EDITOR'S PICK

My choice is based on his recognised expertise around the study of chronic respiratory diseases potentially affecting employees in farms. Dr Stoleski and colleagues present, in the current journal, a cross-sectional study evaluating the incidence of respiratory symptoms and diseases among crop farmers. This study is very interesting, further underlining the expertise of Dr Stoleski in this setting.

Dr Antonio Rossi

RESPIRATORY SYMPTOMS, LUNG FUNCTION IMPAIRMENT, AND CHRONIC RESPIRATORY DISEASES AMONG CROP FARMERS: ASSESSMENT BY JOB EXPOSURE MATRICES

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Disclosure: The authors have declared no conflicts of interest.
Received: 15.02.16 **Accepted:** 30.08.16
Citation: EMJ Respir. 2016;4[1]:72-80.

ABSTRACT

Objective: To evaluate the prevalence of chronic respiratory symptoms, lung function impairment, and chronic obstructive respiratory diseases in crop farmers. Our objective is to then examine their relation to exposure duration, and to explore the usefulness of job exposure matrices as tools for exposure assessment, and predictors for respiratory health impairment.

Methods: A cross-sectional study was performed, including 50 males (mean age: 45.4±10.7 years) employed as crop farmers (duration of exposure: 21.6±9.7 years) and 50 male office workers as a control group (mean age: 44.1±9.8 years) matched for age, smoking habits, and socioeconomic status. Methods of evaluating examined subjects included the completion of a questionnaire on respiratory symptoms in the last 12 months (cough, phlegm, dyspnoea, wheezing, chest tightness, and nasal symptoms), spirometry and histamine challenge (provocative concentration producing a 20% fall in forced expiratory volume in 1 second [FEV_1]: ≤8 mg/mL), as well as use of job exposure matrices.

Results: Crop farmers had a significantly higher prevalence of cough (29.4%), phlegm (16.7%), and wheezing (11.9%), than the control group ($p<0.05$). All spirometric parameters (forced vital capacity [FVC], FEV_1, FEV_1/FVC%, maximal expiratory flow (MEF) at 75%, 50%, and 25%) were lower in crop farmers compared to the control patients, but statistical significance was confirmed only for MEF at 25%, 50%, and 25–75% ($p=0.021$, $p=0.011$, and $p=0.003$, respectively). The prevalence of bronchial hyperresponsiveness, asthma, and chronic obstructive pulmonary disease was higher in crop farmers but without statistical significance. JEM were useful tools for exposure assessment and predictors of factors for asthma and COPD development.

Conclusion: The results suggest that occupational exposure among crop farmers is associated with a higher prevalence of respiratory symptoms, lung function impairment, and a higher prevalence of chronic respiratory diseases.

Keywords: Respiratory symptoms, farming, lung function, asthma, chronic obstructive pulmonary disease (COPD), job exposure.

INTRODUCTION

Respiratory hazards are one of the most prevalent occupational agents in agriculture, causing different types of respiratory disorders among exposed workers.[1] Such exposure occurs during soil processing, harvesting, treatment, and storage of corn and other plants.[2]

Despite exposure to respiratory hazards, smoking is also an important factor that leads to the development of chronic respiratory disorders among crop farmers. Many epidemiological studies that have analysed respiratory diseases in agriculture follow the effect of smoking, especially the 'joint effect' of smoking and occupational exposure among crop farmers.[3] Namely, the frequency of active smokers among farmers in France is 28%, and according to our previous research, the frequency of active smokers within agricultural workers in Macedonia is 40.2%.[4]

Most of the mineral soil fraction is predominantly of a silicate nature, i.e. respirable dust that contains quartz. The association between respirable quartz dust and silicosis has previously been established, but there is a special scientific interest in the pathological potential for quartz dust causing other chronic respiratory diseases, such as chronic obstructive pulmonary disease (COPD).[5] Organic dust exposure has qualitative and quantitative variations, and depends on the type of agricultural activity. Wheat dust includes mould spores, mycotoxins, bacteria and their components, excreta, dust mites, insects, animal products, particles of cotton, paper, flour, tobacco, and other types of dust.[6] Crop farmers are exposed to numerous plants (such as grains, grasses, weeds, and trees) and animal allergens (such as livestock hairs and poultry feathers).[7]

In the case of occupational exposure, skin absorption is more frequent than through the inhalation pathway for pesticides, but sometimes inhalation can be of great concern due to pesticides having high solubility and rapid evaporation rates.[1] Occupational exposure is most intensive in crop farmers involved in the mixing and loading of the pesticides; inhalation occurs while dealing with soluble liquids.[8] Exposure to aero-pollutants derived from welding, as well as the use of solvents, fuels, and disinfectants are considered as occupational hazards for crop farmers.[9] Disinfectants are used mostly in cattle breeding, and contain chloramine-T or quaternary ammonia compounds which are known to cause occupational asthma.[10]

Exposure to most respiratory hazards in agriculture are controllable and subsequently, work-related respiratory diseases in crop farmers caused by these agents are potentially preventable.[11]

In the present study we have compared the prevalence of chronic respiratory symptoms, lung function impairment, and chronic obstructive respiratory diseases between crop farmers and office workers. We have further examined this prevalence in relation to exposure duration, and explored the usefulness of job exposure matrices as tools for exposure assessment in crop farmers, as well as predictors for respiratory health impairment.

SUBJECTS AND METHODS

Study Design and Setting

Our team conducted a cross-sectional study at the Center for Respiratory Functional Diagnostics at the Institute for Occupational Health of Republic of Macedonia, Skopje, WHO Collaborating Center for Occupational Health and GA²LEN Collaborating Center, within the period March 2014–February 2015.

Study Sample

The representative study sample was calculated by the software program 'Programs for Epidemiologists version 4.04', with a 95% confidence level (0.05 significance) and a confidence interval ±5. In order to achieve the necessary sample size (with consideration for possible selection and response bias), we have taken a representative sample of 50 crop farmers and 50 matched office controls in a large scale agricultural enterprise.

Subjects

We have examined 50 male subjects (mean age: 45.4±10.7) employed as crop farmers (mean duration of exposure: 21.6±9.7). They were engaged in crop farming with main activities composed of cultivating crops and vegetables, planting, digging, use of mechanised equipment, irrigation, and pesticide handling. They were exposed to various respiratory agents, including dust, inappropriate climate, fumes, vapours, and pesticides. The inclusion criteria for the examined group required employed males with an age range of 18–64 years, who were involved in crop farming and exposed to at least one occupational respiratory hazard (dust, gases, fumes, vapours, and pesticides).

Exclusion criteria for the examined group were subjects younger than 18 years, or older than 64 years, and subjects not engaged in crop farming. To avoid selection bias and results deviations, the study did not include subjects with exposure to respiratory hazards other than crop farming. Depending on the exposure duration, the examined subjects were divided into two subgroups: i) exposure <15 years; ii) exposure >15 years. In addition, a similar group of 50 male office workers (mean age: 44.1±9.8 years) matched for age, duration of employment, daily smoking, and socioeconomic status was studied as a control, with no data for occupational exposure to respiratory hazards.

The subjects in both groups who were diagnosed with a chronic respiratory disorder (asthma, COPD, bronchiectasis, sarcoidosis, etc.) by physicians, or were treated with bronchodilators and/or corticosteroids were not included in the study. Also, both groups did not comprise any subjects in whom either spirometry or bronchodilator reversibility testing was contraindicated.

Our institute's ethics committee has approved the content of our study protocol and each examined subject gave written informed consent before any involvement in the study.

Questionnaire

All study participants were interviewed by a physician and completed the standardised questionnaire (including questions on work history, respiratory symptoms in the last 12 months, and smoking habits). Chronic respiratory symptoms in the last 12 months (cough, phlegm, dyspnoea, wheezing, and chest tightness) were obtained using the European Community for Coal and Steel questionnaire (ECCS-87), and the European Community Respiratory Health Survey (ECRHS) questionnaire.[12,13]

Table 1: The prevalence of respiratory symptoms in the last 12 months in both examined groups and the prevalence of respiratory symptoms in the last 12 months in crop farmers with a duration of workplace exposure of more and less than 15 years.

Respiratory symptoms in the last 12 months	Crop farmers (n=50)	Office workers (n=50)	p-value*
Any respiratory symptom	17 (34%)	13 (26%)	0.383
Cough	14 (28%)	6 (12%)	0.045
Phlegm	8 (16%)	2 (4%)	0.045
Dyspnoea	7 (14%)	3 (6%)	0.182
Wheezing	8 (16%)	2 (4%)	0.046
Chest tightness	5 (10%)	3 (6%)	0.461
Crop farmers			
Respiratory symptoms in the last 12 months	**Exposed >15 years (n=27)**	**Exposed <15 years (n=23)**	**p-value***
Any respiratory symptom	12 (44.4%)	4 (17.4%)	0.041
Cough	8 (29.6%)	3 (17.4%)	0.158
Phlegm	6 (22.2%)	2 (8.7%)	0.193
Dyspnoea	7 (25.9%)	1 (4.3%)	0.042
Wheezing	6 (22.2%)	2 (8.7%)	0.193
Chest tightness	3 (11.1%)	2 (8.7%)	0.578

Data are expressed as a number and percentage of study subjects with certain variables.
*Tested by chi-square test or Fisher's exact test where appropriate.

Classification of smoking status was determined according to the World Health Organization (WHO) guidelines on definitions of smoking status.[14] A 'daily smoker' was defined as a subject who, at the time of the field survey, smoked at least once a day, except on days of religious fasting. Among daily smokers, lifetime cigarette smoking and daily mean of cigarettes smoked were also assessed. Pack-years smoked were calculated according to recommendations.[15] An 'ex-smoker' was defined as a former daily smoker, who no longer smokes. Passive smoking or exposure to environmental tobacco smoke was defined as the exposure of a person to tobacco combustion products from smoking by others.[16]

Spirometry

All study subjects underwent spirometry testing performed by the spirometer Ganshorn SanoScope LF8 (Ganshorn Medizin Electronic GmbH, Niederlauer, Germany), measuring forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, and maximal expiratory flow (MEF) at 50%, 75%, and 25–75% of FVC (MEF_{50}, MEF_{75}, and MEF_{25-75}, respectively), by recording the best result from three measurements of the values of FEV_1 within 5% of each other. The spirometry results were given as a percentage of their predicted values, according to the current European Respiratory Society (ERS) and American Thoracic Society (ATS) recommendations, including reproducibility and acceptability.[17]

Histamine Challenge

Bronchial hyperresponsiveness (BHR) was assessed by the histamine challenge test performed according to the ERS/ATS recommendations.[18,19] Namely, concentrations of 0.5, 1.0, 2.0, 4.0, and 8.0 mg/mL histamine (Torlak, Beograd, Serbia) were prepared by dilution with buffered saline.

Table 2: Mean values of spirometric parameters in examined groups and mean values of spirometric parameters in crop farmers, with a duration of workplace exposure of more and less than 15 years.

Spirometric parameter	Crop farmers (n=50)	Office workers (n=50)	p-value*
FVC (% pred)	85.3±8.2	86.1±8.5	0.633
FEV_1 (% pred)	83.2±7.9	85.6±8.3	0.142
FEV_1/FVC%	72.9±4.3	74.2±4.7	0.152
MEF_{25} (% pred)	57.7±6.1	60.5±5.9	0.021
MEF_{50} (% pred)	56.7±5.4	59.3±6.2	0.011
MEF_{75} (% pred)	59.3±6.9	61.5±5.8	0.087
MEF_{25-75} (% pred)	58.3±7.1	62.9±8.1	0.003
	Crop farmers		
Spirometric parameter	**Exposed >15 years (n=27)**	**Exposed <15 years (n=23)**	**p-value***
FVC (% pred)	83.6±8.1	84.9±8.7	0.587
FEV_1 (% pred)	80.9±5.9	81.3±6.2	0.816
FEV_1/FVC%	72.3±3.9	74.1±4.3	0.127
MEF_{25} (% pred)	55.2±5.2	57.8±4.9	0.076
MEF_{50} (% pred)	53.2±5.3	56.2±4.9	0.044
MEF_{75} (% pred)	49.5±5.5	52.6±5.1	0.045
MEF_{25-75} (% pred)	58.2±6.1	61.1±7.3	0.132

Data are expressed as a mean value with standard deviation.
*Tested by independent-sample T-test.
FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 second; MEF_{25}, MEF_{50}, MEF_{75}, MEF_{25-75}: maximal expiratory flow at 25%, 50%, 75%, and 25-75% of FVC, respectively; % pred: percentage of predicted value.

Table 3: Risk of developing asthma and chronic obstructive pulmonary disease due to occupational exposure to respiratory agents, according to the matrices for job exposure among crop farmers.

	OR (95% CI)	
	Asthma	COPD
Qualitative job exposure matrix		
Dust	1.78 (0.34–3.59)	1.82 (0.41–3.86)
Gases/fumes/vapours	1.83 (0.41–3.90)	1.75 (0.30–3.72)
Pesticides	1.45 (0.21–3.02)	1.34 (0.17–3.24)
Matrix with exposure intensity		
Dust exposure		
Low	1.63 (0.21–3.76)	1.75 (0.35–3.82)
Intermediate	1.76 (0.29–3.91)	1.84 (0.42–4.01)
High	2.25* (1.12–4.17)	2.34* (1.23–4.45)
Gases/fumes/vapours exposure		
Low	1.87 (0.67–4.02)	1.63 (0.39–3.46)
Intermediate	2.37* (1.22–4.30)	1.78 (0.56–3.89)
High	3.12* (1.56–5.97)	2.36* (1.34–4.78)
Pesticide exposure		
Low	1.21 (0.17–2.68)	1.17 (0.09–2.56)
Intermediate	1.42 (0.31–2.90)	1.38 (0.23–2.87)
High	1.73 (0.54–3.45)	1.64 (0.45–3.21)
Matrix with exposure frequency		
Dust exposure		
Rare	1.54 (0.39–3.04)	1.63 (0.43–3.12)
Sporadic	1.76 (0.62–3.79)	2.04* (1.03–4.11)
Regular	2.18* (1.04–4.05)	2.45* (1.38–4.23)
Gases/fumes/vapours exposure		
Rare	1.65 (0.41–3.12)	1.59 (0.33–3.09)
Sporadic	1.73 (0.52–3.32)	1.66 (0.43–3.21)
Regular	3.28* (1.63–6.25)	2.67* (1.41–4.15)
Pesticide exposure		
Rare	1.17 (0.12–2.45)	1.12 (0.06–2.32)
Sporadic	1.36 (0.24–2.86)	1.32 (0.20–2.75)
Regular	1.69 (0.43–3.35)	1.58 (0.41–3.17)

Data are given as ORs with 95% CIs.
*$p<0.05$
*Tested by logistic regression after adjustment for age and smoking habit.
OR: odds ratio; CI: confidence interval; COPD: chronic obstructive pulmonary disease.

Afterwards, the doses of aerosol generated by a Pari LC® nebuliser, with an output rate 0.17 mL/min, were inhaled by mouthpiece. Subjects inhaled increasing concentrations of histamine using a tidal breathing method, until FEV_1 fell by more than 20% of its base value (provocative concentration $[PC]_{20}$) or until the highest concentration was reached. According to ATS recommendations, BHR was categorised as moderate-to-severe BHR (PC_{20} <1.0 mg/mL), mild BHR (PC_{20}=1.0–4.0 mg/mL), and borderline BHR (PC_{20}=4.0–8.0 mg/mL).[19]

Job Exposure Matrices

In order to assess occupational exposure to respiratory agents among crop farmers, we have used job exposure matrices recommended by the

European Association of Schools of Occupational Medicine (EASOM), including both a qualitative and quantitative matrix, with exposure intensity and exposure frequency.[20]

Diagnostic Criteria for Asthma and Chronic Obstructive Pulmonary Disease

According to the current recommendations of the Global Initiative for Asthma (GINA), asthma in subjects with normal spirometry findings is defined as symptomatic BHR with PC_{20} ≤4 mg/mL, whereas in subjects with respiratory impairment a positive bronchodilator test is sufficient.[21] According to the current recommendations by the Global Initiative for Chronic Obstructive Lung Disease (GOLD), COPD is defined by a post-bronchodilator FEV_1/FVC ratio <0.70 in subjects with dyspnoea, chronic cough, and/or cough with phlegm.[22]

Statistical Analysis

We have analysed the data using STATISTICA for Windows® version 7. Continuous variables were expressed as mean values, with standard deviation and categorical variables as numbers and percentages. The chi-square test (or Fisher's exact test) was used for testing differences in the prevalence of respiratory symptoms, while the comparison of spirometric measurements was performed by an independent-samples T-test. A p-value of <0.05 was considered statistically significant. Logistic regression analysis was used to assess the risk of chronic respiratory symptoms, asthma, and COPD development within job exposure matrices, adjusted for age and smoking habits. Study variables were checked for normality by the Kolmogorov–Smirnov and Shapiro–Wilk W tests.

RESULTS

Demographic characteristics of the study subjects were similar in both crop farmers and office controls. Crop farmers had a higher prevalence of respiratory symptoms in the last 12 months than office workers, with significant differences for cough (29.4%), phlegm (16.7%), and wheezing (11.9%). The prevalence of respiratory symptoms in the last 12 months was higher in crop farmers exposed for >15 years than in those with workplace exposure <15 years, being significantly different for overall respiratory symptoms and dyspnoea (Table 1).

All spirometric parameters (FVC, FEV_1, FEV_1/FVC%, MEF_{75}, MEF_{50}, and MEF_{25}) were lower in crop farmers compared to the office controls, but statistical significance was reached for MEF_{25}, MEF_{50}, and MEF_{25-75} (p=0.021, p=0.011, and p=0.003, respectively). Mean values of spirometric parameters were lower in crop farmers exposed <15 years, than in those exposed for <15 years, with statistical significance for MEF_{50} and MEF_{75} (Table 2).

Restrictive and obstructive spirometric changes were more frequent in crop farmers compared to controls, but a significant difference was found only for small airway obstruction. The prevalence of non-specific BHR was higher in exposed crop farmers, but statistical significance was not reached (22% versus 12%). Prevalence of mild and borderline BHR was higher in crop farmers, but was not statistically significant. Asthma and COPD were more prevalent in crop farmers compared with office workers, but without reaching statistical significance.

Occupational exposure to respiratory agents among crop farmers was assessed by the job exposure matrices, providing conformity of occupational exposure to respiratory agents with their specific job activities. In order to prevent the influence of possible confounding factors on the results obtained by job exposure matrix, we have used logistic regression analyses, adjusted by age and smoking habit. The association of asthma and COPD, with the exposure to respiratory agents according to the job exposure matrices in crop farmers, is shown in Table 3.

The data obtained show that a high degree of dust exposure on a regular basis significantly increases the asthma risk in crop farmers. The same statement is valid for an intermediate and high degree of exposure to gases, fumes, and vapours on a regular basis. On the other hand, sporadic and regular dust exposure with high intensity significantly increases COPD risk. Concerning exposure to gases, fumes, and vapours, COPD risk is significantly associated with a high degree of exposure on a regular basis. Pesticide exposure does not influence the risk of asthma and COPD development in crop farmers.

DISCUSSION

Chronic respiratory symptoms, lung function impairment, and respiratory disorders remain important clinical and public health issues for farmers worldwide.[23] This study compares the prevalence of chronic respiratory symptoms, lung function impairment, and chronic obstructive respiratory diseases between crop farmers and office workers, and introduces job exposure matrices as tools for exposure assessment.

The prevalence of chronic respiratory symptoms among crop farmers in this study is 34%, with 70% of them reporting work-related exposure. Office workers, on the other hand, report a frequency of 26%, and no workplace association. The prevalence is higher among exposed workers, and is a significant cause of cough, phlegm, and wheezing symptoms. According to European studies, the prevalence of chronic respiratory symptoms range between 25% and 35%,[24] whereas Stoleski et al.[25] report a prevalence of 26.6% for overall respiratory symptoms among agricultural workers. A frequency of 8.3% is reported for chronic cough with phlegm, similar to our previous research,[26] but also by studies from Slovenia and Croatia.[27] According to the Croatian study, the prevalence of cough with phlegm among agricultural workers is 2–12%, being highest among cattle breeders.[24] The frequency of cough with phlegm among Finnish farmers is 7.5%,[28] and up to 23% according to research from Manitoba, Canada.[29] The Danish study among 834 elderly males reveals that the highest prevalence of cough with phlegm is among retired agricultural workers.[30] A study in France shows the highest frequency of dyspnoea in farmers (37%), while the lowest is recorded in school teachers (15%).[31]

A study in Poland shows a prevalence of 44.7% for overall chronic respiratory symptoms in crop farmers, and the highest rates are registered for chronic cough (26.3%) and dyspnoea (19.7%).[32] Other studies confirm a higher frequency of wheezing in agricultural workers compared with office workers.[33] This study suggests the risk of developing respiratory symptoms increases with >15 years of job exposure. A significant association between exposure duration and chronic bronchitis is reported in the study by Omland et al.[34] with 1,691 farmers exposed to organic and inorganic dust. Many surveys report a higher frequency of chronic respiratory symptoms among agricultural workers with longer occupational exposure,[35] while those examining respiratory effects of organic dust show a significant association between smoking habits and respiratory symptoms.[36] A study among French farmers shows a synergistic effect of occupational exposure and smoking, especially for chronic cough and phlegm.[37]

Our research shows a significant difference for small airways indices in crop farmers compared to controls. The average values of spirometric parameters are lower in crop farmers exposed for >15 years, with significant differences in MEF_{50} and MEF_{75}. The results confirm a higher prevalence of restrictive and obstructive types of ventilatory insufficiency among exposed workers compared to controls, while small airways obstruction is significantly higher in crop farmers. The research on agricultural workers by Stoleski et al.[25] reports lower average values of all spirometric parameters compared to controls, with significant differences in MEF_{50} and MEF_{75}. Ventilatory insufficiency is associated with those aged >60 years, having a job exposure duration of >20 years, a smoking habit, and open to dust and pesticide exposure. Dosman et al.[38] report significantly lower values of all spirometric parameters among Danish crop farmers compared to the control group, despite associations with age and pesticide exposure.

Similar results concerning the effect of grain dust over values of the spirometric parameters in exposed farmers are presented by Huy et al.,[39] Corey at al.,[40] and Enarson et al.[41] Dalphin et al.[42] reported significantly lower values of FVC and FEV_1 among cattle breeders compared to controls. Recent studies show that an increase in the annual decline of lung function is usually associated with job exposure, but also smoking habit.[43] Our previous research confirms lung function decline by exposure duration, significant for MEF indices in farmers exposed for more than 15 years.[44] Leuenberger et al.[45] report a significantly higher prevalence of BHR in subjects exposed to dust, vapours, and fumes compared to those who are not exposed.

The prevalence of asthma in crop farmers in the present study is 10%, which is not significantly higher than office workers (6%). In a cross-sectional study among farmers in Denmark, Iversen et al.[46] detected a prevalence of 27% for chronic bronchitis and 8% for asthma, while Dalphin et al.[37] reported a lower asthma prevalence (5.3%) in French farmers. Previous studies worldwide show that occupational exposure to toxic gases and grain dust on farms, as well as dust and fumes from industrial facilities,[47] are strongly associated with COPD. The ATS performed a large epidemiological survey in 2013 which showed that 15% of COPD cases are connected to occupational exposure,[48] and consequently reports similar estimates.[49]

The prevalence of COPD in the present study is non-significantly higher in crop farmers (8%) compared to office controls (4%). The prevalence of chronic bronchitis and COPD in crop farmers and cattle breeders, assessed by Eduard et al.,[50] confirmed the association between dust exposure on farms with COPD development. Epidemiological surveys in France, Netherlands, and Norway show significant associations between occupational exposure assessed by specific job exposure matrices, and lung function in the rural population.[51]

Occupational exposure to respiratory agents in the actual study beside the questionnaire on job exposure is assessed also by job exposure matrices (qualitative, matrix on exposure intensity, and matrix on exposure frequency). According to the matrix data in this study, a high degree of dust exposure on a regular basis significantly increases the asthma risk among crop farmers. The same fact is reported for a medium and high degree of exposure to gases, fumes, or vapours on a regular basis, while sporadic and regular high intensity dust exposure significantly increases the risk of COPD development. Concerning job exposure to gases, fumes, or vapours, the risk of COPD development is significantly associated with a high degree of exposure on a regular basis. Le Moual et al.[52] evaluated risk factors for COPD development and reported associations between occupational exposure assessed by specific population matrix and lung functional impairment.

Job exposure matrices are relatively easily designed, are not restricted by the number and categories of examined subjects, and have better characteristics and performances compared with the self-reported method, especially when optimal conditions for practical implementation are fulfilled. Matrices should be widely used for occupational exposure assessment and hypothesis deriving, especially in large groups of examinees, and in cases with a lack of adequate questionnaires on workplace exposure. Despite some expected weaknesses, the matrices offer great opportunities in exposure assessment of occupational respiratory hazards. Nevertheless, additional research is also needed in order to improve their performance and predictive values.

This study has certain limitations, namely, the relatively small number of subjects in the study groups, and an absence of ambient monitoring, which could aggravate a clear relationship between occupational exposure and respiratory impairment in crop farmers.

In conclusion, we found a higher prevalence of respiratory symptoms, significantly lower values of small airways indices, and a higher prevalence of asthma and COPD in crop farmers compared to controls, also related to exposure duration. The results recognised the role of job exposure matrices in farming exposure assessment and characterisation, their potential to be a predictive factor in the development of respiratory diseases, and promotes their applicability within the diagnostic algorithm for respiratory health assessment.

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