and nitrogen dioxide

Figure 1: Study Cohort Selection



APPENDIX I

COPD Prevalence and Adjusted Odds-Ratios by Categorical Task Cumulative Exposures Indices

Tasks Performed by Workers	Number Workers	Cumulative Exposure Index (Frequency x Duration) COPD Cases (Prevalence %)			Cochran Armitage Trend P-value[1]	Logistic Model Adjusted Odds-Ratio (95% CI)[2]		Logistic Model Type II Effect P-value
		Low	Mod	High		Mod	High	
MAN-MADE MINERAL FIBER WORK (FIBERGLASS, MINERAL WOOL, ROCKWOOL)								
Cut and Apply Man-Made Mineral Fiber Insulation	3531	**154 (9.1)**	**108 (10.1)**	**88 (11.6)**	**0.05**	1.13	1.28	0.23
Remove Man-Made Fiber Insulation	3498	**203 (9.0)**	**95 (11.4)**	**48 (11.6)**	**0.03**	1.29	1.27	0.11
Scrape or Remove Man-Made Fiber Fireproofing from Beams / Decks	3542	225 (9.3)	81 (11.9)	50 (11.3)	0.06	1.30	1.19	0.15
Clean-up Man-Made Fiber Debris by Sweeping or Blowing	3511	**215 (9.1)**	**82 (11.2)**	**48 (12.0)**	**0.03**	1.28	1.27	0.14
Install Man-Made Fiber Insulation by Pouring or Blowing	3546	**311 (9.6)**	**34 (13.0)**	**9 (16.1)**	**0.02**	1.49	1.45	0.10
CONCRETE AND CEMENT WORK								
Drill into Concrete to Install Duct Hangers or Supports	3462	119 (9.5)	88 (9.8)	137 (10.5)	0.40	1.03	1.08	0.84
Abrasive Cut or Grind Concrete	3546	272 (9.9)	60 (10.0)	21 (11.0)	0.69	1.00	1.21	0.74
Pour Concrete Only (Wet Concrete Work Only)	3634	**324 (9.6)**	**37 (16.5)**	**2 (10.5)**	**<0.01**	**1.98**	**0.90**	**<0.01**
Clean-up Concrete Dust by Sweeping or Blowing	3552	265 (9.9)	57 (9.7)	38 (12.9)	0.22	0.99	1.32	0.35
DRY WALL AND PLASTER WORK								
Work with Dry Wall, Finishing or Plaster Compounds	3777	303 (9.8)	47 (11.4)	28 (10.4)	0.48	1.19	1.12	0.55
PAINTING AND FINISHING								
Spray Apply Paints or Finishes	3820	**279 (9.5)**	**74 (11.4)**	**32 (13.3)**	**0.03**	**1.25**	**1.52**	**0.05**
Scrape or Remove Paints	3751	351 (10.0)	21 (10.8)	3 (7.5)	0.93	1.10	0.71	0.79
Cut or Weld on Painted Surfaces	3713	319 (10.0)	41 (10.7)	17 (12.8)	0.30	1.05	1.24	0.73
WELDING, CUTTING, SOLDERING, BRAZING, AND BONDING								
Brazing	3624	322 (10.0)	35 (11.3)	8 (7.7)	0.89	1.08	0.80	0.76
Carbon Arc Welding (CAW)	3586	**271 (9.4)**	**56 (11.4)**	**33 (15.7)**	**<0.01**	**1.18**	**1.64**	**0.04**
Electron Beam Welding	3660	344 (10.0)	17 (10.0)	8 (13.4)	0.48	0.99	1.37	0.73
Flux-Cored Arc Welding (FCAW)	3604	294 (9.9)	49 (11.1)	23 (12.1)	0.22	1.17	1.21	0.50
Gas Metal Arc Welding (GMAW)	3634	276 (10.0)	55 (11.2)	37 (9.7)	0.88	1.20	0.94	0.45
Gas Tungsten Arc (GTAW)	3652	297 (9.9)	45 (11.8)	23 (8.5)	0.92	1.22	0.86	0.41
Laser Beam Welding	3678	344 (9.8)	15 (12.2)	4 (12.1)	0.35	1.24	1.53	0.57
Oxy-fuel Cutting (OFC)	3578	275 (9.8)	57 (10.4)	28 (12.1)	0.29	1.04	1.14	0.83
Oxy-fuel Welding (OFW)	3661	334 (9.8)	177 (11.5)	4 (7.6)	0.88	1.24	0.82	0.62
Plasma Arc Welding	3642	311 (9.5)	33 (12.6)	10 (8.9)	0.44	1.49	1.00	0.15

Tasks Performed by Workers	Number Workers	Cumulative Exposure Index (Frequency x Duration) COPD Cases (Prevalence %)			Cochran Armitage Trend P-value[1]	Logistic Model Adjusted Odds-Ratio (95% CI)[2]		Logistic Model Type II Effect P-value
		Low	Mod	High		Mod	High	
Resistance Welding	3689	342 (10.0)	15 (7.8)	9 (10.2)	0.59	0.79	1.03	0.70
Shielded Arc Welding (SMAW)	3591	265 (9.4)	60 (12.0)	30 (11.1)	0.12	1.34	1.08	0.18
Soldering	3527	249 (10.0)	76 (10.9)	29 (8.7)	0.79	1.06	0.80	0.53
Submerged Arc Welding (SAW)	3723	362 (10.0)	7 (8.4)	2 (16.7)	0.92	0.92	1.69	0.80
PLASTIC BONDING, CUTTING, OR HEAT WELDING								
Resin Bond, Heat Weld or Cut PVC Plastic Ducts or Pipes	3873	376 (9.95)	9 (12.0)	1 (5.0)	0.90	1.30	0.51	0.63
SAND BLASTING AND SURFACE CLEANING								
Blast or Clean with Sand	3697	354 (9.9)	12 (10.9)	0 (0.0)	0.98	1.17	---	0.89
Blast or Clean with Shot or Sand Substitute	3694	360 (10.0)	10 (11.1)	0 (0.0)	0.99	1.11	---	0.95
Water or Hydro Blasting	3690	361 (10.0)	8 (9.8)	0 (0.0)	0.69	1.02	---	0.99
Use Solvents or detergents for Cleaning or Degreasing	3718	307 (9.8)	42 (9.8)	17 (10.8)	0.76	1.06	1.16	0.82
Use Acids or Caustics for Cleaning or Degreasing	3657	324 (9.8)	33 (12.1)	9 (12.9)	0.15	1.23	1.30	0.48
Clean, Repair, or Dismantle Oil-fired Furnaces or Boilers	3751	360 (10.1)	17 (11.6)	0 (0.0)	0.55	1.21	---	0.79
MOLDS AND SPORES								
Work in Building Areas with Visible Mold contamination, Renovate/Demolish Ducts or Components with Mold Contamination or Service or Repair HVAC Systems with Mold Contamination	3788	333 (9.9)	34 (10.5)	14 (14.6)	0.19	1.16	1.57	0.27
ASBESTOS WORK BEFORE 1980								
Install Asbestos Insulation	3683	334 (9.7)	20 (12.1)	7 (11.7)	0.29	1.11	0.97	0.92
Asbestos Cement (Transite) Work (drill, cut, grind)	3629	330 (9.9)	27 (11.8)	5 (8.9)	0.64	1.12	0.75	0.73
Remove or Install Asbestos Gaskets, or Packings	3658	341 (9.9)	17 (11.3)	3 (5.9)	0.73	1.11	0.65	0.61
Scrape or Remove Asbestos Fireproofing from Beams/Decks	3635	313 (9.6)	29 (10.4)	10 (10.5)	0.62	1.05	0.96	0.97
Clean-up Asbestos Debris by Sweeping or Blowing	3640	324 (9.7)	28 (11.8)	9 (12.3)	0.23	1.19	1.09	0.71
Spray Apply Asbestos Acoustical Insulation/Fireproofing	3735	359 (9.8)	9 (13.6)	2 (10.5)	0.44	1.49	0.96	0.56
Sand/Refinish Asbestos Floor Tiles	3745	371 (10.0)	3 (8.8)	1 (11.0)	0.93	1.01	0.79	0.99
Use Asbestos Blankets, Cloth, Aprons, or Gloves	3647	329 (9.7)	28 (14.3)	5 (11.1)	0.09	1.31	1.09	0.46

[1] Cochran-Armitage trend test by the cumulative exposure metric are shown. Results are shown for all workers without missing data for each metric.
[2] Logistic regression models controlling for age, race, smoking. Odds-ratios comparing workers with moderate and high cumulative exposures to those classified as having none to low cumulative exposures.

APPENDIX II
COPD Prevalence and Adjusted Odds-Ratios by Categorical Task Worked Near Cumulative Exposures Indices[1]

Tasks Worked Near	Number Workers	Cumulative Exposure Index (Frequency x Duration) COPD Cases (Prevalence %)			Cochran Armitage Trend P-value	Logistic Model Adjusted Odds-Ratio (95% CI)[2]		Logistic Model Type II Effect P-value
		Low	Mod	High		Mod	High	
MAN-MADE MINERAL FIBER WORK (FIBERGLASS, MINERAL WOOL, ROCKWOOL)								
Work Near Cutting, Applying, Removing man-Made Fiber or Clean-up Man-Made Fiber Debris by Sweeping or Blowing	3755	167 (9.1)	99 (10.7)	109 (11.1)	0.08	1.27	1.22	0.15
CONCRETE AND CEMENT WORK								
Work Near Abrasive Cutting or Grinding of Concrete or Clean-up concrete Dust by Sweeping or Blowing	3864	357 (10.1)	14 (7.4)	15 (10.3)	0.63	0.71	0.99	0.49
DRY WALL AND PLASTER WORK								
Work Near Dry Wall or Plaster Sanding, Finishing or Clean-up by Sweeping or Blowing	3790	215 (10.1)	76 (8.8)	89 (11.2)	0.59	0.92	1.13	0.48
PAINTING AND FINISHING								
Work Near Spray Painting Operations	3637	250 (9.8)	64 (8.7)	49 (14.2)	0.10	**0.91**	**1.54**	**0.02**
Work Near Scrapping or Removing Paints	3700	298 (9.7)	47 (10.5)	25 (14.4)	0.10	1.11	1.58	0.13
Work Near Cutting or Welding on Painted Surfaces	3594	223 (9.7)	79 (10.1)	59 (11.8)	0.19	1.00	1.17	0.60
WELDING, CUTTING, SOLDERING, BRAZING, AND BONDING								
Work Near Brazing or Soldering	3615	236 (10.2)	68 (8.9)	59 (11.0)	0.91	0.82	1.05	0.34
Work near Arc or Oxy-fuel Welding or Cutting (OFC)	3873	363 (10.3)	12 (6.2)	14 (8.3)	0.12	0.61	0.70	0.15

[1] Cochran-Armitage trend test by the cumulative exposure metric are shown. Results are shown for all workers without missing data for each metric.
[2] Logistic regression models controlling for age, race, smoking. Odds-ratios comparing workers with moderate and high cumulative exposures to those classified as having none to low cumulative exposures.

APPENDIX III
COPD Prevalence and Adjusted Odds-Ratios by Categorical Material Cumulative Exposures Indices[1]

Material or Exposure Agent	Number Workers	Cumulative Exposure Index (Frequency x Duration) COPD Cases (Prevalence %)			Cochran Armitage Trend P-value	Logistic Model Adjusted Odds-Ratio (95% CI)[2]		Logistic Model Type II Effect P-value
		Low	Mod	High		Mod	High	
DUSTS								
Coal Dust	3687	324 (9.7)	36 (12.9)	5 (7.6)	0.43	1.28	0.60	0.24
Wood Dust	3627	251 (10.2)	59 (8.4)	53 (11.2)	0.97	0.84	1.10	0.39
Particle Board Dust	3651	284 (9.8)	48 (10.4)	32 (10.7)	0.55	1.10	1.05	0.84
Lime Dust	3704	343 (10.1)	18 (8.7)	8 (8.8)	0.49	0.90	0.82	0.82
Vermiculite or Zonolite	3705	332 (9.8)	26 (11.8)	8 (8.7)	0.76	1.23	0.82	0.55
Mixed Dusts from Demolition	3604	213 (10.0)	89 (10.1)	58 (9.6)	0.82	1.02	0.93	0.88
Plastic Dust	3796	348 (10.0)	22 (9.8)	11 (10.7)	0.91	1.22	0.98	0.62
CHEMICALS								
Acids (muriatic, sulfuric, etc.)	3598	264 (10.4)	55 (7.7)	37 (10.9)	0.41	0.67	0.97	0.04
Formaldehyde/ Glutaraldehyde Vapors	3694	333 (9.6)	23 (12.1)	4 (8.0)	0.62	1.26	0.95	0.62
Cutting Oils/Machining Fluids	3647	290 (9.8)	42 (9.2)	28 (11.7)	0.59	1.01	1.15	0.81
Glycols	3765	326 (9.8)	29 (9.7)	13 (15.5)	0.23	1.04	1.47	0.48
Pesticides, Insecticides, Herbicides	3707	336 (9.8)	23 (10.5)	6 (13.6)	0.40	1.11	1.48	0.64
Urethane Foam Insulation	3647	**286 (9.5)**	**46 (11.4)**	**31 (14.0)**	**0.02**	**1.32**	**1.53**	**0.05**
Tar	3634	280 (9.9)	54 (9.6)	26 (10.5)	0.89	0.97	1.03	0.98
Wood Sealers	3710	335 (9.7)	22 (10.5)	6 (11.1)	0.61	1.24	1.11	0.65
Gasoline Engine Exhausts at Work	3645	282 (9.9)	40 (8.4)	40 (12.1)	0.55	0.90	1.20	0.50
Diesel Engine Exhausts at Work	3675	297 (9.6)	35 (9.6)	30 (13.6)	0.10	1.06	1.45	0.22
Sulfur Dioxide (SO_2)	3800	368 (10.0)	7 (7.8)	3 (9.7)	0.62	0.75	0.82	0.73
Ozone (O_3)	3804	366 (9.9)	6 (7.3)	6 (15.0)	0.34	0.74	1.60	0.47
Nitrogen Dioxide (NO_2)	3790	369 (10.0)	7 (8.8)	5 (15.6)	0.56	0.87	1.56	0.64

[1] Cochran-Armitage trend test by the cumulative exposure metric are shown. Results are shown for all workers without missing data for each metric.
[2] Logistic regression models controlling for age, race, smoking. Odds-ratios comparing workers with moderate and high cumulative exposures to those classified as having none to low cumulative exposures.

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