

ORIGINAL ARTICLE

Risk Factors for Respiratory Symptoms and Asthma in the Residential Environment of 5th Grade Schoolchildren in Taipei, Taiwan

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This study examined the association of residential environmental factors with respiratory symptoms and asthma in 2,290 fifth graders in Taipei, Taiwan. A self-report survey questionnaire elicited experiences of respiratory symptoms, disease history, and characteristics of residential environmental factors from schoolchildren. The proportion of schoolchildren having physician-diagnosed asthma was 9.8% and suspected asthma was 16.1%. The proportions of having respiratory symptoms in the past 12 months ranged from 9.8% for wheezing without a cold to 40.5% for exercise-induced cough. Higher proportions of boys had non-exercise-induced respiratory symptoms, physician-diagnosed asthma, and suspected asthma than girls ($p < 0.05$). Exposure to odoriferous chemical vapor was significantly associated with all seven respiratory symptoms considered in the study ($p < 0.05$). After adjusting for confounding factors including residential districts, gender, diagnosed allergy, and parental history of respiratory symptoms, odoriferous chemical vapors, gas leaks, dehumidifier use, presence of cockroaches at home, and leaky water/water puddle at home were significantly associated with the proportions of physician-diagnosed asthma or suspected asthma of the schoolchildren. The adjusted odds ratio (aOR) of physician-diagnosed asthma was 2.35 (95% confidential interval = 1.45–3.82) for odoriferous chemical vapor. The aOR of suspected asthma measure was 2.14 (95% CI = 1.40–3.26) for odoriferous chemical vapor. Odoriferous chemical vapor was the major risk factor of respiratory illness in the residential environment of schoolchildren in Taipei. Other household risk factors included gas leaks, dampness, and cockroaches at home.

Keywords asthma, respiratory symptoms, chemical vapor, gas leaks, residential environment

Asthma and respiratory symptoms affect people of all ages. In schoolchildren, these conditions are one of the major causes of school absenteeism and withdrawal from regular physical activity (1–3). Studies in Taiwan have shown the gradually increasing prevalence of childhood respiratory disease (4, 5). During the recent decades, Taiwan has developed high population density, high pollution levels, and a poor quality of environment with industrial development and urbanization. Environment has been shown to play a role in respiratory diseases.

Studies have identified many respiratory disease risk factors, such as chemical fumes (6, 7), natural gas (8), and cigarette smoke (9, 10) in the residential environment as potential triggering factors of the respiratory symptoms. In the European Community Respiratory Health Survey, subjects with domestic exposure to chemical emissions, such as formaldehyde, or volatile organic compounds, from newly painted surfaces caused inflammation reactions in the airway and increased the risk of asthma by 50% (6). Respiratory symptoms were more common in children of families using gas stoves (8). After adjusting for the nitrogen dioxide level, gas stove exposure was still a risk factor for childhood respiratory symptoms, suggesting additional risk factors associated with gas stove use (8). Another study found that

passive smoking accounted for 6.5% of childhood wheezing in the past 12 months (9). Passive smoking and outdoor air pollution increased the risk of asthma by 8% to 29% in Taiwanese adolescents (10). In the first Nutrition and Health Survey in Taiwan, environmental factors associated with affluent lifestyle, such as dietary factors and body composition, were also observed to be associated with asthma and bronchial hyper-responsiveness in teenagers (11, 12).

The global literature already shows that a variety of environmental factors contribute to childhood respiratory diseases. The goal of this study was to identify the associative effects of the residential environments, diets, and lifestyle of schoolchildren on childhood respiratory diseases in a rapidly developed urban area. This report targets the fifth graders (11 to 12 years of age) in Taipei, Taiwan, and represents one of the few attempts to address the issue of asthma in the increasingly polluted metropolis.

METHODS AND PROCEDURES

Sampling and Procedures

The study used a questionnaire survey. It was conducted among fifth grade schoolchildren in the Taipei metropolitan area in Taiwan, where the prevalence of asthma was known to be increasing rapidly (4–5). Schoolchildren were chosen as study subjects because of the increase in prevalence of childhood respiratory diseases and no current or previous exposures to occupational allergens that could cause asthma. Primary schools were also a convenient setting to recruit study subjects. According to preliminary studies, the fifth grade

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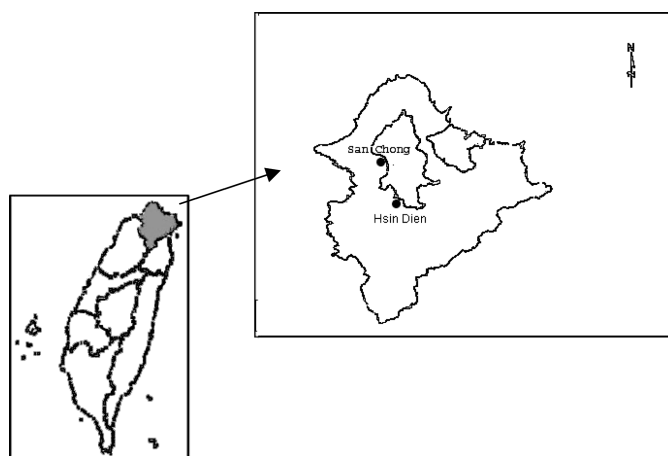


FIGURE 1.—The location of selected school districts in Taipei, Taiwan.

schoolchildren, 11 to 12 years of age, were able to understand and answer accurately the questions in the proposed questionnaire. This made it possible to elicit information from subjects directly and avoid bias from proxy response. The study protocol was approved by the Institutional Review Board of the University of Michigan (IRB H03-00003166).

For this study, two school districts, San-Chong and Hsin-Dien, were chosen to represent the most and least polluted areas within the greater metropolitan Taipei area (Figure 1). The selection criterion was based on the outdoor particulate matter less than $10\ \mu\text{m}$ (PM 10) of year 2000 (latest available information of the study at the time), published by the Environmental Protection Administration of Taiwan. Primary schools within each selected district were contacted to arrange for participation in the study. Target schools were first contacted by phone. The study proposal and sample questionnaires were provided for review by school administrators and fifth grade teachers. If the school denied participation, contacts went to the next school on the list. The process continued until the study reached the target number of subjects (approximately 1000, schoolchildren per district). Once a school agreed to participate, the fifth grade classes within a school were chosen randomly for survey participation.

A letter describing the study, parental and schoolchild consent forms, and a parental questionnaire were given to each student to be taken home. Only those schoolchildren and their parents who both consented to participate were allowed to take part in the study. Parents were also asked to complete the parental questionnaires, which were then returned to the class teachers by the children. Schoolchildren who consented to participate in the survey were asked to complete a paper-pencil questionnaire during a regular class session. The same interviewer (H.J.T.) conducted all schoolchildren interviews. A total of 2,290 fifth grade schoolchildren participated in the study. The survey was conducted during the spring semester (February to June) in 2004.

Collected questionnaires were reviewed and checked immediately. If any questions were missed, schoolchildren were asked to complete them. Data were entered into a computer database twice and were checked for discrepancy between the two entries. If there were discrepancies, the original questionnaire was checked to verify accuracy.

Questionnaire Surveys

The study involved two questionnaires, one for the schoolchildren, and the other for their parents. Questionnaires for children were composed of four sections: anthropometric data, screening for respiratory symptoms, screening for exposure to residential risk factors, and dietary habits and nutritional knowledge.

Section I: Anthropometric data included the child's self-reported gender, height, and weight. The data were also confirmed with the child's health records, which were provided by the health center of the school.

Section II: Screening for respiratory symptoms. The questions were adopted and modified from the screening criteria of the American Thoracic Society (13) and studies of Samet (14), Woolcock (15), and Clark et al. (16). Questions included the experiences of respiratory symptoms (persistent cough, chest tightness, wheezing with a cold, wheezing without a cold, dyspnea associated with wheezing, exercise-induced cough, and exercise-induced wheezing) in the past 12 months and self-reported physician-diagnosed disease history. Descriptions of these questions are shown in Table 1. Answers were "yes" or "no."

Section III: Screening for exposure to residential risk factors. The questions were related to the number of occupants at home, exposure to passive smoking, smoke from mosquito repellent burning and incense burning, the use of a dehumidifier and air conditioner, number of indoor plants, exposure to chemical vapor and gas leaks, having carpeted floor at home, use of wool blanket, keeping indoor pets (dogs, cats, birds, rodents/rabbits), stuffed toys, the presence of cockroaches and rodents at home, having leaky water/standing water at home, and visible mold on the surface of walls or furniture. These environmental factors were chosen based on extensive literature research and on results from preliminary studies.

Section IV: Dietary habits and nutritional knowledge section. Section IV was for evaluating the risk of dietary pattern, dietary habits, nutritional knowledge, psychosocial factors, and lifestyle.

The parental questionnaire was a shortened version of the child questionnaire, mainly for the purpose of confirming children's responses. It included the questions of the child's experiences of respiratory symptoms over the past 12 months,

TABLE 1.—Descriptions of questions for respiratory symptoms screening and physician-diagnosed disease history.

Respiratory symptoms screening	
Have you ever had a cough that would not go away in the past 12 months?	
Have you ever felt tight or heavy in your chest in the past 12 months?	
Have you ever had wheezing when you had a cold in the past 12 months?	
Have you ever had wheezing when you did not have a cold in the past 12 months?	
Have you ever had a wheezing attack that made it hard for you to breath in the past 12 months?	
Have you ever coughed with/after exercise in the past 12 months?	
Have you ever wheezed with/after exercise in the past 12 months?	
Physician-diagnosed disease history	
Have you ever been diagnosed with asthma by a physician?	
Have you ever been diagnosed with bronchitis by a physician?	
Have you ever been diagnosed with pneumonia by a physician?	
Have you ever been diagnosed with allergy by a physician?	

physician-diagnosed disease history, and the status of some risk factors in the residential environment and diet.

Respiratory Health Outcomes

Respiratory symptoms included non-exercise-induced and exercise-induced respiratory symptoms. Non-exercise-induced respiratory symptoms were persistent cough, chest tightness, wheezing with a cold, wheezing without a cold, and dyspnea associated with wheezing without being under the condition of physical exercise. Exercise-induced respiratory symptoms were cough and wheezing induced by physical exercise. Physician-diagnosed asthma was defined as the positive response to the question: "Have you ever been diagnosed with asthma by a physician?" Suspected asthma was defined as having any two or more wheezing-associated non-exercise-induced respiratory symptoms (wheezing with cold, wheezing without cold, and dyspnea associated with wheezing over the past 12 months) or having physician-diagnosed asthma by a physician.

Statistics Analyses

The association of residential environmental factors with respiratory symptoms was assessed by χ^2 tests. The crude odds ratio (OR) with 95% confidential interval (CI) was reported. Multivariate logistic regression analyses were used to evaluate the associations of residential environmental factors with physician-diagnosed and suspected asthma after adjusting for potential confounders including gender, residential districts, physician-diagnosed allergy, and parental history of respiratory symptoms. Adjusted OR (aOR) and 95% CI of multivariate analysis were reported. The statistical software package SAS (SAS Institute Inc, Cary, NC, USA) was used for all analyses. Statistical significance was set at $p < 0.05$; $p < 0.01$ and $p < 0.001$ were also reported.

RESULTS

Of the participating pupils, 2,218 pupils completed a written questionnaire, a 96.9% completion rate. Among the participants, 1,118 were from the high-pollution district, San Chong, and 1,172 from the low-pollution district, Hsin-Dien. Table 2 shows the demographic and household characteristics of schoolchildren respondents. Figure 1 shows the location of the selected districts in Taipei, Taiwan.

Proportions of Schoolchildren Having Physician-Diagnosed Asthma, Suspected Asthma, and Respiratory Symptoms

The proportion of schoolchildren having physician-diagnosed asthma was 9.8% and the proportion of schoolchildren having suspected asthma was 16.1%. The proportions of respiratory symptoms ranged from 9.8% for wheezing without a cold to 40.5% for exercise-induced cough. The percentages of schoolchildren experiencing one to seven respiratory symptoms are shown in Table 3.

There were no significant differences in the proportions of physician-diagnosed asthma, suspected asthma, and non-exercise-induced respiratory symptoms between the high-pollution district and the low-pollution district. The proportion of exercise-induced wheezing was higher in the high-pollution district; while the proportion of exercise-induced cough was higher in the low-pollution district ($p < 0.05$).

TABLE 2.—Demographic and household characteristics of respondents.

Characteristics	Values
Demographic	
Age range (y)	11–12
Gender (%)	
Boys	51.7
Girls	48.3
Average height (m) (mean $\pm$ SD)	
Boys	1.44 $\pm$ 0.07
Girls	1.46 $\pm$ 0.07
Average weight (kg) (mean $\pm$ SD)	
Boys	41.45 $\pm$ 10.81
Girls	40.24 $\pm$ 9.50
Household (%)	
Exposure to passive smoking	28.2
Exposure to mosquito-repellent fumes	32.3
Exposure to incense-burning fumes	38.2
Use of dehumidifier	47.9
Use of air conditioner	87.5
Exposure to chemical vapor	9.8
Having gas leaks at home	5.7
Use of wool blanket	22.4
Having pets	28.0
Cockroaches at home	29.1
Rodents at home	7.6
Leaky water/water puddle at home	13.8

Proportions of physician-diagnosed asthma and suspected asthma were significantly higher in boys than in girls (12.6% vs. 6.7% for physician-diagnosed asthma; 19.9% vs. 12.0% for suspected asthma, both $p < 0.05$). Boys had significantly higher proportions of persistent cough, wheezing with a cold, wheezing without a cold, and dyspnea associated with wheezing than in girls (21.4% vs. 17.9% for persistent cough; 18.1%

TABLE 3.—Proportions of physician-diagnosed asthma,^a suspected asthma^b and respiratory symptoms^c, stratified by pollution status (PM 10 level)^d and gender.

	Self-report Rate (%)	Pollution status		Gender	
		High	Low	Boys	Girls
Physician-diagnosed asthma	9.8	9.8	9.7	12.6	6.7**
Suspected asthma	16.1	16.3	15.9	19.9	12.0**
Respiratory symptoms					
Non-exercise-induced symptoms					
Persistent cough	19.7	20.7	18.8	21.4	17.9*
Chest tightness	15.9	16.4	15.4	15.8	16.0
Wheezing with a cold	15.5	14.2	16.8	18.1	12.8**
Wheezing without a cold	9.8	10.4	9.3	11.8	7.7**
Dyspnea associated wheezing	16.5	16.9	16.1	18.8	13.9**
Exercise-induced symptoms					
Wheezing	34.4	36.8	32.2*	37.2	31.5**
Cough	40.5	37.8	43.1*	38.2	43.0*
Number of experiences of respiratory symptoms					
1	24.3	24.2	24.3	23.4	25.1
2	16.7	17.0	16.4	17.2	16.2
3	9.8	9.1	10.4	10.2	9.4
4	5.3	5.6	5.0	5.3	5.4
5	3.5	3.9	3.1	4.0	3.0
6	3.0	3.4	2.7	4.0	2.1*
7	1.2	0.7	1.7	1.1	1.3

^aPhysician-diagnosed asthma was defined as ever being diagnosed asthma by a physician.

^bSuspected asthma was defined as having the experience of two or more wheezing-associated non-exercise-induced respiratory symptoms in the past 12 months or ever being diagnosed asthma by physician.

^cRespiratory symptoms included persistent cough, chest tightness, wheezing with a cold, wheezing without a cold, dyspnea associated with wheezing, exercise-induced wheezing, or exercise-induced cough in the past 12 months.

^dPollution level was determined by the average concentration of particulate material less than 10 μ m (PM10) in 2000. The district with the highest and the district with the lowest PM10 values in metropolitan Taipei area were chosen.

* $p < 0.05$; ** $p < 0.01$.

vs. 12.8% for wheezing with a cold; 11.8% vs. 7.7% for wheezing without a cold; and 18.8% vs. 13.9% for dyspnea associated with wheezing, respectively, all $p < 0.05$). Boys had a higher proportion of exercise-induced wheezing, but girls had a higher proportion of exercise-induced cough ($p < 0.05$). A higher proportion of boys than girls had six respiratory symptoms ($p < 0.05$).

Residential Environmental Factors

Table 4 shows the associations of exposures to residential environmental factors with respiratory symptoms. Passive smoking, mosquito repellent burning, incense burning, dehumidifier use, odoriferous chemical vapor, gas leaks, wool blanket use, indoor pets, cockroaches and rodents at home, and leaky water/water puddle at home were significantly associated with one or more respiratory symptoms ($p < 0.05$). Among the residential environmental factors, exposure to odoriferous chemical vapor was strongly associated with all seven respiratory symptoms. The unadjusted ORs of exposure to odoriferous chemical vapor were 2.59 (95% CI = 1.92–3.49) for persistent cough, 2.78 (95% CI = 2.03–3.80) for chest tightness, 2.20 (95% CI = 1.59–3.05) for wheezing with a cold, 2.44 (95% CI = 1.68–3.54) for wheezing without a cold, 2.64 (95% CI = 1.93–3.61) for dyspnea-associated with wheezing, 2.41 (95% CI = 1.81–3.23) for exercise-induced wheezing, and 1.58 (95% CI = 1.19–2.11) for exercise-induced cough (all are $p < 0.05$).

Table 5 shows the associations of residential environment factors with the proportions of physician-diagnosed asthma and suspected asthma. Dehumidifier use, odoriferous chemical vapor, and having cockroaches at home were significantly associated with the proportion of physician-diagnosed asthma. The aORs of physician-diagnosed asthma were 1.54 (95% CI = 1.07–2.22) for dehumidifier use, 2.35 (95% CI = 1.45–3.82) for exposure to odoriferous chemical vapor, and 2.16 (95% CI = 1.18–3.93) for having cockroaches at home. Dehumidifier use, odoriferous chemical vapor, gas leaks, and leaky water/water puddle at home were significantly associated with the proportion of suspected asthma. The aORs of suspected asthma were 1.56 (95% CI = 1.16–2.11) for the

TABLE 5.—Multivariate regression analysis for the association^a of exposed residential environmental factors with the proportions of physician-diagnosed asthma^b and suspected asthma^c.

	PDA		SA	
	aOR ^d	95% CI ^e	aOR	95% CI
No. of occupants/residents				
≤3	1.00		1.00	
4–6	1.19	0.68–2.09	1.13	0.71–1.80
≥7	1.19	0.57–2.49	1.09	0.59–2.00
Passive smoking	0.82	0.55–1.23	0.90	0.65–1.26
Mosquito-repellent fumes	0.81	0.55–1.20	0.82	0.60–1.14
Incense-burning fumes	0.88	0.61–1.28	0.96	0.71–1.31
Use of dehumidifier	1.54	1.07–2.22*	1.56	1.16–2.11**
Use of air conditioner	1.27	0.69–2.35	1.12	0.68–1.82
Having indoor plants	0.87	0.70–1.08	0.94	0.79–1.11
Chemical vapor	2.35	1.45–3.82***	2.14	1.40–3.26***
Gas leaks	1.75	0.95–3.21	2.01	1.20–3.35**
Carpeted floor	1.13	0.75–1.72	1.03	0.73–1.46
Use of wool blanket	1.10	0.71–1.70	1.24	0.87–1.77
Having pets				
Dogs	1.16	0.68–1.98	1.24	0.81–1.91
Cats	0.80	0.27–2.39	0.72	0.29–1.79
Birds	0.76	0.36–1.61	1.03	0.59–1.81
Rodents/rabbits	1.57	0.92–2.68	1.40	0.88–2.20
Having stuffed toys/fur pets	0.92	0.64–1.33	1.07	0.79–1.44
Cockroaches at home				
Never	1.00		1.00	
1–2 times/week	1.07	0.69–1.65	1.23	0.87–1.75
Every day	2.16	1.18–3.93*	1.42	0.81–2.47
Rodents at home				
Never	1.00		1.00	
≥1 times/month	1.79	0.84–3.80	1.54	0.80–2.94
≥1 times/week	1.06	0.34–3.28	0.61	0.20–1.83
Leaky water/water puddle at home	1.22	0.76–1.96	1.50	1.02–2.19*
Moldy wall/furniture	1.14	0.52–2.50	1.21	0.64–2.28

^aAdjusted for residential districts, gender, physician-diagnosed allergy, parental history of respiratory symptoms, and all other respective factors in tables.

^bPDA (see Table 3 footnote a).

^cSA (see Table 3 footnote b).

^dAdjusted odds ratio.

^eConfidence interval.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

use of dehumidifier, 2.14 (95% CI = 1.40–3.26) for exposure to odoriferous chemical vapor, 2.01 (95% CI = 1.20–3.35) for gas leaks, and 1.50 (95% CI = 1.02–2.19) for leaky water/water puddle at home.

TABLE 4.—Univariate analysis of the association of respiratory symptoms^a with exposed residential environmental factors.

Environmental factors	Respiratory symptoms						
	Persistent cough cOR ^b (95% CI) ^c	Chest tightness cOR (95% CI)	Wheezing with a cold cOR (95% CI)	Wheezing without a cold cOR (95% CI)	Dyspnea-associated with wheezing cOR (95% CI)	Exercise-induced wheezing cOR (95% CI)	Exercise-induced coughing cOR (95% CI)
Passive smoking	1.34 (1.07–1.68)*	1.55 (1.22–1.97)**	1.30 (1.01–1.66)*	1.05 (0.77–1.43)	1.30 (1.02–1.66)*	1.55 (1.28–1.89)**	1.78 (1.47–2.16)**
Mosquito repellent fumes	1.33 (1.07–1.65)*	1.22 (0.96–1.55)	1.12 (0.88–1.43)	1.21 (0.90–1.63)	1.17 (0.92–1.48)	1.17 (0.96–1.41)	1.21 (1.01–1.46)*
Incense-burning fumes	1.42 (1.15–1.76)**	1.55 (1.23–1.95)**	1.31 (1.04–1.66)*	1.46 (1.10–1.94)**	1.25 (0.99–1.57)	1.18 (0.98–1.42)	1.18 (0.99–1.41)
Use of dehumidifier	1.13 (0.91–1.39)	1.20 (0.95–1.51)	1.31 (1.04–1.65)*	1.17 (0.88–1.55)	1.13 (0.90–1.42)	1.07 (0.89–1.29)	1.17 (0.98–1.39)
Use of air conditioner	1.19 (0.85–1.65)	0.94 (0.67–1.32)	1.17 (0.81–1.68)	1.16 (0.75–1.81)	1.04 (0.74–1.46)	1.03 (0.78–1.35)	1.28 (0.98–1.67)
Chemical vapor	2.59 (1.92–3.49)**	2.78 (2.03–3.80)**	2.20 (1.59–3.05)**	2.44 (1.68–3.54)**	2.64 (1.93–3.61)**	2.41 (1.81–3.23)**	1.58 (1.19–2.11)**
Having gas leaks at home	2.01 (1.36–2.97)**	1.35 (0.85–2.12)	2.71 (1.83–4.02)**	2.72 (1.73–4.27)**	2.05 (1.36–3.08)**	1.95 (1.34–2.84)**	1.58 (1.10–2.28)*
Use of wool blanket	1.76 (1.39–2.22)**	1.45 (1.12–1.88)**	1.35 (1.04–1.76)*	1.36 (0.99–1.87)	1.56 (1.21–2.01)**	1.45 (1.17–1.79)**	1.52 (1.23–1.87)**
Having pets	1.50 (1.20–1.87)**	1.47 (1.16–1.88)**	1.29 (1.00–1.65)*	1.45 (1.08–1.95)*	1.23 (0.96–1.57)	1.29 (1.06–1.58)*	1.24 (1.02–1.50)*
Cockroaches at home	1.58 (1.27–1.98)**	1.24 (0.97–1.58)	1.59 (1.25–2.03)**	1.52 (1.14–2.04)**	1.50 (1.19–1.91)**	1.34 (1.10–1.63)**	1.39 (1.15–1.69)**
Rodents at home	1.78 (1.24–2.55)**	1.57 (1.06–2.33)*	1.42 (0.94–2.13)	1.24 (0.75–2.05)	1.65 (1.12–2.43)*	1.44 (1.02–2.02)*	1.71 (1.22–2.38)**
Leaky water/water puddle at home	1.52 (1.14–2.03)**	1.63 (1.20–2.20)**	1.35 (0.98–1.85)	1.42 (0.97–2.07)	2.02 (1.51–2.70)**	1.39 (1.07–1.80)*	1.88 (1.46–2.42)**

^aRespiratory symptoms (Table 3 footnote c).

^bCrude odds ratio.

^cConfidence interval.

* $p < 0.05$; ** $p < 0.01$.

DISCUSSION

Proportions of Asthma and Respiratory Symptoms

The prevalences of respiratory diseases, including asthma, in Taiwanese children appear to be on the rise. Hsieh and Shen (4) observed a rate of 1.3% for bronchial asthma in schoolchildren 7 to 15 years of age in 1974, and 5.07% for bronchial asthma in schoolchildren of the same age range in 1985. In a 1993 study, Li et al. (17) observed that the prevalence of physician-diagnosed asthma was 7.25%, and the rates of respiratory symptoms ranged from 3.35% for cough to 9.42% for exercise-induced cough in 8–12 years old children in Taipei. This current study shows a proportion of 9.8% of fifth grade schoolchildren having physician-diagnosed asthma and a proportion of 16.1% having suspected asthma, according to the definitions used in the study. The proportions of respiratory symptoms ranged from 9.8% for wheezing without a cold to 40.5% for exercise-induced cough. It must be noted that results of these studies may only provide a rough general trend because each asthma study defines respiratory diseases differently.

There were no significant differences in the proportions of non-exercise-induced respiratory symptoms, physician-diagnosed asthma, and suspected asthma between the two school districts. The study used PM10 values of the preceding year as a pollution indicator in selecting the study locations. However, data released after this study was completed indicated that pollution levels between the two districts were not drastically different. This might be the reason why we observed no significant differences in respiratory diseases between these two districts.

Results of the present study show that boys have higher proportions of physician-diagnosed asthma, suspected asthma, and non-exercise-induced respiratory symptoms than girls. The results are consistent with the observations of Hsieh et al. (4) and Li and Hsu (17). Higher proportions of boys often have asthma and respiratory symptoms than girls before puberty. By using the database of the European Community Respiratory Health Survey Study, Marco et al. (18) suggested that hormonal factors and airway caliber could play a role in explaining the different patterns of asthma incidence in men and women.

Residential Environmental Factors

Results of this study suggest that exposure to odoriferous chemical vapor is a major risk factor of respiratory symptoms for schoolchildren in Taipei. Children exposed to odoriferous chemical vapors had a 58% to 178% increase in risk of respiratory symptoms. After adjusting for the confounding factors, chemical vapor significantly increased the risk of physician-diagnosed asthma by 135% and the risk of suspected asthma by 114%. Irritant chemicals come from a variety of sources: exhaust from nearby factories, painted surfaces, wood furniture, indoor decorations, and cooking fumes. The irritant chemicals contain a variety of potential asthma-triggering factors. In a randomized, cross-design trial of controlled human exposure, mixtures of volatile organic compounds caused dose-related increases in lower and upper respiratory symptoms and induced biomarkers of airway inflammation, such as interleukin 8 (19). In the European Community Respiratory Health Survey, formaldehyde and volatile

organic compounds emitted from newly painted indoor surfaces were observed to increase blood eosinophil, cause the inflammation reactions in the airway, and increase the risk of asthma by 50% (95% CI = 1.0–2.4) (6). In a study by Rumchev et al. (20), children exposed to formaldehyde at a level $\geq 60 \mu\text{g}/\text{m}^3$ were 39% more likely to have asthma compared to those who were not exposed to such levels. Similarly, exposure to total volatile organic compounds at a level $\geq 60 \mu\text{g}/\text{m}^3$ in residential setting were four times more likely to have asthma (21).

This current study also shows that exposure to gas leaks increased the risk of respiratory symptoms by 58% to 172%. After adjusting for confounding factors, it increased the risk of having suspected asthma by 101%. Natural gas is the most common fuel for heating water and cooking in Taiwan, and minor leaks are common. A study found that women who used gas for cooking were more likely to have wheezing (aOR = 2.07, 95% CI = 1.41–3.05), waking with shortness of breath (aOR = 2.32, 95% CI = 1.25–4.34), and asthma attacks (aOR = 2.60, 95% CI = 1.20–5.65) (22). Women who used a gas stove or had an open gas fire had reduced lung function and increased airway obstruction (22). Garrett et al. (8) reported that respiratory symptoms were more common in children living in homes with gas stoves (OR = 2.3, 95% CI = 1.0–5.2). From the current and earlier studies, the use of certain fuels may be a potential risk factor for respiratory symptoms and could also be a surrogate of incomplete combustion of fuel, products of burning fuel, or release of oil fumes during cooking.

Leaky roofs and walls cause indoor dampness. These risk factors increased the odds of respiratory symptoms by 39%–102% and the odds of suspected asthma by 50% in present study. High humidity and dampness are prevalent in the indoor environment in subtropical and tropical regions. Li et al. (17) reported that the prevalence of respiratory symptoms in children was higher in homes with the occurrence of molds and dampness. Home dampness had a significantly positive association with asthma in primary schoolchildren (aOR = 2.65, 95% CI = 1.52–4.62) (23). Dehumidifier use has not been common until recent years. Families with asthmatic children might have tried to eliminate in-home dampness by using the dehumidifier. The present data indicates that 58.9% children with physician-diagnosed asthma had dehumidifiers in the home. The positive associations between dehumidifier use and physician-diagnosed and suspected asthma in the present study support the efficacy of this intervention and suggest that dampness is a risk factor for respiratory diseases.

The presence of cockroaches at home was associated with increased odds of respiratory symptoms and physician-diagnosed asthma. As many as 29% of schoolchildren reported sighting cockroaches frequently at home. Cockroaches have been suggested as a source of allergen and as a risk factor for asthma (24–26). Gruchalla et al. (26) reported that cockroach allergen levels were higher than dust mites in high-rise apartments and exposure to cockroach allergens was associated with increased asthma morbidity. Sohn et al. (27) found that German cockroach extract induced activation of human eosinophils, with subsequent release of cytotoxic inflammatory mediators. Sarinho et al. (28) demonstrated that asthma occurred more frequently in children living in home with high cockroach infestation.

In addition, results of the present study show that having indoor pets increased the risk of respiratory symptoms. Bener et al. (29) observed that prevalence of asthma in children with pets was twice than children without pets (OR = 2.4, 95% CI = 1.8–3.1). The odds of having chronic cough (OR = 3.9, 95% CI = 2.8–5.2) and chronic wheeze (OR = 4.2, 95% CI = 3.3–5.4) were higher in children with pets than children without pets. Ingram et al. (30) demonstrated an association of dog and cat allergen exposure with asthma morbidity in sensitized children with asthma with asthma. In a Japanese population-based study, hamster ownership was found to be associated with increased odds of respiratory symptoms (OR = 1.57, 95% CI = 1.18–2.10) (31). The current study suggests that indoor pets can be potential risk factors for childhood respiratory illness.

Exposure to cigarette smokes or fumes from burning mosquito-repellent or incense increases the risk of childhood respiratory symptoms (9, 10, 32–35). One study reported that passive smoking accounted for 6.5% of wheezing for schoolchildren in the past 12 months (9). Azizi et al. (33) found that exposure to mosquito coil smoke for more than three nights a week was significantly and independently associated with asthma (OR = 1.4, 95% CI = 1.1–1.6) and persistent wheeze (OR = 1.4, 95% CI = 1.1–1.8). Yang et al. (34) reported that burning of incense or mosquito repellent was associated with cough symptoms (aOR = 1.28, 95% CI = 1.03–1.57 for incense burning; aOR = 1.26; 95% CI = 1.05–1.5 for mosquito repellent, respectively). The present study shows that passive exposure to cigarette smokes, fumes of mosquito-repellent burning, and incense burning was associated with the increased risk in respiratory symptoms by 21%–78%, but not physician-diagnosed asthma or suspected asthma after adjusting for confounding factors. The discrepancy could be explained by a reverse bias. The smoking cessation campaign in Taiwan might have reduced the number of smokers, especially those who have children with asthma. Families with asthmatic children might have avoided smoking and burning incense and also might have used alternative methods to keep away mosquitoes instead of using mosquito repellent.

Limitations of this Study

Some limitations to the study should be noted. The study only involved fifth graders in selected schools in Taipei, Taiwan, leading to the possibility that the children in the sample were not truly representative of the population in Metropolitan Taipei. The results may not be applicable to the total population. Physician-diagnosed asthma is based on self-reports of the lifetime-diagnosed asthma, a process that may have affected the rates and relative risk estimates. Children might have outgrown the asthma. Conversely, seeking a physician diagnosis is related to the socio-economic and educational status of the family. Differences in access to health care and variations in practice or criteria of asthma among physicians also contribute to results of asthma diagnosis. As with any research using self-reported data, the quality of data in this study is dependent on the accurate understanding and recall of children regarding asthma symptoms over a full year and their willingness to reveal the information. Asthma remains a stigmatizing diagnosis in some parts of the popu-

lation. Some parents or children may have minimized symptoms to avoid the stigma.

The current study is a cross-sectional observation study. It is not known whether the onset of respiratory symptoms and asthma follows the onset of exposure to potential risk factors. Consequently, the causality cannot be interpreted. Although this study suggests that chemical vapor is the major risk factor in residential settings, the study does not have more detailed information concerning the sources, concentrations, and components of chemical vapors to evaluate further associations and develop intervention strategies. More studies are needed to gain a better understanding of the relationship among the risk variables and the consequent development of asthma or respiratory symptoms. Since the present study examines the risk factors for respiratory symptoms and asthma in a residential environment, it is possible that families with knowledge or having asthmatic children are more likely to report high exposures to risk factors.

CONCLUSION

The present results suggest that the residential environment plays a significant role in increasing the risk of respiratory diseases in primary schoolchildren in Taipei, Taiwan. Odoriferous chemical vapors contribute as the major risk factors in the residential settings. Other risk factors include gas leaks, dampness, and cockroaches at home. In terms of public health, the information is important for asthma intervention and management.

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