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The association of chronic bronchitis and airflow obstruction with lifetime and current farm activities in a sample of rural adults in Iowa

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Abstract

Objective—Farmers have an increased risk for chronic bronchitis and airflow obstruction. The objective of this study was to investigate the association of these health outcomes with farm activities.

Methods—We evaluated the Keokuk County Rural Health Study (KCRHS) enrollment data for farm activities and the two health outcomes chronic bronchitis based on self-reported symptoms and airflow obstruction based on spirometry. We used logistic regression to model the health outcomes, yielding an odds ratio (OR) and 95% confidence interval (95% CI) for farm activities while adjusting for potential confounders and other risk factors.

Results—Of the 1234 farmers, 104 (8.4%) had chronic bronchitis, 75 (6.1%) fulfilled the criteria for airflow obstruction, and the two outcomes overlapped by 18 participants. Chronic bronchitis without airflow obstruction ($n = 86$) had a statistically significant association with crop storage insecticides (OR 3.1, 95% CI 1.6, 6.1) and a low number of years (≤ 3) worked with turkeys (OR 3.3, 95% CI 1.2, 9.4). The latter result should be interpreted with caution because it is based on a

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Author contributions KMK contributed to the design and implementation (including data collection) of the Keokuk County Rural Health Study, which was the source of the data used in the current study. PKH, MJH, XL, BCD, and KMK made substantial contributions to the concept and design of the current study. All authors made substantial contributions to the implementation of the current study. SP, XL, and MLH conducted data management. SP conducted most data analyses and drafted the manuscript, assisted by all other authors. All authors contributed to the interpretation of the results, provided a critical review of the manuscript, and approved the final version that was submitted for publication.

Availability of data and materials The data are participant-level and cannot be shared publicly.

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Ethical approval The Institutional Review Board (IRB) of the University of Iowa approved the KCRHS study protocol, and the current analysis is part of a project approved by the National Institute for Occupational Safety and Health IRB. Each KCRHS participant provided written informed consent before taking part in the study.

Disclaimer The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

Declarations

Conflict of interest The authors have no competing interests to report.

small number of cases ($n = 5$). Airflow obstruction with or without chronic bronchitis ($n = 75$) was significantly associated with ever working in a hog or chicken confinement setting (OR 2.2, 95% CI 1.0, 4.5).

Conclusions—These results suggest that work with crop storage insecticides or turkeys may increase the risk for chronic bronchitis and work in hog or chicken confinement may increase the risk for airflow obstruction.

Keywords

Airflow obstruction; Chronic bronchitis; Farm activities; Rural adults

Introduction

Chronic obstructive pulmonary disease (COPD) is a leading international public health problem characterized by irreversible chronic airflow obstruction and interference with normal breathing (Vogelmeier et al. 2017). In 2019, COPD was the third leading cause of death worldwide and accounted for approximately 3.23 million deaths (WHO 2020, 2021).

Spirometry is the primary test used to detect airflow obstruction and confirm a suspected case (Vogelmeier et al. 2017). COPD is a heterogeneous disease, and chronic bronchitis is one of the conditions included in the broader category of COPD. Chronic bronchitis is operationally defined as chronic cough and phlegm production for at least 3 months a year for at least 2 consecutive years (WHO 2007). While airflow obstruction and chronic bronchitis are associated with each other, many patients also present with one condition but not the other (Kim and Criner 2013).

Although smoking tobacco is a major preventable risk factor for COPD, studies have shown that never-smoking individuals are also afflicted with COPD (Hnizdo et al. 2002), suggesting that other indoor and outdoor exposures are risk factors (Postma et al. 2015). For example, a 2019 statement of the American Thoracic Society concluded that occupational exposures are responsible for approximately 14% of the total population burden of COPD (Blanc et al. 2019). However, the percentage of COPD burden attributable to occupation is even greater among never-smokers, with estimates as high as 48% (Wurtz et al. 2015).

Farmers and agricultural workers have a higher prevalence of COPD than those who do not work in agriculture (Guillien et al. 2016), suggesting a possible causal relationship between agricultural exposures and the development of COPD (Eduard et al. 2009; Fontana et al. 2017; Monsó et al. 2004; Monsó et al. 2003). Researchers have identified various farm activities associated with COPD including working with livestock, harvesting, processing or storing grains, and treating soils, plants, and stables with chemical agents such as pesticides and disinfectants (Chakraborty et al. 2009; Eduard et al. 2009; Fontana et al. 2017; Jouneau et al. 2012; Lamprecht et al. 2011; Monsó et al. 2004).

Overall, an association has been observed between the airways obstruction and a variety of farm activities and exposures (Fontana et al. 2017). However, due to the wide array of tasks and exposures that can occur on a farm, determining the burden of COPD attributed to particular exposures can be challenging. In addition, it is important to note that past research has at times found inverse relationships between agricultural exposures and respiratory outcomes (Radon et al. 2006). This is potentially due, in part, to a healthy worker effect, in which less healthy workers either never enter or they depart a profession and more healthy workers remain on the job. Another potential cause for an inverse relationship is that living or working on a farm as a child can alter your susceptibility to certain allergic conditions in adulthood (Radon et al. 2006). It is important to consider these phenomena when examining the association between COPD and farm exposures in adults.

A recent systematic review of COPD in farmers (Fontana et al. 2017) calls for additional research that takes a more nuanced approach to exposure assessment. It recommends characterizing occupational exposure by types of farm work and specific farm activities, as well as using measurements of airborne contaminants when possible. The findings from studies of COPD that use these types of exposure metrics have the potential to provide useful evidence for prevention.

The Keokuk County Rural Health Study (KCRHS) was a large prospective study of environmental exposures and human health, started in 1994, in a rural county in south-eastern Iowa (Stromquist et al. 1997). Data from KCRHS provides the opportunity to better understand occupational risk factors for COPD among all rural workers, including those in agriculture. In previous analyses using KCRHS data, a COPD-specific job-exposure matrix was used to assign occupational exposure to vapor–gas, dust, and fumes (VGDF) based on participants' last jobs. These exposures were considerably more common for current farmers (80.2%) than for former farmers (38.7%) or never farmers (27.4%) (Doney et al. 2017). Also, airflow obstruction based on cross-sectional spirometry results was associated with occupational VGDF exposure, but only among ever smokers (Henneberger et al. 2020). These investigations included workers from all types of jobs, and did not focus on whether COPD outcomes were associated with specific farm tasks and products.

The overall objective of this study is to investigate the association of COPD with agricultural work, and more specifically to examine the association of chronic bronchitis and airflow obstruction with both lifetime and current farm activities.

Materials and methods

Human subjects research approval

An Institutional Review Board at The University of Iowa reviewed and approved the KCRHS study protocol. In addition, the current analysis is part of a project approved by the National Institute for Occupational Safety and Health (NIOSH) Institutional Review Board. KCRHS participants provided written informed consent before they took part in the study.

KCRHS cohort

The KCRHS cohort was selected from residents of Keokuk County in southeast Iowa due to the county's completely rural nature (all towns < 2500 people) and the ability to represent the work experience of inhabitants in rural Iowa, including their work in agriculture. The methods for participant selection were published elsewhere (Merchant et al. 2002). The sampling frame was Keokuk county residents, and their names and addresses were compiled using sources such as vehicle registration, voter registration, and birth records, as well as telephone directories, county records, and the county plat book (Merchant et al. 2002). Stratified random sampling was conducted using a computer-generated list of random numbers to select households for recruitment. All people within each household were invited to participate in the study. Any participating household that moved out of the county or chose to no longer take part in the study was randomly replaced using the sampling frame from the primary cohort. About two-thirds (67.1%) of the 2496 eligible households agreed to immediate participation or to be contacted in the future, 31.3% chose not to participate, and 1.6% were undecided. In total, the sample comprised 341 farm households (34%), 202 rural (non-town) nonfarm households (20%), and 461 town households (46%) (Merchant et al. 2002).

Two hundred non-participant households were randomly selected for a telephone-administered survey to serve as a comparison group for the KCRHS households (Merchant et al. 2002). This comparison revealed substantial concordance between the participant and nonparticipant households, although participant households had a higher education level and slightly younger adult women than non-participant households (Merchant et al. 2002).

KCRHS data collection

The first of three rounds of data collection began in June 1994 and concluded in February 1998 (Merchant et al. 2002). Participants visited the KCRHS clinic in Sigourney, Iowa, to complete environmental assessment questionnaires, an occupational history, and medical evaluations that included spirometry. Questionnaires and medical protocols were pretested, revised, and documented for quality assurance (Ferris 1978; Merchant et al. 2002). In-person interviews were used to complete the study questionnaires with participants, and trained interviewers utilized direct computer data entry to record responses (Merchant et al. 2002). The second and third rounds occurred in 1999–2004 and 2006–2011, respectively, and followed the same protocol as the first round with minor changes (Merchant et al. 2002).

Study population

The present study used KCRHS data from baseline enrollment, which was the round when an individual first took part. Initially, 1847 adult participants (≥ 18 years) completed spirometry testing, questionnaires, and occupational history at enrollment. Exclusions included 115 participants for low-quality spirometry, characterized by fewer than two acceptable curves or failure to meet repeatability criteria for both the forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) (CDC 2011); 23 participants with smoking status, body mass index (BMI), or asthma status missing; and ten nonwhite participants due to small numbers, which left 1699 white adult participants (Merchant et al. 2002). Most were enrolled in the first round ($n = 1256$), with fewer in the second ($n = 354$) and third ($n = 89$) rounds. The 1699 participants included farmers (current and former), operationally defined as those who reported both specific farm tasks and years of farm work, as well as never-farmers.

The never-farmers, defined as participants with no indication of performing farm tasks and no years of farm work ($n = 433$) were excluded from the current study sample (Fig. 1). Additional participants were excluded if they indicated years of farm work but were missing responses to all farm task questions ($n = 32$), making it impossible to determine what type of farm work they had done. The final sample for the current cross-sectional analysis ($n = 1234$) included participants from baseline enrollment who participated in any farm work currently or in their lifetime (ever farmed) (Fig. 1).

Demographic characteristics

Demographic characteristics included age at baseline enrollment, sex (male, female), and cigarette smoking status (never, former, current). BMI was calculated from body weight and height measurements, and cut points were based on common categories for BMI: underweight/normal [< 25 kg/m^2 (kg/m^2)], overweight (25 to < 30 kg/m^2), obesity class I (30 to < 35 kg/m^2), and obesity class II and above (≥ 35 kg/m^2) (CDC 2015). Cigarette pack-years were calculated by taking the average number of cigarettes smoked per day over a participant's lifetime and dividing it by 20, then multiplying by the number of years smoked. The nonzero cigarette pack-years observations were further divided into high and low groups based on the median cut point (15 pack-years, range: 0.05, 120), and these groups were used when presenting crude results.

Farming status and farm activities

We assigned a farming status of current or former to all participants based either on the work history or, in the absence of a farm job in the work history, on the past 12 months and lifetime farm task variables. We also created a dichotomous variable for farm work as a child based on current age minus the number of years lived or worked on a farm (whichever was greater). If the difference was less than 18 then they were positive for childhood farm work.

At the time of the KCRHS, the principal crops grown in Keokuk County were corn, soybeans, oats, and hay; and the most common livestock were hogs, cattle, and sheep. Farm activities among current and former farmers were determined using participants' answers to farm tasks and exposure regarding job tasks, hobbies, and agricultural and occupational exposures (Merchant et al. 2002). In this study, the exposure variables of interest were livestock work, specific farm and animal chores, and chemicals handled, notably fertilizers and pesticides used for various types of applications. We investigated the association of chronic bronchitis and airflow obstruction with specific farm activities and the duration of these farm activities.

General dichotomous (ever/never) variables for working with different types of livestock (hogs, chicken, cattle, horses, sheep, turkey, and goats) were developed by combining original dichotomous (yes/no) livestock variables. Questions about livestock confinement activities were limited to baseline data from the first two rounds. Cell counts were sufficiently large to support meaningful variables for confinement work with hogs and chicken, but too small for cattle, horses, sheep, turkey, and goats. The considerable overlap of hog and chicken work motivated the creation of a single variable (hog/chicken) with three levels: never hog or chicken work, ever hog or chicken work but never confinement work with these animals, and ever hog or chicken confinement work.

Additional metrics of farm activity from enrollment data included separate dichotomous variables for several types of pesticide applications. However, few participants reported using specific fumigants and fungicides, necessitating the development of a single dichotomous (ever/never) fumigant/fungicide variable. Substantial correlation between chemical fertilizers and crop insecticides led to creating a single variable (chemical fertilizers/crop insecticides) for participants who ever used either of these chemicals. Other variables addressed maintenance and field tasks.

The nonzero reports of years ever worked with livestock within a lifetime and hours worked per week at a farm task in the past 12 months were divided into low and high categories according to the median values, with zero years or hours as a third never category (Supplemental Table 1). The use of median values to define the two exposed categories ensured sufficient numbers in both groups when investigating associations with health outcomes.

Respiratory health outcomes

A dichotomous airflow obstruction (yes/no) outcome variable was based on spirometry measurements. Spirometry experts at NIOSH used criteria from the American Thoracic Society and European Respiratory Society (Miller et al. 2005) to review the spirometry data for acceptability and repeatability. We used the highest recorded FEV_1 and FVC values for each participant. Airflow obstruction was defined as having both the FEV_1 and FEV_1/FVC ratio less than the lower limit of normal values, which were calculated based on each participant's sex, age, height, and race/ethnicity (Hankinson et al. 1999; Miller et al. 2005; Townsend 2020). The dichotomous chronic bronchitis (yes/no) outcome variable was based on responses to questionnaire items, and was positive for participants who reported chronic cough and phlegm for at least 3 months in each of 2 consecutive years. We created a three-category outcome variable with mutually exclusive categories for chronic bronchitis without airflow obstruction, airflow obstruction with or without chronic bronchitis, and neither chronic bronchitis nor airflow obstruction. Throughout the text, this is what we mean by 'chronic bronchitis' and 'airflow obstruction.'

Data analysis

Frequencies of demographic characteristics and exposures of interest (i.e., both farm activities and duration of those activities) were calculated for all participants in the study sample; Chi-square tests were used to assess the associations between each categorical independent variable and the outcomes of chronic bronchitis and airflow obstruction. Fisher's exact tests were used for situations with expected cell counts < 5.

Multinomial logistic regression models were used to compute odds ratios (OR) and 95% confidence intervals (95% CI). We constructed a base model to which we later added covariates for farm activities. We started with several common risk factors for the health outcomes and forced them into the model: age, sex, smoking status, and cigarette pack-years (log transformed to correct for skewness). We then created a full model by including additional covariates for BMI, doctor-diagnosed asthma, farming status, and childhood farm work. Starting with the full model we implemented backward selection, excluding the additional covariates one at a time based on a covariate-specific $p > 0.20$ for both outcomes. BMI was not associated with airflow obstruction or chronic bronchitis when examined as either a continuous or categorical variable, and, therefore, was excluded from the base model (Supplemental Table 2). We did not report OR results for farm activities if there were fewer than 3 cases.

Statistical significance was defined as $p \le 0.05$, and borderline statistical significance as $0.05 < p \le 0.10$. Statistical analyses were performed with SAS® 9.4 statistical software (SAS Institute Inc., Cary, NC, USA).

Results

The mean age of the 1234 participants was 51.5 years (standard deviation 16.9, range 18–92 years) and they were almost equally divided between males ($n = 632$) and females ($n = 602$) (Table 1). Thirty-nine percent of the sample had ever smoked cigarettes (14.4% current and 24.6% former smokers), 37.9% had a BMI of at least 30 kg/m^2, 35.2% were current farmers, and 7.8% reported asthma.

Concerning respiratory health outcomes of interest, 8.4% ($n = 104$) had chronic bronchitis, 6.1% ($n = 75$) fulfilled the spirometric criteria for airflow obstruction, and these two overlapped by only 18 participants. The multinomial regression outcome variable included 86 participants with chronic bronchitis without airflow obstruction, 75 with airflow obstruction with or without chronic bronchitis, and 1073 with neither condition. From unadjusted comparisons using the crude data, both outcomes were associated with cigarette smoking status and pack years (Table 1). Airflow obstruction was also positively associated with three other variables, with greater frequency for the categories of age 65 + (11.0%), male sex (8.1%), and asthma (15.6%). In the logistic regression base model, both outcomes had a strong positive association with age (Supplemental Table 2). The two outcomes differed regarding cigarette smoking, with elevated ORs most evident for current smoking status with chronic bronchitis and for pack-years with airflow obstruction. Asthma had a strong positive association only with airflow obstruction. Inverse associations were most apparent for chronic bronchitis with childhood farm work and for airflow obstruction with former smoking and former farming, although none were statistically significant.

Among the lifetime farming variables, the major categories for livestock farm work were hogs ($n = 722$), cattle ($n = 696$), and chicken ($n = 518$). Of the two livestock confinement workgroups, the number of participants handling hogs ($n = 239$) exceeded the number for chickens ($n = 119$). Additionally, fewer participants with hog/chicken work experience had done so in a confinement setting ($n = 292$) versus a non-confinement setting ($n = 477$) (Table 2). The major groups for chemical use were herbicides ($n = 290$), and chemical fertilizers/crop insecticides ($n = 315$). The prevalence of chronic bronchitis was highest by lifetime activities for those participants who had ever worked with turkeys (10.6%), and by chemicals for handling crop storage insecticides (13.4%) and fumigants/fungicides (14.6%) (Table 2). The prevalence of airflow obstruction was highest by lifetime activities for those participants who had ever worked in hog/chicken confinement (7.5%) and with turkeys (9.1%), and by chemicals for handling crop storage insecticides (6.7%) (Table 2). Without controlling for other factors, there were statistically significant associations of chronic bronchitis with exposure to crop storage insecticides and fumigants/fungicides (Table 2). None of the associations of airflow obstruction with exposure was statistically significant based on the crude data.

For farm activities in the past 12 months (Table 2), participants more often engaged in farm tasks not involving pesticides. The most common farm activities were field tasks with a vehicle ($n = 181$), outdoor animal chores ($n = 173$), and field tasks without a vehicle ($n = 165$). The largest categories for chemicals were herbicides ($n = 66$), field crop insecticides ($n = 59$), and livestock insecticides ($n = 53$). Chronic bronchitis prevalence was highest for ever worked with crop storage insecticides (12.1%) and ever worked with fungicides (16.7%). Airflow obstruction prevalence was the highest for ever worked with fungicides (8.3%). The 'ever' category for each of the five chemicals (all pesticides) had fewer than three cases of airflow obstruction, so a summary variable "Worked with any chemicals" was created based on working with at least one of the chemicals in the past 12 months. The 118 who fulfilled the criteria for this new variable included 9 (7.6%) with chronic bronchitis and 4 (3.4%) with airflow obstruction. There were no statistically significant differences in the crude prevalence of the two health outcomes between participants who did or did not perform farm tasks or handle pesticides in the past 12 months.

There were no statistically significant differences in the crude prevalence of chronic bronchitis and airflow obstruction by categories of either lifetime years worked with livestock or hours per week worked at farm chores in the past 12 months (Table 3). For lifetime work with livestock, exposure to turkeys had the highest prevalence of chronic bronchitis in the low years group (16.1%) and for airflow obstruction in the high years group (10.0%). Among the different farm chores performed in the past 12 months, the prevalence of chronic bronchitis was highest in the high hours per week groups for building maintenance (8.3%) and field tasks performed with a vehicle (8.4%). The prevalence of airflow obstruction was highest in the high groups for field tasks with no vehicle (9.7%) and equipment maintenance (8.9%).

Farm activity and chronic bronchitis

Statistically significant elevated ORs were observed for fumigants/fungicides (OR 2.5, 95% CI 1.3, 5.1) and crop storage insecticides (OR 3.1, 95% CI 1.6, 6.1) in association with chronic bronchitis (Table 4). We investigated whether the effects of these two chemicals on chronic bronchitis were independent of each other. The two variables were correlated with a Pearson correlation coefficient of 0.46, $p < 0.0001$. When we created a combined variable the association with chronic bronchitis was apparent for crop storage insecticides alone (OR 2.9, 95% CI 1.2, 6.8) and the two insecticides together (OR 3.7, 95% CI 1.6, 9.0) but not for fumigants/fungicides alone (OR 2.2, 95% CI 0.7, 6.7).

The low number of years (≤ 3) worked with turkeys also had a statistically significant association with chronic bronchitis (OR 3.3, 95% CI 1.2, 9.4). No statistically significant associations were found for occupational exposures in the past 12 months.

Farm activity and airflow obstruction

We observed a statistically significant elevated OR for ever working in hog/chicken confinement (OR 2.2, 95% CI 1.0, 4.5) with airflow obstruction (Table 4). In addition, a significant inverse relationship was observed for lifetime exposure to ever working with chemical fertilizers/crop insecticides (OR 0.5, 95% CI 0.2, 1.0). Lastly, the lifetime exposure of a high number of years (> 3) worked with turkey vs never worked with turkey (OR 3.1, 95% CI 0.8, 11.4) was borderline statistically significant. No statistically significant associations were found for occupational exposures in the past 12 months.

Interaction of farm activity with ever smoked

A previous analysis using baseline KCRHS data identified an association of airflow obstruction with occupational VGDF only among ever smokers (Henneberger et al. 2020). We accomplished a similar analysis in the current study by characterizing cigarette use with a single indicator variable for having ever smoked, introducing the variable into regression models, and interacting the variable with farm activity covariates that had a statistically significant association with airflow obstruction or chronic bronchitis. However, the small number of cases for low and high turkey years (Table 3) blocked exploration of the interaction of these variables with smoking. The results for the interaction of other candidate farm task variables with smoking were unremarkable except for the combination of both fumigants/fungicides and crop storage insecticides with the outcome of chronic bronchitis, which had an inverse interaction that was borderline statistically significant, $p = 0.055$. The crude data for this interaction are presented in Supplemental Table 3. Effect estimates for the combination of both fumigants/fungicides and crop storage insecticides were OR = 9.8 (95% CI 3.0–32.0, $p < 0.001$) among never smokers and OR = 2.0 (95% CI 0.6–6.5, $p = 0.24$) among ever smokers.

Discussion

Chronic bronchitis without airflow obstruction and farm exposures

Lifetime exposure to crop storage insecticides without fumigants/fungicides and the combination of both types of chemicals demonstrated a statistically significant increased risk for chronic bronchitis. Moreover, the latter association was observed for never smokers but not ever smokers. These findings are consistent with existing evidence that general and specific pesticide use may increase chronic bronchitis prevalence (Hoppin et al. 2007; Valcin et al. 2007). Investigators have reported that nonspecific insecticide use was associated with respiratory symptoms of cough and phlegm, characteristic of chronic bronchitis (LeVan et al. 2005; Sprince et al. 2000). In addition, previous evidence suggests that insecticides are the functional group most associated with chronic bronchitis and has implicated four specific chemical classes of insecticides: organochlorines, organophosphates, carbamates, and pyrethroids (Hoppin et al. 2007). Organophosphates are among the variety of insecticides used for crop storage (Thomason 2005). In particular, previous studies reported an association between chronic bronchitis and the organophosphate pesticides dichlorvos and malathion, which are used as crop storage insecticides (Hoppin et al. 2007; Valcin et al. 2007). The results of the current analysis and previous findings suggest that the use of crop storage insecticides in addition to other agricultural risk factors may contribute to chronic bronchitis risk.

An elevated risk was observed for chronic bronchitis with a low number of years (≤ 3) worked with turkey. This observation could be due to the healthy worker effect, in which unhealthy individuals may have selected themselves away from exposure leaving healthy individuals to continue working with turkeys and eventually represent the high number of years worked. However, this finding for low turkey years is based on a small number of cases ($n = 5$) and should be interpreted with caution.

Airflow obstruction and farm exposures

Work in hog/chicken confinement demonstrated a statistically significant elevated risk for airflow obstruction. This finding is consistent with previous studies that reported a lung function decline characteristic of airflow obstruction associated with pesticide exposure in general (Cha et al. 2012; de Jong et al. 2014) and more specifically with indoor animal confinement work in agriculture (Eduard et al. 2009; Kirychuk et al. 1998; May et al. 2012; Schwartz et al. 1995; Senthilselvan et al. 1997; Viegas et al. 2013). Studies published since the 1990s show multiple respiratory diseases, including chronic bronchitis and COPD, have been associated with working in animal confinement environments and the related organic dusts (May et al. 2012). Although many years have passed since these associations were first published in the literature, the exact agents of causality are not fully understood due to the complexity of exposures in animal confinement work.

Organic dust can induce several respiratory symptoms and is usually defined as an airborne mixture of viable and non-viable microorganisms, their metabolites, and solid particles of plant and animal origin. This includes bacteria, fungi, viruses, endotoxins, mycotoxins, peptidoglycans, enzymes, and allergens (Viegas et al. 2017). In vitro tests revealed that air samples from occupations associated with high levels of organic dust, such as poultry production, promoted cytotoxic and pro-inflammatory responses (Viegas et al. 2017). Organic dust composed of high concentrations of coarse particulate matter is connected to enhanced inflammation (May et al. 2012; Viegas et al. 2013). Furthermore, the presence of elevated levels of common barn gases, produced by animals living in confinement buildings, are capable of enhancing inflammation in response to organic hog barn dust (Schneberger et al. 2017).

The current study supports the existing literature by demonstrating significant relationships of COPD with confinement work and handling chemicals. With the abundance of mixed exposures in agricultural work, it is important to address the implementation of controls to minimize exposure. We had intended to examine whether using personal protective equipment (PPE), more specifically a respirator, modified the relationship between exposure and obstruction. However, very few participants answered the questions pertaining to respirator use during mixing-loading and application, resulting in the inability to accurately examine the interaction between respirator use and chemicals in association with airflow obstruction. The lack of reporting may be attributed to the absence of respirator use, which would be consistent with findings from other studies where the frequency of respirator use was extremely low among agricultural workers. For example, a study examining PPE use in a sample of farmers based in North Carolina found that the majority never or rarely used cartridge respirators (69%) or canister respirators (77%) when working with chemicals (Kearney et al. 2015). Another study specific to Midwestern farmers had comparable findings with farmers rarely using any PPE aside from chemical resistant gloves while working with agricultural chemicals (Carpenter et al. 2002).

A previous analysis of KCRHS baseline data reported an association of airflow obstruction with VGDF exposure for all occupations was limited to ever smokers (Henneberger et al. 2020). The current analysis limited to participants with agricultural experience did not find an interaction with smoking for airflow obstruction but did reveal the effect of selected combinations of pesticides on chronic bronchitis was limited to never smokers. This finding is consistent with results from other studies in which the association of COPD with occupational exposures was greater among never smokers (Wurtz et al. 2015).

Governmental guidance and recommendations for occupational health and safety are limited for agricultural industries as a whole (Von Essen et al. 2010). There is a need for up-to-date recommendations for each agricultural sector that target more effective ways of controlling hazardous exposures. PPE is the least effective means of controlling harmful exposures because it requires a high level of employee involvement and commitment, and the correct PPE must be chosen for each hazard (CDC 2017). However, PPE should be used until effective engineering and administrative controls are in place to isolate people from the hazard and change the manner in which people work, respectively. For example, installing improved ventilation in animal buildings to eliminate some respiratory exposures and placing people on rotating schedules are ways to reduce harmful exposures among agricultural workers. Specific to confinement, there is an opportunity to develop new and improved methods for controlling dust and endotoxin exposure based on current knowledge about determinants of exposure (Basinas et al. 2015).

Our study contributes to the existing literature by examining the risk of COPD for particular farm activities. A strength of this study was the ability to assess specific farm activities, as well as the type and duration of farm work likely to be linked with chronic bronchitis and airflow obstruction. Other strengths include quality spirometry measurements that were reviewed for acceptability and repeatability by NIOSH experts, and attention to enrollment of participants in a population-based setting that were representative of rural households with current and/or past farming exposures. Potential weaknesses include lack of exposure specificity, lack of information regarding the timing of exposure, small sample sizes for selected comparisons, and an all-white study population that may not be reflective of non-white farm workers. Furthermore, despite our attempt to control for the overall healthiness of participants by including covariates for farming status and childhood farm work in the models, our results may be subject to the bias of the healthy worker effect. Additionally, we investigated many potential associations but did not adjust the level of significance, which may have resulted in some false-positive findings. However, the fact that the positive results are consistent with findings from other studies suggests that the results were not false positives.

Conclusions

The findings from our study indicate that farmers who ever worked with crop storage insecticides are at an increased risk for chronic bronchitis. We also reported a similar finding for a low number of years worked with turkeys, although this should be interpreted with caution due to a small number of cases in this category. Furthermore, farmers who ever worked in hog and/or chicken confinement are at an increased risk of airflow obstruction. Future studies should attempt to better characterize agricultural exposures and consider the complexity of mixed exposures that are typical of farm work environments. We recommend analyses of longitudinal data from KCRHS and other studies to examine the onset of chronic bronchitis and changes in spirometry in relation to participants' agricultural exposures.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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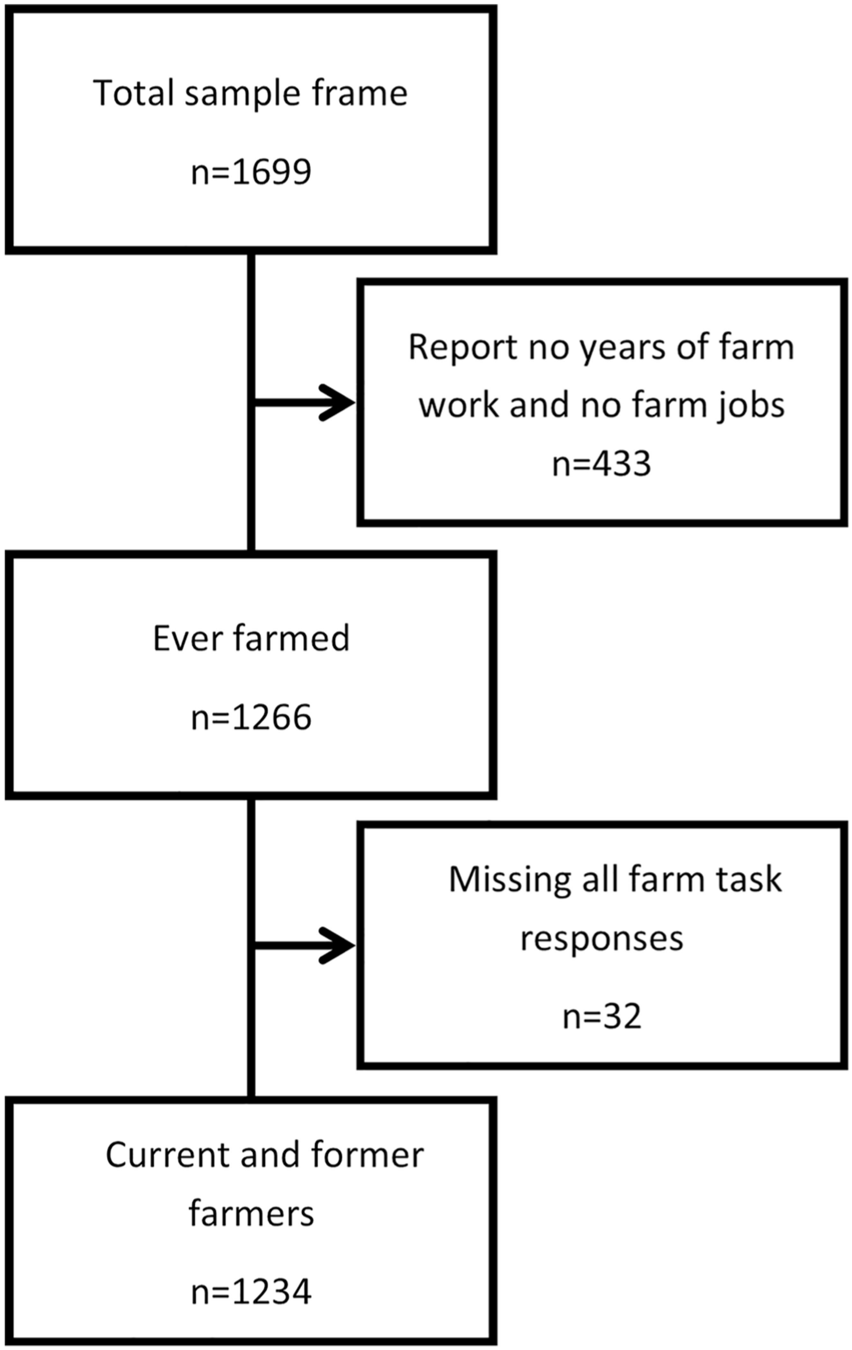

Fig. 1.
Sample size flow chart

Table 1

Distribution of farming participants ($N = 1234$) in the Keokuk County Rural Health Study at enrollment and distribution of chronic bronchitis ($N = 86$) and airflow obstruction ($N = 75$) by demographic and farm work characteristics and asthma status

Characteristic	Ever-farm participants		Chronic bronchitis		Airflow obstruction	
	n	**%**	***n***	**%**	***n***	**%**
Age % *						
18–39 years	342	27.7	22	6.4	8	2.3
40–54 years	343	27.8	22	6.4	15	4.4
55–64 years	214	17.3	14	6.5	15	7.0
65 + years	335	27.2	28	8.4	37	11.0
Sex *						
Male	632	51.2	51	8.1	51	8.1
Female	602	48.8	35	5.8	24	4.0
Smoking status **						
Current smoker	178	14.4	29	16.3	24	13.5
Former smoker	303	24.6	20	6.6	31	10.2
Never smoker	753	61.0	37	4.9	20	2.7
Cigarette pack-years **						
High	226	18.7	29	12.8	44	19.5
Low	214	17.7	16	7.5	10	4.7
Never	772	63.7	40	5.2	21	2.7
BMI						
Underweight/normal (< 25 kg/m^2)	311	25.2	18	5.8	20	6.4
Overweight (25 to < 30 kg/m^2)	455	36.9	37	8.1	30	6.6
Obesity class I (30 to < 35 kg/m^2)	300	24.3	21	7.0	14	4.7
Obesity class II (≥ 35 kg/m^2)	168	13.6	10	6.0	11	6.6
Asthma *						
Yes	96	7.8	7	7.3	15	15.6
No	1138	92.2	79	6.9	60	5.3
Farming status						

Characteristic	Ever-farm participants		Chronic bronchitis		Airflow obstruction	
	n	**%**	***n***	**%**	***n***	**%**
Current farmer	434	35.2	32	7.4	27	6.2
Former farmer	800	64.8	54	6.8	48	6.0
Childhood farm work						
Ever	500	40.5	26	5.2	25	5.0
Never	734	59.5	59	8.0	49	6.7
Years farm work						
0–7 years	550	44.6	44	8.0	32	5.8
8–19 years	210	17.0	14	6.7	13	6.2
20–39 years	256	20.8	15	5.9	17	6.6
40 + years	218	17.7	13	6.0	13	6.0

Chronic bronchitis is without airflow obstruction

Airflow obstruction is with or without chronic bronchitis

* Statistical significance, $p \leq 0.05$ for airflow obstruction

** Statistical significance, $p \leq 0.05$ for both outcomes

Table 2

Chronic bronchitis and airflow obstruction by farm activity

Farm activity	Ever-farm participants		Chronic bronchitis		Airflow obstruction	
	n	**%**	***n***	**%**	***n***	**%**
Lifetime						
Hog/chicken and confinement work **						
Confinement work	292	24.8	16	5.5	22	7.5
No confinement work	477	40.4	33	6.9	31	6.5
Never	411	34.8	33	8.0	20	4.9
Cattle						
Ever	696	56.4	40	5.8	47	6.8
Never	538	43.6	46	8.6	28	5.2
Horses						
Ever	308	25.0	23	7.5	19	6.2
Never	926	75.0	63	6.8	56	6.1
Sheep						
Ever	293	23.7	18	6.1	19	6.5
Never	941	76.3	68	7.2	56	6.0
Turkey						
Ever	66	5.4	7	10.6	6	9.1
Never	1168	94.7	79	6.8	69	5.9
Goats						
Ever	87	7.1	6	6.9	3	3.5
Never	1147	93.0	80	7.0	72	6.3
Livestock insecticides						
Ever	255	20.7	20	7.8	16	6.3
Never	979	79.3	66	6.7	59	6.0
Crop storage insecticides						
Ever	134	10.9	18	13.4 *	9	6.7
Never	1100	89.1	68	6.2	66	6.0
Herbicides						

Farm activity	Ever-farm participants		Chronic bronchitis		Airflow obstruction	
	n	**%**	***n***	**%**	***n***	**%**
Ever	290	23.5	24	8.3	14	4.8
Never	944	76.5	62	6.6	61	6.5
Fumigants/fungicides						
Ever	89	7.2	13	14.6 *	5	5.6
Never	1145	92.8	73	6.4	70	6.1
Any chemical fertilizers/crop insecticides						
Ever	315	25.5	28	8.9	15	4.8
Never	919	74.5	58	6.3	60	6.5
Past 12 months						
Indoor animal chores						
Ever	122	9.9	8	6.6	6	4.9
Never	1112	90.1	78	7.0	69	6.2
Outdoor animal chores						
Ever	173	14.0	10	5.8	10	5.8
Never	1061	86.0	76	7.2	65	6.1
Equipment maintenance						
Ever	160	13.0	9	5.6	10	6.3
Never	1074	87.0	77	7.2	65	6.1
Building maintenance						
Ever	161	13.1	10	6.2	11	6.8
Never	1073	87.0	76	7.1	64	6.0
Field tasks w/o vehicle						
Ever	165	13.4	10	6.1	9	5.5
Never	1069	86.6	76	7.1	66	6.2
Field tasks w/vehicle						
Ever	181	14.7	13	7.2	10	5.5
Never	1053	85.3	73	6.9	65	6.2
Operate slow moving vehicle						
Ever	122	9.9	8	6.6	6	4.9
Never	112	90.1	78	7.0	69	6.2

Farm activity	Ever-farm participants		Chronic bronchitis		Airflow obstruction	
	n	**%**	***n***	**%**	***n***	**%**
Field crop insecticides						
Ever	59	4.8	4	6.8	2	3.4
Never	1175	95.2	82	7.0	73	6.2
Livestock insecticides						
Ever	53	4.3	4	7.6	2	3.8
Never	1181	95.7	82	6.9	73	6.2
Crop storage insecticides						
Ever	33	2.7	4	12.1	0	0.0
Never	1201	97.3	82	6.8	75	6.2
Herbicides						
Ever	66	5.4	4	6.1	2	3.0
Never	1168	94.7	82	7.0	73	6.3
Fungicides						
Ever	12	1.0	2	16.7	1	8.3
Never	1222	99.0	84	6.9	74	6.1
Worked with any chemicals						
Ever	118	9.6	9	7.6	4	3.4
Never	1116	90.4	77	6.9	71	6.4

Worked with chemicals summary variable was created based on working with at least one of the chemicals in the past 12 months

Chronic bronchitis is without airflow obstruction

Airflow obstruction is with or without chronic bronchitis

* Statistical significance, $p \leq 0.05$

** Hog/chicken and confinement work has 54 fewer participants who were not asked about confinement work

Table 3

Chronic bronchitis and airflow obstruction by the time of farm activity

Farm activity	Ever-farm participants		Chronic bronchitis		Airflow obstruction	
	n	**%**	***n***	**%**	***n***	**%**
Lifetime, years						
Hog/chicken years						
High	384	31.1	29	7.6	20	5.2
Low	390	31.6	22	5.6	30	7.7
Never	460	37.3	35	7.6	25	5.4
Cattle years						
High	310	25.1	20	6.5	21	6.8
Low	322	26.1	19	5.9	20	6.2
Never	602	48.8	47	7.8	34	5.7
Horses years						
High	99	8.0	6	6.1	7	7.1
Low	175	14.2	15	8.6	9	5.1
Never	960	77.8	65	6.8	59	6.2
Sheep years						
High	128	10.4	9	7.0	7	5.5
Low	133	10.8	9	6.8	8	6.0
Never	973	78.9	68	7.0	60	6.2
Turkey years						
High	30	2.4	2	6.7	3	10.0
Low	31	2.5	5	16.1	3	9.7
Never	1173	95.1	79	6.7	69	5.9
Goats years						
High	37	3.0	3	8.1	1	2.7
Low	47	3.8	3	6.4	2	4.3
Never	1150	93.2	80	7.0	72	6.3
Past 12 months, hours/week						
Indoor animal chores						

Farm activity	Ever-farm participants		Chronic bronchitis		Airflow obstruction	
	n	**%**	***n***	**%**	***n***	**%**
High	55	4.5	3	5.5	4	7.3
Low	67	5.4	5	7.5	2	3.0
Never	1112	90.1	78	7.0	69	6.2
Outdoor animal chores						
High	82	6.7	5	6.1	4	4.9
Low	91	7.4	5	5.5	6	6.6
Never	1061	86.0	76	7.2	65	6.1
Equipment maintenance						
High	79	6.4	6	7.6	7	8.9
Low	81	6.6	3	3.7	3	3.7
Never	1074	87.0	77	7.2	65	6.1
Building maintenance						
High	72	5.8	6	8.3	6	8.3
Low	89	7.2	4	4.5	5	5.6
Never	1073	87.0	76	7.1	64	6.0
Field tasks w/o vehicle						
High	72	5.8	5	6.9	7	9.7
Low	93	7.5	5	5.4	2	2.2
Never	1069	86.6	76	7.1	66	6.2
Field tasks w/vehicle						
High	83	6.7	7	8.4	3	3.6
Low	98	7.9	6	6.1	7	7.1
Never	1053	85.3	73	6.9	65	6.2
Operate slow moving vehicle						
High	55	4.5	3	5.5	4	7.3
Low	67	5.4	5	7.5	2	3.0
Never	1112	90.1	78	7.0	69	6.2

None of the comparisons were statistically significant

Chronic bronchitis is without airflow obstruction

Airflow obstruction is with or without chronic bronchitis

Table 4

Statistically significant and borderline significant associations of chronic bronchitis and airflow obstruction with farm activities

Model number	Farm activity	Outcome	OR (95% CI)	*p* value
	Lifetime			
1	*Hog/chicken* Ref: never Hog/chicken, no confinement	Chronic bronchitis	0.9 (0.5, 1.5)	0.72
		Airflow obstruction	1.3 (0.7, 2.5)	0.41
	Hog/chicken, confinement	Chronic bronchitis	0.7 (0.5, 1.5)	0.40
		Airflow obstruction	2.2 (1.0, 4.5)	0.04 *
2	*Chemical fertilizers/crop insecticides* Ref: never	Chronic bronchitis	1.6 (0.9, 2.8)	0.11
		Airflow obstruction	0.5 (0.2, 1.0)	0.048 *
3	*Fumigants/fungicides* Ref: never	Chronic bronchitis	2.5 (1.3, 5.1)	0.01 *
		Airflow obstruction	0.8 (0.3, 2.1)	0.65
4	*Crop storage insecticides* Ref: never	Chronic bronchitis	3.1 (1.6, 6.1)	0.001 *
		Airflow obstruction	1.0 (0.4, 2.4)	0.95
5	*Fumigants/fungicides, crop storage insecticides* Ref: never Fumigants/fungicides, but no crop storage insecticides	Chronic bronchitis	2.2 (0.7, 6.7)	0.17
		Airflow obstruction	0.9 (0.2, 4.1)	0.88
	Crop storage insecticides, but no fumigants/fungicides	Chronic bronchitis	2.9 (1.2, 6.8)	0.02 *
		Airflow obstruction	1.2 (0.4, 3.5)	0.68
	Both fumigants/fungicides, and crop storage insecticides	Chronic bronchitis	3.7 (1.6, 9.0)	0.003 *
	Lifetime, years	Airflow obstruction	0.8 (0.2, 2.8)	0.71
6	*Turkey years* Ref: 0 years High: > 3 years	Chronic bronchitis	NR	NR
		Airflow obstruction	3.1 (0.8, 11.4)	0.098
	Low: ≤ 3 years	Chronic bronchitis	3.3 (1.2, 9.4)	0.02 *
	Past 12 months—none	Airflow obstruction	2.1 (0.5, 8.1)	0.28

NR, results for OR not reported due to fewer than three participants with the outcome

Ref, reference category for farm activity

All models controlled for age, sex, smoking status, cigarette pack years, asthma, farming status, childhood farm work

Chronic bronchitis is without airflow obstruction

Airflow obstruction is with or without chronic bronchitis

*Statistical significance, $p \leq 0.05$