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The association of self-reported respiratory system diseases with farming activity among farmers of greenhouse vegetables

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Abstract

Objectives: Several studies have investigated the link between agricultural activities of open-field farmers and the prevalence of respiratory diseases, but the relationship with greenhouse vegetable farmers remains unclear.

Methods: A total of 1,366 participants from four villages in China provided information about their agricultural activities and symptoms of diagnosed respiratory system diseases. The Poisson regression model and zero-inflated Poisson regression model were used to assess the association between diseases, symptoms, and agricultural activities.

Results: The prevalence of respiratory diseases was 3.59%, and the rates of four main symptoms (cough, tachypnea, chest distress, and hemoptysis) were 17.21%, 8.56%, 10.25%, and 1.61%, respectively. Mix spray of pesticides associated with cough, tachypnea and chest distress, 1.740-, 3.385- and 2.882-fold likelihood were found than hand spray, and the significant association were detected in empty, general information, life-style information adjusted models.

Conclusions: The relationship between agricultural activities and respiratory diseases is unclear. However, use of the mix spray method of pesticide application may increase the risk of cough, tachypnea, and chest distress.

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Keywords
Respiratory disease, symptoms, farming activities, greenhouse vegetables, pesticide application, Poisson regression

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Introduction

Respiratory diseases and related symptoms associated with agricultural activities were one of the first occupational hazards to be recognized.[1] The prevalence of respiratory diseases[2–4] such as asthma, chronic bronchitis,[2–5] chronic obstructive pulmonary diseases (COPD), accelerated lung function decline, and organic dust toxic syndrome[6–11] is higher among farmers than in the general population, which is a public health concern for greenhouse farmers because of their specific working environment. Major exposure conditions for these farmers include organic and mineral dust,[11] agricultural activities, labor intensity,[2,12] and, most notably, pesticide use.[13] A study in Ghana showed that the use of specific pesticides is positively linked with respiratory diseases among farmers in open-air pastoral areas.[13] Further evidence from the American Agriculture Health Study[14] and a French study[15] revealed that pesticide use may increase the incidence of chronic bronchitis. Unfortunately, little direct evidence of the relationship between respiratory diseases and greenhouse farming is available.

Pesticides are extensively used worldwide in agricultural activities because of the need to feed increasingly growing populations of middle-income countries. However, the overuse and high exposure to pesticides among workers in developing countries have been reported.[13,16–18] Data from the Food and Agriculture Organization of the United Nations showed that the average and sum pesticide usage in China was larger than that of other developed and developing countries.[19] Compared with open-field agricultural farmers, greenhouse farmers are more likely to have exposure to pesticides or their cumulative residues.[20] Moreover, the working environment of greenhouse agriculture has a high labor intensity that might impact on farmers' health.[21] In the northwest of China, greenhouse vegetable products play an important role in the daily lives of urban residents by ensuring a daily fresh vegetable supply in the city.[22] Therefore, this study aimed to evaluate the association between respiratory disease and agricultural activity, and to estimate the prevalence of respiratory diseases and their symptoms in greenhouse vegetable farmers.

Materials and methods

Study design and setting

This cross-sectional study was conducted in April and May from 2015 to 2017 in four cooperative villages (Yinhe, Wudu, Maosheng, and Heshun) located on the outskirts of Yinchuan City, Northwest China. This region has a temperate, continental climate. Because the nearby Tengger Desert can reduce annual rainfall and affect the natural agricultural crop yield, more than 60,000 ha of plastic greenhouses have been financed by local government[23] to satisfy the daily vegetable supply.

Source and study population

Our study population included all vegetable greenhouse farmers (both men and women) from the selected survey sites. One non-repetitive team of residents was randomly selected from each village in each survey year. Participant selection criteria were that the citizen or their spouse had been living at their current address for at least 1 year, and that participants had been working as a greenhouse farmer for at least 1 year. All greenhouses were plastic polytunnels. The main vegetables grown in the greenhouses included tomatoes, cucumbers, celery, green peppers, and squash.

Definition of respiratory diseases and symptoms

Information about diseases and symptoms were collected for the previous year. The presence of respiratory disease was determined by the participant response to the multiple choice question: "Do you have any of the following system diseases diagnosed at a hospital of county level or above?" The response options included "chronic bronchitis", "emphysema", "asthma", "respiratory failure", "allergic lung disease", and "other".

Related symptoms were measured by four questions: "Have you ever had cough or expectoration for unknown reasons?"; "Have you ever had dyspnea or tachypnea for unknown reasons?"; "Have you ever had chest distress or shortness of breath for unknown reasons?", and "Have you ever had hemoptysis for unknown reasons?" The response options for all questions were: "never", "occasionally", and "frequently".

Participants with respiratory disease were defined as cases and those who reported no respiratory disease were defined as the control group.

Agricultural activities and pesticide exposure assessment

Agricultural activities and pesticide exposure-related information for study participants during the past year were the number of cumulative planting years, planting areas, working duration in the greenhouse, the number of years of pesticide use, whether pesticides were mixed in a spray, the average spray length), pesticide spraying methods, and protection awareness and attitude. The information was collected by face-to-face interviews using a self-administrated questionnaire. Personal protective equipment (PPE) use was measured as previously described[24] using a multiple choice question: "What protective measures did you take when using pesticides?" Response options were "none", "masks", "protective suit", "protective goggles", "protective gloves", and "protective rubber shoes". A lower PPE score represented better personal protection.

The personal hygiene (Hyg) score was aggregated from three single choice questions: Question 1 was "After spraying pesticide, when do you usually wash or change into clean clothes?" Response options were "immediately", "after going home that day", or "do not usually change clothes". Question 2 was "When do you take a shower after spraying pesticides?", and question 3 was "When do you wash your hands after spraying pesticide?" Response options for both questions were "immediately", "the same day", or "do not wash that day". A previous validation method[23] was used to calculate the Hyg score, with a lower score representing better personal hygiene habits.

Demographic variables

Sex, age, ethnicity, education level, marital status, family income status, and lifestyle were also considered. The family income status was calculated as the raw family income minus the total family expenditure, then quartered. 'Quartile 1' represented the lowest family financial status, while 'Quartile 4' was the highest family financial status. Data quality control methods were performed twice by telephone interview to complete key missing information, which was checked if any inconsistencies were detected.

Statistical analysis

Analyses were performed using Stata 15.0 software (StataCorp LP, College Station, TX, USA). Differences in agricultural activities, pesticide exposure, lifestyle characteristics, and symptoms between groups were examined using the chi-squared test or Fisher's exact test for categorical variables, and the independent t-test or Mann–Whitney U test for continuous variables.

The Vuong statistical test[25] was used to select models. If the value was positive, then a zero-inflated Poisson regression (ZIP) model was selected; otherwise, a standard Poisson regression model or negative Poisson regression model was used. Incidence–rate ratios (IRR) and 95% confidence intervals were reported for Poisson regression models. The ZIP model was used to identify associations between agricultural activities and other respiratory symptoms because the Vuong value was larger than zero.

Ethical Approval

Ethical approval (No. 2014-090) for this study was obtained from the Medical Ethics Committee of Ningxia Medical University, and verbal consent of the respondents was obtained before the interviews were conducted.

Results

Among the 1,366 greenhouse vegetable farmers, respiratory system diseases were confirmed in 49 participants. The prevalence rate was 3.59%, and there were 33 patients with chronic bronchitis, two with emphysema, eight with asthma, and eight with other diseases. Two subjects had two types of respiratory diseases simultaneously: chronic bronchitis and asthma. Table 1 shows the demographic, agricultural activity, and lifestyle characteristics of the participants, and differences between groups. Participants who were married had a significantly lower prevalence of respiratory disease than other groups (unmarried, 11.90%; married, 3.01%; others (divorced or widowed), 17.86%). Participants with higher PPE scores showed a significantly higher prevalence of respiratory diseases than those with lower scores.

The prevalence of symptoms between cases and controls is shown in Table 2. Significantly higher frequencies of all symptoms were observed in cases compared with controls.

A multivariate Poisson regression model was then used to assess the association between agricultural activities and respiratory diseases and hemoptysis symptoms because the Vuong value was less than zero. Table 3 shows that several agricultural activities were not associated with respiratory disease. However, planting areas was shown to increase the likelihood of aspiratory diseases by 7.2% after adjusting for lifestyle factors.

The association between agricultural activities and symptoms is shown in Table 4. Associations between mix spray methods (hand and machines used together) and symptoms of cough, tachypnea, and chest distress were estimated to be 1.740-, 3.385-, and 2.882-fold more likely than hand spray, and significant associations were detected using empty, general

Table 1. Demographic, agricultural activity, and lifestyle characteristics of respiratory system disease cases and controls identified among greenhouse farmers from Yinchuan City, Northwest China.

Variable	Controls (n, %)	Cases (n, %)
General information		
Sex		
Male	705 (53.5)	20 (40.8)
Female	612 (46.5)	29 (59.2)
Education		
No formal school education	357 (27.1)	16 (32.7)
Primary school	422 (32.1)	14 (28.6)
Junior high school	452 (34.3)	14 (28.6)
High school and above	85 (6.5)	5 (10.2)
Marital status		
Unmarried	37 (2.8)	5 (10.2)
Married	1,256 (95.4)	39 (79.6)†
Others	23 (1.8)	5 (10.2)
Age (years, ±sd)	46.8±10.3	47.5±10.4
Ethnicity		
Han	1,169 (88.8)	40 (81.6)
Hui	148 (11.2)	9 (18.4)
Family income		
Quartile 1	332 (25.2)	15 (30.6)
Quartile 2	411 (31.2)	11 (22.5)
Quartile 3	293 (22.3)	12 (24.5)
Quartile 4	281 (21.3)	11 (22.5)
Survey year		
2015	432 (32.8)	16 (32.7)
2016	444 (33.7)	16 (32.7)
2017	441 (33.5)	17 (34.7)
Lifestyle		
Smoking status		
Daily	475 (36.1)	15 (30.6)
Not daily	22 (1.7)	0 (0.0)
Former smoker, now quit	56 (4.3)	6 (12.2)
Never	763 (58.0)	28 (57.1)
Second-hand smoke status		
Daily	538 (52.9)	19 (47.5)
1 to 3 days per week	72 (7.1)	3 (7.5)
4 to 6 days per week	29 (2.9)	1 (2.5)
None	379 (37.2)	17 (42.5)
Drinking status		
30 days ago,	199 (15.1)	10 (20.8)
Within the last 30 days	291 (22.1)	6 (12.5)
Never drink	826 (62.8)	32 (66.7)
Regular exercise		
Yes	206 (16.0)	11 (22.5)
No	1,081 (84.0)	38 (77.6)

(continued)

Table 1. Continued.

Variable	Controls (n, %)	Cases (n, %)
Number of meals per day		
One	18 (1.4)	0 (0.0)
Two	517 (39.3)	20 (40.8)
Three	767 (58.3)	29 (59.2)
More than three	13 (1.0)	0 (0.0)
Breakfast consumption		
(Almost) daily	786 (59.8)	27 (55.1)
Occasionally	189 (14.4)	11 (22.5)
Rarely	110 (8.4)	5 (10.2)
Never	229 (17.4)	6 (12.2)
Agricultural activities		
Planting years (years, $\pm$sd)	8.4$\pm$5.7	8.6$\pm$5.8
Planting areas (MU[a], $\pm$sd)	3.2$\pm$4.1	3.2$\pm$3.0
Days in greenhouse per year		
$<$50	5 (0.4)	0 (0.0)
50–99	18 (1.4)	1 (2.1)
100–199	206 (15.7)	14 (29.2)
200–299	355 (27.1)	10 (20.8)
$\geq$300	725 (55.4)	23 (47.9)
Major posture at work		
Standing	764 (61.8)	30 (65.2)
Half squatting	260 (21.0)	8 (17.4)
Bending down	208 (16.8)	8 (17.4)
Others	5 (0.4)	0 (0.0)
Pesticide mixing status		
None	262 (21.1)	9 (20.5)
Occasionally ($<$50%)	398 (32.1)	11 (25.0)
Regularly ($\geq$50%)	580 (46.8)	24 (54.6)
Average spraying length (hours, $\pm$sd)	1.4$\pm$0.9	1.4$\pm$0.7
Spraying method		
Hand spray	1099 (89.3)	39 (88.6)
Machine spray	110 (8.9)	3 (6.8)
Mix spray	22 (1.8)	2 (4.6)
Behavior during spraying‡		
Drinking water	71 (5.8)	6 (13.6)
Eating	26 (2.1)	0 (0.0)
Smoking	48 (3.9)	3 (6.8)
Chatting	437 (35.6)	7 (15.9)
None	644(52.5)	28 (63.6)
PPE (score, $\pm$sd)	0.8$\pm$0.2	0.9$\pm$0.2‡
Hyg (score, $\pm$sd)	0.5$\pm$0.2	0.5$\pm$0.2

[a]MU is a traditional Chinese area measurement unit; one MU equals 666.67 m^2; PPE: personal protective equipment; Hyg: personal hygiene.
†: $P<0.01$; ‡: $P<0.05$.

Table 2. Distribution of symptoms between cases and controls.

Symptoms	All (n, %)	Control (n, %)	Cases (n, %)	χ^2	P
Cough				72.485	<0.001
Never	1,126 (82.4)	1,105 (84.2)	21 (42.9)		
Occasionally	189 (13.8)	171 (13.0)	18 (36.7)		
Frequently	46 (3.4)	36 (2.7)	10 (20.4)		
Tachypnea				48.395	<0.001
Never	1,245 (91.1)	1,217 (92.7)	28 (57.1)		
Occasionally	100 (7.3)	84 (6.4)	16 (32.7)		
Frequently	17 (1.2)	12 (0.9)	5 (10.2)		
Chest distress				61.778	<0.001
Never	1,222 (89.5)	1,198 (91.2)	24 (49.0)		
Occasionally	117 (8.6)	100 (7.6)	17 (34.7)		
Frequently	23 (1.7)	15 (1.1)	8 (16.3)		
Hemoptysis[a]				–	0.042
Never	1,339 (98.0)	1,293 (98.6)	46 (93.9)		
Occasionally	22 (1.6)	19 (1.5)	3 (6.1)		

[a]Chi-squared vales and *P*-values were used to calculate Fisher's exact test. For the 2*2 table the Chi-squared value was not reported.

Table 3. Respiratory disease factors and Poisson regression.

	IRR (95% confidence interval)			
Variable	Model 1	Model 2	Model 3	Model 4
Planting years	0.977 (0.910–1.049)	0.975 (0.906–1.049)	0.954 (0.879–1.037)	0.964 (0.887–1.047)
Planting areas	1.024 (0.985–1.065)	1.012 (0.966–1.061)	1.072 (1.002–1.146)‡	1.056 (0.980–1.139)
Days in greenhouse per year	0.741 (0.486–1.130)	0.747 (0.480–1.163)	0.720 (0.496–1.046)	0.685 (0.428–1.095)
Major posture at work	0.961 (0.443–2.084)	0.995 (0.436–2.270)	1.060 (0.438–2.565)	1.310 (0.504–3.403)
Pesticide mixing status	1.405 (0.833–2.371)	1.472 (0.873–2.482)	1.389 (0.837–2.303)	1.568 (0.916–2.685)
Average spraying time	0.976 (0.646–1.474)	0.924 (0.595–1.434)	1.012 (0.657–1.558)	1.006 (0.613–1.653)
Spray method[a]				
Machine spray	0.727 (0.215–2.464)	0.722 (0.239–2.182)	0.773 (0.240–2.485)	0.601 (0.248–1.460)
Mix spray	3.120 (0.372–26.185)	1.848 (0.156–21.926)	6.616 (0.723–60.538)	3.360 (0.219–51.478)
Behavior during spraying[b]				
Drinking water or eating	1.510 (0.458–4.974)	1.363 (0.359–5.170)	1.290 (0.277–6.008)	1.173 (0.220–6.246)
Smoking or chatting	1.626 (0.415–6.371)	1.838 (0.508–6.652)	2.002 (0.593–6.763)	1.500 (0.505–4.456)
Others[c]	0.272 (0.089–0.833)‡	0.299 (0.084–1.067)	0.184 (0.048–0.704)‡	0.136 (0.032–0.574)†
PPE	2.585 (0.172–38.918)	2.572 (0.169–39.096)	4.548 (0.298–69.462)	3.080 (0.221–42.833)
Hyg	1.393 (0.320–6.067)	1.176 (0.271–5.106)	1.078 (0.255–4.561)	0.606 (0.124–2.973)

Note: Model 1 represents an empty model, containing agricultural activity as independent variables; Model 2 adjusts general information; Model 3 adjusts lifestyle information; Model 4 adjusts general information and lifestyle information.
IRR: Incidence–rate ratio; PPE: personal protective equipment; Hyg: personal hygiene.
[a]Reference set as hand spray.
[b]No reference set.
[c]Behavior such as dozing, which occurred infrequently during spraying.
†: $P<0.01$; ‡: $P<0.05$.

Table 4. Symptoms of respiratory disease and Poisson regression.

Variable	IRR (95% confidence interval) Cough[#]	Tachypnea[#]	Chest distress[#]	Hemoptysis*
Planting years	0.953 (0.91–0.993)[†,‖]	0.974 (0.927–1.024)	0.958 (0.909–1.010)	0.903 (0.813–1.003)[†]
Planting areas	1.011 (0.959–1.066)	1.050 (0.994–1.109)	1.053 (0.992–1.117)	1.080 (0.961–1.214)
Days in greenhouse per year	0.897 (0.739–1.088)	0.866 (0.668–1.123)[‡]	0.975 (0.751–1.268)	0.876 (0.489–1.570)
Major posture at work	1.203 (0.850–1.703)	1.375 (0.843–2.242)	1.367 (0.849–2.201)[‡]	1.758 (0.592–5.223)
Pesticide mixing status	1.046 (0.837–1.306)	1.174 (0.851–1.619)	1.156 (0.853–1.565)	0.735 (0.393–1.373)
Average spraying time	0.983 (0.794–1.217)	0.601 (0.412–0.877)[†,‡,§,‖]	0.770 (0.560–1.059)[§]	0.734 (0.354–1.522)
Spray method[a]				
Machine spray	1.224 (0.711–2.108)	0.442 (0.152–1.284)	0.331 (0.100–1.095)	0.644 (0.046–9.030)
Mix spray	1.740 (0.557–5.435)[‡,§]	3.385 (0.721–15.892)[‡,§]	2.882 (0.806–10.309)[†,‡]	2.36E-06 (2.88E-07–1.94E-05)[†,‡,§,‖]
Behavior during spraying[b]				
Drinking water or eating	1.653 (0.872–3.134)[‡,§]	0.583 (0.219–1.549)	1.258 (0.521–3.042)	0.262 (0.025–2.700)
Smoking or chatting	1.339 (0.518–3.459)	0.743 (0.094–5.889)	1.017 (0.219–4.712)	1.994 (0.122–32.492)
Others	1.056 (0.621–1.794)	0.557 (0.274–1.134)	0.777 (0.364–1.657)	0.237 (0.068–0.831)[‖]
PPE	0.766 (0.241–2.440)	1.728 (0.341–8.748)	0.585 (0.118–2.898)	2.592 (0.098–68.755)
Hyg	0.616 (0.299–1.271)	0.853 (0.325–2.238)	1.746 (0.664–4.590)	0.776 (0.121–4.970)

#: Zero-inflated Poisson regression model; *: Poisson regression model.

IRR: Incidence–rate ratio; PPE: personal protective equipment; Hyg: personal hygiene.

[a]Reference set as hand spray.

[b]No reference set.

†: Adjusted lifestyle information model $P < 0.05$; ‡: Empty model $P < 0.05$; §: Adjusted general information model $P < 0.05$; ‖: Full model $P < 0.05$.

information, and lifestyle information-adjusted models. For hemoptysis, the mix spray method appeared to serve as a protector against respiratory diseases. Average spray time was negatively associated with tachypnea, while a long duration of spray time was associated with a low tachypnea prevalence rate. A long planting year significantly lowered the occurrence of cough ($P<0.05$).

Discussion

An increasing number of studies have investigated the relationship between agricultural-related activities and respiratory disease among farmers, but not all have shown a positive association. Respiratory symptoms associated with work intensity and chemical exposure have been documented in animal farmers from south Germany,[2] and agricultural activities were related to system diseases in greenhouse farmers from Northeast China.[26] However, these findings are inconsistent with those of the present study, which detected no associations between pesticide exposure, PPE, Hyg, and respiratory disease. We showed that the prevalence of respiratory disease among greenhouse farmers was 3.59%, which is lower than that seen in European farmers (including open-field and greenhouse farmers with rates of more than 20.00%),[4] Icelandic animal farmers (9.4%),[27] farmers from southern Brazil (asthma symptom prevalence >10%),[11] New Zealand farmers (current asthma prevalence, 11.8%),[28] sheep breeders in southern Germany (20.9%),[2] Northeast China greenhouse farmers (COPD prevalence, 12.6%),[29] and the general Chinese population.[30] The prevalence was also lower than the 14.91% reported for an old population from Gansu province, Northwest China.[31]

It is therefore possible that the younger age of the participants in this study (average age, 46 years) was responsible for the lower rate of respiratory disease, although the prevalence was higher than that for self-reported asthma in a similar age population of India (2.82%) to those of the current study.[32] This age corresponds to the prime of life,[33] and overall good health may hide or delay corresponding disease occurrence. Another possibility is that rural vegetable greenhouses typically have less plant dust than open-air farming, which may reduce a correlation with respiratory disease.[11] Our results were in accordance with the prevalence seen in Iceland in a study that showed respiratory disorders were not more common in farmers than in the general population.[27] The lower prevalence of respiratory diseases in greenhouse farmers may also reflect the healthy worker effect,[28] and the fact that modernization of the agricultural environment has had a positive effect on workers' health.[27] The self-reported prevalence of symptoms in this study was 17.21%, 8.56%, 10.25%, and 1.61% for cough, tachypnea, chest distress, and hemoptysis, respectively, which is lower than that previously reported for animal farmer-related respiratory symptoms (38.4%)[2] and in a survey of organic farmers (22.0%).[34] Our study also showed an interesting significantly negative association between other behaviors carried out during spraying and respiratory disease. It is conceivable that this reflects the lack of a precise definition of 'other behavior' in the questionnaire, and this should be clarified in a future study of longitudinal design.

Previous studies[4,11] indicated that work in greenhouses was associated with an increased risk of respiratory symptoms. We showed that mix spray technology was positively associated with three major symptoms: cough, tachypnea, and chest distress, while decreasing the risk of hemoptysis. This is in accordance with a study performed in southern Ghana,[13] which revealed a positive association between pesticide exposure and prevalence of respiratory symptoms. The mixed spray method may increase exposure to pesticides, resulting in pesticide residues, organic and inorganic dusts, and disinfectants entering the body through respiration.[13–15] This can impact on the respiratory system, leading to rhinitis, asthma, asthma-like syndrome, chronic airway disease, allergic pneumonia, and interstitial fibrosis.[35] Mixed spray activities could also lead to coughing, shortness of breath, and chest tightness, although our work suggests they reduce the risk of hemoptysis; additional data are required to verify this. No significant association was detected between mix spray use and respiratory symptoms in our study, which could reflect the small sample size.

The present study has a number of limitations. First, recall bias was evident in the information collected about respiratory diseases and symptoms and agricultural activities. Second, the cross-sectional design of the study prevented causal inference. Third, the types of pesticides used were not recorded. Fourth, data were collected at a single time point so did not consider seasonal effects of agricultural activities and pesticide usage. Finally, the study was conducted in Yinchuan City, so it may not be representative of all greenhouse farmers in China. Further long-term studies with a fixed-line follow-up are necessary to determine the long-term health effects on a mature labor force.

Conclusions

Despite the above limitations, this study showed that the prevalence of respiratory disease is lower than that reported in corresponding studies. We found no direct association between agricultural activities and respiratory diseases, although some disease symptoms were documented, which could lead to cumulative effects over time. Use of mix spray technology may be a major contributing factor to symptom development, so local governments should encourage farmers to use machine spray technology as an alternative.

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Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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