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Dusty Occupations and Pulmonary Obstruction in Kentucky: A Proportionate Mortality Analysis

CAPSTONE PROJECT PAPER

A paper submitted in partial fulfillment of the requirements for the degree of
Masters of Public Health in the
University of Kentucky College of Public Health

By:
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Lexington, Kentucky
May 3rd, 2017

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Abstract

Background

Chronic obstructive pulmonary disease (COPD) is the third leading cause of death in the United States. Occupational exposure to vapors, gases, dusts, or fumes (VGDFs), in combination with smoking, significantly increases the risk of developing COPD. Amongst agricultural workers, exposure to pesticides has been found to cause significantly elevated rates of annual decline in lung function, ultimately leading to a clinical diagnosis of pulmonary obstruction if the period of exposure is sufficient.

Purpose

It is hypothesized that, when compared to the standard population, workers in "dusty" occupations (where VGDF workplace exposure is significant) die at significantly elevated rates from certain cardiac and pulmonary pathologies (AMI, stroke, COPD, chronic lower respiratory disease), due to the pulmonary obstruction caused by workplace VGDF exposure.

Methods

Using death certificate data provided by the Kentucky Office of Vital Statistics, Cabinet for Health & Family Services, proportionate mortality ratios of dusty occupations versus non-dusty occupations were calculated for select pulmonary and cardiovascular causes of death. These calculations were done for both winter months (December, January, and February) and non-winter months (March through November).

A logistic model was created with following covariates: age, race, gender, occupation type (dusty vs. non-dusty), and time of death (winter month versus non-winter month).

The outcome of interest was a death due to stroke, cardiac pathology, chronic respiratory pathology, or acute respiratory pathology.

Results

PMR values for those above the median age (75 years) were significantly elevated for myocardial infarction in both winter and non-winter deaths. PMR values for those of the 25th percentile in age and older were significantly elevated for COPD in non-winter months. PMR values for all age groups in non-winter deaths were significantly elevated for respiratory illness from occupational agent exposure. PMR values were significantly elevated for those of the 25th percentile age group and older in non-winter deaths from respiratory cancer. In both winter and non-winter deaths, the PMR for chronic lower respiratory disease was significantly higher only for those above the 75th percentile in age group. For winter deaths, only those in the 25th-50th percentile age group and those above the 75th percentile had significantly elevated PMR values for COPD. For winter deaths, significantly elevated PMR values existed for at least one age group for deaths from respiratory cancer and respiratory illness from an occupational agent.

Being older than the median value of age more than doubles one's odds of death from stroke (OR 2.23 (1.479, 3.541) for 50th to 75th percentiles, OR 2.959 (1.913, 4.575) for 76th percentile and older). Dusty occupation was associated with increased odds of death from a cardiac pathology only in female workers above the median age (OR 1.139 (1.056, 1.228) for ages from 50th to 75th percentile, OR 1.161 for ages from 75th percentile onward). Male workers are 1.5 (OR 1.504 (1.429, 1.583)) times as likely to die from chronic respiratory diseases as their female colleagues. As age increases, the odds of dying from acute respiratory pathologies increase dramatically (ages from 25th to 50th

percentile: OR 1.976 (1.637, 2.384), ages from 50^{th} to 75^{th} percentile OR 3.908 (3.292, 4.640), ages from 75^{th} percentile onward OR 6.209 (5.244, 7.352)). OR for winter time and acute respiratory pathology is 1.204 (1.094, 1.326)

Discussion

A higher proportion of the deaths in workers from dusty occupations are due to COPD, myocardial infarction, chronic lower respiratory disease, respiratory illness caused by an occupational agent, and respiratory cancers when compared to workers of similar socio-economic status in non-dusty occupations. Furthermore, working in a dusty occupation is not a significant predictor of increased risk of death from stroke. Dusty occupation is a significant predictor of increased death from a cardiac pathology only in women between the 25^{th} and 75^{th} percentiles of the age distribution. Male workers in the study were 1.5 times as likely to die from a chronic respiratory pathology as female workers. Non-Caucasian workers were 0.73 times as likely to die from chronic respiratory pathologies as their Caucasian colleagues. Winter time increases ones odds of dying from an acute respiratory disease by 1.2 times. Furthermore, as age increases, the odds of dying from an acute respiratory pathology or stroke increase dramatically, regardless of one's industry type.

Introduction

Chronic obstructive pulmonary disease (COPD) is the third leading cause of death in the United States. (Johnson et al., 2014) Approximately 5-10% of the U.S. population (15-31 million people) are affected by COPD.(Eisner et al., 2010) Furthermore, currently available therapies (smoking cessation and supplemental oxygen) for controlling loss of pulmonary function are only slightly effective.(Dement et al., 2015; Eisner et al., 2010) Though cigarette smoking is the greatest risk factor for the development of COPD and accelerated loss of pulmonary function, (Balmes et al., 2003; Dement et al., 2015; Eisner et al., 2010) multiple studies suggest that occupational exposure to vapors, gases, dust, or fumes (VGDFs) contributes significantly to incident COPD and occupational lung diseases such as CWP.(Blackley, Crum, Halldin, Storey, & Laney, 2016; Graber, Stayner, Cohen, Conroy, & Attfield, 2014; Mannino, Homa, Akinbami, Ford, & Redd, 2002) Exposure to the following occupational agents has been associated with increased risk for the development of COPD: coal dust, asbestos, silica welding, cutting gases and fumes, cement dust, diesel exhausts, spray painting, organic solvents, and mineral fibers.(Dement et al., 2015) The current field of knowledge suggests that the population attributable fraction (PAF) of occupational exposure to VGDFs for those with obstructive impairment of the lungs ranges from 0.15 for smokers to 0.53 for never smokers.(Dement et al., 2015)

Among agricultural workers, exposure to pesticides has been found to cause significantly elevated rates of annual decline in lung function, approximately 6.9 mL/year in forced expiratory volume in one second (FEV_1), ultimately leading to a clinical diagnosis of pulmonary obstruction if the period of exposure is sufficient. (de Jong et al., 2014) In the Portegies et al. study, (2016) it was determined that a higher risk of both ischemic and hemorrhagic stroke exists in subjects with COPD; after an acute severe exacerbation episode, those with COPD had an over six-fold increase in stroke risk.

In the state of Kentucky, 91.8% of the construction industry is constituted of small-business firms. For white male small-business owners, 97.1% of the industry in this demographic group is construction.(*Kentucky Small Business Profile*, 2015) Furthermore, Kentucky employs the second highest number of coal-mine employees in the country, which constitute 14.3% of all coal miners in the country.(Ellis, 2016) There are over 77,000 farms in the state of Kentucky with over 111,000 total employees. Kentucky rates 2nd in tobacco production in the country and ranks in the top ten for hay and grass silage production.(*2012 Census of Agriculture State Profile : Kentucky*, 2014)

In Eastern Kentucky and the Appalachian region, counties with the highest levels of coal mining have significantly elevated mortality rates from chronic heart, respiratory and kidney disease when compared with the non-coal mining counties in the same region.(Hendryx, 2009) The prevalence of coal workers' pneumoconiosis (CWP), a type of occupational lung disease caused by overexposure to respirable coal dust and colloquially known as "black lung", initially declined after passage of the Coal Mine Health and Safety Act of 1969, but has been steadily increasing since the late 1990's. (Beggs, Slavova, & Bunn, 2015; Blackley et al., 2016; Graber et al., 2014) Given this resurgence of occupationally related lung diseases and the lack of effective therapies to prevent progression of COPD or CWP, mitigation and prevention of these diseases is vital. (Dement et al., 2015)

Contemporary literature suggests that there is a correlation between temperature extremes and increases in pneumonia & influenza (P&I) mortality rates. (Claeys et al., 2015; Davis, Dougherty, McArthur, Huang, & Baker, 2016; Davis, Rossier, & Enfield, 2012; Imai, Barnett, Hashizume, & Honda, 2016; Nawrot, Perez, Kunzli, Munters, & Nemery, 2011) Specifically, cold temperature extremes cause a significant increase in P&I mortality in those with compromised respiratory symptoms (e.g. a patient with pulmonary obstruction). (Claeys et al., 2015; Davis et al., 2016; Davis et al., 2012; Imai et al., 2016) Throughout the 20th century, no reduction in mortality risk has been seen with regards to extreme cold temperatures; in fact, the opposite effect has been seen, with either no effect on or a worsening of mortality during cold weather.(Astrom, Forsberg, Edvinsson, & Rocklov, 2013; Diaz, Carmona, Miron, Ortiz, & Linares, 2015) Furthermore, P&I and respiratory disease have been found to contribute significantly to incident Acute Myocardial Infarction (AMI) rates.(Claeys et al., 2015; Davis et al., 2016)

Multiple contributing factors have been suggested as to the mechanism by which cold temperatures and low humidity contribute to P&I mortality: namely, the contribution of acute respiratory infections to blood coagulation and inflammation in the vasculature, (Imai et al., 2016) seasonal indoor crowding enhancing transmission of influenza, low humidity conditions enhancing survival times of viral aerosols, (Davis et al., 2012) and drying of nasal mucous membranes.(Davis et al., 2016) A study conducted in Belgium (Claeys et al., 2015) examined mortality rates as a function of the following variables: air pollution (measured as PM_{10}, $PM_{2.5}$, black smoke, and ozone), influenza like illness (ILI) incidence rates (ILI/day per 10,000 inhabitants), temperature, and relative humidity. Multivariate Poisson regression determined that only temperature was significantly correlated with AMI incidence, leading to an 8% increase in risk of AMI for each 18^{o}F decrease in temperature.(Claeys et al., 2015) Other studies referenced in the text corroborated this increase in risk with decreasing temperature. In addition, incidence of AMI was highest during days with an average temperature below 32°F.(Claeys et al., 2015)

It is hypothesized that, when compared to the standard population, workers in "dusty" occupations (where VGDF workplace exposure is significant) die at significantly elevated rates from certain cardiac and pulmonary pathologies (AMI, stroke, COPD, chronic lower respiratory disease), due to the pulmonary obstruction caused by workplace VGDF exposure. Furthermore, it is hypothesized that, due to significantly lower temperatures and the excess risk of AMI or death from pulmonary conditions (e.g. pneumonia & influenza), (Astrom et al., 2013; Claeys et al., 2015; Davis et al., 2016; Davis et al., 2012; Diaz et al., 2015; Imai et al., 2016; Nawrot et al., 2011) there exists a temporal trend in mortality rates from pulmonary pathologies (e.g. asthma, pneumonia, acute exacerbation of COPD, lung neoplasms, chronic lower respiratory diseases), cardiovascular disease, and AMIs in the state of Kentucky (i.e. higher mortality rates exist in winter months).

Literature Review

A literature review utilizing PubMed was conducted to determine the current field of knowledge pertaining to occupational VGDF exposures and pulmonary function loss as well as increased mortality rates in exposed workers. Furthermore, multiple proportionate and standardized mortality studies were examined to establish a methodology for analyzing the data in this study.

A case-control study conducted on airway obstruction among construction workers examined the association between occupational VGDF exposures and risk for the development of COPD.(Dement et al., 2015) After adjustment for age, gender, race/ethnicity, smoking status (Current, Past, Never), cigarette pack-years, having a blood relative with COPD, and BMI the OR for developing COPD from all VGDF exposure ranged from 1.19 for those in the lower 25% of the 95^{th} percentile to 2.03 for those with exposure levels greater than 75% of the 95^{th} percentile for VGDF exposure.(Dement et al., 2015). Furthermore, the authors determined that occupational exposure to biological dusts led to significant increase in the odds of developing symptomatic emphysema (OR 3.18, 95% CI 1.41-7.13), asymptomatic emphysema (OR 1.89, 95% CI 1.07-3.34).

In a cohort study of Chinese pottery factory and metal mine workers, the association between long-term silica dust exposure and all-cause mortality and cause-specific mortality was examined. (Chen et al., 2012) The authors completed over 2 million person-years of follow up of the cohort; in the cohort, cardiovascular disease was the leading cause of death. (Chen et al., 2012) Non-malignant respiratory diseases, malignant neoplasms, infectious diseases, and cerebrovascular disease were the second to fifth causes of death respectively for all cohort members. After controlling for gender, year of hire, age at hire, type of mine/factory, and smoking, all-cause mortality was significantly higher in the group exposed to silica dust compared with the non-exposed group (HR 1.38, 95% CI 1.33–1.43). (Chen et al., 2012) Each $1mg/m^3$-year increase in cumulative silica dust exposure was associated with a 2.6% increase in mortality risk for all-cause mortality, 6.9% increase in mortality risk from respiratory diseases, and 3.1% increase in the mortality risk from cardiovascular disease.(Chen et al., 2012) After adjustment for potential confounders including smoking, silica exposure accounted for 15.2% of all-cause mortality, 63.9% of respiratory disease mortality, and 21.0% of mortality from CVDs among exposed workers.(Chen et al., 2012) Perhaps most intriguing is that, among individuals who worked in an environment with respirable silica dust concentrations equal to or lower than 0.1 mg/m^3, (which is the exposure limit for respirable silica dust promulgated by the US Occupational Safety and Health Administration) there was elevated mortality from all causes, pneumoconiosis, infectious diseases, malignant neoplasms including nasopharynx cancer and liver cancer, and CVDs including ischemic heart disease and hypertensive heart disease. (Chen et al., 2012)

Inherent in the use of death certificate data is the inability to determine the total number of exposed individuals. Without this denominator value, it is impossible to determine mortality rates due to a specific cause of death. However, this may be overcome by the calculation of a mortality ratio such as the standardized mortality ratio (SMR) or the proportionate mortality ratio (PMR).(Coggon, Harris, Brown, Rice, & Palmer, 2010) In comparing proportions of deaths due to a specific disease, the PMR and SMR do not require the total number of population at risk to be known. Multiple studies have utilized the SMR/PMR methodology to evaluate occupational exposure-related mortality rates and how these cause-specific rates compare to the general population.(Attfield & Kuempel, 2008; Coggon et al., 2010; Graber et al., 2014; Meltzer, Griffiths, Brock, Rooney, & Jenkins, 2008; Mohner, 2016; Welch, Dement, & West, 2015).

The work-related mortality in England and Wales study (2010) utilized death certificate data on all men in England and Wales age 20-74 years from 1979-1980 and 1982-2000. The study determined that, among the occupation groups, the highest number of excess deaths were attributed to COPD and pneumoconiosis in coal miners and pleural cancer related to asbestos exposure.(Coggon et al., 2010) Similarly, the Coggon, Inskip, Winter, and Pannett (1995) study utilized death certificate data from the census office (The Office of Population Censuses and Surveys) for all males aged 20-74 in Britain. PMR values for CWP varied from 1.35 to 38.25; indeed, mortality from chronic bronchitis and emphysema in coal miners was higher than in all other occupations combined.(Coggon et al., 1995).

Methods

Data Set

The study is a case-control analysis of Kentucky Death Certificate data from 2000 to 2006. The data used in this study was provided by the Office of Vital Statistics from the Kentucky Department of Health. The study is part of the broad spectrum of the Kentucky Occupational Safety and Health surveillance program which is approved by the University of Kentucky Institutional Review Board. Given that the data set did not include any personal identifiers and also that this study was supported by NIOSH grant number 5 U60 OH 008483-12 funded by the Centers for Disease Control and Prevention, IRB approval request was not submitted. However, given the lack of personal identifiers in the data and the fact that the data are for decedents, this study is exempt from IRB approval.

The data set included all death certificates from 1997 to 2016. Initially, the dataset included 849, 265 cases. Inclusion criteria in the dataset were the following: date of death between 01/01/2000 and 01/01/2007, resident of Kentucky, known gender, industry type coded for the case. Exclusion criteria were: not a resident of Kentucky, unknown gender, and industry type not coded. In order to sequester the cases of interest (i.e. those from specific occupations who died of pulmonary obstruction and / or pathologies associated with VGDF exposure), several criteria were applied to the data set. Figure 1 illustrates the steps taken to reduce the initial data set.

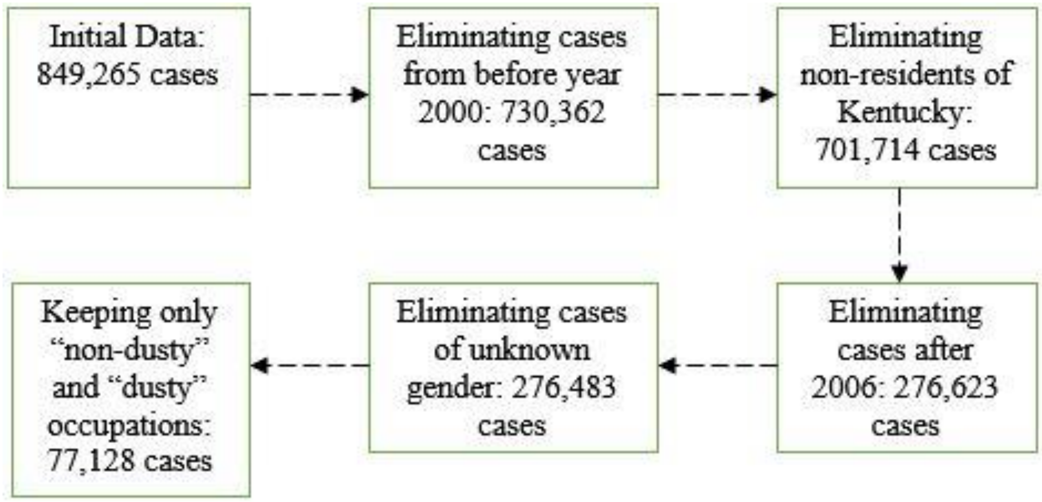

Figure 1: Flowchart indicating the process used to sequester the cases of interest from the initial dataset.

First, in order to eliminate the overlap between (ICD-9) and *International Classification of Diseases Tenth Revision* (ICD-10) coding for causes of death, all cases before the year 2000 were eliminated (ICD-10 was promulgated for coding cause of death beginning in 1999). Then, cases who were not residents of Kentucky at the time of death were eliminated. Within the dataset, industry classification was not coded for cases that occurred after 2006. Therefore, the next step eliminated all cases after 2006. The final step was to eliminate cases of unknown gender, which reduced the dataset to 276, 483 cases. Finally, the specific industry types of interest were identified and only cases from those industries kept in the dataset.

Industry Classification

Industry type was coded in the dataset using *1990 Census Industrial & Occupational Classification Codes*. Three industry types were chosen as “dusty”: coal mining (code: 041), agriculture & crop production (code: 010), and construction (code: 060). There were 35,494 cases classified as working in dusty occupations. Then, “non-dusty” industries of similar socioeconomic status were identified: manufacturing (unspecified) (code: 392), manufacturing (beverage) (code: 120), manufacturing (steel mill and blast furnace) (code: 270), manufacturing (motor vehicle assembly) (code: 351), manufacturing (apparel and accessories) (code: 151), manufacturing (household appliances) (code: 340), elementary and secondary schools (code: 842), trucking (code: 410), automotive repair (code: 751), railroad (code: 400), and the U. S. Postal Service (code: 412). 41, 634 cases were classified as working in non-dusty occupations. Descriptive statistics by industry are provided in Table 1.

For analysis, the pathologies of interest were: stroke (ICD-10 code: I63), myocardial infarction (ICD-10 codes: I21, I22, or I23), heart disease (ICD-10 codes: I24 or I25), COPD (ICD-10 code: J44), acute upper respiratory infection (ICD-10 codes: J00, J01, J02, J03, J04, J05, or J06), pneumonia and influenza (ICD-10 codes: J09, J10, J11, J12, J13, J14, J15, J16, J17, or J18), acute lower respiratory infection (ICD-10 codes: J20, J21, or J22), chronic lower respiratory disease (ICD-10 codes: J40, J41, J42, J43, J45, or J47), respiratory illness (due to occupational agent exposure) (ICD-10 codes: J60, J61, J62, J63, J64, J65, J66, J67, J68, J69, or J70), acute respiratory distress (ICD-10 code: J80), and respiratory cancers (unidentified neoplasms of the lung or bronchus) (ICD-10 codes: C30, C31, C32, C33, C34).

Analysis of age distribution

The median, 25th percentile, 75th percentile, and standard deviation of the age distribution of all cases in the final dataset (N=77, 128) were determined. Then, a dummy variable was created that placed cases in the following categories: age group 1 (0-25th percentile), age group 2 (26th percentile to median age), age group 3 (after the median age, up to 75th percentile) and age group 4 (after 75th percentile). The age values for these categories were: age group 1 (18-63 years), age group 2 (64-75 years), age group 3 (76-84 years), age group 4 (>84 years).

Proportionate Mortality Ratio Calculations

The proportionate mortality ratio (PMR) is a measure of how more or less likely a death in a dusty occupation is to be from a specific cause of death rather than other causes, than a death of someone of the same age and gender in non-dusty occupations.(Meltzer et al., 2008) It is absolutely vital that age-adjustment occur when calculating PMR values.(Meltzer et al., 2008) The PMR is calculated by firstly determining the proportion of deaths in the non-dusty industries caused by one of the eleven previously mentioned pathologies. Then, this expected proportion is compared to the proportion of deaths caused by the same cause of death in the dusty industries. The PMR fraction represents the chance of deaths from a specific cause in workers from dusty industries compared to those in non-dusty industries.(Meltzer et al., 2008)

PMR's for dusty versus non-dusty industries were calculated for each of the eleven pathologies of interest. Furthermore, the PMR values were age-adjusted by age group (the previously created dummy variable). Distinct PMR values were calculated for deaths occurring in winter and non-winter months. Winter months were defined as

December, January, and February, with non-winter months being March through November. The chi-squared statistic and corresponding p-values were calculated for each of the PMR values to elucidate statistically significant differences between dusty and non-dusty occupations.

Logistic Model

The outcome of interest in the model was that the underlying cause of death is included within one of the following pathology types: stroke, cardiac diseases, chronic respiratory diseases, or acute respiratory diseases. The ICD-10 code: I63 was used to classify stroke. Cardiac diseases included myocardial infarction, and heart disease. The following ICD-10 codes were used to classify a cardiac disease (ICD-10 codes: I21, I22, I23, I24, I25). Chronic respiratory diseases included COPD, chronic lower respiratory disease, respiratory illness from occupational agent exposure, and respiratory cancers or unspecified neoplasms of the bronchus or lungs. The following ICD-10 codes were used to classify a chronic respiratory disease (ICD-10 codes: C30, C31, C32, C33, C34, J40, J41, J42, J43, J44, J45, J47, J60, J61, J62, J63, J64, J65, J66, J67, J68, J69, J70). Acute respiratory diseases included acute upper respiratory infection, acute lower respiratory infection, pneumonia and influenza, and acute respiratory distress. The following ICD-10 codes were used to classify an acute respiratory disease (ICD-10 codes: J00, J01, J02, J03, J04, J05, J06, J09, J10, J11, J12, J13, J14, J15, J16, J17, J18, J80).

The covariates included in the model were the following: dusty occupation, age group, winter/non-winter status at time of death, gender, and race. Dusty occupation was coded as a dichotomous variable (1 representing yes, 0 representing no) with 0 (no) being the reference group. Age group was a categorical variable with 4 levels (please see

Analysis of Age Distribution subsection above for details of each level of the variable). The reference group for the age group variable was group 1, which represented values from the minimum of the age distribution up to quartile 1 (25^{th} percentile). Winter was dichotomous with the reference group being non-winter months. Gender was dichotomous with female being the reference group. Race was dichotomous (Caucasian or non-Caucasian) with Caucasian being the reference group.

Results

PMR Results, Non-Winter Deaths

PMR values and corresponding chi-square p-values for non-winter deaths are presented in Table 2. For non-winter deaths, the PMR for stroke was not significantly different between any of the age groups. For cardiac causes of death, in age groups 2, 3, and 4, the PMR due to myocardial infarction was significant: age group 2 (PMR 1.19, p = 0.002), age group 3 (PMR 1.31, p = < 0.0001), age group 4 (PMR 1.13, p = 0.03). There was no significant difference in the proportion of deaths due to heart disease in any of the age groups between dusty and non-dusty occupations. For the chronic respiratory diseases, the PMR's for death due to COPD were significant in age groups 2, 3, and 4: age group 2 (PMR 1.19, p = 0.0039), age group 3 (PMR 1.35, p = < 0.0001), age group 4 (PMR 1.80, p = < 0.0001). The PMR for chronic lower respiratory disease was significant only in age group 4 (PMR 1.58, p = < 0.0411). The PMR's for respiratory illness caused by occupational agent exposure were significant for all age groups: age group 1 (PMR 2.26, p = < 0.01), age group 2 (PMR 3.00, p = 0.0039), age group 3 (PMR 1.70, p = < 0.0001), age group 4 (PMR 1.75, p = < 0.0001). The PMR's for death due to respiratory cancer were significant in age groups 2, 3, and 4: age group 2 (PMR 1.14, p =

0.0004), age group 3 (PMR 1.22, p = < 0.0001), age group 4 (PMR 1.67, p = < 0.0001). None of the PMR's for the acute respiratory diseases were significant.

PMR Results, Winter Deaths

PMR values and their corresponding chi-square p-values for winter deaths are presented in table 3. For stroke as the cause of death, only age group 4 had a statistically significant PMR value (PMR 0.24, p = 0.04). For cardiac causes of death, in age groups 3 and 4 the PMR due to myocardial infarction was significant: age group 3 (PMR 1.29, p = < 0.0013), age group 4 (PMR 1.22, p = 0.03). As with non-winter deaths, there was no significant difference in the proportion of deaths due to heart disease in any of the age groups between dusty and non-dusty occupations. For the chronic respiratory diseases, the PMR's for death due to COPD were significant in age groups 2 and 4: age group 2 (PMR 1.25, p = 0.0174), age group 4 (PMR 1.77, p = < 0.0001). The PMR for chronic lower respiratory disease was only significant in age group 4: age group 4 (PMR 2.06, p = < 0.028). The PMR's for respiratory illness caused by occupational agent exposure were significant for age groups 2 and 3: age group 2 (PMR 2.68, p = 0.0014), age group 3 (PMR 1.62, p = 0.031). The PMR's for death due to respiratory cancer were significant in age groups 2 and 3: age group 2 (PMR 1.19, p = 0.005), age group 3 (PMR 1.26, p = 0.008). None of the PMR's for the acute respiratory diseases were significant.

Logistic Regression Results

Adjusted Odds Ratio estimates and corresponding 95% confidence intervals are presented in Table 4. For the outcome being an underlying cause of death of stroke, age group 3 and age group 4 were the only significant predictors; when controlling for all other variables in the model, the OR values were: age group 3 (OR 2.289, 95% C.I.

1.479, 3.541), age group 4 (OR 2.959, 95% C.I. 1.913, 4.575). In the model for an underlying cause of death from a cardiac pathology, when controlling for all other variables in the model, race (OR 0.885, 95% C.I. 0.815, 0.960) was a significant predictor; furthermore, significant interaction was present between dusty occupation and age group as well as between dusty occupation and gender. Odds ratios were calculated for all possible levels of interaction; the following levels were significant: dusty occupation for a female and age group 2 (OR 1.139, 95% C.I. 1.056, 1.228), dusty occupation for a female in age group 3 (OR 1.161, 95% C.I. 1.079, 1.250), dusty occupation for a male in age group 1 (OR 0.89, 95% C.I. 0.827, 0.958), and dusty occupation for a male in age group 4 (OR 0.85, 95% C.I. 0.785, 0.920). In the model for an underlying cause of death from a chronic respiratory pathology, gender (OR 1.504, 95% C.I. 1.429, 1.583) and race (OR 0.733, 95% C.I. 0.671, 0.801) were significant predictors of the outcome. Furthermore, significant interaction existed between dusty occupation and age group. The odds ratios were calculated for all possible levels of interaction; the following levels of interaction were significant: dusty occupation and age group 1 (OR 0.84, 95% C.I. 0.787, 0.898), and dusty occupation and age group 4 (OR 1.117, 95% C.I. 1.036, 1.204). In the model for an underlying cause of death from an acute respiratory pathology, winter (OR 1.204, 95% C.I. 1.094, 1.326) and age group were significant predictors of the outcome: age group 2 (OR 1.976, 95% C.I. 1.637, 2.384), age group 3 (OR 3.908, 95% C.I. 3.292, 4.640), age group 4 (OR 6.209, 95% C.I. 5.244, 7.352).

Discussion

The objective of this study was to determine if workers in dusty occupations died more frequently from chronic conditions caused by the VGDF exposure they experience in the workplace. Furthermore, it was hypothesized that cold temperatures would cause an increase in mortality from pulmonary and cardiovascular diseases. Two methods were used to analyze the relationship between occupational VGDF exposure and mortality rates from specific pulmonary and cardiovascular pathologies: proportionate mortality ratio calculations and a logistic model for determining which covariates are significant predictors of a death from a specific cause of interest.

The PMR results indicate that, in both winter and non-winter months, workers in dusty occupations had, in at least one age group, significantly higher PMR's for myocardial infarction, COPD, chronic lower respiratory disease, respiratory illness caused by an occupational agent, and respiratory cancers. However, in non-winter months, more age groups (14 out of the 28 total age groups) had significantly higher PMR's for dusty occupations. In winter months, only eleven of the possible 24 total age groups had significantly different PMR's for dusty versus non-dusty occupations. Therefore, this data suggest that overall, a higher proportion of the deaths in workers from dusty occupations are due to COPD, myocardial infarction, chronic lower respiratory disease, respiratory illness caused by an occupational agent, and respiratory cancers, which supports the original hypothesis that workers in dusty occupations would die at significantly higher rates from these diseases than those in non-dusty occupations.

The logistic results indicate that for death due to stroke, out of the covariates included in the model, only age group was a significant predictor. The OR estimates suggest that someone in age group 3 is over twice as likely to die from a stroke as someone from age group 1 who is of the same gender, race, occupation type, and time of year (winter or non-winter). Furthermore, the results suggest that someone in age group 4 is nearly three times as likely to die from a stroke as someone of the same gender, race, occupation type, and time of year (winter or non-winter) in age group 1.

For death due to a cardiac pathology, out of all the covariates included in the model, race, dusty occupation, age group, and gender were significant predictor variables. However, it should be noted that significant interaction was present between dusty occupation, age group, and gender. The OR estimate for race suggests that, when compared to a Caucasian of the same gender, age group, occupation type, and time of year, a non-caucasian is 0.885 times as likely to die from a cardiac pathology. Furthermore, a protective effect is seen in males in age group 1 and age group 4, where being in a dusty occupation for these groups makes 0.89 and 0.85 times as likely to die from a cardiac pathology, respectively. However, for a female worker in age groups 2 and 3, an increase in the odds of death due to cardiac pathology was seen, with a female worker in a dusty occupation being 1.139 and 1.161 times as likely to die from a cardiac pathology than a female worker of the same race, age group, and time of year in a non-dusty occupation. The suggested protective effect from the results is likely attributable to the healthy worker effect in that each of the industry types chosen for the dusty category is extremely labor intensive. If a worker develops cardiac issues, he is likely to stop working in these labor intensive jobs. Therefore, he would be missed when recording industry type, which is likely to be classified as unemployed or as the most recent job he worked before death.

For death due to a chronic respiratory pathology, gender, race, and dusty occupation were significant predictors of the outcome. Significant interaction existed between age group and dusty occupation. Keeping all other covariates in the model the same, a male worker is 1.5 times as likely to die from a chronic respiratory pathology as a female worker. Furthermore, if all other covariates are the same, a non-caucasian is 0.73 times as likely to die from a chronic respiratory pathology as a Caucasian worker. For workers in age group 1 and age group 4, working in a dusty occupation makes them 0.84 times and 1.117 times as likely to die from a chronic respiratory pathology respectively.

It should be noted that pneumonia and influenza were responsible for essentially all of the deaths caused by an acute respiratory pathology. For death due to an acute respiratory pathology, the logistic model suggests that, if all other covariates are kept the same, the time of year being a winter month leads to 1.204 times the odds of a worker dying from an acute respiratory pathology than a worker in a non-winter month. Furthermore, workers in age group 2 are 1.976 times as likely to die from acute pathologies as those in age group 1 with the same gender, race, time of year, and occupation type. Workers in age group 3 are 3.908 times as likely to die from acute pathologies as those in age group 1 with the same gender, race, time of year, and occupation type. Workers in age group 4 are 6.209 times as likely to die from acute respiratory pathologies in comparison with those in age group 1 with the same gender, race, time of year, and occupation type. These results are expected, because flu season peaks in the winter time and has higher fatality rates in elderly populations.

When using death certificate data, it is impossible to quantify exposure amounts. This is a limitation of this study that is unable to be mitigated, due to the type of data used. Furthermore, smoking status was not available for the cases used in the study. Given that smoking is the number one risk factor for both cardiovascular disease and chronic pulmonary obstruction, this is a significant weakness in the study. The investigators chose non-dusty occupations that were of very similar socioeconomic status in an attempt to compensate for the lack of smoking data. Also, industry data and work history data were reported by next of kin and as such are susceptible to recall bias. The selection of industries was subjective to the authors and introduces possible selection bias into the study.

The results of this study suggest that, overall, throughout the entire year, workers in dusty occupations die at significantly higher rates from acute myocardial infarctions, COPD, chronic lower respiratory disease, respiratory illness caused by occupational exposures, and respiratory cancers. Furthermore, winter time increases ones odds of dying from an acute respiratory disease by 1.2 times. Furthermore, as age increases, the odds of dying from an acute respiratory pathology or stroke increase, regardless of one's industry type.

The authors suggest that further research be conducted into effective methods of reducing workplace VGDF exposures and reducing risk factors for cardiovascular and chronic respiratory diseases among workers in dusty occupations. Furthermore, increased prudence should be used in the winter months to help mitigate the increased odds of dying from acute respiratory pathologies such as pneumonia and influenza that occurs in older populations.

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Appendix

		Age (years)		Gender		Race	
	N	**(Mean)**	**(SD)**	**(% Male)**	**(% Female)**	**(% White)**	**(% Non-White)**
Total	77128	75	15.7	78.4	21.6	94.5	5.5
Dusty Occupations	35494	74	16.3	97.4	2.6	95.6	4.4
Coal Mining	6675	74	14.5	98.9	1.1	98.3	1.7
Agriculture	11299	81	13.0	96.6	3.4	96.6	3.5
Construction	17520	69	17.1	97.3	2.7	94.0	6.0
Non-Dusty Occupations	41634	76	15.2	62.3	37.7	93.6	6.5
Manufacturing, unspecified	9881	73	15.2	65.8	34.2	93.5	6.5
Manufacturing, beverage	1322	80	12.2	66.5	33.5	94.9	5.1
Manufacturing, steel mill and blast furnace	1226	75	12.9	95.4	4.6	95.4	4.6
Manufacturing, motor vehicle	2883	72	14.9	85.4	14.6	93.8	6.2
Manufacturing, apparel and accessories	2342	81	12.7	11.1	88.9	95.5	4.5
Manufacturing, household appliances	1740	75	11.4	72.1	27.9	88.1	12.0
Elementary and Secondary Schools	10528	81	14.5	24.0	76.0	93.1	6.9
Trucking	5078	68	14.7	96.2	3.8	94.1	5.9
Automotive Repair	2625	66	17.1	97.6	2.4	95.2	4.8
Railroad	2320	78	11.8	95.0	5.0	94.2	5.8
U. S. Postal Service	1689	80	12.7	72.1	27.9	91.6	8.4

Table 1: Descriptive statistics by occupation

Non-Winter Deaths	Dusty	Non-Dusty		
Primary Cause of Death	**N (%)**	**N (%)**	**PMR**	**p-value**
Stroke				
age group 1	11 (0.15)	13 (0.17)	0.88	0.70
age group 2	13 (0.20)	20 (0.26)	0.77	0.50
age group 3	23 (0.34)	33 (0.42)	0.81	0.47
age group 4	21 (0.39)	34 (0.48)	0.81	0.46
Cardiac Pathologies				
Myocardial Infarction				
age group 1	815 (11.00)	831 (11.13)	0.99	0.81
age group 2	**798 (12.40)**	**809 (10.40)**	**1.19**	**0.0002**
age group 3	**769 (11.50)**	**692 (8.75)**	**1.31**	**< 0.0001**
age group 4	**553 (10.37)**	**649 (9.2)**	**1.13**	**0.03**
Heart Disease				
age group 1	426 (5.75)	432 (5.79)	0.99	0.93
age group 2	522 (8.11)	636 (8.18)	0.99	0.89
age group 3	632 (9.45)	787 (9.96)	0.95	0.31
age group 4	611 (11.46)	856 (12.14)	0.94	0.25
Chronic Respiratory Diseases				
COPD				
age group 1	213 (2.88)	179 (2.40)	1.20	0.07
age group 2	**489 (7.60)**	**495 (6.36)**	**1.19**	**0.0039**
age group 3	**575 (8.6)**	**502 (6.35)**	**1.35**	**< 0.0001**
age group 4	**375 (7.03)**	**276 (3.91)**	**1.80**	**< 0.0001**
Chronic Lower Respiratory Disease				
age group 1	28 (0.38)	37 (0.50)	0.76	0.28
age group 2	74 (1.15)	95 (1.22)	0.94	0.70
age group 3	63 (0.94)	80 (1.01)	0.93	0.67
age group 4	**42 (0.79)**	**35 (0.5)**	**1.58**	**0.0411**
Respiratory Illness (occupational agent)				
age group 1	**32 (0.43)**	**14 (0.19)**	**2.26**	**0.01**
age group 2	**79 (1.23)**	**32 (0.41)**	**3.00**	**< 0.0001**
age group 3	**132 (1.97)**	**92 (1.16)**	**1.70**	**< 0.0001**
age group 4	**136 (2.55)**	**103 (1.46)**	**1.75**	**< 0.0001**
Respiratory Cancer				
age group 1	948 (12.80)	937 (12.55)	1.02	0.65
age group 2	**1190 (18.5)**	**1262 (16.23)**	**1.14**	**0.0004**
age group 3	**707 (10.57)**	**684 (8.65)**	**1.22**	**< 0.0001**
age group 4	**226 (4.24)**	**179 (2.54)**	**1.67**	**< 0.0001**
Acute Respiratory Diseases				
Pneumonia & Influenza				
age group 1	53 (0.72)	53 (0.71)	1.01	0.97
age group 2	98 (1.52)	120 (1.54)	0.99	0.92
age group 3	212 (3.17)	232 (2.93)	1.08	0.41
age group 4	239 (4.48)	312 (4.42)	1.01	0.88
Note: There were less than 10 cases in every age group for acute respiratory distress and acute lower respiratory disease. Thus, these two causes of death were eliminated from the PMR calculations due to insufficient sample size.				

Table 2: Proportionate Mortality Ratio (PMR) values and corresponding chi-square p-values for non-winter deaths. Values in bold are statistically significant

Winter Deaths	Dusty	Non-Dusty		
Primary Cause of Death	**N (%)**	**N (%)**	**PMR**	**p-value**
Cardiac Pathologies				
Myocardial Infarction				
age group 1	301 (12.01)	286 (11.02)	1.09	0.27
age group 2	300 (12.20)	339 (11.38)	1.07	0.35
age group 3	**300 (11.75)**	**278 (9.11)**	**1.29**	**0.0013**
age group 4	**214 (10.12)**	**234 (8.32)**	**1.22**	**0.03**
Heart Disease				
age group 1	146 (5.82)	206 (7.94)	0.73	0.003
age group 2	193 (7.85)	251 (8.43)	0.93	0.43
age group 3	250 (9.79)	307 (10.07)	0.97	0.73
age group 4	238 (11.25)	335 (11.92)	0.94	0.47
Chronic Respiratory Diseases				
COPD				
age group 1	88 (3.51)	67 (2.58)	1.36	0.053
age group 2	**209 (8.5)**	**202 (6.78)**	**1.25**	**0.0174**
age group 3	215 (8.42)	219 (7.18)	1.17	0.084
age group 4	**144 (6.81)**	**108 (3.84)**	**1.77**	**< 0.0001**
Chronic Lower Respiratory Disease				
age group 1	21 (0.84)	22 (0.85)	0.99	0.97
age group 2	28 (1.14)	34 (1.14)	1.00	0.99
age group 3	32 (1.25)	30 (0.98)	1.28	0.34
age group 4	**23 (1.09)**	**15 (0.53)**	**2.06**	**0.028**
Respiratory Illness (occupational agent)				
age group 1	9 (0.36)	5 (0.19)	1.89	0.26
age group 2	**31 (1.26)**	**14 (0.47)**	**2.68**	**0.0014**
age group 3	**46 (1.80)**	**34 (1.11)**	**1.62**	**0.031**
age group 4	41 (1.94)	43 (1.53)	1.27	0.2726
Respiratory Cancer				
age group 1	321 (12.80)	326 (12.56)	1.02	0.80
age group 2	**439 (17.85)**	**447 (15.01)**	**1.19**	**0.005**
age group 3	**250 (9.79)**	**237 (7.77)**	**1.26**	**0.008**
age group 4	60 (2.84)	68 (2.42)	1.17	0.36
Acute Respiratory Diseases				
Pneumonia & Influenza				
age group 1	23 (0.92)	24 (0.92)	1.00	0.98
age group 2	42 (1.71)	47 (1.58)	1.08	0.71
age group 3	91 (3.56)	89 (2.92)	1.22	0.17
age group 4	134 (6.34)	157 (5.59)	1.13	0.27
Note: There were less than 10 cases in every age group for stroke, acute respiratory distress, and acute lower respiratory disease. Thus, these three causes of death were eliminated from the PMR calculations due to insufficient sample size.				

Table 3: Proportionate Mortality Ratio (PMR) values and corresponding chi-square p-values for winter deaths. Values in bold are statistically significant.

	OR	95% C.I.
Stroke		
Dusty occupation	0.74	(0.543, 1.009)
Winter	0.745	(0.540, 1.027)
Gender	0.907	(0.647, 1.270)
Race	0.975	(0.530, 1.792)
age_group 1 [A]	1	**
age_group 2	1.458	(0.908, 2.342)
age_group 3	**2.289**	**(1.479, 3.541)**
age_group 4	**2.959**	**(1.913, 4.575)**
Cardiac Pathology		
Race	**0.885**	**(0.815, 0.960)**
Winter	1.03	(0.990, 1.072)
Dusty Occupation [B]		
female, age_group 1	1.013	(0.939, 1.093)
female, age_group 2	**1.139**	**(1.056, 1.228)**
female, age_group 3	**1.161**	**(1.079, 1.250)**
female, age_group 4	0.968	(0.901, 1.039)
male, age_group 1	**0.89**	**(0.827, 0.958)**
male, age_group 2	1	(0.931, 1.074)
male, age_group 3	1.02	(0.950, 1.095)
male, age_group 4	**0.85**	**(0.785, 0.920)**
Chronic Respiratory Pathology		
Winter	0.986	(0.946, 1.028)
Gender	**1.504**	**(1.429, 1.583)**
Race	**0.733**	**(0.671, 0.801)**
Dusty Occupation [B]		
age_group 1	**0.84**	**(0.787, 0.898)**
age_group 2	1.026	(0.968, 1.088)
age_group 3	1.039	(0.976, 0.106)
age_group 4	**1.117**	**(1.036, 1.204)**
Acute Respiratory Pathology		
dusty occupation	1.047	(0.945, 1.160)
winter	**1.204**	**(1.094, 1.326)**
gender	1.047	(0.929, 1.181)
race	0.843	(0.674, 1.054)
age_group 1 [A]	1	**
age_group 2	**1.976**	**(1.637, 2.384)**
age_group 3	**3.908**	**(3.292, 4.640)**
age_group 4	**6.209**	**(5.244, 7.352)**

[A] This age group is used as reference for the other age groups. As such, it's OR=1

[B] Significant interaction between dusty occupation and age group and/or gender existed in the model. The specific conditions listed under dusty occupation represent all levels of interaction.

** This represents a value that is not applicable, since the covariate is used as reference.

Table 4: OR value estimates with 95% confidence intervals.

Note: values in bold are statistically significant.

	Beta (S.E.)	*p* -value
Stroke		
Dusty Occupation	-0.151 (0.079)	0.057
Winter	-0.148 (0.082)	0.072
Gender	-0.049 (0.086)	0.569
Race	-0.013 (0.155)	0.935
age_group 1 [A]	0 (**)	**
age_group 2	-0.195 (0.132)	0.139
age_group 3	**0.256 (0.113)**	**0.024**
age_group 4	**0.512 (0.113)**	**< 0.0001**
Cardiac Pathology		
Winter	0.015 (0.010)	0.148
Race	**- 0.061 (0.021)**	**0.004**
Dusty Occupation [B]		
age_group 1 [A]	0 (**)	**
age_group 2	**0.032 (0.016)**	**0.04**
age_group 3	**0.042 (0.016)**	**0.006**
age_group 4	**-0.049 (0.016)**	**0.003**
Gender	**-0.032 (0.010)**	**0.001**
Chronic Respiratory Pathology		
Winter	-0.007 (0.011)	0.516
Gender	**0.204 (0.013)**	**< 0.0001**
Race	**- 0.155 (0.023)**	**< 0.0001**
Dusty Occupation [B]		
age_group 1 [A]	0 (**)	**
age_group 2	0.0189 (0.015)	0.388
age_group 3	0.019 (0.016)	0.236
age_group 4	**0.055 (0.019)**	**0.004**
Acute Respiratory Pathology		
Dusty Occupation	0.023 (0.026)	0.377
Winter	**0.093 (0.025)**	**0.0002**
Gender	0.023 (0.031)	0.45
Race	-0.085 (0.057)	0.134
age_group 1 [A]	0 (**)	**
age_group 2	**-0.287 (0.048)**	**< 0.0001**
age_group 3	**0.396 (0.039)**	**< 0.0001**
age_group 4	**0.858 (0.038)**	**< 0.0001**

[A] This age group is used as reference for the other age groups. As such, it's parameter estimate is 0 (OR=1)

[B] Significant interaction between dusty occupation and age group and/or gender existed in the model. The specific conditions listed under dusty occupation represent all levels of interaction. For example, the beta value for Gender in the cardiac pathologies model represents the interaction term between dusty_occupation and gender (i.e. gender*dusty occupation)

** This represents a value that is not applicable, since the covariate is used as reference.

Table 5: Covariate parameter estimates with corresponding standard errors and p-values. Note: bold values are statistically significant.

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