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Agricultural Work Exposures and Pulmonary Function Among Hired Farm Workers in California (The MICASA Study)

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ABSTRACT. Despite California's dependence on hired farm labor, scarce research has been conducted on the respiratory health of hired farm workers. Agricultural exposures to inorganic and organic dusts can adversely affect an individual's respiratory health and differ by farm type and job task. The purpose of the present analysis was to examine associations between agricultural work exposures and pulmonary function among 450 California farm workers. Data were collected as part of the Mexican Immigration to California: Agricultural Safety and Acculturation (MICASA) study, a prospective cohort study examining occupational risk factors and health of hired farm worker families in Mendota, California. Time-weighted self-reported average (TWSRA) dust scores were calculated from assessments of past-12-month agricultural work history. Other dust exposure indicator variables included months worked in agriculture in the past 12 months and years worked in agriculture. Multiple linear regression modeled FEV₁ (forced expiratory volume in 1 second), FEF_{25–75%} (forced midexpiratory flow rate), FVC (forced vital capacity), FEV₆, FEV₁/FVC, and FEV₁/FEV₆ separately. Seventy-six percent of participants had worked in agriculture in the past year. In models conducted for crops and tasks separately, high TWSRA dust score was associated with better FEV₆. Crop and task models showed associations between greater months worked in agriculture in the past year and better FEV₁, FEF_{25–75%}, and FEV₆. Both models also found greater years worked in agriculture to be associated with worse FEV₁/FEV₆. Results were generally in the opposite direction as expected given past research but not uncommon. Future research should investigate relationships between pulmonary function and agricultural dust exposure over a lifetime and changes in pulmonary function over time.

KEYWORDS. Agriculture, Hispanic Americans, respiratory function tests

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INTRODUCTION

The agriculture industry in California is the nation's largest and most diverse.¹ Approximately 70% of the industry's sales are non-animal-related products such as field crops, vegetables and melons, fruits and nuts, and nursery and floriculture. California's Fresno County, home to the rural town of Mendota, is the most agriculturally productive county in the United States.² It is estimated that between 372,600 and 648,000 persons are employed in California's agricultural work force. Between 63% and 95% of workers are born outside of the United States and almost all self-identify as Latino or Hispanic.^{3,4}

Despite the importance of hired farm labor to California's agriculture, scarce research has been conducted on the respiratory health of hired farm workers.⁵ The majority of investigations regarding agricultural work and respiratory symptoms have focused on farm operators and primarily on farms with livestock.⁵⁻¹⁰ Agricultural work exposures to inorganic dusts from soil^{5,11} and organic dusts containing microorganisms or allergens^{5,12-39} can adversely affect an individual's respiratory health and differ by farm type and job task.^{10,40-44} In the dry climate of California, exposure to agricultural dust has been found to be associated with persistent wheeze and chronic bronchitis.¹⁰ Additionally, mineral dust has been implicated in cases of small airway disease and pneumoconiosis, although its clinical significance is unknown.⁴⁴

Spirometry, a component of pulmonary function testing, is an invaluable screening tool of respiratory function.⁴⁵ Testing maneuvers are highly reproducible when performed adequately and can detect respiratory disease in its early stages, but spirometric measures don't always correlate with clinically relevant outcomes and minimal clinically important differences have not been clearly defined for all respiratory conditions.⁴⁶⁻⁵⁰

The purpose of the present analysis was to examine associations between agricultural work exposures and pulmonary function among California farm workers. Our objective was to assess the associations between self-reported

dust scores in the past 12 months, months worked in agriculture in the past 12 months, and years worked in agriculture and worse pulmonary function.

METHODS

Data were collected as part of the Mexican Immigration to California: Agricultural Safety and Acculturation (MICASA) study,⁵¹ a prospective cohort study examining occupational risk factors and health of hired farm worker families residing in Mendota, California. Households were sampled from randomly selected census blocks, and those containing at least one hired farm worker were contacted for recruitment into the study. Methods of sampling and recruitment for the MICASA study have been described in detail elsewhere.⁵¹

Participants consisted of men and women, aged 22 to 70 years, who self-identified as Mexican or Central American. Those who completed the follow-up interview, conducted between August 2008 and February 2010, and spirometry, conducted between February 2009 and June 2010, were included in the present analysis. In total, 640 participants completed the follow-up interview and 472 were screened for pulmonary function testing. Of these, 5 were screened out of spirometry for medical reasons. Seventeen participants who did not reproduce an acceptable maneuver according to American Thoracic Society (ATS) criteria were excluded.⁵²

Most interviews were conducted in the participant's home and assessed demographic characteristics, cigarette smoking,⁵³ and agricultural work history exposures. Spirometry was conducted according to standards established by ATS and the European Respiratory Society^{45,54} by certified⁵⁵ spirometry technicians using New Diagnostic Designs EasyOne spirometers (Andover, Massachusetts).

Questions regarding dust exposure and agricultural work history exposures were adapted from the California Agricultural Workers Health Survey.⁵⁶ Time-weighted self-reported average (TWSRA) dust scores were calculated for dust

exposure in the past year. Calculation of a participant's overall TWSRA dust score began by multiplying the number of weeks a participant worked in each crop type and job task combination by the average number of days worked per week. Next, the number of days worked for each crop type and job task combination was multiplied by its corresponding self-rated dust score. These values were summed over all time periods in the 12-month work history grid and divided by the number of days worked in agriculture in the past year. Participants with TWSRA dust scores above the mean were categorized as high TWSRA dust scores. Other dust exposure indicator variables included months worked in agriculture in the past 12 months and years worked in agriculture. Pesticide exposure was neither measured objectively nor assessed by self-report among participants enrolled in the broader MICASA study.

Crop-specific and task-specific TWSRA dust scores were calculated using the same procedure to calculate the overall TWSRA dust score. Time periods in the past year were identified by crop and task. For time periods that specified more than one crop or more than one task, the number of days worked in that time period was divided by the number of crops or number of tasks specified and each crop or each task received an equal number of days worked for that time period. Among the crops reported were melons, tomatoes, grapes, nuts, cotton, lettuce, asparagus, onion, pomegranates, and other less frequently reported crops. Reported tasks included packing/sorting, hoeing/weeding, pruning/cutting, irrigation, picking, cleaning, planting, machine driving, supervising, and other less common tasks.

For the present analysis, the following spirometric measures were modeled separately as primary outcomes: FEV₁ (forced expiratory volume in 1 second), FEF_{25-75%} (forced mid-expiratory flow rate), FVC (forced vital capacity), FEV₆, FEV₁/FVC, and FEV₁/FEV₆. Their reproducibility was assessed following ATS recommendations.⁵⁷ Participants with variability up to 8% on spirometric measures were included because their estimates remained stable during sensitivity analyses.⁵⁸⁻⁶¹

Multiple linear regression was used to model observed values of FEV₁, FEF_{25-75%}, FVC, FEV₆, FEV₁/FVC, and FEV₁/FEV₆ in separate models. All models were adjusted for age, sex, height squared,⁶² and current smoking because of their influence on pulmonary function. Estimates modeling FEV₆ had lower standard errors than those modeling FVC; therefore, estimates and standard errors for FVC and FEV₁/FVC were excluded from the results. FEV₆ can be used as a more reproducible surrogate for FVC, since it is a less physically demanding measure and is therefore easier to complete for individuals with respiratory conditions.⁴⁵ All analyses were performed using Statistical Analysis Software, version 9.2 (SAS Institute, Cary, NC).

RESULTS

A total of 450 participants, who completed the follow-up interview and spirometry, were included in analyses. Of these, 76% had worked in agriculture in the past year (Table 1). Participants who worked in agriculture in the past year did not differ from their counterparts by age but were more likely to be male and less likely to be born in the United States. Fifty-three percent of those who worked in agriculture in the past year were men ($P < .0001$). There were no differences by agricultural work status on years lived in the United States, household income, and proportion of participants reporting fair or poor health.

Among participants who worked in agriculture in the past year, women worked significantly less and had different work experience than men. Women worked an average of 10.6 years in agriculture compared with 17.4 years for men ($P < .0001$) (Table 2). In the past year, women worked fewer months in agriculture than men (5.0 months compared with 7.3 months, respectively; $P < .0001$).

Based upon TWSRA dust scores for each crop and task the least dusty crops were asparagus (TWSRA dust score = 2.4) and lettuce (TWSRA dust score = 3.2) (Figure 1). Most crops had TWSRA dust scores that fell between those of pomegranates (TWSRA

TABLE 1. Description of Study Cohort at Spirometry Testing

Characteristic	Total (N = 450)	Worked in agriculture in past year (n = 340)	Didn't work in agriculture in past year ^a (n = 110)
Age, % (n)			
30 years old or younger	18 (82)	18 (62)	18 (20)
31–40 years old	32 (145)	33 (112)	30 (33)
41–50 years old	33 (147)	33 (112)	32 (35)
51 years old or older	17 (76)	16 (54)	20 (22)
Male, % (n)	43 (192)	53 (179)	12 (13)***
Married/living with partner, % (n)	95 (427)	94 (321)	96 (106)
Country of birth, % (n) ^b			
United States	3 (13)	2 (6)	6 (7)**
Mexico	67 (290)	64 (208)	75 (82)
El Salvador	28 (121)	31 (101)	18 (20)
Other Central American	3 (11)	3 (10)	1 (1)
Years lived in the United States, mean ± SD ^b	15.3 ± 9.4	15.1 ± 9.2	15.6 ± 10.1
Highest grade completed in school, % (n)			
No school	6 (25)	7 (24)	1 (1)*
Primary or less	58 (262)	57 (192)	64 (70)
Greater than primary	36 (162)	36 (123)	35 (39)
Household income <\$30,000, % (n)	74 (311)	73 (233)	78 (78)
Current smoking, % (n)	6 (25)	6 (19)	5 (6)
Smoking pack years, mean ± SD	7.4 ± 8.6	6.5 ± 7.6	12.3 ± 12.4

^aIncludes those who worked in other occupations or didn't work in the past year.

^bData assessed at the baseline interview, conducted between January 2006 and May 2007.

* $P < .05$ for the comparison between those who worked and didn't work in agriculture in the past year.

** $P < .01$ for the comparison between those who worked and didn't work in agriculture in the past year.

*** $P < .001$ for the comparison between those who worked and didn't work in agriculture in the past year.

TABLE 2. Twelve-Month Agricultural Work History

Work history	Total (N = 340)	Men (n = 180)	Women (n = 160)
Months worked in agriculture in past year, mean ± SD	6.2 ± 2.6	7.3 ± 2.3	5.0 ± 2.3***
Years worked in agriculture, mean ± SD ^a	14.2 ± 9.2	17.4 ± 9.7	10.6 ± 7.1***

^aData assessed at the baseline interview, conducted between January 2006 and May 2007.

*** $P < .001$ for the comparison between men and women

dust score = 5.7) and cotton (TWSRA dust score = 7.4). Little variability existed among TWSRA dust scores for tasks; hoeing/weeding being the highest (TWSRA dust score = 7.2) and pruning/cutting being the lowest (TWSRA dust score = 5.4).

All multiple linear regression models were adjusted for age, sex, height squared, and current smoking (Table 3). Models assessing high TWSRA dust score, months worked in agriculture in the past year, and years worked in agriculture were analyzed for crops (Model 1)

and tasks (Model 2) separately. Although non-significant in both crops and tasks models, workers with high TWSRA dust scores in the past year had worse FEV₁/FEV₆. However, workers with high TWSRA dust scores also had better FEV₆ in both models. Assessment of months worked in agriculture in the past year for crops and tasks showed that individuals who worked more months had significantly better FEV₁, FEF_{25–75%}, and FEV₆ but non-significantly worse FEV₁/FEV₆. Years worked in agriculture produced nonsignificant results in

FIGURE 1. Mean (\pm SD) self-reported dust scores by crop and task ($N = 450$). Self-reported scores of participants in a given crop type or job task were time-weighted then averaged.
¹ag. = agricultural; dust score across all crop types and job tasks.

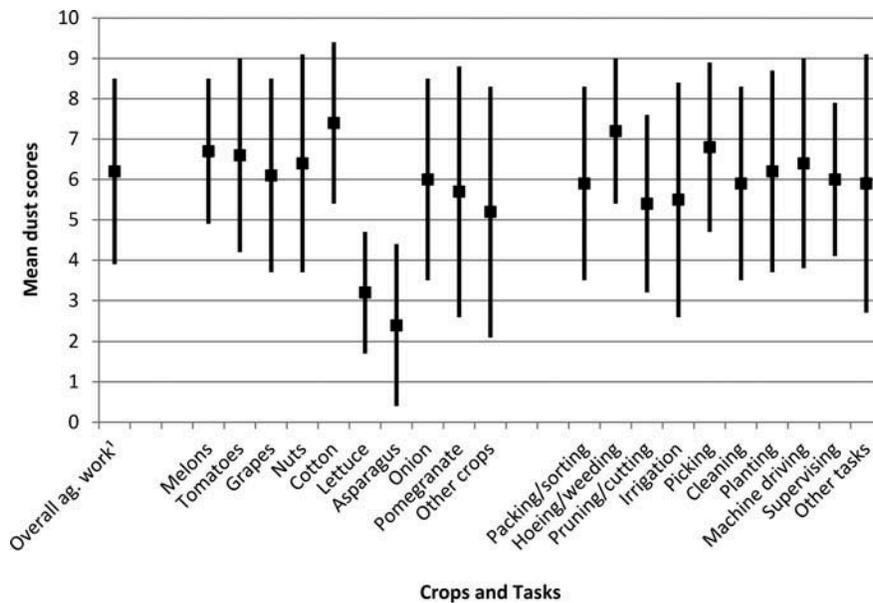


TABLE 3. Twelve-Month Agricultural Work History Percent-Time Regression Coefficients by Crop and Task ($N = 340$)^a

Work history	FEV ₁		FEF _{25-75%}		FEV ₆		FEV ₁ /FEV ₆	
	Estimate (SE)	P value	Estimate (SE)	P value	Estimate (SE)	P value	Estimate (SE)	P value
Model 1: Crops								
High TWSRA dust score in past year ^b	.13 (.09)	.16	.08 (.15)	.57	.22 (.10)	.04	-.008 (.006)	.14
Months worked in agriculture in past year	.08 (.01)	<.001	.11 (.03)	<.001	.11 (.02)	<.001	-.00003 (.001)	.97
Years worked in agriculture	.006 (.003)	.08	-.004 (.005)	.42	.009 (.005)	.05	-.0005 (.0002)	.03
Model 2: Tasks								
High TWSRA dust score in past year ^b	.14 (.09)	.12	.02 (.16)	.89	.22 (.10)	.02	-.008 (.006)	.20
Months worked in agriculture in past year	.08 (.01)	<.001	.11 (.03)	<.001	.11 (.02)	<.001	-.00001 (.001)	.99
Years worked in agriculture	.006 (.003)	.07	-.005 (.005)	.39	.009 (.004)	.05	-.0005 (.0002)	.04

^aAdjusted for age, sex, height squared, and current smoking.

^bTWSRA = time-weighted self-reported average.

Bold font indicates statistical significance.

the same direction as months worked in agriculture in the past year and TWSRA dust score in both models with regards to FEV₁ and FEV₆, but longer time in agriculture was significantly associated with worse FEV₁/FEV₆ and non-significantly associated with worse FEF_{25-75%}.

DISCUSSION

Analytical findings were relatively consistent across all three measures of agricultural work history exposure but unexpected given past research. High TWSRA dust score in the past

year was associated with better FEV₆, more months worked in agriculture in the past year was associated with better FEV₁, FEF_{25-75%}, and FEV₆, and more years worked in agriculture was associated with worse FEV₁/FEV₆.

Surprisingly, there were few differences between individuals who worked in agriculture in the past 12 months compared with those who didn't. Demographically, those who worked in agriculture in the past year were more likely to be men and less likely to be US-born. This is consistent with what we know about farm workers in California. The National Agricultural Workers Survey estimated that 73% of farm workers in California were men and 5% were born in the United States.³

Agricultural dust exposure in California's Central Valley differs from most traditional agricultural work.^{43,44,63} Therefore, occupational exposure concentrations have been quantified within the broader MICASA study.⁶⁴ Moran and colleagues⁶⁴ found that personal dust exposure levels were higher for almond workers than melon or tomato workers; which shared similar exposure concentrations. Although we didn't observe TWSRA dust scores to be higher for nuts, TWSRA dust scores were comparable between melons and tomatoes. They also reported that exposure concentrations were slightly lower for workers tasked with packing/sorting compared with harvesting and weeding/sweeping. These results support our findings of higher TWSRA dust scores for picking and hoeing/weeding tasks than packing/sorting. Moran et al. also assessed the correlation between actual dust concentrations and self-reported assessments of dust exposure. They noted that as time working in a crop increased, participants were less able to accurately predict dust exposure. This may explain why TWSRA dust scores did not always agree with the objective measures of dust exposure in the MICASA study.

In regression models that assessed TWSRA dust scores in the past year, the lack of association and positive association between dust exposure and pulmonary function were unexpected findings. Previous research among farm workers in California has linked particulate matter with persistent wheeze and chronic bronchitis

and implicated mineral dust in cases of small airway disease and pneumoconiosis.^{10,44} We also expected months worked in agriculture in the past year and years worked in agriculture to be associated with worse pulmonary function, although years worked in agriculture was associated with worse FEV₁/FEV₆. Prior analyses of MICASA farm worker cohort data found the number of years worked in agriculture to be associated with chronic cough and asthma.⁶⁵ Among farm workers in California's Central Valley, researchers observed that working >8 months per year in agriculture was associated with coughing most days at work while also observing pulmonary function to be better than predicted.⁶⁶ It is not uncommon in the literature for agricultural work to be associated with respiratory symptoms but not worse pulmonary function. Cross-sectional studies have linked work and dust exposure in animal confinement and herbal tea farming to respiratory symptoms, such as chronic bronchitis, wheezing, shortness of breath, and chronic cough, but not decrements in pulmonary function.⁶⁷⁻⁷¹

It has been suggested that cross-sectional investigations may not detect associations between exposure and worse pulmonary function because only the mean level of function in a group of workers is analyzed, therefore covering up an association that may exist among a minority of workers susceptible to the effects of exposure.⁷²⁻⁷⁴ This would explain why Bigham⁶⁵ found years worked in agriculture to be associated with respiratory symptoms among MICASA farm workers but we didn't observe an association between TWSRA dust scores in the past year, months worked in agriculture in the past year, or years worked in agriculture and worse pulmonary function with the exception of years worked in agriculture and worse FEV₁/FEV₆.

Ideally, measured exposure concentrations in agricultural settings are used to assess the amount of dust present in the work environment. Unfortunately, assessing exposure using objective measurements was not possible in the present analysis. Nieuwenhuijsen et al. determined that self-reported measures (scores) of dust by farm workers were reliable predictors of personal dust exposure when averaged

independent of age, the number of years worked in agriculture, level of education, the presence of respiratory symptoms, and the language of the questionnaire, providing confidence in the reliability of these assessments.⁷⁵

The present study benefited from the design of the MICASA study. First, established relationships with participants encouraged their continued participation as the study progressed. The study's presence in the community prior to the follow-up interview promoted the trust of participants, some of whom likely reside in the United States without legal authorization. Second, work history and exposures were assessed prior to pulmonary function ensuring that exposures of interest preceded spirometry outcomes. Third, use of dust exposure and agricultural work history exposure questions from the California Agricultural Workers Health Survey allowed participants to specify agricultural work by week for up to 12 months. Previous studies of respiratory health among farm workers identified only one job type, which may not reflect true patterns of work and exposure over the course of a year.^{76,77}

A limitation of the present analysis was the potential for a "healthy worker" bias. Results suggested that participants who worked in agriculture longer in the past year may have been healthier. This is an issue that plagues occupational studies with varying magnitude, and little consensus has been reached on how to control it.^{78–80} Past research has described the existence of the "healthy worker" bias among farmers^{81–85} as well as hired farm workers^{66,86–90} and warned researchers to anticipate it when assessing their respiratory health.⁹¹ Another limitation of this study is its limited sample size given the enormity of California's agricultural work force. Although data from a representative sample of farm workers in California's Central Valley were analyzed, caution should be exercised when generalizing these results to farm workers working in other areas of the state.

CONCLUSION

The present analysis has illustrated the challenges of assessing the respiratory health

of hired farm workers. Recommendations for future research include investigating relationships between dust exposure over a lifetime of agricultural work and pulmonary function, assessing changes in pulmonary function over time among hired farm workers, and using objective measures of dust exposure. Findings can be used as an example of the challenges when conducting research on the respiratory health of hired farm workers.

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