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The Association of Airflow Obstruction with Occupational Exposures in a Sample of Rural Adults in Iowa

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Abstract

A recent article reported that occupational exposure to vapor-gas, dust, and fumes (VGDF) was more common in a sample of rural adults than in a sample of adults in urban settings. In another study of the same urban adults, airflow obstruction (AO) was associated with occupational VGDF and the combination of smoking and occupational exposure. The goal of the current study was to determine if similar associations were evident in the sample of rural adults. We analyzed enrollment data from the Keokuk County Rural Health Study (KCRHS), which investigated the health of rural residents in Iowa. We used the same methods as the study of urban adults. A job-exposure matrix (JEM) assigned an occupational VGDF exposure level based on each participants' last reported job. The health outcome was AO, defined as both the forced expiratory volume in one second (FEV1) and the FEV1/forced vital capacity (FVC) ratio< lower limit of normal. Of the 1699 KCRHS participants, 436 (25.7%) had high total VGDF occupational exposure, 661 (38.9%) had ever smoked cigarettes, and 110 (6.5%) had AO. The crude frequency of AO increased across the joint categories of smoking (never, ever) and high exposure (no, yes) ($p < 0.05$ for linear trend). After adjusting for potential confounders, AO was associated with high total occupational VGDF exposure only among smokers (OR = 1.81, 95% CI 1.002 to 3.26). In conclusion, the association of AO with occupational exposure in the current study of rural adults was similar to what was previously observed among urban adults.

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Disclosure of interest
The authors report no conflict of interest.

Institutional review board 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 Centers for Disease Control and Prevention (CDC) 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 views of the National Institute for Occupational Safety and Health.

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Keywords

Airflow obstruction; occupational exposure; rural adults

Introduction

Chronic obstructive pulmonary disease (COPD) is a major contributor to morbidity and mortality in the United States (US) and worldwide [1–3]. Based on data from 2015, an estimated 15.5 million adults in the US had diagnosed COPD [4]. The national medical costs for COPD and related sequelae were approximately $32.1 billion in 2010 and were projected to increase to $49.0 billion by 2020 [5]. Mortality attributed to COPD in the US increased by 30.8% between 1980 and 2014, so that in 2014 there were an estimated 151,200 deaths due to COPD, a mortality rate of 45.1/100,000 population, and over 2 million years of life lost [6]. Cigarette smoking has been the primary risk factor for COPD, accounting for about 75% of cases in the US [7–11]. However, a joint official statement of the American Thoracic Society (ATS) and European Respiratory Society (ERS) estimated that 14% of the population burden of COPD can be attributed to occupational exposures [12], updating an earlier ATS estimate of 15% [13].

Prior studies of work-related COPD in rural settings have focused on agricultural work, and a systematic review published in 2017 concluded that COPD is associated with farming [16]. However, many rural residents work in nonagricultural jobs, and it is necessary to consider these as well as agricultural jobs in order to evaluate the extent of work-related COPD in rural communities. We recently reported that rural adults were more likely to experience occupational exposure to vapor-gas, dust, and fumes (VGDF) than adults living in urban communities [17]. The data on rural adults was from the Keokuk County Rural Health Study (KCRHS), a population-based study of residents from a county in the Survey (NHIS), rural residence was a risk factor for COPD defined by both self-reported disease [14] and airflow obstruction based on spirometric tests of participants [15]. In the second study, the odds of COPD were greater for rural than urban residents, with an adjusted odds ratio (OR) of 2.06, $p = 0.005$ [15]. In another study that used 2015 national US data from several sources, those living in rural communities had higher age-adjusted prevalences of COPD cases, hospitalizations, and deaths due to COPD than their counterparts in micropolitan and metropolitan communities [4].

Evidence from national studies indicate rural residents have a higher risk of COPD than urban residents in the US. In two recently published reports from the National Health Interview state of Iowa. Occupational exposures to VGDF were assessed using a job-exposure matrix (JEM) that had been developed for the study of COPD [18]. Researchers used the same JEM to assess occupational exposures in the Multi-Ethnic Study of Atherosclerosis (MESA), providing an urban sample to which the KCRHS data were compared. While 43.2% of the rural KCRHS participants had medium or high VGDF exposure at their last job, the comparable percentage was 15.0% for the urban MESA adults. The contrast with MESA was especially evident for KCRHS participants who were currently farming (80.2% exposed) or had formerly farmed (38.7% exposed) but was evident as well for rural residents who had never worked in agriculture (27.4% exposed).

The MESA study also reported that the frequency of airflow obstruction (AO) had a positive linear trend with increasing occupational exposure to total dust ($p = 0.07$) and organic dust ($p = 0.05$) [18]. After adjusting for potential confounders, AO was associated with high total dust exposure (odds ratio (OR) = 2.35, 95% confidence interval (CI) 1.10, 5.04). Based on regression models fit to investigate the combined effect of smoking and occupational exposure, although the trend remained, AO was associated with neither total dust (OR = 1.39, 95% CI 0.39–4.88) nor vapor-gas (OR = 1.46, 95% CI 0.11–2.03) among never smokers. The investigators observed that ORs for AO increased with the combination of smoking and occupational exposure to total dust, but there was not a statistically significant multiplicative interaction between these two risk factors.

The objective of the current study was to investigate the association of AO with occupational VGDF exposure among rural adults who participated in the KCRHS. This study used the same methods as MESA for spirometric testing, and therefore, it was possible to use the same definition of AO and similar approaches to data analysis as MESA. This similarity of methods facilitated comparing results from the two samples. The specific aims were (1) investigate the cross-sectional association of spirometry-defined AO with occupational VGDF exposure in the last job held by adults living in a rural community. (2) Determine whether the association of AO with occupational VGDF varied by cigarette smoking status. (3) Compare the results for rural adults to those of their urban counterparts in MESA.

Materials and methods

Human subjects 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 Centers for Disease Control and Prevention (CDC) IRB. Each KCRHS participant provided written informed consent before taking part in the study.

Identification and testing of KCRHS cohort

The methods for KCRHS have been published previously [19, 20]. The KCRHS cohort is a stratified random sample of occupants of households in Keokuk County in southeast Iowa. All members of selected households were invited to take part. Participants were surveyed in three rounds during 1994–2011, with round 1 in 1994–1998, round 2 in 1999–2004, and round 3 in 2006–2011. Medical protocols and all questionnaires were pre-tested and revised, and quality assurance and control measures were implemented. Questionnaires were based primarily on the ATS respiratory questionnaire [21] and instruments used in established national studies such as the National Health Interview Survey and the Third National Health and Nutrition Examination Survey [19].

Interviewing and testing of the cohort was conducted at the KCRHS clinic in Sigourney, IA. At the beginning of each round, participants completed a set of standard clinical screening tests that included spirometry. A NIOSH-trained staff person administered spirometry using a calibrated SpiroTech®dry-rolling-seal spirometer (Sensormedics Corp., Yorba Linda, CA) that was borrowed from the Division of Respiratory Disease Studies at NIOSH. Spirometry testing followed a standard protocol developed by NIOSH that was consistent with ATS recommendations [22]. They also administered questionnaires to collect data about demographics, respiratory health status and risk factors, and occupational exposures. Adult participants completed an occupational history for jobs held since age 12.

Members of the KCRHS cohort in the current study

The current cross-sectional study utilized KCRHS data collected at enrollment. The 1847 adult participants (≥ 18 years) completed a spirometry test, questionnaire, and occupational history at enrollment. Exclusions included 115 (6.2%) with low spirometry quality, characterized by having fewer than two acceptable curves or having two or more acceptable curves that did not meet repeatability criteria for both FEV1 and FVC [23]; 23 (1.2%) who had missing values for smoking status, body mass index (BMI), ever asthma, or education; and 10 nonwhite participants (0.5%) who were excluded due to their small numbers. The final sample included 1699 white adults, age 18 to 92 years. Those excluded were somewhat older than the 1699 (mean age 55.6 versus 51.2 years, respectively, $p = 0.003$) and more likely to be male (55.4% versus 43.4%, respectively, $p = 0.006$), but not more likely to have ever smoked (38.7% versus 38.9%, respectively).

Comparing results to MESA

Results from the current analysis of KCRHS data were compared to results previously reported for urban adults who took part in MESA [18]. MESA is a population-based study of adults age 45–84 years who resided in six predominantly large urban communities in the U.S.: Baltimore, Maryland; Chicago, Illinois; Forsyth County, North Carolina; Los Angeles, California; New York City, New York; and St. Paul, Minnesota [18]. Participants were recruited and interviewed in 2000–2002 and completed spirometry 2004–2006. The assignment of occupational exposure for last job using a JEM, the definition of AO, and the approach to modeling AO were intentionally the same or similar to what was done in the MESA study.

Assigning occupational exposures

Occupational exposures for the last reported job were assigned using in a COPD-specific JEM (COPD JEM) that had been used previously with the MESA data [18]. Last job was either the job reported for the year when enrollment spirometry was conducted or the most recent job if retired or no longer working. Development of the COPD JEM has been explained in previous publications [18, 24]. An industrial hygienist assembled the COPD JEM by judging the likelihood and severity of exposure to VGDF for each 2002 U.S. Census occupational code (COC) and assigning an exposure level of no-low, medium, or high. The hygienist assigned exposures separately for vapor-gas, total dust, mineral dust, organic dust, and fumes. The level of total VGDF exposure usually was assigned based on the highest level of exposure for any of the exposures already mentioned, but also took into consideration an estimate of secondhand tobacco smoke for each occupation. Two other industrial hygienists reviewed these preliminary exposure assessments and assigned a final consensus exposure. Occupational exposures for each participant were assessed by first having a trained NIOSH staff assign a COC to the last reported job, and then combining the code with the COPD JEM to yield exposure to total VGDF; the three components of vapor-gas, total dust, and fumes; and the two dust subcomponents of mineral dust and organic dust.

Airflow obstruction

AO was dichotomous (yes/no) and based on spirometric measurements. NIOSH spirometry experts reviewed and classified the spirometry data for acceptability and repeatability using criteria from the ATS and ERS [25]. The largest forced expiratory volume in one second (FEV_1) and forced 1 vital capacity (FVC) from the acceptable spirometry curves were selected and compared to lower limit of normal (LLN) values [25, 26]. AO was defined as both the FEV_1 and FEV1/FVC ratio less than LLN, which is the same definition used in the MESA study [18].

Data analysis

The association between AO and occupational exposure was estimated by fitting logistic regression models while adjusting for other risk factors and potential confounders, with separate models for each VGDF exposure metric. We fit a base model of AO starting with continuous variables for age, logarithm of BMI, and logarithm of cigarette pack-years, and categorical variables for sex, smoking status (never, former, current), education (less than high school diploma, high school diploma, some college or tech school, bachelor’s degree or higher), and ever asthma (self-reported). There was evidence of collinearity between the two smoking variables. When we tried each in the base model alone with the other nonsmoking variables, the model fit was better with the logarithm of pack-years than smoking status, so we retained only the former. We then added covariates for farm work status (never, former, current) and farming as a child (no, yes), but only farm work status fulfilled the criterion of $p < 0.20$ and was retained in the base model. The distribution of the 1699 participants by these variables is presented in Table 1.

The categories for VGDF exposure were the three levels of no-low, medium, and high in some analyses, while for other analyses we used only the two categories of high versus not high to minimize situations with fewer than five AO cases. We did not report ORs based on fewer than five AO cases due to concerns about stability of effect estimates. Small cell sizes were especially a concern when investigating the combined effect of occupational exposure and cigarette smoking status. We tested for linear trend using the Cochran-Armitage test of linear trend. We applied this test to both the frequency of AO across three levels of occupational VGDF exposure (no-low, medium, and high) and to the combination of smoking (never, ever) and high occupational exposure (no, yes), in the progression from never/no to never/yes to ever/no to ever/yes. We used parameter estimates from regression models to check for indications that the effect of occupational exposure was modified by smoking. We fit logistic regression models with interaction terms for ever smoking (never, ever) and high occupational exposure (no, yes) to directly test for multiplicative interactions.

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

Results

Descriptive characteristics of KCRHS participants and comparison to MESA

The 1699 KCRHS participants had the following characteristics at enrollment (Table 1): mean age was 51.2 years (standard deviation (SD) 17.0), 56.6% were female, just less than 40% had ever smoked (23.7% former and 15.2% current smokers), mean pack-years of cigarettes was 8.6 (SD = 16.8) for all participants and 22.2 (SD = 20.6) for the 661 ever-smokers, mean BMI was 29.1 (SD = 5.9), and 37.5% were obese based on the criterion of a BMI ≥ 30. At the extremes of highest level of education completed, 7.8% had less than a high school diploma and 16.4% had a bachelor’s degree or higher. A history of asthma was reported by 8.7% of the participants. By farm work status, approximately one-fifth (20.8%) of KCRHS participants were current farmers, 43.1% were former farmers, and approximately one-third (36.1%) had never farmed. Nearly one-third of the participants (31.7%) had conducted farm work as a child. With the occupations for last job divided into four categories and a fifth “Other” category, management and professional jobs (including farmers, ranchers, and farm and ranch managers) were the most frequent with about one-third (32.7%) of the participants, and blue-collar occupations were the second most common with one-fourth (25.8%) of the participants.

The crude frequency of AO was 6.5% (*n* = 110) and varied by several characteristics of the KCRHS sample (Table 1). Specifically, an elevated frequency of AO was associated with older age, male sex, ever smoking, high pack-years of cigarettes, less than a high school education, and a history of asthma (Table 1). In contrast, the percentage with AO varied little by BMI, farming status, and occupational group, and was somewhat lower for those who had engaged in farm work as a child.

Supplementary material Table 1 includes descriptive information for both the 1699 KCRHS participants and the 3667 MESA participants. Compared to KCRHS, the MESA participants were about 10 years older (mean age 61.1 years), less likely to be female (48.8%), more likely to have ever smoked (45.2% former and 9.8% current) and to have smoked more (mean cigarette pack-years = 12.5 for all participants), and somewhat less likely to be obese (30.3%). Members of the MESA sample were twice as likely to have less than a high school diploma (15.4%) or at least a bachelor’s degree (38.4%). In addition, they were more likely to have a management/professional occupation (44.3%) and somewhat less likely to be in a blue-collar occupation (19.3%) than members of the KCRHS sample. The MESA and KCRHS participants were about equally likely to have AO, with values of 5.7% and 6.5%, respectively.

Crude frequency of airflow obstruction by three levels of occupational VGDF exposure

Based on the summary variable of total VGDF, one-fourth of the participants worked in jobs with high exposure (*n* = 436, 25.7%) and another 17.5% (*n* = 298) worked in jobs with medium exposure (Supplementary material Table 2). Among the three major components of VGDF, high exposure was equally common for vapor-gas (22.4%) and total dust (21.2%), and less common for fumes (2.4%). Of the two dust subcomponents, more participants had high exposure to organic dust (19.4%) than mineral dust (13.1%).

AO was relatively common for no-low and high exposure to most of the VGDF components, but medium exposure to total dust, mineral dust, organic dust, and fumes each had fewer than ten participants with this health outcome. The crude frequency of AO was positively associated with increasing occupational exposure to each of the VGDF metrics as indicated by tests of trend (Supplementary material Table 2). These tests were statistically significant for total VGDF ($p = 0.01$) and borderline significant for vapor-gas ($p = 0.09$) and total dust ($p = 0.06$).

Association of airflow obstruction with two levels of occupational VGDF exposure: crude frequencies and adjusted ORs

With each VGDF metric, the crude frequency of AO was elevated for those with high exposure (Table 2). These contrasts were statistically significant for total VGDF (8.9% versus 5.6%) and total dust (8.9% versus 5.8%). However, when we fit models of AO that included covariates for other risk factors and potential confounders, the ORs for high exposure to total VGDF (OR = 1.50, 95% CI 0.87–2.57), $p = 0.14$) and total dust (OR = 1.49, 95% CI 0.81–2.76, $p = 0.20$) were elevated but not statistically significant (Table 2).

Effect of high occupational exposure and smoking status

When KCRHS participants were stratified by the combination of smoking status (never, ever) and high occupational exposure (no, yes), the crude frequency of AO had a statistically significant (i.e., $p \leq 0.05$) positive linear trend across the four smoking/exposure categories of never/no to never/yes to ever/no to ever/yes (Table 3). This was true for each of the VGDF metrics tested: total VGDF, vapor-gas, total dust, mineral dust, and organic dust. Stratifying the crude results by smoking status, the frequency of AO increased from not high exposure to high exposure among ever smokers but not among never smokers. Similar trends were observed when we fit regression models of AO that included covariates to adjust for other risk factors and potential confounders (Table 3). The first set of models had never smoking/no high occupational exposure as the common reference category. For each of the VGDF metrics, the ORs for high exposure among never smokers were somewhat less than one and had wide confidence intervals. The ORs from these models for smokers were greater than one for each of the VGDF metrics, and somewhat greater with versus without high occupational exposure. For example, for total VGDF, the ORs were 0.82 (95% CI 0.32, 2.12, $p = 0.69$) never smoking/high exposure, 2.95 (95% CI 1.72, 5.08, $p < 0.0001$) ever smoking/not high exposure, and 5.34 (95% CI 2.66, 10.7, $p < 0.0001$) ever smoking/high exposure. The second set of regression models had ever smoking/no high occupational exposure as the common reference category, and the results for ever smokers are presented in the last two columns of Table 3. In these models, total VGDF had the only statistically significant elevated OR for high exposure in ever smokers: OR = 1.81 (95% CI 1.002–3.26, $p = 0.049$). The OR for high exposure to total dust among ever smokers was a similar magnitude, with OR = 1.74, but the 95% CI was wide (0.89–3.38) and $p = 0.105$. The comparable values for high exposure among never smokers from the first set of models were OR = 0.82 (95% CI 0.32–2.12, $p = 0.69$) for total VGDF and OR = 0.76 (95% CI 0.28–2.12, $p = 0.60$) for total dust.

Similar to statistical testing conducted in the MESA study, we fit additional logistic regression models of AO to directly test whether the interaction of ever smoking with high exposure to the different VGDF metrics was multiplicative. The interaction terms in these models were not statistically significant (Supplementary material Table 3), but their p values were in the range of 0.10 to 0.15 for total VGDF, total dust, and mineral dust.

Discussion

Comparing findings for KCRHS rural adults to MESA urban adults

The two cohorts differed somewhat in their distribution by characteristics potentially related to AO, including age, sex, smoking, BMI, and education. These differences might suggest that results from the two cohorts should not be compared. However, both studies fit regression models of AO that adjusted for these characteristics when investigating associations with occupational exposure.

Several findings for the rural KCRHS cohort were very similar to those for the urban MESA cohort (Table 4) [18] Both studies reported a positive trend in the crude frequency of AO with increasing level of occupational exposure, especially for dust. Specifically, this trend was observed for total VGDF ($p = 0.01$), vapor-gas ($p = 0.09$), and total dust ($p = 0.06$) (but not for mineral or organic dust) in the current study, and for total dust ($p = 0.07$) and organic dust ($p = 0.05$) in MESA. Both studies identified a positive trend in AO frequency associated with the combination of smoking and various metrics of VGDF exposure. AO was associated with high total dust for all MESA participants, with OR = 2.35, 95% CI 1.10–5.04, but the comparable effect estimate in the current study was only OR = 1.49, 95% CI 0.81–2.76. In fact, none of the VGDF metrics was a risk factor for AO among all KCRHS participants. However, total VGDF did have a statistically significant OR = 1.81 (95% CI 1.002–3.26, $p = 0.049$) among ever smokers, but not among never smokers (OR = 0.82, 95% CI 0.32–2.12), in the KCRHS sample. It is unclear if the MESA study explored similar effect estimates by cigarette smoking status. Both studies reported neither a statistically significant effect of high exposure among never smokers nor a multiplicative interaction of smoking and high exposure.

The frequencies of JEM-assigned occupational exposures to total VGDF and total dust were considerably greater for KCRHS in comparison to published values for MESA [18]. Specifically, the frequencies of high and medium total VGDF were 25.7% and 17.5%, respectively, in KCRHS]. (Supplementary material Table 2), versus 5.3% and 9.8%, respectively, in MESA. Similarly, high and medium total dust were assigned by the JEM to 21.2% and 9.7%, respectively, of the KCRHS participants, versus 2.8% and 9.8%, respectively, of the MESA participants. As revealed by these numbers, the contrast was most apparent for high exposure, being more common in KCRHS by a factor of approximately 5 for total VGDF and 7.5 for total dust. Beyond these differences in frequency of exposure, the KCRHS participants were likely to have had exposure to a variety of agricultural dusts that their urban counterparts in MESA did not experience. This variability within exposure categories may have contributed to some of the differences in results for AO when comparing the two samples.

Why is the association of airflow obstruction with occupational exposures limited to smokers?

Unlike the current investigation, other studies have reported an association of AO with occupational exposure among nonsmokers. In fact, estimates of the fraction of COPD attributed to occupation are often higher among never smokers compared to smokers [27, 28]. At the same time, other studies have reported effect estimates for the COPD-occupational exposure relationship that were elevated but not statistically significant [29–31]. The current study appears to be unusual in providing no evidence that occupational exposure poses a risk for AO among never smokers. We examined various issues that may have contributed to this finding. Nonsmokers were about equally likely as smokers to have high total VGDF exposure, with 24.5% (254/1028) among never smokers and 27.5% (182/915) among ever smokers ($p = 0.16$). It is conceivable that high occupational exposure was different in nature or extent for never smokers versus smokers. While we could not investigate this possibility extensively using the current data, we did examine whether the 254 never smoking participants with high total VGDF differed by occupational group from their 182 smoking counterparts. In fact, the never smoking and smoking groups with high total VGDF exposure had nearly the same percentage of participants working in blue collar occupations (52.0% and 52.7%, respectively) and management/professional occupations (45.3% and 42.9%, respectively), with the few other individuals working in services.

Both the current investigation and other studies reported a combined effect of smoking and occupational exposure that was additive or greater [29–31]. One possible explanation for this finding is that harmful agents in cigarette smoking adsorb onto particulate matter in occupational exposures and make an outsized contribution to the onset of COPD. One area of investigation along these lines has focused on cadmium (Cd), which is present as cadmium oxide (CdO) in cigarette smoke [32]. An analysis of data from the National Health and Nutrition Examination Survey revealed an association of lung function decrements with urinary Cd levels among former and current smokers [33]. Also, older studies reported an increased risk for emphysema and decrements in FEV1 and the FEV1/FVC ratio associated with occupational Cd exposure [34, 35]. A recent study using human lung epithelial cells demonstrated that CdO nanoparticle exposure facilitated post-translational citrullination of proteins, which could play a role in the pathogenesis of COPD [36]. The absorption of CdO from cigarette smoke onto the particulate matter inhaled in occupational settings could contribute to the elevated risk for AO observed in the current study and in other investigations.

Limitations

The cross-sectional nature of the study raises concern about temporality, specifically that exposure did not necessarily precede the health outcome. Small sample sizes limited analyses and contributed to wide confidence intervals, most notably for effect estimates among exposed never smokers (Table 3). The assessment of occupational exposures based on last job made it possible to compare the results from this study of rural participants to comparable results for the urban MESA participants. However, last job could be susceptible to the healthy worker effect and represent lower-exposed positions to which some less-healthy workers had moved. Cumulative occupational exposure based on lifetime work history might be a more appropriate metric given the outcome of AO. In addition, about two-thirds of the KCRHS sample reported farming during their lifetime, but the current analysis did not investigate the contribution of specific agricultural tasks or exposures to AO. Neither the MESA study nor the current analysis used a common unexposed comparison group when studying the effect of different occupational exposures. Ambient air pollution could potentially confound effect estimates for the association of AO with occupational exposure. However, it was not apparent that air pollution was distributed differentially by occupational exposure status. The study sample was limited to a single county so ambient air quality at that level was the same for all participants.

Strengths

The KCRHS provides the advantage of a relatively large cohort of rural adults who completed questionnaires and spirometry. Moreover, the spirometry results were high quality, and only 6.2% of the original 1847 participants with complete questionnaire data were excluded due to low-quality spirometry. A COPD-specific JEM was used to assign occupational exposure, a method that is usually considered to introduce less bias than self-reported exposures [37]. As already noted, the similarity of methods used in the current study of rural residents and the MESA study of urban residents facilitated comparisons.

Further research

Data gathered in the KCRHS are available to develop other metrics of occupational VGDF exposure. In particular, lifetime work histories can be combined with the COPD JEM to estimate cumulative VGDF exposure for each KCRHS participant. Answers to questionnaire items that inquired about lifetime and recent agricultural tasks provide the means to characterize agricultural exposure in the KCRHS cohort. The results from investigating the association of AO in KCRHS participants with these additional metrics of exposure might provide insight about the causes of COPD in rural communities and opportunities for prevention.

Conclusion

Reducing occupational airborne VGDF exposure might help prevent AO, especially among ever smokers.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Distribution of participants in the Keokuk County Rural Health Study by demographic and health characteristics, and frequency of airflow obstruction by same characteristics.

		Participants		Airflow obstruction	
Characteristic	**Categories**	**n**	**%**	**N**	**%**
Age[a]	18–39 years	474	27.9	11	2.3
	40–54 years	487	28.7	22	4.5
	55–64 years	282	16.6	25	8.9
	≥65 years	456	26.8	52	11.4
Sex[a]	Female	961	56.6	48	5.0
	Male	738	43.4	62	8.4
Smoking status[a]	Never smoker	1038	61.1	32	3.1
	Former smoker	402	23.7	44	10.9
	Current smoker	259	15.2	34	13.1
Cigarette pack-years[a]	None	1038	61.1	32	3.1
	Low, >0 and ≤16.5 pack years	333	19.6	14	4.2
	High, >16.5 pack-years	328	19.3	64	19.5
BMI	<25	438	25.8	28	6.4
	25 to <30	623	36.7	43	6.9
	30 to <35	403	23.7	26	6.5
	≥35	235	13.8	13	5.5
Education[a]	Less than high school diploma	133	7.8	16	12.0
	High school diploma	871	51.3	66	7.6
	Some college/tech school	417	24.5	19	4.6
	Bachelor’s degree or higher	278	16.4	9	3.2
Asthma[a]	No	1552	91.4	83	5.4
	Yes	147	8.7	27	18.4
Farm work	Never	614	36.1	42	6.8
	Former farmer	732	43.1	44	6.0
	Current farmer	353	20.8	24	6.8

Characteristic	Categories	Participants		Airflow obstruction	
		n	%	N	%
Farm work as a child	Never	1160	68.3	83	7.2
	Ever	539	31.7	27	5.0
Occupational group	Management/professional	556	32.7	29	5.2
	Service	253	14.9	18	7.1
	Sales/office	381	22.4	25	6.6
	Blue-collar	439	25.8	34	7.7
	Other	70	4.1	4	5.7

[a]Statistical significance ($p \leq 0.05$ by chi square) for airflow obstruction.

Table 2.

Distribution of 1699 participants by occupational VGDF exposure, frequency of airflow obstruction by exposure, and association of airflow obstruction with high exposure.

	Distribution of 1699 by exposure		Airflow obstruction				
			Frequency by exposure		Association with exposure		
High occupational exposure	**N**	**%**	**n**	**n/N, %**	**OR[a]**	**95% CI**	***p***
Total VGDF							
No	1263	74.3	71	5.6	1.0	Reference	
Yes	436	25.7	39	8.9[b]	1.50	0.87, 2.57	0.14
Vapor-gas							
No	1319	77.6	78	5.9	1.0	Reference	
Yes	380	22.4	32	8.4	1.37	0.75, 2.49	0.31
Total dust							
No	1339	78.8	78	5.8	1.0	Reference	
Yes	360	21.2	32	8.9[b]	1.49	0.81, 2.76	0.20
Mineral dust							
No	1477	86.9	91	6.2	1.0	Reference	
Yes	222	13.1	19	8.6	1.01	0.51, 1.99	0.98
Organic dust							
No	1370	80.6	82	6.0	1.0	reference	
Yes	329	19.4	28	8.5	1.41	0.73, 2.72	0.31
Fumes							
No	1659	97.6	105	6.3	1.0	reference	
Yes	40	2.4	5	12.5	1.56	0.55, 4.47	0.41

95% CI = 95% confidence interval; VGDF = vapor-gas, dust, and fumes.

[a] A separate regression model of airflow obstruction was fit for each VGDF exposure. Each model included covariates for age, sex, logarithm of cigarette pack-years, logarithm of BMI, highest level of education, ever asthma, farm work status, and the VGDF exposures indicated in the table.

[b] $p \leq 0.05$, by Yates continuity corrected chi square.

Table 3.

Association of airflow obstruction with the combination of smoking and high occupational exposures[a].

	Frequency of airflow obstruction		Regression models of airflow obstruction with different reference categories				
			Never/No as reference			Ever/No as reference	
Smoking/High occupational exposure	N in category	n cases	n/N, %	OR	95% CI	OR	95% CI
Smoking/Total VGDF							
Never/No	784	25	3.2	1.00	reference		
Never/Yes	254	7	2.8	0.82	0.32, 2.12		
Ever/No	479	46	9.6	2.95	1.72, 5.08	1.00	reference
Ever/Yes	182	32	17.6[b,c]	5.34	2.66, 10.7	1.81	1.002, 3.26
Smoking/Vapor-gas							
Never/No	808	25	3.1	1.00	reference		
Never/Yes	230	7	3.0	0.91	0.35, 2.38		
Ever/No	511	53	10.4	3.30	1.94, 5.60	1.00	reference
Ever/Yes	150	25	16.7[b,c]	4.77	2.26, 10.0	1.44	0.76, 2.76
Smoking/Total dust							
Never/No	815	26	3.2	1.00	reference		
Never/Yes	223	6	2.7	0.76	0.28, 2.12		
Ever/No	524	52	9.9	3.05	1.80, 5.17	1.00	reference
Ever/Yes	137	26	19.0[b,c]	5.30	2.46, 11.4	1.74	0.89, 3.38
Smoking/Mineral dust							
Never/No	909	30	3.3	1.00	reference		
Never/Yes	129	2	1.6	NR	NR		
Ever/No	568	61	10.7	3.18	1.94, 5.20	1.00	reference
Ever/Yes	93	17	18.3[c]	3.80	1.71, 8.44	1.20	0.58, 2.45
Smoking/Organic dust							
Never/No	831	26	3.1	1.00	reference		
Never/Yes	207	6	2.9	0.78	0.28, 2.20		
Ever/No	539	56	10.4	3.21	1.91, 5.40	1.00	reference

	Frequency of airflow obstruction		Regression models of airflow obstruction with different reference categories				
			Never/No as reference			Ever/No as reference	
Smoking/High occupational exposure	**N in category**	**n cases**	**n/N, %**	**OR**	**95% CI**	**OR**	**95% CI**
Ever/Yes	122	22	18.0[b,c]	4.81	2.14, 10.8	1.50	0.73, 3.07

95% CI = 95% confidence interval; NR = OR and confidence intervals not reported because <3 participants with airflow obstruction; OR = odds ratio; VGDF = vapor-gas, dust, and fumes.

Bolded OR indicates $p \leq 0.05$.

[a] A separate regression model of airflow obstruction was fit for each type of occupational exposure. Each model included covariates for age, sex, logarithm of BMI, highest level of education, ever asthma, farm work status, and the combination of smoking and high occupational exposure indicated in the table.

[b] $p \leq 0.05$ for Yates continuity corrected chi square test of Ever smoking/Yes High VGDF versus Ever smoking/No High VGDF.

[c] $p \leq 0.05$ for Cochran-Armitage test of linear trend across the four smoking/exposure categories.

Table 4.

Comparison of results for association of airflow obstruction with occupational exposure for MESA urban adults and KCRHS rural adults.

Result	MESA [18]	KCRHS (Current study)
Positive linear trend in crude frequency of airflow obstruction		
Across three levels of occupational exposure (no-low, medium, high)	Yes, for total dust ($p = 0.07$) and organic dust ($p = 0.05$)	Yes, for total VGDF ($p = 0.01$), vapor-gas ($p = 0.09$), and total dust ($p = 0.06$), but not for mineral or organic dust (Supplementary material Table 2)
Across the combination of smoking and occupational exposure	Yes, for vapor-gas and total dust, but no report of statistical testing	Yes, $p < 0.05$ for total VGDF, vapor-gas, total dust, mineral dust, and organic dust (Table 3)
Airflow obstruction associated with high occupational exposure		
Among all participants	Yes, for total dust OR = 2.35, 95% CI 1.10–5.04	No, for all VGDF metrics (Table 2)
Among never smokers	No	No (Table 3)
Among ever smokers	Not clear if tested	Yes, for total VGDF OR = 1.81, 95% CI 1.002–3.26 (Table 3)
Statistically significant multiplicative interaction of smoking and occupational exposure	No	No (Supplementary material Table 3)

95% CI = 95% confidence interval; MESA = Multi-Ethnic Study of Atherosclerosis; KCRHS = Keokuk County Rural Health Study; OR = odds ratio; VGDF = vapor-gas, dust, and fumes.