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Original Contribution

Pesticide Exposure and Respiratory Health of Indigenous Women in Costa Rica

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A cross-sectional study was conducted in 2007 to evaluate the relation between pesticide exposure and respiratory health in a population of indigenous women in Costa Rica. Exposed women ($n = 69$) all worked at plantain plantations. Unexposed women ($n = 58$) worked at organic banana plantations or other locations without pesticide exposure. Study participants were interviewed using questionnaires to estimate exposure and presence of respiratory symptoms. Spirometry tests were conducted to obtain forced vital capacity and forced expiratory volume in 1 second. Among the exposed, prevalence of wheeze was 20% and of shortness of breath was 36% versus 9% and 26%, respectively, for the unexposed. Prevalence of chronic cough, asthma, and atopic symptoms was similar for exposed and unexposed women. Among nonsmokers ($n = 105$), reported exposures to the organophosphate insecticides chlorpyrifos ($n = 25$) and terbufos ($n = 38$) were strongly associated with wheeze (odd ratio = 6.7, 95% confidence interval: 1.6, 28.0; odds ratio = 5.9, 95% confidence interval: 1.4, 25.6, respectively). For both insecticides, a statistically significant exposure-effect association was found. Multiple organophosphate exposure was common; 81% of exposed women were exposed to both chlorpyrifos and terbufos. Consequently, their effects could not be separated. All findings were based on questionnaire data. No relation between pesticide exposure and ventilatory lung function was found.

Costa Rica; occupational exposure; pesticides; respiratory function tests; signs and symptoms, respiratory

Abbreviations: CI, confidence interval; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; OR, odds ratio.

In Costa Rica, the use of synthetic pesticides in agriculture is widespread and among the highest in Central America in terms of kilograms of active ingredient per cultivated area (1). The majority of Costa Rican plantain cultivation occurs in Talamanca County. In the Bribri indigenous territory, located in this county, most households depend on plantain cultivation as their sole economic support. Herbicides, fungicides, and organophosphate insecticides are extensively used to meet product standards for exportation.

Previous studies of farmers have linked pesticide exposure, particularly to organophosphate insecticides and paraquat, to respiratory symptoms such as wheeze, chronic cough, and shortness of breath (2–5). Recently, pesticide exposure has also been associated with a higher prevalence of atopic disease, including rhinitis and allergic asthma (5–10). Studies on the effects of pesticide exposure on ventilatory lung function measured by forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and FEV_1/FVC ratio have shown inconsistent results. Exposure to organophosphate insecticides has been associated with lower FVC, FEV_1, and FEV_1/FVC ratio among Sri Lankan farmers (11), Lebanese pesticide factory workers (12), and Ethiopian pesticide sprayers (13). However, paraquat exposure was not associated with FVC and FEV_1 values among Nicaraguan, Costa Rican, and South African plantation workers (14–16). Although a substantial number of women are employed in agriculture, there have been few epidemiologic studies regarding agricultural occupational exposure and women's health, even though a substantial number of women are employed in agriculture (6, 17). In the Bribri indigenous territory, both men and women work on plantain plantations, and exposure is expected to be substantial for both sexes.

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The present study was conducted to investigate the association of pesticide exposure with respiratory symptoms and ventilatory lung function among women. The study focused on the respiratory health effects of exposure to the organophosphate insecticides chlorpyrifos and terbufos and to the herbicide paraquat because these pesticides are most commonly used in the research area.

MATERIALS AND METHODS

Study population

A cross-sectional study was conducted in the Bribri indigenous territory of Talamanca County from May to June 2007. Women ($n = 134$) between 24 and 58 years of age from 3 villages were invited to participate in the study; 3% refused to participate, and 2% could not be contacted. Exposed participants ($n = 69$) worked on plantain plantations where pesticides were used, and unexposed participants ($n = 58$) worked on organic banana plantations or at other locations (home, school, etc.).

All participants gave their written informed consent according to the principles outlined in the Declaration of Helsinki, 1990. The study was approved by the medical ethical committee of the Universidad Nacional, Costa Rica.

Data collection

Data collection included an interviewer-administered questionnaire and spirometry testing. All participants were interviewed in their homes by the same interviewer. Demographic factors, work history, occupational and domestic exposure, use of personal protective equipment, and presence of respiratory symptoms were assessed.

To assess exposure, a questionnaire was designed based on open interviews and field observations in the region (this questionnaire is reproduced in the Web Appendix, which is posted on the *Journal*'s website (http://aje.oupjournals.org/)). This questionnaire was designed to include various tasks during which occupational contact with pesticides occurred, based on previous field observations and focus group discussions (D. Barraza, personal communication, Central American Institute for Studies on Toxic Substances (IRET), Universidad Nacional, Heredia, Costa Rica).

Pesticide use was task specific and gender related. In general, women performed the less demanding physical tasks, such as applying terbufos and handling chlorpyrifos-impregnated bags. Few women applied paraquat with a backpack sprayer. Information on pesticide use and exposure was limited to a small number of pesticides applied by the women weekly to monthly and included terbufos, chlorpyrifos, and paraquat. Previous studies have demonstrated that exposure to these pesticides is associated with respiratory symptoms (2–5). General exposure due to reentry activities was also assessed. For each pesticide, the frequency (average days a week as reported during the period of use) and duration (number of years) of exposure were estimated by using the questionnaire. Cumulative exposure was estimated for each pesticide. Frequency of exposure per year was calculated and multiplied by total years of exposure, resulting in the number of lifetime days of pesticide application.

The questionnaire was extensively reviewed and pretested in the region to ensure that the language was appropriate. Prior to this study, no exposure questionnaire for this region existed. The constructed exposure questionnaire has not been validated with urinary or other quantitative measures.

The questions on respiratory symptoms were based on the European Community Respiratory Health Survey and were adapted to the local Spanish language (18). Wheeze was defined as the occurrence of whistling sounds in the chest in the past 12 months, without having a cold or the flu. Shortness of breath was defined as waking up at night because of shortness of breath in the past 12 months. Chronic cough was defined as having reported waking up at night because of a cough attack as well as coughing for at least 3 consecutive months in the last 12 months. Asthma was defined as asthma diagnosed by a physician or the occurrence of an asthma attack in the last year. Rhinitis was defined as the occurrence of 2 or more nasal symptoms, such as sneezing, runny nose, or nasal itching, during the last 12 months, without having a cold or the flu. Eczema was defined as the appearance and disappearance of an itchy rash during the last 6 months in the folds of the elbows; behind the knees; around the ankles; under the buttocks; or around the neck, ears, or eyes. Participants were defined as atopic when they reported symptoms of either rhinitis or eczema, or both, during the last year.

All participants were examined with an MIR spirotel spirometer (Medical International Research, Rome, Italy) following the most recent guidelines (19). Each subject was asked to perform 8 maneuvers, after which 3 technically acceptable curves were selected (19). FVC and FEV_1 were measured. Spirometric measurements were performed by the same investigator to avoid interresearcher differences.

Data analysis

SPSS v12.0 software (SPSS, Inc., Chicago, Illinois) was used for statistical analysis, and descriptive statistics were produced. χ^2 tests were conducted to test for differences in frequencies. Prevalence of respiratory symptoms among exposed and unexposed women was estimated, and 95% confidence intervals were estimated by assuming validity statistics as a proportion (ρ) drawn from a normal distribution: $\rho \pm 1.96\sqrt{(\rho(1-\rho)/n)}$. Crude odds ratios were estimated for several exposure estimates and respiratory symptoms. Subsequently, multiple logistic regression analysis was performed to estimate adjusted odds ratios. No odds ratio was presented if the maximum likelihood estimate was uncertain because of a small number of observations. Covariates were included in the multiple logistic regression models if the odds ratio showed at least a 10% change with a P value of <0.20 or if they were determinants of respiratory symptoms according to existing literature, resulting in the inclusion of age, smoking, and atopic symptoms in the models. Because living in a humid house may be a determinant of respiratory symptoms and could thus act as a confounder, we considered this variable in the analysis as well. However, in the end, it was not included in the models because it correlated with atopic symptoms and because adding it to the models did not change the estimated odds ratio.

Because of the difference in symptom prevalence between former smokers and nonsmokers, a modifying effect of smoking was suspected. Including smoking status as an interaction term in the model indicated an effect (odds ratio (OR) = 1.8, 95% confidence interval (CI): 0.5, 6.4) but was not statistically significant ($P = 0.23$). Nevertheless, because the latter could be due to the unequal distribution of smokers ($n = 22$) versus nonsmokers ($n = 105$), a stratified analysis was performed for smoking status, and a Mantel-Haenszel weighted odds ratio was calculated for pesticide exposure.

To explore exposure-effect associations, an additional analysis was performed for the women nonsmokers by using the following approach. The median number of lifetime pesticide application days was calculated for each pesticide and was used as a cutoff point to divide the exposed population into high- and medium-exposure groups. The exposed women who had never applied the particular pesticide were assigned to a low-exposure group because of reentry activities, whereas the unexposed women formed the reference group. Subsequently, to identify exposure-effect associations, adjusted odds ratios were estimated for the low-, medium-, and high-exposure groups compared with the unexposed with logistic regression modeling. To test for a trend between the cumulative exposure estimates and respiratory symptoms, logistic regression was performed for log-transformed values of the constructed exposure proxy for each pesticide. Consequently, the odds ratio per 10 lifetime days of pesticide application was estimated.

To relate pulmonary function and pesticide exposure, associations were analyzed with linear regression modeling. Age, height, and smoking status were included as potential confounders in the model. For all statistical tests, a probability of greater than 0.05 (2 sided) was used to indicate statistical significance.

RESULTS

A total of 127 women completed the questionnaire and spirometry tests successfully. Exposed ($n = 69$) and unexposed participants were similar in age, education, and socioeconomic status (Table 1). Exposed women worked at plantations, and unexposed women were homemakers, store workers, or teachers. On average, women in the exposed group were somewhat heavier than the unexposed women (body mass index = 31.5 kg/m^2 vs. 30.2 kg/m^2). There were more smokers and former smokers in the exposed group ($P = 0.02$). Of the 69 exposed women, 19% did not apply pesticides themselves but were exposed during reentry activities; 51% applied both terbufos and chlorpyrifos; and 30% applied terbufos, chlorpyrifos, and paraquat. Terbufos was generally applied by pouring granules from the bottle directly to the soil approximately every 3 months. Chlorpyrifos exposure occurred weekly, usually by handling newly impregnated bags. Paraquat was generally applied every 3 months with a knapsack sprayer.

Table 1. Characteristics of Exposed and Unexposed Women ($n = 127$) Living in the Bribri Indigenous Territory, Costa Rica, Stratified by Pesticide Exposure Status, 2007

	Exposed (n = 69), Mean (SD)		Unexposed (n = 58), Mean (SD)	
Age, years	35 (8)		35 (9)	
Height, m	1.55 (0.05)		1.52 (0.06)	
Weight, kg	76 (13)		70 (12)	
Body mass index, kg/m^2	31.5 (4.9)		30.2 (5.0)	
FVC	3.24 (0.5)		3.10 (0.59)	
FEV_1	2.61 (0.4)		2.61 (0.52)	
FEV_1/FVC ratio	0.81 (0.09)		0.84 (0.06)	
	No.	**%**	**No.**	**%**
Current smoker	5	7	1	2
Former smoker	12	17	4	7
Living in a humid house	14	20	8	14

Abbreviations: FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; SD, standard deviation.

No personal protective equipment, such as respiratory protection or gloves, was used when working with pesticides. Women wore rubber boots and long pants with a short-sleeved (71%) or long-sleeved (17%) shirt. Some wore shorts (12%). We found no association with the occurrence of respiratory symptoms for different types of clothing used. Exposed women wearing short pants did not report more wheeze compared with exposed women wearing long pants ($P = 0.9$), and no difference regarding the use of long-sleeved versus short-sleeved shirts was found ($P = 0.7$). Most women reported that they continued working in the field during pesticide application by other workers. Number of working hours varied between 4 and 60 hours a week, with an average of 27 hours a week.

The prevalence of wheeze was 20%; shortness of breath, 36%; chronic cough, 10%; asthma, 10%; and atopic symptoms, 29% in the exposed group ($n = 69$) (Table 2). Wheezing was more prevalent in the exposed group ($P = 0.07$). Prevalence of chronic cough, asthma, and atopic symptoms was similar among exposed and unexposed women. Women exposed to organophosphate insecticides, compared with unexposed women, were much more likely to report wheezing, in particular when only nonsmokers were included in the data analysis (Table 3). Among women nonsmokers, exposure to both chlorpyrifos ($n = 25$) and terbufos ($n = 38$) was associated with an increased risk of wheeze (OR = 6.7, 95% CI: 1.6, 28.0 and OR = 5.9, 95% CI: 1.4, 25.6, respectively) (Table 3). When both chlorpyrifos and terbufos were included in the model, the odds ratios decreased to 3.6 (95% CI: 0.7, 19.4) for chlorpyrifos and 3.1 (95% CI: 0.6, 17.1) for terbufos. However, chlorpyrifos and terbufos were strongly correlated ($\rho = 0.59$, $P < 0.001$). Shortness of breath was reported more often among women nonsmokers exposed to organophosphate insecticides (for chlorpyrifos exposure, OR = 2.6,

Table 2. Prevalence of Respiratory Symptoms in Exposed (n = 69) and Unexposed (n = 58) Women Living in the Bribri Indigenous Territory, Costa Rica, Stratified by Pesticide Exposure Status, 2007

Respiratory Symptom	Exposed (n = 69)			Unexposed (n = 58)		
	No.	%	95% CI	No.	%	95% CI
Wheeze	14	20	11, 29	5	9	2, 16
Shortness of breath	25	36	25, 47	15	26	15, 37
Chronic cough	7	10	3, 17	6	10	2, 18
Asthma	7	10	3, 17	6	10	2, 18
Atopic symptoms[a]	20	29	18, 40	18	31	19, 43

Abbreviation: CI, confidence interval.
[a] Self-reported symptoms of either rhinitis or eczema, or both, during the last year.

95% CI: 1.0, 7.3; for terbufos, odds ratio = 2.2, 95% CI: 0.8, 5.7) (Table 3).

Using the pesticide-specific cumulative exposure indices, we divided nonsmokers into low-, medium-, and high-exposure groups (refer to the data analysis portion of the Materials and Methods section) and subsequently compared them with the unexposed group, estimating the adjusted odds ratio for each pesticide (Table 4). For the organophosphate insecticides terbufos and chlorpyrifos, increasing exposure was associated with an increasing odds ratio for wheeze. The tests for trend performed on log-transformed values of the cumulative exposure index were statistically significant. For wheeze, the odds ratios per 10 lifetime days of pesticide application were 1.9 (95% CI: 1.0, 3.6) for terbufos and 2.2 (95% CI: 1.2, 3.9) for chlorpyrifos. Logistic regression models with duration and frequency of exposure as individual variables produced results similar to those from the constructed cumulative exposure index (data not shown). For the other pesticides, no associations between the cumulative exposure estimates and reported symptoms were observed (data not shown).

Regression analysis showed that pesticide exposure was not associated with the lung function parameters FVC and FEV_1 (Table 5). In addition, no statistically significant effect of smoking on FEV_1 was found, whereas other known predictors such as age and height were clearly related to spirometric variables. No relation between pesticide exposure and abnormal spirometric values was found (data not shown).

DISCUSSION

The association of pesticide exposure with respiratory symptoms and ventilatory lung function among indigenous women was investigated with a cross-sectional study. Exposure to the organophosphates chlorpyrifos (n = 25) and terbufos (n = 38), as estimated with a questionnaire, was

Table 3. Crude and Adjusted Odds Ratios for Defined Respiratory Symptoms Related to Pesticide Exposure for All Women (n = 127) and Women Nonsmokers (n = 105) Living in the Bribri Indigenous Territory, Costa Rica, 2007[a]

	Wheeze		Shortness of Breath		Chronic Cough		Asthma	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
All women								
Crude (n = 127)								
Exposed (n = 69)	2.7	0.9, 8.0	1.6	0.8, 3.5	1.0	0.3, 3.1	1.0	0.3, 3.1
Terbufos (n = 51)	2.3	0.9, 6.3	1.6	0.7, 3.3	0.9	0.3, 3.0	0.6	0.2, 2.2
Chlorpyrifos (n = 36)	2.7*	1.0, 7.3	2.2*	1.0, 5.0	1.7	0.5, 5.5	0.4	0.1, 2.0
Paraquat (n = 22)	2.6	0.9, 8.0	2.1	0.8, 5.3	—[b]		0.9	0.2, 4.2
Weighted after stratifying by smoking (n = 127)								
Exposed (n = 69)	3.3*	1.0, 11.0	1.8	0.8, 4.0	1.0	0.3, 3.1	1.0	0.3, 3.1
Terbufos (n = 51)	2.8*	1.0, 8.4	1.7	0.8, 3.8	0.9	0.3, 3.0	0.6	0.2, 2.1
Chlorpyrifos (n = 36)	3.5*	1.2, 10.7	2.5	1.0, 5.8	1.7	0.5, 5.6	0.4	0.1, 2.1
Paraquat (n = 22)	2.4	0.7, 8.3	1.7	0.6, 4.7	—[b]		0.9	0.2, 4.6
Nonsmokers only (n = 105)								
Exposed (n = 52)	5.6*	1.2, 26.7	1.7	0.7, 4.3	0.9	0.2, 3.6	—[b]	
Terbufos (n = 38)	5.9*	1.4, 25.6	2.2	0.8, 5.7	0.6	0.1, 2.5	—[b]	
Chlorpyrifos (n = 25)	6.7*	1.6, 28.0	2.6*	1.0, 7.3	1.3	0.3, 5.6	—[b]	
Paraquat (n = 14)	1.4	0.3, 7.4	1.1	0.3, 4.4	—[b]		—[b]	

Abbreviations: CI, confidence interval; OR, odds ratio.
* $P < 0.05$ (statistically significant).
[a] Odds ratios were adjusted for age and atopic symptoms, defined as self-reported symptoms of either rhinitis or eczema, or both, during the last year.
[b] —, no valid estimate.

Table 4. Adjusted Odds Ratios for Respiratory Symptoms Among Women Nonsmokers ($n = 105$) From 3 Villages in the Bribri Indigenous Territory, Costa Rica, Classified Into Low-, Medium-, and High-Exposure Groups According to Lifetime Number of Application Days of Each Pesticide and Compared With Unexposed Women, 2007[a]

Factor[b]	Wheeze		Shortness of Breath		Chronic Cough		Asthma	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Terbufos exposure								
Not exposed ($n = 53$)	1.0		1.0		1.0		1.0	
Low (reentry) ($n = 14$)	1.7	0.1, 20.9	1.0	0.2, 4.6	1.7	0.3, 9.8	0.7	0.1, 6.1
Medium (<1–21 application days) ($n = 19$)	5.4	0.8, 36.6	1.6	0.4, 5.6	0.5	0.1, 5.1	1.0	0.2, 5.4
High (22–2,052 application days) ($n = 19$)	8.7*,[c]	1.6, 46.4	2.4	0.8, 7.7	1.1	0.2, 6.1	0.4	0.0, 3.5
Chlorpyrifos exposure								
Not exposed ($n = 53$)	1.0		1.0		1.0		1.0	
Low (reentry) ($n = 27$)	2.6	0.4, 16.6	1.1	0.3, 3.3	0.8	0.1, 4.3	0.6	0.1, 3.4
Medium (<4–181 application days) ($n = 12$)	8.9*	1.4, 56.8	4.0*	1.1, 15.2	—[d]		0.6	0.1, 5.4
High (182–780 application days) ($n = 13$)	12.9*,[c]	1.6, 101.0	1.4	0.3, 6.2	3.8	0.7, 17.9	0.8	0.1, 7.1
Paraquat exposure								
Not exposed ($n = 53$)	1.0		1.0		1.0		1.0	
Low (reentry) ($n = 39$)	7.9*	1.5, 41.9	1.8	0.7, 4.8	1.5	0.4, 5.6	0.7	0.2, 2.9
Medium (<2–11 application days) ($n = 6$)	4.3	0.3, 72.8	0.6	0.1, 5.6	—[d]		1.5	0.1, 15.1
High (12–52 application days) ($n = 7$)	1.7	0.1, 24.7	2.7	0.4, 16.6	—[d]		—[d]	

Abbreviations: CI, confidence interval; OR, odds ratio.

* $P < 0.05$ (statistically significant).

[a] All odds ratios were adjusted for age and atopic symptoms, defined as self-reported symptoms of either rhinitis or eczema, or both, during the last year.

[b] Not exposed women worked on organic banana plantations or at other locations (home, school, etc.); low-exposure women worked on plantain plantations where pesticides were used, but they did not apply the pesticide themselves; medium-exposure women applied the pesticide themselves but less than or equal to the median number of lifetime application days reported in the interviewer-administered questionnaire; and high-exposure women applied the pesticide themselves for more than the median number of lifetime application days reported in the interviewer-administered questionnaire.

[c] For wheeze, the odds ratios per 10 lifetime days of pesticide application were 1.9 (95% CI: 1.0, 3.6) for terbufos and 2.2 (95% CI: 1.2, 3.9) for chlorpyrifos.

[d] —, no valid estimate.

associated with 6-fold increased odds ratios for wheeze among nonsmokers ($n = 105$), with a clear exposure-effect relation present. Because multiple organophosphate exposure was common, the effects of chlorpyrifos and terbufos could not be separated. The main limitation of our study was its small sample size ($n = 127$).

The observed prevalence rate of wheeze among exposed women was very similar to that in other studies investigating pesticide-exposed workers (3, 14, 20). In these studies, pesticide exposure was associated with an increased risk of wheeze, chronic cough, and shortness of breath. Self-reported use of paraquat and organophosphate insecticides, especially chlorpyrifos, was associated with increased wheezing among US farmers and commercial applicators (2, 4, 20).

A constraint of our study was that multiple exposure occurred frequently, with 56 of 69 women (81%) being exposed to both chlorpyrifos and terbufos. Chlorpyrifos exposure typically occurred weekly, whereas terbufos exposure occurred monthly. The effects of chlorpyrifos and terbufos could not be separated because the variables were strongly correlated, resulting in possible confounding of the results. When both variables were included in the logistic regression model, odds ratios for both pesticides decreased but remained similar. For both organophosphate insecticides, wheezing was reported more frequently among women with a higher cumulative exposure index, suggesting an exposure-effect trend. This trend was confirmed for both pesticides with logistic regression analysis, including log-transformed values of the cumulative exposure index as an independent variable in the model. An exposure-effect trend has been suggested for chlorpyrifos (20).

Organophosphate exposure has previously been associated with asthma (21). Among North-American farm

Table 5. Regression Coefficients Estimated With Multiple Regression Models Using Lung Function Parameters FVC or FEV_1 as the Dependent Variable and Height, Age, Smoking Status, and Pesticide Exposure as Independent Variables for Exposed and Unexposed Women (n = 127) in the Bribri Indigenous Territory, Costa Rica, 2007

	β (SE)	
	FVC (L)	FEV_1 (L)
Height, m	5.40 (0.73)*	3.85 (0.67)*
Age, years	−0.03 (0.01)*	−0.03 (0.04)*
Ever smoked (yes/no)	−0.03 (0.13)	−0.07 (0.11)
Exposed to pesticide (yes/no)	0.03 (0.1)	0.01 (0.09)
Terbufos exposure (yes/no)	0.1 (0.1)	0.01 (0.09)
Chlorpyrifos exposure (yes/no)	0.12 (0.11)	0.11 (0.09)
Paraquat exposure (yes/no)	0.16 (0.13)	0.18 (0.11)

Abbreviations: FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; SE, standard error.

* $P < 0.0001$.

women, the use of herbicides and organophosphate insecticides has more specifically been associated with atopic asthma (6). No association between organophosphate exposure and asthma or chronic cough was observed in our study. However, physician-diagnosed asthma was used for asthma classification, and study participants reported that they relied on traditional medicine rather than visiting the local health clinic, which could have biased the results.

Regression analysis showed the influence of well-known predictors such as age and height on spirometric variables. The lack of an association with smoking status could be due to the small number of women who currently smoked ($n = 6$). No influence of pesticide exposure on spirometric lung function was observed (Table 5). The frequency of observed abnormal spirometric values was similar to that for other Costa Rican plantation workers (15). It is possible that other variables such as forced expiratory $flow_{25–75}$ would be affected, as found in other studies (5, 12). These values were not measured in our study.

Type of work clothes was not associated with occurrence of respiratory symptoms. There was little difference between work clothes used (short or long pants/sleeves). Most women changed clothes at the end of the work day. Because of the heat and humidity and of limited work hygiene (hand washing and showering), exposure is expected to be high for all exposed women.

Agricultural exposure to grains, hays, or animals was not specifically assessed. However, the study population was homogenous, and little commercial cultivation of crops other than plantain existed in the area. A small group of women produced organic chocolate, and rice and beans were cultivated for personal use. Few exposed and unexposed women had contact with other farm animals such as cows or pigs.

The main limitation of our study is its small sample size. Only 14 pesticide-exposed and 5 unexposed women reported wheeze. The numbers for other endpoints were similarly small. Another limitation is that exposure was assessed with questionnaire data only; however, this finding is not unusual (4, 6, 15). There was little concern about pesticide exposure in the area. The information as reported by the women is therefore unlikely to be biased. Our exposure questionnaire was not validated with quantitative measures. Quantitative measures would allow a comparison with only currently reported exposures, whereas our index concerned life-time exposure.

In general, exposure to pesticides differs considerably between different countries and consequently between different studies. Crops, work conditions, work practices, and pesticide regulations vary between countries, which can lead to distinct exposure patterns, thus resulting in different study findings. In our study, exposure to organophosphates was expected to be high. Pesticide use in the Bribri indigenous territory has been increasing and diversifying in the last 2 decades, and pesticides are generally handled with little caution. Personal protection is neither available nor used, and its effectiveness may be reduced in tropical work conditions. Exposure through reentry into fields treated with pesticides is expected to be high because of limited infrastructure and poverty.

The present cross-sectional study could not establish a causal relation between exposure to pesticides and respiratory symptoms but does suggest associations. Major limitations of the study were the small study population and the lack of quantitative exposure estimates.

Nevertheless, this study is one of the few focusing on respiratory health and pesticide exposure among women. The strong association between exposure to chlorpyrifos and wheeze is in concordance with recently published studies of male pesticide applicators. Further research through quantitative exposure measurements is needed to determine whether there is a respiratory health threat as a result of occupational pesticide exposure in this and other vulnerable populations becoming increasingly exposed to pesticides.

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