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UNDIAGNOSED PULMONARY OBSTRUCTION AND RESTRICTION AND DUST EXPOSURE: PILOT INVESTIGATIONS EXAMINING THE RELATIONSHIP AMONG AGRICULTURAL WORKERS

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ABSTRACT OF CAPSTONE

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UNDIAGNOSED PULMONARY OBSTRUCTION AND RESTRICTION AND DUST EXPOSURE: PILOT INVESTIGATIONS EXAMINING THE RELATIONSHIP AMONG AGRICULTURAL WORKERS

ABSTRACT OF CAPSTONE

A Capstone project submitted in partial fulfillment of the requirements for the degree of Doctor of Public Health in the College of Public Health at the University of Kentucky

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ABSTRACT OF CAPSTONE

UNDIAGNOSED PULMONARY OBSTRUCTION AND RESTRICTION AND DUST EXPOSURE: PILOT INVESTIGATIONS AMONG FARM, TRADE, AND STATE FAIR PARTICIPANTS

Chronic obstructive pulmonary disease (COPD) is a progressive disease that is characterized by limited airflow.[1] In the United States (U.S.) alone, COPD is the third leading cause of death.[2,3] While smoking remains the strongest risk factor for COPD, 20 percent of patients who die from COPD have never smoked.[5–7] The American Thoracic

Society showed that about 15% of COPD cases might be attributable to workplace exposure.[8] Agricultural dust exposure has long been recognized as a cause of decreased respiratory function, and exposures to both forms of dust may exacerbate other important risk factors of COPD and lead to the development of lower respiratory disease.[17] The purpose of this capstone was to evaluate if there is an association between self-reported occupational/agricultural dust exposure and respiratory lung function through two independent pilot studies. The primary results from these pilot studies have identified an occupational group, agricultural workers, which may be at risk for pulmonary obstruction and restriction. Further, the results of these studies indicated that primary job occupational dust exposure may also increase the likelihood of pulmonary restriction in those exposed. The information collected in these pilot studies provided the authors with a range of risk factors that may place individuals susceptible for pulmonary obstruction and restriction and showed general trends which will be useful in the development of larger studies that further assess risk factors and the presence of obstructed and restricted pulmonary disease.

KEYWORDS: Chronic Obstructive Pulmonary Disease, Agriculture, Dust Exposure, Restrictive Airway Disease, Occupational Dust, Occupational Health and Safety

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UNDIAGNOSED PULMONARY OBSTRUCTION AND RESTRICTION AND DUST EXPOSURE: PILOT INVESTIGATIONS EXAMINING THE RELATIONSHIP AMONG AGRICULTURAL WORKERS

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2016

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UNDIAGNOSED PULMONARY OBSTRUCTION AND RESTRICTION AND DUST EXPOSURE: PILOT INVESTIGATIONS EXAMINING THE RELATIONSHIP AMONG AGRICULTURAL WORKERS

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Chapter 1: Introduction

Chronic obstructive pulmonary disease (COPD) is a progressive disease, characterized by limited airflow, that can present as emphysema and/or chronic bronchitis.[1] In the United States (U.S.), COPD kills approximately 120,000 individuals each year and is the third leading cause of death.[2,3] Affecting more than five percent of the population, COPD is also associated with high morbidity.[3] Despite being underdiagnosed, extensive medical resources use and frequent hospitalizations are a direct consequence of its prevalence and chronicity.[4] While smoking remains the strongest risk factor for COPD, 20 percent of patients who die from COPD have never smoked.[5–7] Furthermore, the American Thoracic Society showed that about 15% of COPD cases might be attributable to workplace exposure.[8] Additional risk factors for COPD include environmental exposure,[9–11] particularly among farmers and agricultural workers,[12–14] asthma,[15] atopy,[16] and other less defined attributes.

Since the 16th century, agricultural dust exposure has been recognized as a cause of decreased respiratory function.[17] There are two forms of agricultural dust that exists, organic and inorganic. Organic dust is a derivative of plant and animal sources and can be a contributing factor for restrictive airway diseases, such as asthma. Inorganic dust originates from soil and is a contributing factor to non-allergic lung reactions, such as obstructive lung diseases.[17] Exposures to both dust forms of dust may exacerbate other important risk factors for the development of COPD, and lead to the development of lower respiratory disease. Organic and inorganic dust exposures in an agricultural setting are often challenging to separate; therefore, they are typically assessed together.

Additionally, the various farming commodities produce different levels and types of dust exposure.

Screening for pulmonary disease in a primary care setting is a daunting task. The majority of patients with mild to moderate COPD have few symptoms, and often do not disclose symptoms to their providers.[18] COPD screening tests are rarely performed, even when symptoms of COPD are reported.[19] If tests are conducted, misdiagnosis is a common problem. Some of the COPD screening barriers include this lack of testing availability and experience using spirometry devices in primary care settings.[20]

Handheld spirometry was introduced into primary care settings to assess FEV_1/FEV_6. The forced expiratory volume in one second (FEV_1) is the maximal amount of air forcefully exhaled in one second, and the forced expiratory volume in six seconds (FEV_6) is the maximal amount of air forcefully exhaled in six seconds.[21] Handheld spirometry devices offer better patient compliance due to shorter testing times, increased ease of use, and increased repeatability without a loss of instrument sensitivity or specificity. And, the incorporation of handheld devices into primary practices is expected to increase early diagnoses of pulmonary disease, leading to better clinical outcomes and reduced disease progression.

The health risk for COPD can be measured by screening devices such as the Vitalograph® COPD-6® which measures FEV_1 and FEV_1/FEV_6. The ratio of FEV_1/FEV_6 has been identified as an alternative to FEV_1/FVC (forced vital capacity), the current Global Initiative for Chronic Obstructive Lung Disease (GOLD) standard.[22] The GOLD is a collaboration between the National Institute of Health (NIH) and the World

Health Organization (WHO) and provides guidance for the staging system that is used to classify people with COPD based on the degree of airflow limitation.

Problem Statement

Chronic obstructive pulmonary disease (COPD) is a progressive disease that is characterized by limited airflow.[1] In the United States (U.S.) alone, COPD is the third leading cause of death.[2,3] While smoking remains the strongest risk factor for COPD, 20 percent of patients who die from COPD have never smoked.[5–7] The American Thoracic Society showed that about 15% of COPD cases might be attributable to workplace exposure.[8] Agricultural dust exposure has long been recognized as a cause of decreased respiratory function, and exposures to both forms of dust may exacerbate other important risk factors of COPD and lead to the development of lower respiratory disease.[17]

Purpose of Capstone

The purpose of this capstone was to evaluate if there is a correlation between dust exposure and respiratory lung function. To this end, the authors enrolled in the study participants attending farm trade and health shows, and the Kentucky State Fair. The authors also evaluated additional risk factors that might influence the presence of undiagnosed obstructive pulmonary disease in the study population.

Research Question and Hypothesis

The present study addressed the association between self-reported occupational dust exposure and the presence of undiagnosed chronic obstructive pulmonary disease (COPD) via a cross-sectional study design. By using a Vitalograph® device to measure FEV_1 and FEV_1/FEV_6, participants were screened for COPD. The authors identified those participants at the pre-symptomatic stage of COPD, allowing for early medical intervention and better clinical outcomes.[23–25] The authors hypothesized, that relative to participants who reported no occupational dust exposure, individuals with reported occupational dust exposure would have a higher prevalence of abnormal lung function.

Significance

Previous epidemiologic data on occupational hazards suggest an association between farm work and the development of respiratory disease. The most significant of farm occupational hazard exposures come from dust, vapors, and gases that occur as part of daily routines, often in confined spaces, like barns.[26] The few prior studies that have focused on this association have found an association after adjusting to certain factors between COPD and dust exposure in small cohorts of agricultural workers, but these studies focused on individuals subgroups of agricultural workers, such as dairy farmers, poultry producers, and hog/pig farmers.[17] However, no study has evaluated the prevalence of COPD across a broad range of agricultural workers.

The current addresses the prevalence of undiagnosed COPD among agricultural workers and assesses the association between agricultural dust exposure levels and the presence of COPD. An additional aim focused on undiagnosed COPD among a general population of state fair participants with special focus on occupational dust exposure. Previous research has been limited to individual farming commodities and has not evaluated the prevalence of undiagnosed COPD among a population-based sample of agricultural workers. Therefore, the authors proposed to investigate the prevalence of undiagnosed COPD among agricultural workers and to assess the relationship between COPD and agricultural dust exposure as well as other pertinent risk factors via a cross-sectional study design.

Chapter 2: Literature Review

The following literature review is a summary of key concepts in Chronic Obstructive Pulmonary Disease (COPD) and occupational exposures and represents the theoretical and empirical knowledge including the pathogenesis, risk factors, and prognoses of COPD and occupational exposure. The works cited for this literature review are collected from medical texts, peer-reviewed articles, doctoral dissertations, and government documents. The databases and sources used to identify these areas of literature include Medline, PubMed, ProQuest, AgriCola, and AGRIS.

The first section of the literature review includes the historical background of occupational respiratory disease, with special consideration of target populations, the continuum of exposures and respiratory effects, and dust exposure assessment and evaluation. This section concludes with public health implications for future research, and a restatement of exposure and outcome assessments. The second section will consist of a summary of existing literature pertinent to the research questions, including the theoretical and empirical basis for investigating the association between COPD and exposure variables among occupations.

History of Occupational Respiratory Disease in Agriculture

Bernadino Ramazzini has been deemed the father of occupational medicine. His research focused on diseases of workers, and through clinical observation, Ramazzini documented workers' health problems, creating a knowledge base published in his earliest works *De Morbis Artificum*. As early as 1700, Ramazzini noted the risk of inhaling grain dust.[27] Despite the early recognition of agricultural hazards contributing to health risks, it is only since the 20th century that agricultural health hazards have been studied and documented by occupational health researchers.

Prior to the Industrial Revolution, agricultural workers came into close contact with animals, animal waste, crop commodities, particulate matter, and zoonotic infectious diseases. The majority of labor during this time was done by hand, or with the use of large livestock, making laborers vulnerable to health risks incurred by close contact with farming commodities. As veterinary schools were established following the Civil War, concern grew regarding zoonoses, e.g., hog cholera, trichinosis, and tuberculosis.[28] One of the first studies linking respiratory illness to agricultural workers was published in 1932 by U.S. researchers who found that hypersensitivity pneumonitis or "farmer's lung" was associated with exposure to spoiled hay. This was centuries after Ramazzini had a made a similar comparison.[29] As the 19th century approached, farming practices transformed along with scientific, medical, and educational standards. While innovations to agriculture improved some conditions that were previously thought to cause illness, the introduction of other innovations, such as pesticides brought additional concerns that global researchers and industry leaders continue to address.

Agricultural workers have long been championed as a physically fit class of workers. In Thomas Jefferson's letters, he wrote of farmers:

> "Cultivators of the earth are the most valuable citizens. They are the most vigorous, the most independent, the most virtuous, and they are tied to their country and wedded to its liberty and interests by the most lasting bonds".[30]

Unfortunately, the notion of the reliable, healthy farmer is inaccurate. Agriculture is one of the most hazardous professions with significant morbidity and mortality risks due to agricultural hazards. Respiratory disease among agricultural workers remains an important public health problem, for example, in the U.S. alone, this affected population is comprised of more than five million individuals.[31]

Target Population

In April, 1962, the World Health Organization (WHO) convened to discuss the topic of occupational health in agriculture. Farming had established itself as an industry, and given the farming labor force size, the industry was deemed "big business". The committee established a definition for agricultural worker, which stated that an "agricultural worker be taken to mean any person engaged either permanently or temporarily, irrespective of his legal status, in activities related to agriculture…" Furthermore, agriculture was defined as activities connected with the growing, harvesting, and processing of farm commodities which includes crops, animals, and garden produce. The committee went on to broadly describe public health problems related to agriculture including issues related to demography, physical environment, significant diseases, the social environment, and working conditions.[32]

In 1962 the worldwide agricultural workforce reportedly consisted of 207,869,325 persons in a global working population of 476,476,556, or 43.6 percent of all working individuals.[32] According to the U.S. Department of Agriculture's Economic Research Service, in 2012 there were 1,063,000 agricultural workers and the total employment was only one percent of all U.S. wage and salary workers. This sharp decline is attributed to the growth of the U.S. labor force.[33] Current statistics indicate that the number of farms and individuals living on farms in the U.S. is steadily declining. However, the decrease in traditional farm families has been matched by an increase in seasonal and migrant agricultural workers. While the agriculture industry has experienced great changes in the last century, the industry continues to thrive as one of the largest U.S. industries.

The U.S. agricultural workforce (owner and operator) predominately consists of older, white males. According to the 2012 agricultural census, 96 percent of all farm operators were white and the average age of principal farm operators was 58.3 years, which is consistent with a 30-year trend of increase in age. Of all hired agricultural workers, 45 percent are Hispanic and 27 percent have less than a 9th grade education.[34] More specifically, the seasonal labor force is predominately young, male, Hispanic, and without U.S. citizen status.[35]

The number of U.S. farms has been steadily declining since the mid-20th century, but this decline was met by the arrival of factory farming, bringing more rigorous and industrious agricultural methods. With this six-fold increase in productivity, agricultural workers face new hazards such as chemicals, fertilizers, increased mechanization, and other innovations.[36] These changes have brought forth a number of concerns regarding the respiratory health of the agricultural workforce.

Special Considerations for Agricultural Workers

Smoking

It has generally been accepted that farmers smoke less than other occupations.[31] According to the National Health Interview Survey for the years 2004-2012, the prevalence of smoking is 18.3 percent for men and women working in the agriculture, forestry, fishing, and hunting industry, which is below 19 percent, the smoking prevalence for all working adults in the United States.[37]

Healthy Worker Effect

There are four components of the healthy worker effect including the healthy hire effect, the healthy worker survivor effect, the time since hire effect, and the beneficial effect of work itself. The healthy worker effect has been shown to occur in the agricultural sector.[38] Despite variability among individual components of the healthy worker effect, instances of this effect are well documented and are a primary consideration in assessing this report.

A healthy hire effect occurs because employers have the right to reject individuals for employment due to limitations in physical abilities and/or poor health.[39] Therefore, an employer will inherently choose to hire individuals who are healthy and capable of performing job duties. Healthy hire effect often comes into consideration when extensive pre-employment screening is done prior to a formal offer of employment. In the agricultural industry, this is not a primary concern. However, if the healthy hire effect were to occur, it would result in a lower than expected morbidity rate.

The healthy worker survivor effect occurs when employees do not have a strong desire to work because of health problems. These employees self-select themselves out of the workplace and these employees generally change jobs or retire early. Research has demonstrated that agricultural workers change jobs due to health problems.[40–42] The time since hire effect occurs when a decline in health occurs the longer the time since hire. For instance, farmers with dust exposure that have been working for over 15 years have a higher cumulative exposure of dust, but recent hires exposed to dust would have a lower cumulative exposure.

Beneficial effect of work itself is another component of the healthy worker effect that implies that working individuals will have better access to healthcare, disease screening, and physical exercise. It seems reasonable to assume that working increases access to healthcare by giving employees insurance and other access to medical benefits. However, the extent of this beneficial effect of work in occupational health studies is debatable.[39] The majority of farmers are self-employed and, prior to the Affordable Care Act, many relied on insurance coverage from a spouse.[43]

Continuum of Exposures in Agriculture

Agricultural workers are exposed to a wide variety of inhalation exposures on the job: organic and inorganic dust; microorganisms; fungal toxins; endotoxins; allergens; gases and fumes; chemicals; and fertilizers and pesticides. While there are several industry standards that regulate exposure to chemical agents, some standards are still lacking for biological agents. It is widely acknowledged that agricultural workers are often exposed to levels of chemical and biological agents in excess of industry standards.[31]

Exposure patterns are variable among agricultural workers, which can often pose challenges with assessing exposure. For instance, most agricultural workers are involved in a wide variety of farming activities, placing these individuals at an increased risk for multiple respiratory exposures. These exposure patterns can be cyclical so that individuals are exposed disproportionately given the season, and what commodity might be ready for tending and harvesting. Geography and climate can also play a role in the exposures of agricultural workers.

Exposure assessments for respiratory irritants use the same principals as in general industry.[44,45] With the exception of measuring organic dust, sampling and analytic techniques have been well defined by the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Government Industrial Hygienist (ACGIH). While measurements of gases and dust are possible, the agriculture industry proves to be a challenging area to obtain accurate samples. Despite repeated sampling, costly and time-consuming variations still occur due to geography, climate, and seasonality.[31] Some researchers have turned to proxy measurements for gases and dust, given the costly nature of exposure assessment in the agriculture industry. Additionally, since many standards do not exist for organic dust and biologics, the industry must rely on exposure-response relationships to demonstrate hazards. However, these agents can be challenging to obtain given that little knowledge is known regarding the health effects of dust exposure in agriculture.

Inorganic Dust Exposure

Dust can broadly be characterized as inorganic or organic dust. Inorganic dust exposure occurs as a result of agricultural workers plowing and transplanting crops. Inorganic dust comes predominately from soil, and contains harmful inhalant minerals such as silicates, calcium carbonate, and salts. Respirable crystalline silicates pose the most intense threat as they predominate most soils in moist climates. Associations between silicates and respiratory health effects have been well documented.[46] According to Guthrie et al. (1993), exposure to agricultural quartz is generally considered less hazardous than quartz from other industries due to the industrial exposure of quartz to weathering and chemical interactions. However, clays in soil potentially contain hazardous minerals such as pesticides and other chemical residues which can be carried into the airway.[47]

The National Institute of Occupational Safety and Health and other international agencies have well-established standards for sampling and analyzing inorganic dust.[44,45,48,49] Despite these establishment standards, few studies have been conducted in agriculture to evaluate the extent to which workers are exposed to inorganic dust. The available data focuses on one commodity, rather than representing the more common trend of agricultural laborers working across a continuum of exposures. As previously noted, there are challenges with obtaining samples to reflect accurate exposures, with the exception of the agriculturally unimportant respirable quartz analysis.

Inorganic dust exposure on farms is most often associated with soil preparation and crop harvesting. These farming activities are significantly affected by whether or not an individual is working with an open or closed cab tractor; tractors tending to soil can generate large dust clouds.[50–52] The NIOSH standard for particulates not otherwise regulated (PNOR) cites that OSHA permissible exposure limit at 15 mg/m^3 for total dust concentrations and 5 mg/m^3 for respirable dust concentrations.[53] Studies have shown that open cab operators are exposed to 80-100mg/m^3 of total dust. In one study, investigators found dust levels as high as 80mg/m^3 during California farming operations in open cab tractors.[54] Personal respirable quartz exposure was found to be up to 3.91 mg/m^3 in one North Carolina study of closed cab operations, leaving industry leaders to question what level might be found in open cab operations. Sandy soil, such as in North Carolina, is known to increase risk of crystalline silica exposure.[55] An Swedish study found similar quartz exposures of farmers, averaging 2mg/m^3.[52] While around ten percent of total dust that has been identified in haymaking and combine operations, total dust concentrations are found to be in the range of 1-20 mg/m^3.[50,56] In several studies evaluating tree and fruit harvesting, the majority of total dust exposure exceeded industry standards[57] with quartz concentration at a higher percentage than inhalable dust fractions.[58] Grain operation is generally reported to predominantly cause organic dust exposure; however, one study reported inorganic dust exposure to be 15 to 53 percent of total dust. It is thought the majority of this exposure occurs via the distribution system as inorganic matter deposits due to cleaning procedures.[59]

Few studies have estimated the number of agricultural workers exposed to inorganic dust. The majority of these studies made inferences regarding farming operation and commodity, and drew conclusions based on the inorganic dust composition present in those operations. Prevention efforts become challenging with regard to inorganic dust particles given the absence of prolific data. Furthermore, agriculture is a multifaceted industry and consideration must be given to an array of factors to appropriately assess inorganic dust exposure.

Organic Dust Exposure

Organic dust has been broadly defined as the dried particles of plants, animals, fungi, or bacteria that are fine enough to be inhalable or respirable. Exposure to organic dust occurs in agriculture as a result of a variety of farming practices and commodities. Generally, organic dust exposure varies significantly from one occupation to the other, and it is not always the predominate dust found. For instance, mold, spores, mycotoxins, and endotoxins frequently comprise organic dust particles. Exposure to organic dust has been documented to cause respiratory illness and disease, including allergic asthma, chronic bronchitis, hypersensitivity pneumonitis, organic dust toxic syndrome, and 'silo fillers disease'.

Few standards exist for the majority of organic dust. In the U.S., OSHA issues nonspecific dust standards for particulates not otherwise regulated (PNOR). The OSHA permissible exposure limit (PEL) is 15mg/m^3 for inert or nuisance dust. The American Conference of Governmental Industrial Hygienist (ACGIH) sets limits at a 10mg/m^3 time weight average (TWA) for inhalable particles. International standards have been established that are similar or more stringent with regard to dust PNOR. Additional standards have been developed for grain, wood, and cotton dusts. NIOSH and the ACGIH have issued a threshold limit value (TLV) and a recommended exposure limit (REL) of 4mg/m^3 for grain dust. OSHA has issued a PEL of 15mg/m^3 for wood dust as it falls under the PNOR while NIOSH recommends a TWA of 1mg/m^3 and ACGIH a TWA of 0.5-1mg/m^3 depending on the wood type. Cotton dust carries a TWA of $<$0.200mg/m^3 set by NIOSH. [60]

Microorganisms

Agricultural workers are often exposed to microorganisms, as bacteria are common in soil. There are several components of bioaerosols including viruses, bacteria, fungi, endotoxins, mycotoxins, allergens, and other animal proteins. These organisms are harmful to respiratory health when infectious and non-infectious bioaerosols are present in an agriculture setting. Non-infectious bioaerosols are known to be responsible for more frequent morbidity in agriculture, including being an array of pulmonary conditions induced by dust exposure. Exposure to infectious organisms may cause more serious consequences for agricultural workers.[61,62]

Assessing bioaerosols in agriculture presents challenges for several reasons. Multiple samples are generally needed to appropriately assess the level of bioaerosols in the environment. Organisms can impede the growth of each other in culture, therefore some organisms might be underestimated or not even fully acknowledged. Further, geography, time, and spatial variation play a role in agricultural environments, making accuracy assessment of bioaerosols a challenge. While the methodology has been established to assess bioaersols there are no standards for microorganisms presence in the agriculture industry.[63]

Prevention of agricultural exposure to microorganisms includes personal protective equipment, environmental modifications, and innovative exhaust and ventilation systems. Farm tasks such as: chopping and dropping hay or compost; handling spoiled hay, grain, or feed; tilling; and uncapping silos all pose significant threats to exposure to microorganisms. Wearing respirators, wetting down materials prior to handling, and implementation of ventilation and exhaust systems can significantly reduce the likelihood of exposure to these harmful microorganisms.

Mycotoxins and Endotoxins

Mycotoxins are toxins that are produced by fungi that are hazardous to both humans and animals. Some fungal species produce mycotoxins to inhibit the growth of other organisms. The health effects of mycotoxins are unknown in agriculture, with few exceptions. Aflatoxin from *Aspergillus* spp. is one of the most well-known mycotoxins identified in the agriculture industry, and is also a known human carcinogen.[64] Other mycotoxins of *Fusarium* spp. and *Penicillium* spp. can contaminate the respirable fraction of airborne corn dust and cotton dust. While many studies have been published evaluating mycotoxins in the food chain, few studies have been published that evaluate airborne concentrations in the agriculture industry.

Endotoxins are lipopolysaccharides that are heat-stable molecules from the outer membrane of gram-negative pathogens. Exposure to endotoxins has been recognized as an important etiologic factor in occupational respiratory conditions caused by organic dust exposure.[31] The International Commission of Occupational Health has determined that 'organic dust toxic syndrome' can occur in exposed workers at 1000-2000ng/m^3 and bronchoconstriction can occur at 100-200ng/m^3.[65] Limitations in pulmonary function and chronic respiratory conditions have been reported, along with a significant dose-response relationship.[66] Previous literature suggests that farmers especially are at an increased risk for respiratory morbidity as a result of endotoxin exposure.[67–76] There are no regulatory standards for mycotoxin and endotoxin exposures, however the ACGIH has proposed that levels be compared to background levels and that levels exceeding ten times the background level be considered hazardous.[45] Control of animal waste is an important component of preventive strategies for endotoxin exposure. While elimination efforts are paramount, these are unrealistic in the agriculture industry therefore efforts should be shifted to focus on modification to how feed or bedding is distributed, e.g. wetting or the implementation of oil misting systems.

Allergens

Allergens are specific antigens that are capable of mounting a hypersensitivity reaction in individuals via immunoglobulin responses. In agriculture, microbial exposure can lead to a Type-I hypersensitivity in atopic individuals. These hypersensitivities can produce immune response and provoke allergic reactions that consist of various respiratory responses. Allergens specific to agriculture have been defined as potential occupational allergens, and include domestic, food, and wild animal proteins, and mold.[31] Agricultural dust does not just contain allergens that are specific to the farming environment, but also carries the common allergens that affect individuals nationwide, including house dust, pet dander, and pollens.

Type-I allergens of storage mites have been extensively studied; these mites flourish in humid, moldy environments. Storage mites Type-I allergens have been linked to agricultural worker health since the 1980s, and while there is a paucity of reliable exposure levels, respiratory effects have been well documented.[77–82] Cross-reactivity has been cited as a major concern in assessing the impact storage mites have on the respiratory tract of agricultural workers, and several studies have determined that storage mites themselves are not a specific problem in the agricultural industry.[82]

Animal proteins have not only been established to be a potent allergen for the general population, but they are especially important in the etiology of allergies among agricultural workers. Animal proteins are associated with hair, dander, feces, and any other biologic that is associated with dust. Farmers are highly exposed to these proteins in the livestock industry and yet only a few studies have evaluated the association between animal protein allergens and agricultural workers. Of those that have evaluated this association, work-related respiratory allergy symptoms were reported.[12]

Pesticides

Pesticide exposure in the agriculture industry is a common occurrence. With over 1,000 registered insecticides, herbicides, fungicides, and other subcategories of pesticides, the most common routes of exposure for agricultural workers are dermal and inhalation. Exposure has been found to occur in a variety of farming tasks, including the production, transportation, preparation, and application of pesticides.[83] Exposure is greatly influenced by the method, quantity, duration, temperature, humidity, and presence of personal protective equipment.[84,85] Researchers have also found a substantial amount of evidence that agricultural worker exposures extends beyond the workplace, and is linked with family and in-home exposure.[86–89] Inhalation exposure has been cited with a range of pesticides and in general, volatile liquids were responsible for the report of respiratory symptoms. According to Dowling et al. (2002), inhalation exposure makes up approximately ten percent of all exposure.[85]

Standards exist for some pesticides, especially those recognized by the U.S. Environmental Protection Agency (EPA) as a known or suspected carcinogen. The agencies that support these standards consist of NIOSH, OSHA, and ACGIH. Monitoring for pesticide exposure can be a challenge but with the introduction of biomarkers, research has made significant advancements in understanding the effect of pesticides on humans at specific levels.

Miscellaneous Gases, Fumes, and Chemicals

Additional research has focused on a variety of other gases, fumes, or chemicals to which individuals in the agricultural industry are exposed. Notable sources include exposure to decomposition gases, silo gases, and contaminant gases that result from farming activities such as welding and fuel usage.

Chronic Obstructive Pulmonary Disease in Agriculture Populations

Chronic Obstructive Pulmonary Disease (COPD) is the fourth leading cause of death in the world.[90] Both preventable and treatable, COPD presents an important public health challenge. Affecting more than five percent of the population, COPD is also associated with high mobidity.[3] Despite being underdiagnosed, extensive medical resource utilization and frequent hospitalizations are a direct consequence of its prevalence and chronicity.[4] While smoking remains the strongest risk factor for COPD, 20 percent of patients who die from COPD have never smoked.[5–7] Furthermore, the American Thoracic Society showed that about 15% of COPD cases might be attributable to workplace exposure.[8] Additional risk factors for COPD include environmental exposure,[9–11] particularly among farmers and agricultural workers.[12–14]

Definition and Overview

The American Thoracic Society defines COPD as "a common and treatable disease characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways of the lungs to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients." [90]

COPD is characterized by obstructive and restrictive lung disease. The pathology of COPD is characterized by airway inflammation, structural changes, and mucociliary dysfunction. In patients with COPD, chronic inflammatory changes occur, allowing for immune system inflammatory cell types (i.e. neutrophils, $CD8^+$ T-lymphocytes, B cells and macrophages) to accumulate and release inflammatory mediators. These inflammatory mediators help to sustain the inflammation, leading to tissue damage and other systemic effects. Persistent inflammation causes various structural changes to the lung and affects airflow limitation. Airway remodeling occurs as a result of three main factors: peribronchial fibrosis; scar tissue from airway damage; and hyper-multiplication of the epithelial cells lining the airways. Loss of elasticity leads to emphysema, resulting in impeded airflow, air trapping, and reduced lung capacity. Mucociliary dysfunction also occurs as the inflammation enlarges the mucous glands that line the airways, replacing healthy cells with more mucus-producing cells. The mucociliary transport system becomes damaged and unable to clear the airways, ultimately blocking and worsening airflow.[91]

Spirometry is the best-measured and reproducible test of lung function and is widely available. Other handheld devices have entered the market to identify those at risk of COPD at the pre-symptomatic stage to allow early medical intervention.

Burden of COPD

The burden of COPD varies across countries and among different groups. However, COPD remains a leading cause of morbidity and mortality worldwide and results in substantial economic burden to the health system. Generally, the prevalence of COPD is directly tied to long-term cigarette smoking, as smoking is the most important risk factor for COPD. The Global Initiative for Obstructive and Lung Disease (GOLD) reported in 2015 that the majority of national data show that less than six percent of the adult population has been told they have COPD.[90] Organizations have fully recognized that this reflects the widespread underdiagnosis or missed diagnosis of COPD.[92] While these intricacies have made it a challenge to truly estimate the prevalence of COPD, researchers have developed new strategies to generate more accurate estimations. The

Burden of Obstructive Lung Disease (BOLD) program is one example of such programs. Through survey-based research carried out in several countries, researchers found the prevalence of COPD to range from three to 11 percent among never-smokers.[93] Studies evaluating the morbidity of COPD are generally sparse, given that morbidity from COPD is affected by other chronic conditions such as cardiovascular disease and diabetes; therefore, mortality data remains the most reliable COPD statistic. The definition of COPD is variable; therefore, the data must still be interpreted cautiously in order to account for differences in definition as well as presence or absence on death certificates as a contributing cause of death. Currently, COPD is ranked the fourth leading cause of death in the world and the third in the U.S..[94] The Global Burden of Disease Study projected that COPD will be the third leading cause of death in 2030 unless action is taken to reduce the many underlying risk factors.[95]

Economic and Social Burden

The economic burden of COPD on the world is substantial. The total direct costs of respiratory disease are estimated to be approximately six percent of the total health care budget, and COPD accounts for 56 percent of this cost.[17] Exacerbations from COPD contribute the largest burden, as they require lengthy and costly visits to the hospital. Further, COPD directly impacts family financial stability by often forcing people out of the workforce to care for themselves or a family member suffering from COPD. Researchers have developed a method of estimating the portion of burden of individual health problems, called Disability-Adjusted Life Years (DALYs). It represents the sum of years lost because of premature death and years lived with disability from disease. Researchers found that COPD ranked ninth among the leading causes of DALYs in 2010, and they found that chronic respiratory disease accounted for 4.7 percent of global DALYs, with COPD representing two thirds of the total.[96]

Risk Factors for the Agricultural Worker

Exposure to Particles

Exposure to cigarette smoke, through active or passive smoking, is the most commonly reported risk factor for COPD. Active smokers report a high prevalence of respiratory symptoms, lung function decline, and mortality rates relative to non-smokers (44). Passive smoking increases lung exposure to harmful particles and gases resulting in increased respiratory symptoms and COPD (49,50).

Occupational exposures, including organic and inorganic dust, chemicals, vapors, and fumes are known risk factors for COPD. While these agents are often underrepresented in the literature, they are considered to be a major contributor to the 20 percent of non-smoking individuals diagnosed with COPD.[59] In one large, population-based-study utilizing the NHANES III survey, researchers found that for adults aged 30-75, COPD was attributable to work exposure in 19.2 percent overall, and in 31.3 percent among never smokers.[58] While not a large concern in developed countries, in less developed countries, exposure to wood and biomass fuel presents a large opportunity for exposure to particles that contribute to disease development and progression of COPD. An estimated three billion people are reported to use these sources for heating, cooking, and other household needs.[60-63] Indoor and outdoor air pollution has also been linked to the presence of COPD. While potentially small, the role of outdoor air pollution in the development of COPD is exacerbated by long-term exposures. Difficulty remains in assessing the effects of the single pollutants responsible for such spurious associations.

Smoking has been widely accepted as the primary risk factor for COPD. However, there are extensive epidemiologic studies that demonstrate chronic obstructive lung disease among non-smokers. It is clear that COPD results from gene-environment interactions. Despite the presence of smoking, it is understood that not all smokers will develop disease due to their differences in genetic predispositions. Therefore, researchers have acknowledged that risk factors are interrelated in the emergence of COPD. For instance, age and gender are risk factors that can affect if individual smokes or what occupation they may hold. These various interactions can all impact the COPD gene-environment. Extensive research is required to understand the relationships and interactions among the many risk factors that influence COPD.

Smoking

Research has shown that farmers smoke less often than the general population.[97–99] Despite this finding, a higher prevalence of COPD has been found in agricultural workers exposed to livestock, particularly those exposed to swine, cattle, and poultry.[26,100–102] Hoppin et al. (2014) reported that, despite lower smoking rates, a reduced risk of obstructive airway disease and symptoms was not present in agricultural workers.[98] These findings indicate that while smoking is a causal pathway for COPD, additional factors such as occupational particulate exposure maybe contribute to disease development and progression.

Age and Gender and Socioeconomic Status

Age is an independent risk factor for COPD; however, it remains unclear if normal aging leads to COPD or if age is correlated with exposure over time. This is especially significant for an agricultural population with known exposures. Typically, farmers and farm workers work well into their 60s, some even longer. It is possible the development of COPD is related to natural, healthy aging, but it equally possible that it is a result of cumulative exposure to occupational hazards such as dust, pesticides, and toxins. Gender has also been found to be an independent risk factor for COPD. Some studies have shown the prevalence of COPD to be greater among men than women.[18,34,96] However, recent reports suggest the prevalence is more equivocal, citing changes in tobacco use.[36-38] It is unclear if women are more susceptible to COPD than men given equal exposure; however, several reports have emerged supporting this hypothesis.[103,104]

Farmers have been predominately male; however, recent reports suggest women are more commonly entering the agricultural field. Agricultural workers often are faced with synergistic components influencing the presence of COPD. For instance, agricultural workers that do not have to leave the profession due to illness (healthy worker bias) often remain employed longer than the average employee. In addition, these workers are faced with significant occupational hazards, which also places them at an increased risk for COPD. Strong evidence suggests that socioeconomic status is a risk factor for COPD. Poverty and chronic diseases are often correlated. Individuals from a lower socioeconomic status generally have access to a lower quality of care, and have limited knowledge of prevention methods.[105] This is especially apparent in rural areas, where farming practices are common.

Genes

The primary genetic risk factor that is most documented in the literature is the presence of the alpha-1 antitrypsin gene. While this affects a small portion of the world's population, there has been a document association between the presence of the gene and

COPD.[106] Additionally, familial history of COPD has also been observed, especially among siblings who smoke and have severe COPD.[107] While few genome-wide association studies (GWAS) link the sections of the genome to COPD, researchers acknowledge the vast possibility of other genes that may contribute to disease development and progression. As the human genome continues to be studied, revelations are likely to be made regarding COPD as well as other respiratory conditions.

Chapter 3: Methodology

<u>Introduction</u>

The following chapter will be broken up into several sections for the two independent studies conducted. While some aspects of the methodology are the same for each study, careful consideration will be given to specify the differences in the participants, procedures, and data analysis conducted for the two pilot studies. Additionally, a summary of the methodology will be provided, and an introduction into the third qualitative paper will discuss findings, public health practices, policy implications, and future considerations.

<u>Research Methodology</u>

The current study represents a quantitative study that was conducted in two different settings: an agricultural trade/health show throughout Kentucky, Virginia, and Pennsylvania; and a state fair held in Kentucky. The agricultural trade/health show will be referred to as the original pilot study, and the state fair held in Kentucky will be referred to as the continuous study. While the methodology was similar for both pilots, small difference in data collection will be noted.

Participants

Farm, trade, and health show participants were selected for this study from Virginia, Pennsylvania, and Kentucky in order to assess the role of undiagnosed COPD among dust exposed agricultural workers. This population was selected because of the high proportion of agricultural workers that frequent these events. Additionally, it was likely that we would obtain individuals who did not have agricultural dust exposure but were from from the same source population as those that did have agricultural dust exposure. Twenty participants were excluded because they indicated a physician had diagnosed them with COPD. The survey was a 26-item pen-and-paper anonymous questionnaire that took approximately 3-5 minutes to complete. Study personnel traveled to each of the data collection sites to administer the questionnaire and screening. A booth was established at each event and study personnel invited all attendees who visited the booth to participate in the pilot study. All surveys were administered between January and May, 2015. This study was approved by the University of Kentucky Institutional Review Board (study protocol 14–0862-P1H).

Measures

In the original pilot study, the primary exposure was determined by self-reported agricultural dust exposure queried in the survey with two questions: (1) Have you ever worked in the agricultural industry? Response options included “yes”, “no”, and “don’t know/prefer not to answer”; and (2) If yes, on average how would you characterize your agricultural dust exposure? Response options included “none”, “mild”, “moderate”, “severe” and “don’t know/prefer not to answer”. Participants who responded “yes” to the first question were characterized as agricultural workers. The second question was dichotomized, and any participant responding with “mild”, “moderate”, or “severe” were characterized as agricultural dust-exposed. Therefore, all participants were characterized as either exposed to agricultural dust or not exposed to agricultural dust. Additional covariates were evaluated in the model and included age, sex, marital status, race, education, employment status, agriculture as primary income, living on a farm, years in agriculture, years in primary occupation, and ever-smoking status.

In the continuous study at the Kentucky State Fair, the primary exposure variable was characterized by primary occupation dust exposure. This variable was queried in the survey with two questions: (1) Does/Did your occupation require you to work for a year or more in a dusty environment?; and (2) If yes, on average, how would you characterize your dust exposure? Response options included options of “none”, “mild”, “moderate”, “severe”, and “don’t know/prefer not to answer”. Participants who responded “yes” to the first question were characterized as being exposed to dust in their primary occupation. The second question was dichotomized and any participant responding to “mild” was characterized as “mild”. Those responding “moderate” or “severe” were characterized as “moderate+”. Participants in the continuous study were also asked questions regarding dust exposure as agricultural workers. The methodology for these characterizations were the same as those for the original pilot study, as previously detailed.

The main outcome measure for both studies was lung function, assessed through a Vitalograph COPD ® screening device. Subjects were classified as “Normal”, “Obstructed” (FEV_1/ $FEV_6 < 0.70$), and “Restricted” (FEV_1/ $FEV_6 > 0.70$ and $FEV_1 <$ 80% predicted). Subjects were further classified as “Normal” and “Abnormal” to evaluate the public health impact of pulmonary disease and alleviate some small sample concern. The Vitalograph® devices were shown to be a valid screening tool for the presence of COPD in two studies that reported the that the tool’s sensitivity and specificity for FEV_1/FEV_6 was 70 percent and 73 percent, respectively, with a fixed cut off point.[108,109] Furthermore, the sensitivity and specificity of the Vitalograph® for the original study was 80 percent and 67 respectively, respectively. The sensitivity and specificity of the Vitalograph® for the continuation study was 57.69 percent and 72.14 percent, respectively. Secondary outcomes in the continuation study included the continuous variables FEV_1 %-predicted and FEV_1/ FEV_6.

Instrumentation

The Vitalograph® design company is based in the United Kingdom (U.K.). The company is responsible for the worldwide manufacturing and marketing of respiratory devices to test lung function and other related services. Vitalograph® products have been used in primary care, occupational health and safety, disease management, emergency services and hospitals, and clinical trials. Vitalograph® developed a line of screening devices to aid in the early detection of COPD. The Vitalograph® COPD-6 device states that it identifies individuals at risk for pre-symptomatic stages of COPD to help facilitate early medical intervention and improve clinical outcomes. These devices measure Forced Expired Volume in one second (FEV_1) and Forced Expired Volume in six seconds (FEV_6). The device screens out those individuals with a normal FEV_1, i.e, non-COPD individuals, without the risk of false negatives. Traditional spirometry can be a challenge given the amount of stamina and coaching required for accurate results. The Vitalograph® has a built-in indicator for "good breaths" of air, allowing for more accurate results. While these devices are becoming very popular in primary care settings, they are for screening and should not be used as diagnostic devices.

Participants that agreed to participate in the study were asked to fill out the survey first. Following completion, participants were coached by study staff members on the correct position of the sanitary filter to be placed around their mouth. Participants were then asked to fill their lungs as completely as possible and exhale for six seconds or until the device beeped, indicating that testing was complete. Each participant conducted three tests and the Vitalograph® device reported the best of the three attempts. Participants that were found to have obstructive lung disease were advised to seek further spirometry testing to confirm a diagnosis. Personal results were provided to each participant along with a cover letter explaining the purpose of the study.

Statistical Analysis

Descriptive statistics were used to describe the samples (**Table 1 & Table 6**). Continuous variables were measured by mean and standard deviation, and categorical variables were described using counts and proportions. Chi-square tests, t-tests, and corresponding p-values were used to evaluate the multivariate and bivariate associations of lung function characterization (Normal/Obstructed/Restricted or Normal/Abnormal) (**Table 2-3 & 7-8**). Multinomial logistic regression models were used to model the association between covariates and lung function characterization (**Table 4-5 & 9-10**). Models were adjusted for age, gender, race, and smoking status. A linear regression was conducted on the secondary outcome variables FEV_1 %-predicted and FEV_1/ FEV_6 (**Table 11**). The data analysis for this paper was generated using SAS software, Version 9.4 of the SAS System for Windows. Copyright © 2015 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Chapter 4: Results

Introduction

This chapter outlines the results of two pilot studies conducted in Kentucky, Virginia, and Pennsylvania. The results will be broken into two categories, the Agricultural Farm Show and the Kentucky State Fair. Corresponding tables can be found in the appendix.

Results

Agriculture Farm/Trade Show

All adults over the age of 18 attending the Keystone Farm Show, Virginia Farm Expo, and the Harrison County, KY Agriculture Health Fair were invited to complete a self-administered survey and Vitalograph® COPD screening test. Approximately 2,000 individuals were in attendance at the Keystone and Virginia Farm Shows, while approximately 400 individuals attended the Harrison County, KY Agriculture Health Fair. Among all the attendees, 194 individuals agreed to participate in the pilot study. Twenty participants were excluded after reporting physician-diagnosed chronic obstructive pulmonary disease.

Of 174 participants, the majority were male (59.79%), married (70.47%), Caucasian (96.89%), college graduate (42.19%), and employed (40.41%). Participants were more likely to live on a farm (62.18%) and never smoke (76.22%). Of the 119 participants with normal lung function, the majority were male (61.9%), married (74.6%), non-Hispanic white (98.3%), college graduates (44.0%), and employed (45.38%). These participants were most likely to live on a farm (62.2 %), contribute 40 or more years in agriculture (27.9%), be exposed to agricultural dust (70.95%), and never smoke (80.3%) (**Table 1**).

Among the total population 14 percent had obstructed lung function and 18 percent had restricted lung function. Of the 24 participants with obstructed lung function, individuals were most likely to be male (66.7), married (79.2%), non-Hispanic white (95.7%), college graduates (54.2%), and retired (35.36%). These participants were most likely to not have agriculture as their primary mode of income (62.5%), live on a farm (66.7%), contribute 20 to 39 years in agriculture (50%), be exposed to agricultural dust (70.83%), and never smoke (82.6%). Of the 31 participants with restricted lung function, individuals were most likely to be male (51.6%), married (48.4), non-Hispanic white (90.7%), high school diploma or less (48.4%), and be retired (38.71%). These participants were most likely to not have agriculture as their primary mode of income (61.3%), live on a farm (58.6%), contribute less than 10 years or more than 40 years in agriculture (33.3%), be exposed to agricultural dust (54.84%), and never smoke (66.7%). Significant differences were observed between groups for marital status (**Table 2**).

Among farm show participants, 32 percent of individuals had abnormal lung function. Among those with abnormal lung function, 70.83 percent reported agriculture dust exposure. These participants were most likely to be male (58.2%), married (61.8%), non-hispanic Caucasian (92.6%), graduate from college (47.3%) and be retired (37.7%). Further, these participants were more likely to live on a farm (62.3%), agriculture not serve as primary income (61.8), and farm for 20-39 years (33.3%) (**Table 3**).

Increased prevalence of pulmonary obstruction or restriction was not observed for individuals exposed to agricultural dust. If a subject’s age were to increase by one unit, the odds of pulmonary restriction relative to normal pulmonary function would be expected to increase by a factor of 0.05 given the other variables in the model are held constant. Compared with normal pulmonary function, single participants were 5.492 times as likely to have pulmonary restriction relative to those married. For ever smokers relative to never smokers, the odds of restriction relative to normal pulmonary function would increase by a factor of 3.544 given the other variables in the model are held constant. Results should be interpreted with caution given the instability of the model due to low sample size (**Table 4**).

Kentucky State Fair

All adults over the age of 18 attending the Kentucky State Fair were invited to complete a self-administered survey and Vitalograph® COPD screening test. The Kentucky State Fair brought in 601,672 visitors over the 11-day event held in Louisville, Kentucky. The indoor and outdoor exhibit draws in people from the entire state of Kentucky and neighboring states. Including indoor and outdoor exhibits, fairgoers arrive from all demographics to experience this competitive and recreational gathering. In addition to promoting agriculture among the state, state fairs have expanded to include roller coaster, novelty foods, crafting such as quilt-making, homebrew beers, and fine arts. Further, the 2015 Kentucky State Fair included a health tent where attendees could get screened and evaluated for a number of conditions, free of charge. Among all attendees at the Kentucky State Fair, 623 agreed to participate. Twenty-six participants were excluded following report they had received a physician-diagnosis of COPD.

Of the 597 participants eligible the majority were female (62.52%), non-Hispanic white (94.89%), college graduates (39.97%), and employed (51.63%). Participants were most likely to have worked their primary job for 20-39 years (39.12%) and report dust exposure 37.14 percent of the time in their primary job. Of those participants that reported dust exposure in their primary job, 50.88 percent reported that dust was mild. Of the 597 participants attending the state fair, 19.58 percent worked in agriculture for at least one year. The majority of these participants worked 10-20 years in agriculture (33.33%) and 28.7 percent reported living on a farm. Of all participants, 39.83 percent reported being an ever smoker (**Table 6**).

Among the state fair participants 72.1 percent of the individuals had normal lung function, 5.1 percent had obstructed lung function, and 22.8 percent had restricted lung function. The mean age of participants with normal, obstructed, and restrictive lung function were 49.95(16.33), 51.33(19.15), and 51.53(14.36), respectively. The mean (SD) for FEV_1% predicted for normal, obstructed, and restrictive lung disease were 95.78(12.24), 71.6(24.21), and 68.29(10.68) respectively. The mean (SD) for FEV_1/FEV_6 was 1.28(5.67), 0.54(0.11), and 0.87(0.07) respectively. The majority of participants with normal lung function were female (62.07%), non-Hispanic white (95.07%), college graduates (46.19%), employed (54.16%), and working 20-39 years in their primary occupation (38.68%). The majority of normal lung function participants reported no exposure to dust in their primary occupation (66.01%). Of those that reported dust exposure, the majority reported that dust exposure to be moderate+ (50.98%). Approximately 16.26 percent of participants with normal lung function reported working on a farm, the majority contributing less than 10 years in the agriculture industry (44.68). Further, 35.36 percent of normal lung function participants reported living on a farm and 35.97 percent reported being an ever smoker (**Table 6**).

The majority of participants with obstructed lung function were female (56.67%), non-Hispanic white (86.67%), had some college education (33.33%), employed (46.43%), and having 20-39 years in their primary occupation (58.33%). Only 41.67 percent reported exposure to dust in their primary occupation, the majority of which was moderate+ (54.55%). Of those with obstructed lung function, 19.23 worked in agriculture with majority reported 10-20 years in agriculture (60.0%). Additionally, 30 percent of obstructed participants reported living on a farm and 37.04 percent reported being an ever smoker. The majority of participants with restricted lung function were female (58.96%), non-Hispanic white (94.03%), having graduated high school or less (44.36%), employed (44.78%). The majority of restricted individuals had spent 20-39 years in their primary job (36.67%). Forty-six percent of participants reported having exposure to dust in their primary occupation, the majority describing the dust as mild (56.45%). Of those with restriction, 30.23 percent reported working in agriculture with equivocal time spent in agriculture (27.59%). Further, 39.23 percent of restricted participants reported living on a farm and 52.67 percent reported being an ever smoker (**Table 7**).

Among the state fair participants 27.9 percent of individuals yielded some form of abnormal lung function, either restriction or obstruction. The mean age of those individuals with abnormal lung function was 49.95 with a standard deviation of 16.33. The majority of those with abnormal lung function were female (58.54%), non-Hispanic white (92.68%), high school graduates or fewer (45.40%), employed (45.06%), and working 20-39 years in their primary occupation (40.28%). Approximately 45.89 percent of those with abnormal lung function reported being exposed to dust in their primary job. The majority of participants reported this dust exposure to be mild (54.79%). Only 28.39

percent of participants with abnormal lung function worked in agriculture, the majority contributing 10-20 years in agriculture (32.35%). The majority of abnormal lung function participants did not live on a farm (37.5%) and were ever smokers (50.0%) (**Table 8**).

Those with normal lung function were most likely to be female (64.07%), non-Hispanic white (95.74%), college graduates (46.19%), employed (54.19%), and working in their primary occupation for 20-39 years (38.68%). Approximately, 33.99 percent of the normal lung function participants reported dust exposure in their primary occupation. The majority described this dust exposure as moderate+ (50.98%). Of those participants with normal lung function relative to abnormal lung function, 16.26 percent worked in agriculture, the majority contributing less than 10 years in agriculture (44.68%). The majority of normal lung function participants did not live on a farm (74.64%) and were never smokers (64.03%) (**Table 8**).

Results of multinomial logistic regression were as follows for participants with obstruction relative to not being obstructed. An effect was not seen for the primary exposure variable, primary job dust exposure, for those individuals with obstructive lung function. Those individuals with a college education exhibited a protective effect about obtaining obstructive lung function values (0.26 95% CI 0.08-0.86). An effect was not observed for employment status, years in primary job, primary job dust exposure level, work in agriculture, years in agriculture, or living on a farm (**Table 9**).

The following results are for those individuals with restrictive lung function test results relative to not being restricted. Compared to those without exposure to dust in their primary job, those participants with exposure to dust in their primary occupation were 1.57 times as likely to have a restrictive lung disorder (95% CI 1.02-2.41). Those individuals with a college education exhibited a protective effect with restricted lung disease compared to those reported high school graduate or fewer (0.50 95% CI 0.29-0.85). Participants who worked in agriculture were 2.05 times as likely to have restrictive lung disorders relative to those who did not work in agriculture (2.05 95% CI 1.26-3.33). Similarly, participants who reported living on a farm were 1.67 times as likely to have restrictive lung disorder relative to those not living on a farm (1.76 95% CI 1.08-2.57). While the sample size was too small to generate estimates for those with obstructive lung disorders, an effect was seen for restrictive lung disease and years working in agriculture. However, these results should be interpreted with caution. Those participants that worked 20-39 years in agriculture were 15.84 times as likely to have restricted lung disease relative to those with less than 10 years of experience. Similarly, those with 40+ years in agriculture were 6.58 times as likely to have a restricted lung function test relative to those with less than 10 years of experience. Associations were not observed for education level, years in primary job, or primary job dust exposure level (**Table 9**).

When lung function was treated as abnormal or not, the results were as follows: Compared to those with exposure to dust in their primary occupation, those without dust exposure were 1.52 times as likely to receive an abnormal lung function test (1.52 95% CI 1.01-2.27). Those with a college education yielded a protective effect against an abnormal lung function test (0.45 95% CI 0.28-0.74). Those participants that reported living on a farm were 1.61 times as likely to have an abnormal lung function test relative to those not living on a farm (1.61 95% CI 1.07-2.41). Relative to working less than 10 years in agriculture, the odds of abnormal lung function for those with 10-20 years, 20-39 years, and 40+ years were 4.79 95% CI 1.10-20.74, 2.96 95% CI 2.96-129.33, 8.79 95%, respectively. However, these results for years in agriculture should be interpreted with caution given small sample size. An effect was not seen for employment, years in primary job, primary job dust exposure level, or working in agriculture. (**Table 10**).

Self-employed participants had slightly lower FEV_1 % predicted values (-6.41 95% CI -11.90--0.91) compared to those who were employed. Similarly, those that worked in agriculture or reported living on a farm had significantly lower FEV_1 % predicted, respectively (-5.78 95% CI -9.39--2.16, -4.26 95% CI -7.39--1.14). Those participants with a college education had a slightly higher FEV_1 % predicted relative to those with some college (5.65 95% CI 2.22-9.08). A significant difference was not observed for primary job dust exposure, years in primary job, and years in agriculture. Self-employed participants had a slightly higher FEV_1/FEV_6 relative to employed individuals (1.66 95% CI 0.10-3.22). Similarly, those not employed, self-employed or retired also had a higher FEV_1/FEV_6 (1.94 95% CI 0.43-3.42). A significant difference was not observed for FEV_1/FEV_6 and primary job dust exposure, education, years in primary job, primary job dust exposure, working in agriculture, years in agriculture, and living on a farm (**Table 11**).

Chapter 5: Public Health and Policy Implications

Introduction

Agriculture is one of the most common occupations in the United States with elevated rates of illness for a variety of conditions and diseases. Farming is an especially important industry in Pennsylvania, Virginia, and Kentucky where livestock, field crops, and tree crops are the primary commodities produced. Extensive research has been conducted to evaluate the risk of respiratory disease among agricultural workers, however, fewer studies have evaluated its association with agricultural dust. In order to evaluate individual exposure to agricultural dust during farming activities to assess the risk of COPD, we conducted an original pilot study. The results of the original pilot indicated that agricultural workers had levels of undiagnosed COPD at approximately 14 percent for obstructed lung disorders and 18 percent for restricted lung disorders. With continuation funds, we expanded our study population to the Kentucky State Fair to evaluate primary occupation dust exposures and lung function. The results of these studies have generated valuable information for the field of occupational safety and health and more specifically, agricultural health.

Discussion of Findings

Agriculture Farm/Trade Shows

Our original pilot study found that 13.79 percent of the participants had undiagnosed pulmonary obstruction, and that 17.82 percent had undiagnosed pulmonary restriction as measured by the Vitalograph® COPD screening device. Among those participants with a pulmonary obstruction, 70.83 percent were exposed to agricultural dust. Similarly, among those with pulmonary restriction, 54.84 percent reported exposure to agricultural dust. These findings support the hypothesis that agricultural workers exposed to dust may be at risk for undiagnosed obstructive and restrictive disease. While the Vitalograph® is not diagnostic, this screening tool has been determined to be effective at identifying individuals at risk for COPD. Consistent with findings from population-based cohorts, this study found that 31.61 percent of participants screened had an undiagnosed pulmonary condition.

Age is a well-established risk factor for chronic obstructive and restrictive diseases. Our findings indicated a slight increase in lung function restriction with unit increases in age. While the condition of the lungs naturally ages over time, the slight increase could also be due to the healthy worker bias, or the time-since-hire effect. The time-since-hire effect occurs when a decline in health occurs the longer the time-since-hire. For instance, farmers with dust exposure that have been working for longer will naturally yield higher cumulative levels of dust exposure, which can contribute to decreased lung function, but recent hires would have a lower cumulative exposure. This results in a bias away from the null hypothesis, and overestimates the effects observed at higher cumulative exposures. This bias was addressed via age stratification, and yielded non-significant findings.

Social relationships are established as having important positive physiological effects on health.[110–112] Studies of patients with chronic health problems have suggested that marriage is associated with reduced morbidity and mortality. In the original pilot study, an association was found with regards to marital status and restricted airway disease. Compared to married participants, single participants had five and a half times the risk of airway restriction relative to those participants with normal lung function; however, small sample sizes created an unstable model and these results should be interpreted with caution.

Smoking is the most important risk factor in the development of pulmonary dysfunction. The original pilot study found that compared to non-smokers, smokers were three and a half times more likely to have restricted pulmonary function tests relative to those with normal lung function. This finding is consistent with the literature that places smoking as the number one risk factor for a variety of pulmonary conditions. A similar effect was not seen for those participants with obstructive lung disease; however, sample sizes were limited.

Kentucky State Fair

These primary results from the pilot study presented adequate findings to influence the design and implementation of a continuous project that expanded its population to a more general population in the state of Kentucky. The continuation study found that 5.07 percent of study participants had an obstructed lung function test, and 22.4 percent of study participants were characterized as having restricted lung function. In combining the outcomes to evaluate those with any abnormal lung function test, 27.5 percent of the participants had an abnormal pulmonary function test. Upon evaluating exposure to dust in participant’s primary occupation, our findings indicated that people that were exposed to dust in their primary occupation were 57 percent more likely to be restricted compared to those that did not report an occupational dust exposure. These results are consistent with several studies which have linked respiratory conditions to occupational dust exposure.[9–16]

Our study found that, compared to individuals with some college education, individuals possessing a college degree were protected against obstructive and restricted conditions. Several studies have linked educational levels to improved health outcomes.[113–115] Specifically, in a 2015 study, researchers found that lower educational attainment was associated with pulmonary emphysema and airway thickness.[116] Our findings support that educational attainment may accompany better health outcomes, which may be the result of individuals seeking medical care more often, smoking less, and engaging in physical exercise.

Working in agriculture was associated with pulmonary restriction. Participants that reported working in agriculture for a year or more were more than twice as likely to have pulmonary restriction. Some common conditions caused by airway restriction are interstitial lung disease, pulmonary fibrosis, obesity, and some neuromuscular diseases. While our study lacked the data to evaluate such conditions, it is important to note that hypersensitivity pneumonitis, such as “farmer’s lung”, is the most frequently recognized lung disease among farmers. It has been shown to cause considerable lung restriction in individuals who have prolonged exposure to grain and have inhaled organic dust from moldy plant material, such as hay. Further, restricted lung disease has been associated with other occupational hazards such as asbestosis, byssinosis, and silicosis. Future iterations of this study should focus on past and present interstitial lung diseases and obtain weight as part of the Vitalograph® assessment portion.

Furthermore, living on a farm was associated with pulmonary restriction. Those who reported living on a farm were 67 percent more likely to have a restricted lung function test. Living on a farm, especially in infancy has been linked with decreased risk of asthma and allergic diseases.[117,118] However, exposure on a farm as been linked to decreased pulmonary function. With exposure to organic and inorganic dust, farm animals, chemicals, gases, fumes, vapors, and infectious agents causing irritation and inflammation in the respiratory system has been well documented among agricultural workers.[101,119–127] Therefore, living on a farm during infancy may reduce the risk of asthma and allergic diseases while living on a farm during adulthood may be a risk factor for respiratory disease.

In conclusion, the primary findings of these studies were that individuals exposed to occupational dust were at an increased risk for restrictive lung function relative to individuals who reported no exposure to occupational dust. There was not an increased risk of obstructive lung function in individuals reporting exposure to occupational dust. However, those individuals who reported working in agriculture had an over two-fold increase in risk for restricted lung function compared to those individuals not working in agriculture. Furthermore, those individuals who reported living on a farm were 67 percent more likely to have restricted airway disease relative to those individuals not working on a farm. In both pilot studies, participants screened for undiagnosed obstructive lung disease were present with proportions ranging from 5.03 to 13.7 percent and 17.8 to 22.4 for restricted lung disease.

Limitations

There are a number of limitations of this study. First, given the pilot nature of these studies, the sampling method was one of convenience. In assessing the feasibility of using farm shows and agricultural fairs, we were unable to obtain a sufficient sample of individuals not exposed to agricultural dust. Therefore, the limited numbers of participants did not allow us, with few exceptions, enough power to detect differences between lung function and agricultural dust exposure in the original pilot study. However, we were able to obtain an adequate sample size to detect significant differences in our continuation study at the Kentucky State Fair exposition.

Self-reported dust exposure has its limitations with regard to exposure assessments. Future studies need to focus on improving upon dust exposure assessment in agricultural workers in order to accurately assess the level and type of dust that is contributing to decreased lung function among this population. The authors were further limited in variable selection. Given the pilot nature of these studies, the authors were limited to an array of variables of which their intended use was for exploratory research. Future studies should strive to collect more detailed information on smoking, comorbidities, and particulate types as well as detailed work histories, and industry specific work practices, among others. Furthermore, adequately addressing the healthy worker bias was challenging. With limited work histories from participants it was not possible to address some components of this bias. Future studies must obtain histories in order to address important bias presented by the healthy worker effect.

Despite these limitations, this pilot study indicated that agricultural workers from our sample population were at risk for undiagnosed COPD. Furthermore, our study illustrated, in a general population of Kentucky State Fair-goers, that those exposed to occupational dust, those working in agriculture, and those living on farms were at an increased risk for restricted lung function. Our studies also demonstrated that the use of the Vitalograph® device is an effective method of COPD evaluation, given the high specificity and sensitivity we obtained in our sample. Furthermore, the results of this study identified an occupational group which may be at risk for undiagnosed obstructive and restrictive lung disease. The information collected in these studies provided us with a range of risk factors for pulmonary disease and showed us general trends, which will be useful in the design and evaluation of larger studies that assess dust exposure and undiagnosed COPD.

Public Health and Policy Implications

The agricultural sector has undergone tremendous changes since occupational hazards were first documented by Ramazzani in the 1700s. Improvements in technology, and personal protective equipment, and increased awareness of hazards have been generated via experience and research. Entities like NIOSH have established agencies that are primarily focused on the health of the agricultural worker population. These entities are a network of collaboration among educators, researchers, engineers, and many other disciplines providing a multi-disciplinary approach to agricultural safety and health. But, despite all these advances, there is still much work to be done to identify and quantify hazardous agricultural exposures, and to determine how many people are adversely affected. Specific legislation is also necessary to protect this vital and unique working class of individuals. Once these task have been completed public health entities can begin to address effective and efficient means of implementing the hierarchy of controls.

In evaluating how public health can further promote agricultural safety and health it is important for such entities to recognize the diversity in problems, resources, priorities, and values that are present for agricultural workers. In order to appropriately address the challenges that are faced by this unique workforce, we must first understand the challenges faced by each facet within the agricultural industry. Successful implementation of surveillance and prevention programs are reliant on how well we understand this workforce. Researchers and stakeholders have convened to evaluate useful ways to address concerns for agricultural safety and health. One common theme has been the implementation of coalitions and community-based participatory research. By bringing the researchers, stakeholders, and the workforce to the same table, the needs of this community can be recognized and researchers can target intervention strategies and more successfully implement prevention programs.

The diversity among the agriculture community has not always been as varied in the U.S. In recent years, the majority of agricultural workers shifted from a majority of older, white males to include women and hired farm workers who tend to be foreign-born, young males. As the farm operator population continues to age, it is possible that this might also increase the vulnerability to adverse effects of occupational exposures. Conditions such as chronic obstructive pulmonary disorder are generally more progressive when paired with comorbid conditions such as advanced age. These considerations can be addressed through the health education of older farming populations. Foreign-born farm workers also present a challenge in agricultural safety and health concerns. With most having little to no background in agriculture, these individuals often look to agriculture for entry level positions. Language barriers also presents challenges for hired farm workers such as following safety directions in work practice and in reading safety labels. Investing in identifying and understanding the current agricultural workforce will help identify the areas that require improvement in occupational safety and health practices.

Since the majority of farming operations are exempt from OSHA operations, surveillance for negative health outcomes in the agricultural industry are sparse. Without a sufficient tracking system, identifying trends and determining accurate numbers of health effects will remain nearly impossible. Furthermore, a surveillance system with baseline and ongoing spirometry testing will specifically address concerns regarding agricultural related respiratory conditions. Epidemiological studies are only as informative as the data that contributes to the formulation of these studies. Without a sufficient tracking system and regulations for obtaining such information, studies with limited data will continue to predominate the information available regarding the occupational safety and health of our farmers.

Prevention efforts have been established for the agricultural communities for various activities, however, it is often considered an incomplete and inefficient system. Farmers are unlikely to commit to wearing the necessary personal protective equipment due simply to non-compliance or interference with ability to perform task effectively. While personal respirators are often recommended for certain task these may be overkill for some farming practices. Therefore, without complete exposure assessment models it is often unknown what the requirements are for personal protective equipment during farming operations. Further, in smaller scale farming, outdated machines still exist which do not provide the best outcome for decreasing exposures. With the development of studies which focus on particulate exposure during specific farming operations, industry engineers can begin to implement control measures to limit the amount of exposure by incorporating new technologies to limit exposure.

Future Directions

To date there are only three main cohorts in the United States which follow agricultural workers prospectively. In order to address some of the aforementioned concerns among the agricultural workforce, researchers, stakeholders, and policy-makers must invest in population-based longitudinal studies which address the growing concern of respiratory health presented in the agricultural field. The addition of these large cohorts must go beyond self-administered questionaries' and utilize current technology to measure respirable doses of particulates that affect farmers. This will allow researchers to investigate the dose-response relationship between pulmonary function and dust concentrations. By incorporating such technology, a major limitation presented in current literature, which states that organic and inorganic particulates often cannot be separated with ease, can be eliminated. Further expanding and creating new cohorts of farmers will address the current lack of knowledge of how many people are adversely effected by multiple exposures, particularly how long-term exposures such as dust affect agricultural workers.

Exposure assessment models must be developed for the agricultural section to understand threshold values for particulates such as organic and inorganic dust beyond those that are readily available. As these standards become common practice, researchers and educators can shift priorities toward prevention programs which focus on these agents which cause agricultural related respiratory disease. Furthermore, with better exposure assessment characterization, standards may be established to protect those individuals who are exposed in the workforce. This is especially true of inorganic dust exposure for which little to no standards exist. While the majority of the data that does exist focuses on individual's commodities, with large-scale studies across the entire farming operation continuum, standards can be established specific to certain operations. While it was previously reported that it is widely understood among the agricultural industry that workers are exposed in excess of permissible limits, such acceptance must shift to intolerance. Such intolerance will only be possible with the assistance from legislators investing in protecting one of the founding occupations in America, farming.

Conclusion

The primary results from these pilot studies have identified an occupational group, agricultural workers, which may be at risk for pulmonary obstruction and restriction. Further, the results of these studies indicated that primary job occupational dust exposure may also increase the likelihood of pulmonary restriction in those exposed. The information collected in these pilot studies provided the authors with a range of risk factors that may place individuals susceptible for pulmonary obstruction and restriction and showed general trends which will be useful in the development of larger studies that further assess risk factors and the presence of obstructed and restricted pulmonary disease.

Appendix

Table 1: Demographic Characteristics Among Farm Show Participants (N=174)

Characteristic	Number N	Percentage %
Agriculture Dust		
Yes	130	66.67
No	65	33.33
Age, mean ± SD	52.159±17.29	
Sex		
Female	78	40.21
Male	116	59.79
Marital Status		
Single	38	19.69
Married	136	70.47
Widowed/Sep/Divorced	19	9.84
Race		
Non-Hispanic White	187	96.89
Other	6	3.11
Education		
≤ High School	71	36.98
Some College	40	20.83
College +	81	42.19
Employment Status		
Employed	78	40.41
Self-Employed	48	24.87
Retired	58	30.05
Else	9	4.66
Agriculture as Primary Income		
Yes	74	38.14
No	120	61.86
Live on a Farm		
Yes	120	62.18
No	73	37.82
Years in Agriculture		
<10	24	21.82
10-20	24	21.82
20-39	31	28.18
40+	31	28.18
Agriculture Dust		
Yes	130	66.67
No	65	33.33
Ever Smoker		
Yes	44	23.78
No	141	76.22

Table 2: Demographic Characteristics Among Farm Show Participants by Lung Function Category (N=174)

Characteristic	Normal N=119 N (%)	Obstructed N=24 N (%)	Restricted N=31 N (%)	p-value
Agriculture Dust				
Yes	88 (73.95)	17 (70.83)	17 (54.84)	0.1169
No	31 (26.05)	7 (29.17)	14 (45.16)	
Age, mean ± SD	51.28 (17.28)	50.49 (17.39)	53.13 (17.04)	0.36
Sex				
Female	45 (38.1)	8 (33.3)	15 (48.4)	0.4728
Male	73 (61.9)	16 (66.7)	16 (51.6)	
Marital Status				
Single	20 (17.0)	3 (12.5)	13 (41.9)	**0.0264**
Married	88 (74.6)	19 (79.2)	15 (48.4)	
Widowed/Sep/Divorced	10 (8.5)	2 (8.3)	3 (9.7)	
Race				
Non-Hispanic White	116 (98.3)	22 (95.7)	28 (90.3)	0.0951
Other	2 (1.7)	1 (4.4)	3 (9.7)	
Education				
≤ High School	37 (31.9)	9 (37.5)	15 (48.4)	0.1457
Some College	28 (24.1)	2 (8.3)	3 (9.7)	
College +	51 (44.0)	13 (54.2)	13 (41.9)	
Employment Status				
Employed	54 (45.38)	7 (31.82)	10 (32.26)	0.4034
Self-Employed	31 (26.05)	6 (27.27)	6 (19.35)	
Retired	30 (25.21)	8 (36.36)	12 (38.71)	
Else	4 (3.36)	1 (4.55)	3 (9.68)	
Agriculture as Primary Income				
Yes	47 (39.8)	9 (37.5)	12 (38.7)	0.9748
No	71 (60.2)	15 (62.5)	19 (61.3)	
Live on a Farm				
Yes	74 (62.2)	16 (66.7)	17 (58.6)	0.8346
No	45 (37.8)	8 (33.3)	12 (41.4)	
Years in Agriculture				
<10	18 (22.8)	2 (16.7)	4 (33.3)	0.4602
10-20	19 (24.1)	3 (25.0)	2 (16.7)	
20-39	20 (25.3)	6 (50.0)	2 (16.7)	
40+	22 (27.9)	1 (8.3)	4 (33.3)	
Ever Smoker				
Yes	23 (19.7)	4 (17.4)	10 (33.3)	0.2321
No	94 (80.3)	19 (82.6)	20 (66.7)	

Table 3: Demographic Among Farm Show Participants by Normal/Abnormal Lung Function (N=174)

Characteristic	**Normal** **N=119** N (%)	**Abnormal Lung Function** **N=55** N (%)	**p-value**
Agriculture Dust			
Yes	88 (73.95)	17 (70.83)	0.1041
No	31 (26.05)	7 (29.17)	
Age, mean ± SD	51.28 (17.28)	50.49 (17.39)	0.36
Sex			
Female	45 (38.1)	23 (41.8)	0.6442
Male	73 (61.9)	32 (58.2)	
Marital Status			
Single	20 (17.0)	16 (29.1)	**0.1703**
Married	88 (74.6)	34 (61.8)	
Widowed/Sep/Divorced	10 (8.5)	5 (9.1)	
Race			
Non-Hispanic White	116 (98.3)	50 (92.6)	0.0581
Other	2 (1.7)	4 (7.4)	
Education			
≤ High School	37 (31.9)	24 (43.6)	0.0521
Some College	28 (24.1)	5 (9.1)	
College +	51 (44.0)	26 (47.3)	
Employment Status			
Employed	54 (45.4)	17 (32.1)	0.1644
Self-Employed	31 (26.1)	12 (22.6)	
Retired	30 (25.2)	20 (37.7)	
Else	4 (3.4)	4 (7.6)	
Agriculture as Primary Income			
Yes	47 (39.8)	21 (38.2)	0.8362
No	71 (60.2)	34 (61.8)	
Live on a Farm			
Yes	74 (62.2)	33 (62.3)	0.9921
No	45 (37.8)	20 (37.7)	
Years in Agriculture			
<10	18 (22.8)	6 (25.0)	0.8251
10-20	19 (24.1)	5 (20.8)	
20-39	20 (25.3)	8 (33.3)	
40+	22 (27.9)	5 (20.8)	
Ever Smoker			
Yes	23 (19.7)	14 (26.4)	0.3227
No	94 (80.3)	39 (73.6)	

Table 4: Multinomial Logistic Regression Among Farm Show Participants by Lung Function Category (N=174)

Characteristic	Normal N=119	Obstructed N=24	Restricted N=31
Agriculture Dust			
Yes	-	0.70 (0.20-2.51)	1.57 (0.49-5.03)
No	-	ref	ref
Age	-	1.01 (0.97-1.06)	**1.05 (1.01-1.10)**
Sex			
Female	-	1.27 (0.38-427)	3.12 (0.98-9.89)
Male	-	ref	ref
Marital Status			
Single	-	0.54 (0.09-3.14)	**7.59 (2.08-27.67)**
Married	-	ref	ref
Widowed/Sep/Divorced	-	0.43 (0.04-4.28)	0.80 (0.13-5.13)
Race			
Non-Hispanic White	-	ref	ref
Other	-	3.62 (0.24-55.63)	8.17 (0.83-80.85)
Education			
≤ High School	-	7.05 (0.80-62.09)	2.89 (0.61-13.69)
Some College	-	ref	ref
College +	-	6.06 (0.69-53.42)	3.39 (0.73-15.86)
Employment Status			
Employed	-	ref	ref
Self-Employed	-	1.94 (0.40-9.46)	1.66 (0.32-8.50)
Retired	-	1.92 (0.39-9.57)	1.07 (0.25-5.57)
Else	-	2.56 (0.18-36.79)	5.10 (0.72-36.00)
Agriculture as Primary Income			
Yes	-	1.41 (0.340-5.91)	1.16 (0.31-4.27)
No	-	ref	ref
Live on a Farm			
Yes	-	0.45 (0.13-1.51)	0.84 (0.27-2.60)
No	-	ref	ref
Ever Smoker			
Yes	-	1.17 (0.31-4.42)	**3.48 (1.08-11.24)**
No	-	ref	ref

Table 5: Logistic Regression Among Farm Show Participants by Abnormal v. Normal Lung Function (N=174)

Characteristic	Normal N=119	Abnormal Lung Function N=55
Agriculture Dust		
Yes	-	0.92 (0.37-2.31)
No	-	ref
Age	-	1.03 (1.00-1.07)
Sex		
Female	-	2.10 (0.87-5.09)
Male	-	ref
Marital Status		
Single	-	2.70 (0.96-7.62)
Married	-	ref
Widowed/Sep/Divorced	-	0.61 (0.13-2.81)
Race		
Non-Hispanic White	-	ref
Other	-	5.42 (0.71-40.75)
Education		
≤ High School	-	4.06 (1.13-14.55)
Some College	-	ref
College +	-	4.19 (1.18-14.90)
Employment Status		
Employed	-	ref
Self-Employed	-	1.72 (0.51-5.85)
Retired	-	1.32 (0.41-4.19)
Else	-	3.62 (0.65-20.26)
Agriculture as Primary Income		
Yes	-	1.20 (0.43-3.34)
No	-	ref
Live on a Farm		
Yes	-	0.63 (0.26-1.53)
No	-	ref
Ever Smoker		
Yes	-	2.24 (0.88-5.69)
No	-	ref

Table 6: Demographic Characteristics Among KY State Fair Participants (N=587)

Characteristic	Number (N)	Percentage (%)
Primary Job Dust Exposure		
Yes	205	37.14
No	347	62.86
Age, mean ± SD	51.29±16.14	
Sex		
Female	367	62.52
Male	220	37.48
Race		
Non-Hispanic White	557	94.89
Other	30	5.11
Education		
≤ High School	182	31.22
Some College	168	28.82
College +	233	39.97
Employment Status		
Employed	301	51.63
Self-Employed	45	7.72
Retired	183	31.39
Else	54	9.26
Years Primary Job		
<10	160	30.53
10-20	110	20.99
20-39	205	39.12
40+	49	9.35
Primary Job Dust Exposure Level		
Mild	115	50.88
Moderate +	111	4.12
Work in Agriculture		
Yes	111	19.58
No	456	80.42
Years in Agriculture		
<10	29	35.8
10-20	27	33.33
20-39	12	14.81
40+	13	16.05
Live on a Farm		
Yes	167	28.7
No	415	71.3
Ever Smoker		

Table 7: Demographic Characteristics Among KY State Fair Participants by Lung Function Cat

Characteristic	Normal N=423 N (%)	Obstructed N=30 N (%)	Restricted N=134 N (%)
Primary Job Dust Exposure			
Yes	138 (33.99)	10 (41.67)	57 (46.72)
No	268 (66.01)	14 (58.33)	65 (53.28)
Age, mean ± SD	49.95±16.33	51.13±18.15	51.53±14.36
FEV1% pred, mean ± SD	95.78±12.24	71.6±24.21	68.29±10.68
FEV1/FEV6 , mean ± SD	1.28±5.67	0.54±0.11	0.87±0.07
Sex			
Female	271 (64.07)	17 (56.67)	79 (58.96)
Male	152 (35.93)	13 (43.33)	55 (41.04)
Race			
Non-Hispanic White	405 (95.74)	26 (86.67)	126 (94.03)
Other	18 (4.26)	4 (13.33)	8 (5.97)
Education			
≤ High School	108 (25.71)	15 (50.0)	59 (44.36)
Some College	118 (28.10)	10 (33.33)	40 (30.08)
College +	194 (46.19)	5 (16.67)	34 (25.56)
Employment Status			
Employed	228 (54.16)	13 (46.43)	60 (44.78)
Self-Employed	29 (6.89)	2 (7.14)	14 (10.45)
Retired	124 (29.45)	9 (32.14)	50 (37.31)
Else	40 (9.50)	4 (14.29)	10 (7.46)
Years Primary Job			
<10	118 (31.05)	5 (20.83)	37 (30.83)
10-20	81 (21.32)	5 (20.83)	24 (20.0)
20-39	147 (38.68)	4 (58.33)	44 (36.67)
40+	34 (8.95)	0 (0.0)	15 (12.5)
Primary Dust Exposure Level			
Mild	75 (49.02)	5 (45.45)	35 (56.45)
Moderate+	78 (50.98)	6 (54.55)	27 (43.55)
Work in Agriculture			
Yes	67 (16.26)	5 (19.23)	39 (30.23)
No	345 (83.74)	21 (80.77)	90 (69.77)
Years in Agriculture			
<10	21 (44.68)	0 (0.0)	8 (27.59)
10-20	16 (34.04)	3 (60.0)	8 (27.59)
20-39	3 (6.38)	1 (20.0)	8 (27.59)
40+	7 (14.89)	1 (20.0)	5 (17.24)
Live on a Farm			
Yes	107 (35.36)	9 (30.0)	51 (39.23)
No	315 (74.64)	21 (70.0)	79 (60.77)

Table 8: Demographic Characteristics Among KY State Fair Participants by Lung Function Category (N=587)

Characteristic	**Normal** **N=423** N (%)	**Abnormal Lung Function** **N=164** N (%)	**p-value**
Primary Job Dust Exposure			
Yes	138 (33.99)	67 (45.89)	**0.01**
No	269 (66.01)	79 (54.11)	
Age, mean ± SD	54.72±15.16	49.95±16.33	**0.0013**
Sex			
Female	271 (64.07)	96 (58.54)	0.214
Male	152 (35.93)	68 (41.46)	
Race			
Non-Hispanic White	405 (95.74)	152 (92.68)	0.13
Other	18 (4.26)	12 (7.32)	
Education			
≤ High School	108 (25.71)	74 (45.40)	**<.0001**
Some College	118 (28.10)	50 (30.67)	
College +	194 (46.19)	39 (23.93)	
Employment Status			
Employed	228 (54.16)	73 (45.06)	0.1626
Self-Employed	29 (6.89)	16 (9.88)	
Retired	124 (29.45)	59 (36.42)	
Else	40 (9.5)	14 (8.64)	
Years Primary Job			
<10	118 (31.05)	42 (29.17)	0.64
10-20	81 (21.32)	29 (20.14)	
20-39	147 (38.68)	59 (40.28)	
40+	34 (8.95)	15 (10.42)	
Dust Exposure Level			
Mild	75 (49.02)	40 (54.79)	0.4167
Moderate+	78 (50.98)	33 (45.21)	
Work in Agriculture			
Yes	67 (16.26)	44 (28.39)	**0.0012**
No	345 (83.74)	111 (71.61)	
Years in Agriculture			
<10	21 (44.68)	8 (23.53)	**0.04**
10-20	16 (34.04)	11 (32.35)	
20-39	3 (6.38)	9 (26.47)	
40+	7 (14.89)	6 (17.65)	
Live on a Farm			

Table 9:Multinomial Logistic Regression Analysis for Exposures and Obstruction/Restriction v. Normal Lung Function (N=587)

Characteristic	Obstruction^ N=30		Restriction^ N=134	
	OR	95% CI	OR	95% CI
Primary Job Dust Exposure				
Yes	1.28	0.53, 3.14	**1.57**	**1.02, 2.41**
No	Ref	-	Ref	-
Education				
≤ High School	1.64	0.67, 3.98	1.40	0.85, 2.30
Some College	Ref	-	Ref	-
College +	**0.26**	**0.08, 0.86**	**0.50**	**0.29, 0.85**
Employment Status				
Employed	Ref	-	Ref	-
Self-Employed	1.24	0.26, 5.95	1.57	0.76, 3.27
Retired	1.04	0.34, 3.19	0.93	0.54, 1.62
Else	1.99	0.50, 7.87	1.32	0.60, 2.90
Years Primary Job				
<10	Ref	-	Ref	-
10-19	1.36	0.32, 5.81	0.69	0.37, 1.29
20-39	2.43	0.63, 9.33	0.58	0.32, 1.06
40+	-	-	0.81	0.35, 1.85
Primary Job Dust Exp Level				
Mild	Ref	-	Ref	-
Moderate +	1.31	0.35, 4.91	0.67	0.35, 1.25
Work in Agriculture				
Yes	1.31	0.47, 3.67	**2.05**	**1.26, 3.33**
No	Ref	-	Ref	-
Years in Agriculture				
<10	Ref	-	Ref	-
10-20	-	-	3.24	0.71, 14.88
20-39	-	-	**15.84**	**2.37, 105.80**
40+	-	-	**6.58**	**1.00, 43.29**
Live on a Farm				
Yes	1.38	0.60, 3.20	**1.67**	**1.08, 2.57**
No	Ref	-	Ref	-

^ Reference is normal lung function

*Each exposure variable was included in separate model and adjusted for age, gender race, and smoking status

Table 10: Logistic Regression Analysis for Exposures and Abnormal v. Normal Lung Function (N=587)

Characteristic	Normal N=423		Abnormal Lung Function N=164	
	OR	95% CI	OR	95% CI
Primary Job Dust Exposure				
Yes	-	-	**1.52**	**1.01-2.27**
No	-	-	Ref	-
Education				
≤ High School	-	-	1.44	0.92-2.28
Some College	-	-	Ref	-
College +	-	-	**0.45**	**0.28-0.74**
Employment Status				
Employed	-	-	Ref	-
Self-Employed	-	-	1.52	0.76-3.03
Retired	-	-	0.95	0.57-1.60
Else	-	-	1.43	0.70-2.94
Years Primary Job				
<10	-	-	Ref	-
10-19	-	-	0.75	0.42-1.36
20-39	-	-	0.74	0.42-1.29
40+	-	-	0.77	0.34-1.73
Primary Job Dust Exp Level				
Mild	-	-	Ref	-
Moderate +	-	-	0.74	0.41-1.33
Work in Agriculture				
Yes	-	-	**1.92**	**1.21-3.04**
No	-	-	Ref	-
Years in Agriculture				
<10	-	-	Ref	-
10-20	-	-	**4.79**	**1.10-20.74**
20-39	-	-	**19.56**	**2.96-129.33**
40+	-	-	**8.79**	**1.39-55.29**
Live on a Farm				
Yes	-	-	**1.61**	**1.07-2.41**
No	-	-	Ref	-

*Each exposure variable was included in separate model and adjusted for age, gender, race, and smoking status

Table 11: Linear Regression Analysis for Exposures and FEV1% predicted and FEV1/FEV6 (N=587)

	FEV1% pred, mL*		FEV1/FEV6, mL^	
Characteristic	β	95% CI	β	95% CI
Primary Job Dust Exposure				
Yes	-1.73	-4.73-1.27	-0.62	-1.52-0.28
No	Ref	-	Ref	-
Education				
≤ High School	-3.47	-7.08-0.15	-0.08	-1.13-0.98
Some College	Ref	-	Ref	-
College +	**5.65**	**2.22-9.08**	-0.59	-1.58-0.41
Employment Status				
Employed	Ref	-	Ref	-
Self-Employed	**-6.41**	**-11.90--0.91**	**1.66**	**0.10-3.22**
Retired	-1.61	-4.85-1.62	-0.09	-1.22-1.03
Else	-2.22	-7.34-2.90	**1.93**	**0.43-3.42**
Years Primary Job				
<10	Ref	-	Ref	-
10-19	-4.18	-8.43-0.07	-0.52	-1.83-0.78
20-39	-1.23	-4.84-2.37	-0.49	-1.78-0.79
40+	-3.83	-9.38-1.71	1.23	-0.68-3.14
Primary Job Dust Exp Level				
Mild	Ref	-	Ref	-
Moderate +	2.46	-2.10-7.01	0.00854	-0.02-0.03
Work in Agriculture				
Yes	**-5.78**	**-9.39--2.16**	-0.52	-1.58-0.54
No	Ref	-	Ref	-
Years in Agriculture				
<10	Ref	-	Ref	-
10-20	-4.74	-14.96-5.47	-0.05	-0.11-0.02
20-39	-6.77	-20.05-6.51	-0.06	-0.15-0.02
40+	-10.63	-23.17-1.91	-0.06	-0.14-0.02
Live on a Farm				
Yes	**-4.26**	**-7.39--1.14**	0.26	-0.64-1.16
No	Ref	-	Ref	-

*Adjusted for smoking status

^Adjusted for age, smoking status

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