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A M E R I C A N C O L L E G E O F



P H Y S I C I A N S[®]

Childhood Asthma and the Indoor Environment in a Subtropical Area*

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Study objectives: The objective of this study is to examine the relationship between indoor environmental factors and childhood asthma in a subtropical area.

Design: A case-control study was performed using participants of a prevalence survey that included 165 schoolchildren with asthma and 165 age- and gender-matched control subjects.

Setting: The study was confined to 4,164 schoolchildren aged 6 to 12 years attending eight primary schools in Kaohsiung County rural municipalities who participated in a prevalence study concerning the health effects of the indoor environment.

Participants: Cases (n=165) were defined as children with current asthma confirmed by a physician. Control subjects (n=165) were selected from the same school and class and matched for age and gender, and they did not have a previous diagnosis of asthma, history of physician-confirmed atopic diseases, persistent wheezing, cough, or phlegm, or reported chest illness, pneumonia, or bronchitis.

Measurements and results: Information regarding the home environment was obtained using a structured written questionnaire, completed by the parents of the children. Of the many indoor environmental factors included in this study, only home dampness showed an association with asthma (odds ratio=2.65).

Conclusions: We conclude that dampness in the home is a new public health issue in subtropical areas. (CHEST 1998; 114:393-397)

Key words: asthma; case-control study; dampness; indoor environment

Abbreviations: CI=confidence interval; OR=odds ratio

Asthma, which is an important medical problem worldwide, is the most common chronic disease among pediatric patients. It often leads to costly treatment, disability, and school absence.^{1,2} The prevalence of asthma in developing countries has increased in recent years.³ The prevalence of asthma in schoolchildren in Taipei increased from 1.3% in 1974 to 5.1% in 1985⁴ and to 10.8% in 1994 (unpublished data; K.H. Hsieh; National Taiwan University Hospital; 1994).

Asthma is also the most common lung disease associated with indoor air pollution.⁵ Most people in subtropical areas spend much of their life indoors, and concern about the health effects of the indoor environment has been growing in recent years.⁶ The

indoor environment in developing countries is subjected to pollutants from numerous sources.⁷ In 1994, we conducted a large questionnaire-based study of the respiratory health effects of the indoor environment in the rural areas of Kaohsiung County, which has a subtropical climate. This article focuses on the possible association between indoor environmental factors and asthma among participants of this prevalence survey of elementary schoolchildren.

MATERIALS AND METHODS

Study Areas and Survey Procedures

Four municipalities in Kaohsiung were selected for the present study based on the urban-rural classification in Taiwan.⁸ According to this classification, each municipality was given a 1 to 8 urbanization category. Municipalities with the highest urbanization level, such as the Taipei metropolitan area, were assigned to category 1, while municipalities with the lowest urbanization level were assigned to category 8. The four municipalities selected were predominantly rural and they were assigned to category 8. The rural areas selected for the present study also had no local sources of industrial air pollution.⁹ These areas were judged to have no pollution based on site visits by the authors. Therefore,

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the health of children in these areas was unlikely to be influenced by regional air pollution. We believe that the levels and types of outdoor air pollution were essentially similar in the studied areas.

All 16 public primary schools within the study areas agreed to participate in the study. A random sample of one half of the primary schools was chosen. All school buildings are made of concrete and the conditions inside the classrooms are almost the same—with no particular indoor air pollution sources for the studied schools. All children from the first through the sixth grades (children 6 to 12 years of age) in the eight schools were enrolled in this study. Sample sizes in participating schools varied from 350 to 700 pupils.

A questionnaire that evaluated respiratory illnesses and symptoms of children was distributed to the children in the participating schools by their teachers during the period from September to November, 1994. The questionnaire was completed by a parent or guardian most familiar with the child's health and returned to the school. The questions were obtained or modified from other previously used questionnaires, namely, the American Thoracic Society-Division of Lung Disease Respiratory Symptom Questionnaire,¹⁰ which was used in the Harvard Six Cities Study,¹¹ and the questionnaire used by the Health and Welfare Department in Canada for a community-based study of children's health.¹²

From the questionnaire, the following factors were assessed: environmental exposures in the homes of a chemical nature, including presence of a household smoker in the home; exposure to gas cooking appliances; mosquito repellent burning; and incense burning. Other environmental factors of a physical nature such as whether the house contained an air cleaner, dehumidifier, or air conditioner, and other biologic factors including family ownership of furry pets, carpeting, plants inside the home, and home dampness were also assessed. Home dampness was defined as presence of any one of the following: visible mold or mildew growth on the surfaces inside the home, appearance of standing water within the home; water damage; or water leaks into the building.

Study Subjects

The subjects for the present case-control study were selected from the participants of the prevalence study. The question used for case definition was "Has the child ever had asthma diagnosed by a doctor?" The control subjects, selected from the same school and class and matched on age and gender, did not have a previous diagnosis of asthma, history of physician-confirmed atopic diseases, persistent wheezing, cough, or phlegm, or reported chest illness, pneumonia, or bronchitis.

It was estimated that, if the true odds ratio (OR) was 2, in order to detect an association between indoor environmental factors and asthma with a specificity of 95% ($\alpha=0.05$) and a power of 80% ($\beta=0.2$), a sample size of 75 cases and an equal number of control subjects would be needed.¹³

Statistics

All statistical analyses were performed using statistical software (Statistical Analysis System; SAS; Cary, NC). A conditional logistic regression model was used to calculate OR and 95% confidence intervals (CIs) adjusted for other risk factors and for potential confounding factors.¹⁴ All statistical tests were two sided.

Covariables used to adjust the associations between indoor environmental factors and asthma included the following: age, gender, highest level of education achieved by either parent, the child's allergies, *eg.* to food, dust, or pollen, parental asthma, and breast feeding.

RESULTS

The parents of all 4,389 children enrolled in the eight schools studied received a questionnaire; 4,213 (96%) questionnaires were returned. Complete information was available on 4,164 children. The prevalence of asthma was 4% ($n=165$) and an equal number of matched control subjects were identified. The prevalence is less than that reported by a previous study conducted in Taipei.⁴ This previous study, however, used a different case definition (they defined cases as "a child who had had at least three recurrent, paroxysmal attacks of wheezing and dyspnea in the past 12 months") and was conducted in an urban area.

Table 1 shows the distribution of cases and control subjects by selected personal characteristics. There were more cases than control subjects with allergies, a family history of asthma (parental asthma), and higher paternal education. Control mothers breast fed their child more often than case mothers did. Having a history of pneumonia or tonsillectomy was not reported by any of the cases or control subjects (not shown in Table 1).

Table 2 shows the indoor environmental characteristics of the study subjects. There were no notable differences between the cases and control subjects with regards to household smoking, use of dehumidifiers, use of an air cleaner, use of an air conditioner, owning furry pets, use of carpets, mosquito repellent burning, and having plants inside the home. Home dampness had a positive and statistically significant association with asthma. However, a negative association was observed between asthma and incense burning and frequency of gas cooking.

As shown in Table 3, asthma was only significantly associated with home dampness (OR=2.65, 95% CI=1.52, 4.62) when conditional multiple logistic regression was used to obtain estimates of associa-

Table 1—Characteristics of the Study Population

	Cases, % (n=165)	Control Subjects, % (n=165)
Age, yr, mean \pm SD	10.68 \pm 2.86	10.61 \pm 2.74
Male gender	53.3	53.3
Parental education \geq high school		
Father*	63.6	50.3
Mother	43.6	41.2
Household crowding (people/room)		
\geq 1	88.5	90.3
$<$ 1	11.5	9.7
Parental asthma*	7.9	0.6
Allergy (food, dust, pollen) (any)*	35.8	8.5
Breast feeding*	38.2	44.8

* $p < 0.05$.

Table 2—Crude OR and 95% CI of Indoor Environmental Factors and Asthma

Factors	Cases, No.	Control Subjects, No.	OR (95% CI)
Household smoking			
None	75	67	1.00
Any	90	98	0.83 (0.54-1.27)
Use of a dehumidifier			
No	140	136	1.00
Yes	25	29	0.83 (0.46-1.51)
Use of an air cleaner			
No	157	158	1.00
Yes	8	7	1.16 (0.39-3.47)
Use of an air conditioner			
No	31	38	1.00
Yes	134	127	1.32 (0.76-2.29)
Furry pets			
No	120	105	1.00
Yes	45	60	0.67 (0.43-1.06)
Carpets			
No	144	144	1.00
Yes	21	21	1.00 (0.52-1.92)
Mosquito repellent burning			
No	86	103	1.00
Yes	79	62	1.51 (0.98-2.35)
Incense burning*			
No	72	41	1.00
Yes	93	124	0.42 (0.25-0.68)
Plants inside the home			
No	89	99	1.00
Yes	76	66	1.28 (0.83-1.93)
Gas cooking*			
<1/d	21	10	1.00
≥1/d	144	155	0.48 (0.24-0.96)
Home dampness*			
No	44	85	1.00
Yes	121	80	2.95 (1.80-4.84)

*p<0.05.

tions adjusted for other risk factors. ORs were adjusted for age, sex, parental education, parental asthma, physician-confirmed allergy to food or dust, etc, and breast feeding. After adjustment for these factors, gas cooking and incense burning were not significantly associated with asthma.

DISCUSSION

The present case-control study indicated that reported home dampness was the only indoor environmental factor that is associated with asthma for children residing in Kaohsiung rural areas. This finding is in agreement with the findings of other epidemiologic studies.¹⁵⁻²³

Determination of the presence of home dampness in this study relies on self-reporting and therefore was subjective. If dampness is widely held to be a cause of asthma, an association based entirely on

self-reported information should be considered prone to reporting bias. This could be possible if the parents of asthmatic children report dampness in the home more readily than those whose children are not asthmatic. This seems unlikely, however, because the potential role of dampness in the home as a risk factor for asthma has not received much public attention in Taiwan.

Since determination of the presence of home dampness was based entirely on self-reporting, this could result in misclassification of exposure and reduce the observed associations. However, several studies have reported the validity of self-reported housing conditions and independent objective assessments of temperature, humidity, and mold growth.^{19,20,24-26} In addition, the questionnaire did not focus exclusively on dampness in the home. The questions related to dampness in the home and growth of molds were widely separated in the questionnaire and the respondents generally did not know that dampness in the home and molds could cause adverse health effects. Therefore, it would be reasonable to believe that it is unlikely that overreporting or underreporting of damp housing conditions could have biased the study results.

Though differences in questionnaire design, language, climate, and housing conditions may exist, the ORs found in the present study are similar to those reported from other countries.^{15,17,20,22} The consistency of our results with those of previous studies meets one of the criteria for an epidemiologic association to be considered causal. Therefore, the associations between asthma and dampness in the home are probably causal, although doubt remains because of the subjective nature of the self-reporting.

Fungi, house dust mites, and cockroaches are known to be more prevalent in damp homes than in dry homes, and all are known to produce substances that may trigger allergic reactions.²⁷⁻³⁵ Taiwan is in a subtropical climate, and high relative humidity (>80%) occurs throughout the year. House dust mites and fungi are the major allergens in our subtropical area.³⁶ *Aspergillus*, *Penicillium*, and *Cladosporium* are the predominant genera, and their

Table 3—Adjusted ORs (95% CIs) for the Association Between Indoor Environmental Factors and Asthma*

Variable	Crude OR	Adjusted OR (95% CI)
Gas cooking	0.48	1.16 (0.50-2.68)
Incense burning	0.42	1.53 (0.90-2.58)
Home dampness†	2.95	2.65 (1.52-4.62)

*Adjusted for age, sex, parental education, parental asthma, physician-confirmed allergy to food, dust, or pollen, and breast feeding.
†p<0.05.

indoor levels are higher than levels in other parts of the world.^{37,38} A previous study has demonstrated the validity of questions in regard to dampness and molds as indicators of indoor mold growth, and the respondent's perception of home dampness has been correlated with measured spore levels.²⁰ In the present study, however, the concentrations of fungi, house dust mites, and cockroaches were not determined. Therefore, there is no direct evidence to show that this mechanism is responsible for the observed associations between dampness of the home and asthma.

The indoor environmental factors that have received the most attention in the past are environmental tobacco smoke and directly or indirectly measured nitrogen dioxide, which mainly comes from gas cooking appliances. Although many studies have shown a statistically significant relationship between passive smoking and childhood asthma,^{11,18,39-45} our study did not. This inconsistent finding may be due partly to the fact that we did not assess whether household smokers actually smoked indoors or because, in developing countries, many of those who smoke actually smoke only a few cigarettes per day. Also we did not determine which parent smoked. This could be important since maternal smoking indoors may be a greater risk factor to children. Furthermore, almost all the students in rural Taiwan walk to school. We think that the probability that the effects of parental smoking inside the car with the children present may have affected our results is negligible.

We did not find an association between gas cooking and asthma. This result is consistent with several other reports that also found that the use of gas cooking appliances was not significantly associated with asthma.^{11,41,44,46} In reality, it was not possible to see any impact of gas stove use on respiratory health because nearly 91% of the homes of the study subjects (87.3% of the cases and 93.9% of the control subjects) used gas stoves for food preparation more than one time per day.

The burning of Chinese incense for worshipping deities is a daily routine for most Chinese. The smoke produced by this practice has been found to contain formaldehyde.⁴⁷ Exposure to indoor formaldehyde may cause asthma⁴⁸ or asthma-like symptoms.⁴⁹ Incense burning was not shown to be a significant risk factor in this study (adjusted OR, 1.53 [CI, 0.90 to 2.58]). Burning mosquito repellents is a common source of indoor air pollution in subtropical rural areas. In this study, the prevalences of mosquito repellent burning were 47.9% and 37.6% for the cases and the control subjects, respectively. The potential harmfulness of products produced by burning mosquito repellent has been acknowledged.⁵⁰

Two studies conducted in tropical countries have found that exposure to mosquito repellent smoke was associated with asthma.^{51,52} In this study, we did not find an association between either incense burning smoke or mosquito repellent smoke exposure and asthma. However, their potential for harm merits further study in subtropical areas.

In conclusion, in this study, we investigated the relationship between several indoor environmental factors and childhood asthma. Of the many indoor environmental factors included in this study, only home dampness was found to be associated with asthma. This finding supports the hypothesis of an association between asthma and reported dampness in the home, which has been observed in other recent epidemiologic studies. In view of the high relative humidity in subtropical areas and the results of the present study, home dampness should become a new public health issue for Taiwan's population. The possible adverse health effects of damp housing deserve further study.

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