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ORIGINAL ARTICLES

Respiratory Findings in Farmworkers

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This investigation was designed to study respiratory problems in **farmworkers**. To better define the consequences of this work environment on respiratory health, 814 **farmworkers** (738 male and 76 female) were studied . The mean age of the men in this study was 38 years, and the mean duration of their employment was 15 years. For women, the mean age was 44 years and the mean duration of their employment was 10 years. Of the men, 56.5% were regular smokers, and 23.7% of the women were regular smokers. A group of 635 control workers without significant exposure to air pollutants were matched by sex, age, employment, and smoking habit. The prevalence of chronic symptoms among male **farmworkers** was greater ($P < 0.01$) than among male control subjects for chronic cough (24.8% vs 11.4%), chronic phlegm (22.8% vs 9.1%), and chronic bronchitis (20.1% vs 7.4%). Among women **farmworkers**, a significant difference was noted with controls for chest tightness (**farmworkers**, 21.1%; control subjects, 0%; $P < 0.001$). There was a high prevalence of acute symptoms among male and female **farmworkers**. In particular, **farmworkers** complained of more frequent cough, eye irritation, dyspnea, and throat irritation than did control subjects. For respiratory symptoms in male and female **farmworkers**, odds ratios were generally significant for smoking, age, and duration of employment. Ventilatory capacity tests were significantly reduced for **farmworkers** compared with predicted values. Regression analysis of ventilatory capacity tests in male **farmworkers** as a percentage of predicted values demonstrated significant coefficients for employment and smoking. Our data suggest that **farmworkers** are exposed to noxious agents that cause respiratory symptoms and ventilatory capacity impairment.

Introduction

Historically, the health effects of exposure to agricultural dusts and their by-products represent one of the earliest recognized forms of occupational respiratory disease. [1] [2] As early as 1713, Ramazzini [3] reported that **farmworkers** suffer from diseases of the chest. Currently, farming has been ranked as one of the top three most hazardous occupations, along with construction and mining. [4] Agricultural exposures vary in nature, concentrations, and relative risk. [5] Organic dusts, allergens, chemicals, toxic gases, and infectious agents are all present in this environment. [6]

Health effects that result from occupational exposure in **farmworkers** include grain fever, chronic bronchitis, farmer's lung, silo fillers syndrome, irritant and allergic asthma, irritant and allergic rhinitis, organic dust toxic syndrome, and acute and chronic changes in airway reactivity. [7] [8] [9] [10] [11] Terho [12] reported that 10% of farmers suffer from one of these respiratory diseases. The number of **farmworkers** at risk is large. In Croatia, more than 000 persons are employed in agriculture, hunting and forestry (Croatian Bureau of Statistics; http://www.dzs.hr).

The farm environment is complex, and many interacting agents contribute to respiratory disease in farmworkers. Wilkins et al [13] found that among farmworkers dealing with grain, smoking status was the strongest predictor of increased respiratory symptom prevalence compared with all other factors. James et al [14] and Iversen et al [15] indicated that occupational exposure to grain dust results in respiratory symptoms and changes in lung function, including increased airway responsiveness. Enarson et al [16] observed that the presence of bronchial hyperreactivity to methacholine, and the change in forced expiratory volume in 1 second (FEV_1) over a single work shift, best predict a pathologic trend in FEV_1 over time in grain handlers.

Respiratory diseases and distal airway obstruction in farmworkers were described by Vergnenegre et al [17] and by Manfreda et al, [18] who suggested that current lung function impairment in agricultural workers may reflect the degree of involvement with livestock in the past. Similarly, Terho [12] reported that chronic bronchitis was most prevalent among farmworkers who worked in piggeries, implying a combined effect of grain dust and animal dust on the development of respiratory disease. Heller et al [19] reported that farmworkers were found to have significantly lower FEV_1 and forced expiratory flow, midexpiratory phase, than control subjects. In their study of farmworkers, those workers performing dairy farming and silage work were the only groups to have significantly reduced lung function. Thus, a number of studies imply that respiratory disease in farmworkers may result from combined exposure to grain and animal dust.

Respiratory responses to inhaled organic dusts among farmworkers may result from both immunologic and nonimmunologic mechanisms. [5] Dalphin [20] suggested that immuno-allergic mechanisms play a role in the pathogenesis of chronic bronchitis in farmworkers, which distinguishes their disease from the chronic bronchitis caused by smoking. By contrast, Blaski et al [21] suggested that atopy may play, at most, a minor role in the development of grain dust-induced airway disease. Clapp et al [22] proposed that the airway response to grain dust represents an acute inflammatory response to an inhaled bacterial agent associated with grain dust, such as endotoxin, rather than a response to the dust itself. Schwartz et al [11] and Schwartz [23] performed studies indicating that endotoxin in the grain dust bioaerosol may be a major cause of the development of grain dust-induced lung disease. Although endotoxin undoubtedly contributes to changes seen after grain dust exposure, it is clear that other substances must play a role as well. [24]

The present study began in 1991 and was designed to investigate the prevalence of acute and chronic respiratory symptoms and lung function in farmworkers employed in five large farms in the north of Croatia.

Subjects and Methods

Work Conditions and Environment

This study included workers employed at five large farms operated by the Croatian government. These were cooperative farms on which workers were recruited for long-term employment under the direction of government agencies. Small privately owned farms were not included. At the time of this study, on average, more than 100 workers were employed at each of the five facilities. The participating farmworkers performed all types of agricultural work, including harvesting, threshing, loading and unloading grain trucks, stocking, transporting, handling, inspecting of unprocessed agricultural products, operating tractors, storing grain in barns, and working in silos. Crops included wheat, barley, corn, rye, and oats. Because workers performed multiple tasks on the same farm, it was not possible to study the effects of individual tasks or exposures; hence, these workers were all studied as one group. For farming, they used modern equipment purchased within the previous 10 years, including equipment for planting the seeds, harvesting, threshing, and baling and storing the harvested crops in barns and silos. The farmworkers we studied were not engaged in breeding or managing livestock.

For these workers, the greatest exposure to dust typically begins with the harvesting and transporting of agricultural products. Storage of plant products on the farms (barns or silos) results in further exposure. In particular, storage may result in exposures to "spoiled" grain when grains are cleaned or to "moldy" silage when a silo is uncapped. Another significant silo exposure to which these workers are at risk arose from the fermentation of silage with subsequent exposure to oxides of nitrogen. Vegetable dust exposure also occurs with grinding of grain for the preparation of feed for livestock and the handling of processed grain in the form of animal feed. Farmworkers who seasonally worked in grain elevators, in particular, faced substantial exposure to grain dust and associated hazards. Throughout the year, farmworkers were also involved in plowing the soil, sowing the seeds for different crops, grinding and sifting the grain for animal feed, and preparing compost and pesticides for fertilizing the soil. They also regularly maintained the machines used in this agricultural work.

With the harvesting of plant products, some inorganic soil particles were retained by the final product (accounting for 25% to 45% of the dry weight of material handled). These became a part of the occupational and environmental exposure. Although the occupational aerosol was predominantly from the plant matter itself (estimated to be 60% to 75% of the dust), these products were commonly contaminated with microorganisms, in particular Gram-negative bacteria and their endotoxins and fungi and their glucans and mycotoxins. Other contaminants included insects, such as grain weevils and storage mites; hairs, feathers, and excreta of rodents and birds; and residual chemicals, including fertilizers, pesticides, fungicides, and fumigants. Vegetable dusts also contained constituents of weeds that contaminated the plant crop and were themselves potential irritants or sensitizers.

Subjects

This study included a group of 814 farmworkers (738 male and 76 female). They represented 92% of all the workers employed on the five farms. The mean age of the male workers was 38 years (range, 21 to 61 years), their mean height was 174 cm (range, 155 to 188 cm), and their mean duration of employment was 15 years (range, 2 to 40 years). More than 50% of the male **farmworkers** were smokers (417 of 738, or 56.5%) smoking an average of one pack of cigarettes daily. The mean age of the female **farmworkers** was 44 years (range, 21 to 61 years), their mean height was 162 cm (range, 155 to 175 cm), and their mean duration of employment was 10 years (range, 2 to 31 years). Only 18 of 76 (23.7%) of the female **farmworkers** were smokers, smoking an average of one-half pack of cigarettes daily.

In addition, a group of 570 male and 65 female workers without significant environmental exposure, employed in packing food products in the food industry, were studied as a control group for the prevalence of acute and chronic respiratory symptoms. Lung function measurements were not available for the control group. The age, duration of employment, and smoking habits were matched in exposed and control workers.

In addition, a group of 27 male seasonal **farmworkers** were studied for respiratory symptoms and lung function changes over a 4-hour working cycle during which they loaded and unloaded trucks with grain. This work was very dusty, and these workers were exposed to high concentrations of grain dust. The mean age in this subgroup was 23 years (range, 19 to 26 years). They were predominantly smokers (64%), smoking an average of one pack of cigarettes daily.

Respiratory Symptoms

Chronic respiratory symptoms were recorded using the British Medical Research Council questionnaire on respiratory symptoms [25] with additional questions on occupational asthma. [26] [27] [28] For all workers, a detailed occupational history and answers to questions about their smoking habits were recorded. Both **farmworkers** and controls were interviewed by a physician administering the symptom questionnaire. The following definitions were used:

- chronic cough or phlegm: cough and/or phlegm for a minimum of 3 months a year;
- chronic bronchitis: cough and phlegm for a minimum of 3 months a year and for not less than 2 successive years;
- dyspnea: grade 3, shortness of breath when walking with other people at an ordinary pace on level ground; grade 4, shortness of breath when walking at one's own pace on level ground;
- occupational asthma: recurring attacks of dyspnea, chest tightness, and pulmonary function impairment of the obstructive type diagnosed by physical examination and spirometric measurements during exposure to dust at or following work (decrease of FEV_1 >15%) and confirmed by the medical records.

Acute symptoms that developed during the work shift were also recorded in all farmers and control workers. Symptoms included dry cough, dyspnea, irritation or dryness of the throat; irritation, secretion, dryness, or bleeding of the nose; irritation of eyes; and headache.

Ventilatory Capacity

Ventilatory capacity measurements were performed in farmers by recording the maximum expiratory flow-volume (MEFV) curves on a spirometer Pneumoscreen (Jaeger, Wurzburg, Germany). The same instrument and technicians were used throughout the study. The forced vital capacity (FVC), FEV_1, and the forced expiratory flow rates at 50% and the last 25% of the vital capacity ($FEF_{50\%}$, $FEF_{75\%}$) were measured on the MEFV curves. Measurements were performed during the morning work shift. The spirometer was calibrated on a daily basis. Lung function testing was performed according to the recommendations of Quanjer et al. [29] At least three MEFV curves were recorded for each subject, and the best value of the three technically satisfactory MEFV curves was used as the result of the test (the curve with the greatest FVC and FEV_1). The measured values for ventilatory capacity were compared with the predicted normal values of Quanjer, [30] which are based on sex, age, and height.

Roentgenographic Examinations

Chest roentgenograms of the **farmworkers** were performed before employment and occasionally during the course of their employment as part of a regular preventive medical examination sponsored by the government. Each worker in the course of this examination had a full-size posteroanterior chest radiograph. The results of all the roentgenograms were read by two radiology specialists using the International Labor Office classification. [31]

Statistical Analysis

The chi-squared test (or, when appropriate, the Fisher exact test) was used for testing differences in the prevalence of respiratory symptoms between groups. Odds ratios were calculated using logistic regression analysis for each respiratory symptom (variables) and age, employment, and smoking as predictors (SAS). [32] The results of ventilatory capacity measurements were analyzed by the paired *t* test comparing baseline with predicted values for the **farmworkers** and among the 27 seasonal workers. In addition, for the seasonal workers, the data before and after a 4-hour grain dust exposure were compared using the paired *t* test. Ventilatory capacity data was also analyzed by applying multiple regression analysis with age, employment, and smoking as predictors and percentage of predicted for FVC, FEV_1, $FEF_{50\%}$ and $FEF_{25\%}$ as criterion variables (SAS). [33] A level of $P < 0.05$ was considered statistically significant.

Results

Respiratory Symptoms

Table 1 shows the prevalence of chronic respiratory symptoms in farmworkers and in control workers. Prevalences of chronic cough, chronic phlegm, and chronic bronchitis in male farmworkers and chest tightness in female farmworkers were significantly greater than in control workers ($P < 0.001$). Occupational asthma was diagnosed only in farmworkers (male, 11, 1.5%; female: 5, 6.6%)) and not among controls (male, $P < 0.01$; female, $P < 0.05$).

Table 1. Prevalence of Chronic Respiratory Symptoms in Male and Female Farmworkers and Control Workers

Group	Mean Age (yrs)	Mean Employment (yrs)	Chronic Cough		Chronic Phlegm		Chronic Bronchitis		Dyspnea Grades 3 and 4		Occupational Asthma		Chest Tightness	
			n	%	n	%	n	%	n	%	n	%	n	%
Male														
Farmworkers (*n* = 738)	38 ± 11	15 ± 10	183	24.8	168	22.8	148	20.1	67	9.1	11	1.5	153	20.7
Controls (*n* = 570)	39 ± 10	16 ± 10	65	11.4	52	9.1	42	7.4	12	2.1	0	0	0	0
P value			<0.001		<0.001		<0.001		NS*		NS		NS	
Female														
Farmworkers (*n* = 76)	44 ± 11	10 ± 7	8	10.5	7	9.2	5	6.6	7	9.2	5	6.6	16	21.1
Controls (*n* = 65)	44 ± 9	10 ± 8	5	7.7	4	6.2	3	4.6	0	0	0	0	0	0
P value			NS		NS		NS		NS		NS		<0.001	

* NS, difference not statistically significant ($P > 0.05$).

Table 2 presents the prevalences of chronic respiratory symptoms in farmworkers by smoking habit. Male smokers had significantly higher prevalences of chronic cough, chronic phlegm, chronic bronchitis, and chest tightness than did nonsmokers ($P < 0.001$). Among the female farmworkers, there were no significant differences between smokers and nonsmokers. Comparisons between farmworkers who were nonsmokers and control nonsmokers showed significantly increased prevalences for all recorded chronic symptoms in both men and women.

Table 2. Prevalence of Chronic Respiratory Symptoms in Male and Female Farmworkers by Smoking Habit

Group	Mean Age (yrs)	Mean Employment (yrs)	Chronic Cough		Chronic Phlegm		Chronic Bronchitis		Dyspnea Grades 3 and 4		Occupational Asthma		Chest Tightness	
			n	%	n	%	n	%	n	%	n	%	n	%
Male														
Smokers (*n* = 417)	37 ± 10	14 ± 9	159	38.1	140	33.6	126	30.2	39	9.4	7	1.7	106	25.4
Nonsmokers (*n* = 321)	40 ± 11	16 ± 10	24	7.4	28	8.7	22	6.9	28	8.7	4	1.2	47	14.6
P value			<0.001		<0.001		<0.001		NS*		NS		<0.001	
Female														

Group	Mean Age (yrs)	Mean Employment (yrs)	Chronic Cough n	Chronic Cough %	Chronic Phlegm n	Chronic Phlegm %	Chronic Bronchitis n	Chronic Bronchitis %	Dyspnea Grades 3 and 4 n	Dyspnea Grades 3 and 4 %	Occupational Asthma n	Occupational Asthma %	Chest Tightness n	Chest Tightness %
Smokers (n = 18)	36 ± 12	6 ± 6	2	11.1	1	5.6	1	5.6	1	5.6	1	5.6	2	11.1
Nonsmokers (n = 58)	46 ± 10	11 ± 7	6	10.3	6	10.3	4	6.9	6	10.3	4	6.9	14	24.1
P value			NS		NS		NS		NS		NS		NS	

* NS, difference not statistically significant ($P > 0.05$).

Prevalences of acute symptoms (which occurred during the work shift) in **farmworkers** are presented by smoking habit in Table 3. There were similar prevalences among smokers and nonsmokers that were particularly high for cough, eye irritation, dyspnea, dry throat, and irritation of the throat. Among control workers, only men complained of cough (15 of 570, or 2.6% vs 234 of 738, or 31.7% in **farmworkers**) and throat irritation (10 of 570, or 1.8% vs 179 of 738, or 24.3% in **farmworkers**) ($P < 0.01$). For all other acute symptoms, control workers did not offer any complaints.

Table 3. Prevalence of Acute Symptoms During Work Shift in Farmworkers by Smoking Habit

Group	Cough n	Cough %	Dyspnea n	Dyspnea %	Wheezing n	Wheezing %	Throat Irritation n	Throat Irritation %	Throat Dry n	Throat Dry %	Eye Irritation n	Eye Irritation %	Nose Dry n	Nose Dry %	Nose Secretion n	Nose Secretion %	Nose Bleeding n	Nose Bleeding %	Headache n	Headache %
Male																				
Smokers (n = 417)	150	35.9	118	28.3	54	12.9	101	24.2	113	27.1	154	36.9	88	21.1	37	8.9	36	8.6	80	19.2
Nonsmokers (n = 321)	84	26.2	78	24.3	27	8.4	78	24.3	92	28.7	107	33.3	75	23.4	30	9.3	32	9.9	47	14.6
P value	<0.001		NS*		NS		NS		NS		NS		NS		NS		NS		NS	
Female																				
Smokers (n = 18)	9	50.0	6	33.3	2	11.1	6	33.3	6	33.3	7	38.9	6	33.3	3	16.7	1	5.6	4	22.2
Nonsmokers (n = 58)	27	46.6	21	36.2	8	13.8	22	37.9	21	36.2	23	39.7	15	25.9	7	12.1	6	10.3	23	39.7
P value	NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	

* NS, difference not statistically significant ($p > 0.05$).

Logistic regression analysis for individual symptoms in **farmworkers** are shown in Table 4 for men and in Table 5 for women. The data are arranged by smoking, duration of employment, and age. Regression coefficients for almost all symptoms were statistically significant with regard to smoking, employment, and age.

Table 4. Respiratory Symptoms in Relation to Age, Employment, and Smoking in 738 Male Farmworkers

Respiratory Symptoms	Logistic Regressions	Odds Ratio: Smoking	Odds Ratio: Employment	Odds Ratio: Age
Chronic cough	-1.9656 -0.0142 × age +0.0203 × employment +0.0904 × smoking	1.095*	1.020*	0.986
Chronic phlegm	-2.2912 -0.00159 × age +0.0196 × employment +0.0682 × smoking	1.071*	1.020*	0.998

Respiratory Symptoms	Logistic Regressions	Odds Ratio Smoking	Employment	Age
Chronic bronchitis	-2.9586 +0.00996 × age +0.0128 × employment +0.0766 × smoking	1.080*	1.013*	1.010*
Occupational asthma	-6.1994 +0.0452 × age -0.0193 × employment +0.0349 × smoking	1.036*	0.981	1.046*
Dyspnea	-6.7414 +0.1091 × age -0.0253 × employment +0.0158 × smoking	1.016*	1.023*	1.115*
Throat irritation	-1.9417 +0.0166 × age +0.00299 × employment +0.0101 × smoking	1.010*	1.003	1.017*
Dry throat	-1.8989 +0.0204 × age +0.00412 × employment +0.00744 × smoking	1.007	1.004	1.021*
Eye irritation	-1.7487 +0.0179 × age +0.0144 × employment +0.0211 × smoking	1.021*	1.015*	1.018*
Nasal secretion	-3.5722 +0.0480 × age -0.0429 × employment +0.00350 × smoking	1.004	0.958	1.049*
Dry nose	-1.9447 +0.00712 × age +0.0207 × employment +0.00657 × smoking	1.007	1.021*	1.007
Nasal bleeding	-3.1427 +0.0201 × age +0.00653 × employment -0.00549 × smoking	0.995	1.007	1.020*
Headache	-3.6202 +0.0585 × age -0.0298 × employment -0.0165 × smoking	1.017*	0.971	1.060*
Chest tightness	-3.7930 +0.0276 × age +0.0169 × employment +0.0238 × smoking	1.024*	1.017*	1.028*
Acute work-related cough	-1.1430 -0.0173 × age +0.0471 × employment +0.0287 × smoking	1.029*	1.048*	0.983
Acute work-related dyspnea	-2.1863 +0.0149 × age +0.0229 × employment +0.0191 × smoking	1.019*	1.023*	1.015*

* Statistically significant ($P < 0.05$)

Table 5. Respiratory Symptoms in Relation to Age, Employment, and Smoking in 76 Female Farmworkers

Respiratory Symptoms	Logistic Regressions	Odds Ratio Smoking	Employment	Age
Chronic cough	-4.5787 +0.0386 × age +0.0451 × employment +0.0329 × smoking	1.033*	1.046*	1.039*
Chronic phlegm	-7.0091 +0.0886 × age +0.0399 × employment -0.0479 × smoking	0.953	1.041*	1.093*

Respiratory Symptoms	Logistic Regressions	Odds Ratio Smoking	Odds Ratio Employment	Odds Ratio Age
Chronic bronchitis	-6.5209 +0.0797 × age +0.00748 employment -0.0243 × smoking	0.976	1.008	1.083*
Occupational asthma	-9.4048 +0.1423 × age -0.0259 × employment -0.0153 × smoking	0.985	0.974	1.153*
Dyspnea	-5.7945 +0.0702 × age +0.0201 × employment -0.0486 × smoking	0.953	1.020*	1.073*
Throat irritation	-2.4884 +0.0525 × age -0.0402 × employment +0.0113 × smoking	1.011*	0.961	1.054*
Dry throat	-2.0432 +0.0373 × age -0.0247 × employment +0.0174 × smoking	1.018*	0.976	1.038*
Eye irritation	-2.1585 +0.0360 × age +0.00202 × employment +0.0412 × smoking	1.042*	1.002	1.037*
Nasal secretion	-1.4500 +0.000572 × age -0.0549 × employment +0.0195 × smoking	1.020*	0.947	1.001
Dry nose	-3.1868 +0.0398 × age +0.0192 × employment +0.0750 × smoking	1.078*	1.019*	1.041*
Nasal bleeding	-2.4622 -0.0177 × age +0.0898 × employment -0.1743 × smoking	0.840	1.094*	0.982
Headache	-0.6730 +0.00718 × age -0.0130 × employment -0.0457 × smoking	0.955	0.987	1.007
Chest tightness	-5.2716 +0.0734 × age -0.00296 × employment -0.0194 × smoking	0.981	0.997	1.076*
Acute work-related cough	-0.3368 +0.00245 × age +0.0109 × employment +0.00300 × smoking	1.003	1.011*	1.002
Acute work-related dyspnea	-3.0625 +0.0637 × age -0.0401 × employment +0.0130 × smoking	1.013*	0.961	1.066*

* Statistically significant ($P < 0.05$).

Among the 27 seasonal workers studied during a 4-hour shift, 17 (62.9%) complained of respiratory symptoms, such as dry cough, breathlessness, chest tightness, irritation of the throat, irritation and dryness of the nose, and eye irritation. In addition, 6 of these 27 seasonal workers (35.3%) described an episode of headache and nausea, accompanied by fever, chills, malaise, and myalgia, suggesting that these workers may have developed acute organic dust toxic syndrome as described by Von Essen et al, [34] Rylander et al, [35] and Rylander. [36] These workers recovered from their symptoms within 24 hours.

Ventilatory Capacity

Table 6 demonstrates measured and predicted lung function in male and female farmworkers by smoking habit. In both male smokers and nonsmokers, all ventilatory capacity tests were significantly decreased compared with predicted values ($P < 0.01$). Among women farmworkers, only the FVC in smokers and in nonsmokers and the $FEF_{50\%}$ and $FEF_{25\%}$ in nonsmokers were decreased significantly compared with predicted values ($P < 0.01$).

Table 6. Ventilatory Capacity in Farmworkers by Smoking Habit*

Group	Mean Age (yrs)	Mean Employment (yrs)	Mean Height (cm)	FVC Measured (L)	FVC Predicted (L)	FVC Difference Measured - Predicted (P)	FEV_1 Measured (L)	FEV_1 Predicted (L)	FEV_1 Difference Measured - Predicted (P)	$FEF_{50\%}$ Measured (L/s)	$FEF_{50\%}$ Predicted (L/s)	Di[illegible] M[illegible] Pr[illegible]
Male												
Smokers (n = 417)	38 ± 10	14 ± 9	174 ± 7	4.43 ± 0.95	4.87 ± 0.65	<0.01	3.62 ± 0.85	3.89 ± 0.57	<0.01	4.69 ± 1.66	5.34 ± 0.58	<0.
Nonsmokers (n = 321)	40 ± 11	16 ± 10	174 ± 7	4.38 ± 0.91	4.79 ± 0.64	<0.01	3.65 ± 0.86	3.80 ± 0.57	<0.01	5.06 ± 1.74	5.26 ± 0.59	<0.
Female												
Smokers (n = 18)	36 ± 12	7 ± 6	164 ± 5	3.48 ± 0.50	3.75 ± 0.44	<0.05	2.96 ± 0.57	3.06 ± 0.45	NS*	3.96 ± 1.02	4.34 ± 0.25	NS
Nonsmokers (n = 58)	46 ± 10	11 ± 7	160 ± 6	3.16 ± 0.56	3.38 ± 0.42	<0.01	2.56 ± 0.57	2.67 ± 0.41	NS	3.61 ± 1.23	4.13 ± 0.23	<0.

* FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second; $FEF_{50\%}$, forced expiratory flow rate at 50%; $FEF_{25\%}$, forced expiratory flow rate at 25%; NS, difference not statistically significant ($P > 0.05$).

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table 7, table 8 describe the findings of our multiple regression analysis using age, employment, and smoking as predictors and percentage of lung function parameters as outcome variables for male and female **farmworkers**. Employment and smoking seem to be highly significant predictors of lung function abnormalities in male **farmworkers** but not in female **farmworkers**; however, only 10% of the **farmworkers** were women.

Table 7. Regression Analysis of Ventilatory Capacity Tests in 738 Male Farmworkers as Percentage of Predicted*

Test/Variable	df	Parameter Estimate	Standard Error	T for H0: Parameter = 0	Prob > (T)	P	R^2
FVC							
Intercept	1	94.561718	1.04228255	90.726	0.0001		
Employment	1	-0.215736	0.05679821	-3.798	0.0002		
Smoking	1	-0.015435	0.04860795	-0.318	0.7509		
P, R^2						0.0003	0.0189
FEV_1							
Intercept	1	99.321431	1.11605628	88.993	0.0001		
Employment	1	-0.234785	0.06081844	-3.860	0.0001		
Smoking	1	-0.169364	0.05204846	-3.254	0.0012		
P, R^2						0.0001	0.0417
$FEF_{50\%}$							
Intercept	1	100.624993	1.98348787	50.731	0.0001		
Employment	1	-0.321945	0.10808832	-2.979	0.0030		
Smoking	1	-0.517028	0.09250205	-5.589	0.0001		
P, R^2						0.0001	0.0635
$FEF_{25\%}$							
Intercept	1	95.595010	2.40981135	39.669	0.0001		
Employment	1	-0.598228	0.13132042	-4.555	0.0001		
Smoking	1	-0.475423	0.11238410	-4.230	0.0001		
P, R^2						0.0001	0.0633

* *df*, degrees of freedom; T, *t* statistic for the null hypothesis (H0) that implies the parameter to be 0. For definition of other abbreviations, see Table 6.

Table 8. Regression Analysis of Ventilatory Capacity Tests in 76 Female Farmworkers as Percentage of Predicted*

Test/Variable	df	Parameter Estimate		T for H0: Parameter = 0	Prob > (T)	P	R^2
FVC							
Intercept	1	93.311387	2.46165645	37.906	0.0001		
Employment	1	-0.018348	0.17756411	-0.103	0.9180		
Smoking	1	0.131573	0.23447542	0.561	0.5764		
P, R^2						0.8424	-0.0226
FEV_1							
Intercept	1	95.513573	3.40549259	28.047	0.0001		
Employment	1	0.050205	0.24564486	0.204	0.08386		
Smoking	1	0.170455	0.32437683	0.525	0.6008		
P, R^2						0.8623	-0.0232
$FEF_{50\%}$							
Intercept	1	92.631722	5.61265329	16.504	0.0001		
Employment	1	-0.417436	0.40485168	-1.031	0.3059		
Smoking	1	-0.077344	0.53461126	-0.145	0.8854		
P, R^2						0.5898	-0.01265
$FEF_{25\%}$							
Intercept	1	70.990387	9.06351106	7.833	0.0001		
Employment	1	0.9185522	0.65376882	1.405	0.1643		
Smoking	1	0.131686	0.86330918	0.153	0.8792		
P, R^2						0.3776	-0.0003

* *df*, degrees of freedom (1, number of variables; 2, number of subjects); T, *t* statistic for the null hypothesis (H0) that implies the parameter to be 0. For definition of other abbreviations, see Table 6.

Analysis of the mean measured lung function values for 794 **farmworkers** as a percentage of predicted demonstrated that the lowest mean values were obtained for $FEF_{25\%}$ (varying from 80% to 87% of predicted) in men and women, respectively. Analysis of the individual lung function measurements showed that for male **farmworkers**, values were less than 70% of predicted in 30 (5.3%) for FVC, in 49 (6.6%) for FEV_1, in 184 (24.9%) for $FEF_{50\%}$, and in 319 (43.2%) for $FEF_{25\%}$. For female **farmworkers** these numbers were 3 (3.9%) for FVC, 5 (6.6%) for FEV_1, 19 (25.0%) for $FEF_{50\%}$, and 35 (46.1%) for $FEF_{25\%}$.

For the 27 seasonal workers, there was a significant ($P < 0.01$) acute mean decrease in lung function measurements over the 4-hour work exposure: for FVC (-3.5%), for FEV_1 (-8.0%), for $FEF_{50\%}$ (-13.7%), and for $FEF_{25\%}$ (-21.4%). The changes for $FEF_{50\%}$ and $FEF_{25\%}$ suggest obstruction primarily in the smaller airways. All lung function tests in the 27 seasonal workers were above 85% of predicted before exposure.

Roentgenographic Examinations

No case of pneumoconiosis or any other occupationally caused radiographic abnormality (including allergic alveolitis) was diagnosed in any of the studied **farmworkers** at the time of their roentgenographic examinations.

Discussion

Our study is the first report of respiratory findings in Croatian agricultural workers and suggests that these workers, employed exclusively in the farming of commercial grain products and not involved with livestock, are at risk of developing acute and chronic respiratory symptoms and lung function changes as a result of their occupational exposures. The prevalences of most of the chronic respiratory symptoms were significantly higher in male **farmworkers** than in the control group of workers. Smoking had pronounced deleterious effects, particularly among male **farmworkers**. Typical symptoms of occupational asthma among our **farmworkers** were recorded in 1.5% of male and in 6.6% of female farmers.

Several authors report that the prevalence of occupational asthma in agricultural **farmworkers** varies from 3% to 7.7%. [37] [38] Kimbel-Dunn et al [39] reported a very high prevalence of asthma among New Zealand **farmworkers**, reaching 18.2%. Pahwa et al [40] reported that significant predictors for the first episode of wheezing were current smoking and baseline FEV_1 /FVC ratio. The same authors stress that baseline pulmonary function measurements and smoking habit seem to be important predictors for the future development of asthma-like symptoms in grain elevator workers.

Among our **farmworkers**, a large number of workers complained of acute work-related symptoms that developed during the work shift, particularly cough, dyspnea, and eye and throat irritation. Several authors have reported previously that exposure to grain dust may induce acute and chronic respiratory, nasal, and ocular symptoms in **farmworkers**, which are associated with an obstructive pattern in pulmonary function. [24] [41] [42] [43]

James et al [44] recorded that in 18% of young seasonal grain handlers, breathlessness, chest tightness, cough, or sputum production were accompanied by a significant decline in FEV_1 . In the current study, 17 of 27 of the seasonal workers (62.9%) experienced acute symptoms over a work shift. Organic dust toxic syndrome was suspected in 6 of the 17 (35.3%) seasonal workers. Such symptoms became apparent within several hours of the exposure to dust. Despite the workers' relatively toxic findings, auscultation of their chests failed to show signs of disease. The workers were able to return to work within 24 to 48 hours.

Significant postshift decreases of ventilatory capacity were observed by Skorska et al [45] in **farmworkers** after working with grain. Their results were interpreted as a response of grain **farmworkers** to inhalant microbial allergens. Other data suggest that respiratory disorders in **farmworkers** are associated with levels of ambient endotoxin or more generally with bacterial, fungal, or other microbial components encountered in these workplaces. [46]

In our study of 27 seasonal **farmworkers**, we demonstrated that even an acute 4-hour exposure to high concentrations of grain dust is enough to cause a significant decrease in lung function. This decrease was particularly pronounced for $FEF_{25\%}$, suggesting obstructive changes predominantly in smaller airways. These data are similar to those of Tabona et al, [4] who found acute changes in lung function among grain elevator workers over the course of 1 workweek. These changes were positively correlated with subsequent decline in lung function among these workers.

James et al [47] also found that respiratory symptoms were more frequent among grain handlers than in nonexposed subjects. These symptoms and a decrease in FEV_1 were greatest among grain handlers who worked in jobs in which total exposure to dust was more than 20 mg/m^3 (compared with workers in jobs in which exposure was less than 10 mg/m^3). A strong dose-response relationship between grain dust exposure and both respiratory symptoms and lung function has also been reported by Huy et al. [48]

Conclusion

We showed that **farmworkers** not exposed to livestock are at risk of developing significant work-related respiratory problems. This is a complex environment with many hazards. An integrated medical and technical approach to these problems is required for prevention in this work setting. Moreover, prevention may require the wearing of filtration masks in very dusty work areas and the reduction of allergens, particulates, and microbial by-products by industrial hygiene techniques. Preventive measures should also include worker education and behavior modification. In particular, the role of cigarette smoking in the workplace must receive great attention, and smoking cessation measures must be implemented.

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