Role of Urbanization and Air Pollution in Adolescent Asthma: A Mass Screening in Taiwan

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Background and Purpose: The prevalence of asthma in school children in Taiwan is increasing. This study used mass screening among middle school children in Taiwan to determine the prevalence of asthma and related factors.

Methods: Data were collected from parents using a self-reported questionnaire and from children using the International Study of Asthma and Allergies in Childhood (ISAAC) video questionnaire. Six study teams conducted the survey nationwide in 1995–1996, with the assistance of middle school nurses and teachers.

Results: Among the 1,018,031 students at 795 middle schools who returned questionnaires, 8.5% had a history of asthma (ranging in prevalence from 4.2% to 13% in 25 areas). The prevalence of asthma was higher in boys than in girls (10.0% *vs* 7%) and was highest in more urbanized areas (11.2%), followed by moderately urbanized areas (7.4%) and less urbanized and rural areas (6.5%). Controlling for age, family smoking, family incense burning, and parental education level, multivariate logistic regression models indicated that children living in an area with heavy air pollution were more likely to have asthma than those in an area with no or light pollution (odds ratio, OR = 2.01 and 95% confidence interval, CI = 1.94–2.09 based on parental ranking of pollution level, or OR = 1.30 and 95% CI = 1.18–1.42 based on pollution level reported by the Environmental Protection Administration).

Conclusions: Adolescent asthma in Taiwan is most prevalent in the most urbanized areas and decreases in prevalence in less urbanized areas. This study also found that higher parental education level and higher area air pollution were associated with higher adolescent asthma prevalence.

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Key words:
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Respiratory illnesses, particularly asthma and bronchitis, are the leading causes of chronic and acute morbidity in childhood [1–3]. Recently, increases in both the prevalence and the severity of asthma have been reported in many countries [3–10]. There is increasing evidence for a relationship between ambient and indoor air pollution and respiratory illness, including bronchial asthma and chronic obstructive pulmonary disease [11, 12]. The effects of increasing air pollution in urban areas on respiratory illness are a major public health concern in Taiwan [13]. The prevalence of asthma among 7- to 15-year-old children in Taipei increased four-fold from 1.3% in 1974 to 5.1% in 1985 [14].

In May 1995, Taiwanese legislators authorized the Environmental Protection Administration (EPA) to collect energy consumption fees to clean the air and monitor health problems that may be associated with

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air pollution. EPA provided immediate funding to 10 universities with public health programs to collaborate on childhood asthma studies as part of the effort in air pollution prevention and control. The major objective was to assess the prevalence of childhood asthma nationwide and its associated factors including age and gender differences, geographic variation, urbanization, and air pollution. This report describes the main results from a mass screening for asthma involving more than one million adolescents in Taiwan.

Methods and Materials

Target population

All children attending middle schools (7th–9th grades, mostly 13–15 yr old) were surveyed from October 1995 through June 1996. In September 1995, there were 1,139,452 students enrolled in the 800 middle schools in 25 counties and cities in Taiwan and on Kimmen and Matsu islands. Taiwan is an industrialized island nation and had a population of 21,441,432 in 1996 in an area extending over 35,981 km^2. Two-thirds of the island is mountainous, and the remaining one-third has a highly dense population and is flat and well utilized by farming, industry, and commerce.

Questionnaires

In collaboration with the faculties of public health and medicine at nine other universities in Taiwan, National Taiwan University College of Public Health was designated as the lead school to design and conduct the study. A Respiratory Health Survey Steering Committee, consisting of 35 experts in pediatrics, internal medicine, family medicine, pulmonary function, environmental health, health education, biostatistics, and epidemiology, was responsible for overseeing the study.

The asthma screening instruments were modified Chinese versions adapted from two questionnaires previously used, a self-reported questionnaire for parents [14] and the International Study of Asthma and Allergies in Childhood (ISAAC) video questionnaire for children [1, 14–16]. The self-reported questionnaire for parents includes questions about whether the child has ever had symptoms of respiratory and other allergic disorders, including rhinitis and eczema, physician diagnoses, and the frequency of symptoms in the past 12 months. A separate questionnaire for parents was also used to assess their child's exposure to passive smoking and Chinese incense burning at home. The international version of the ISAAC video questionnaire, also a self-reported instrument completed by students, involves an audiovisual presentation of symptoms and signs of asthma. All symptoms assessed were included in scenes in the video. Students were also asked additional questions about their smoking, drinking, and exercise habits. A pilot study testing the feasibility of both the parental questionnaire and the ISAAC video questionnaire was performed on 1,200 students from six randomly selected schools and their parents.

More than 30 faculty members and 310 research assistants conducted the survey with assistance from school nurses and teachers at all middle schools. Students were assembled in classrooms or school auditoriums to watch the video and complete the ISAAC questionnaire while the video was being shown. Each student was also given 1 week to take home and return the parental self-reported questionnaire to be completed by his/her parents. Questionnaires not returned within 1 week were considered refusals. This study was approved by the appropriate education administrators and by the principals of 795 of 800 schools involved; five schools refused to participate.

Definition of asthma and data analyses

The ISAAC video showed five sequences of clinical asthma in different situations. After each sequence, students were asked whether they had experienced respiratory episodes similar to the ones presented in the video. Students responding affirmatively for any of the episodes were classified as being asthmatic. In addition, children with doctor-diagnosed asthma (reported in the parental questionnaire) and those who had suffered from asthmatic wheezing during the past 12 months were also classified as having asthma. Students who did not have asthmatic symptoms, but suffered from exercise-associated wheezing or any parentally described wheezing, were classified as having suspected asthma. All others were classified as normal.

Collected questionnaires were reviewed, and the results entered into a database and analyzed using the statistical package SAS/STAT (SAS Institute Inc, Cary, NC, USA). Differences between genders and grades, and among regions, were analyzed based on the level of urbanization. A more urbanized area was defined as an area with higher population density and automobile/motorcycle density, and thus had more severe air pollution than a less urbanized area. In addition, the association of asthma with EPA-monitored and parent-reported local air pollution levels, parental education level, passive smoking, Chinese incense burning at home, student-reported smoking behaviors, and exercise were estimated. Regression analysis of the EPA air pollution data showed that the prevalence of asthma by area had the strongest association with the annual average level of carbon monoxide (CO). We therefore used annual average concentrations of CO in each area as an indicator of students' air pollution exposure,

categorizing areas as higher (≥ 1.0 ppm), middle (0.75–0.99 ppm), and lower exposure (< 0.75 ppm). Multiple logistic regression analyses were used to assess the effects of air pollution, controlling for other factors. Crude and adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for the association of asthma with all of the assessed variables.

Results

Study population

Completed ISAAC video questionnaires and parental questionnaires returned within 1 week were available for 1,018,031 students, a response rate of 89.3% of the 1,139,452 students. The response rates among the six study regions ranged from 86.9% to 92.5%. Among the returned questionnaires, 92.3% were completed without data missing for any variables. The rates of returns were similar by sex and grade. The distributions between male (50.4%) and female (49.6%) students were similar with respect to ages, parental education levels, exposure to passive smoking (61.2% *vs* 60.8%), and exposure to Chinese incense burning (52.8% *vs* 52.9%). However, boys had a higher prevalence of smoking than girls, with 4.5% of boys and 0.8% of girls reporting smoking. Boys were also more likely to exercise than girls (53.4% *vs* 21.7%).

Prevalence of asthma

The overall prevalence of asthma for all the surveyed students averaged 8.5%, ranging from 4.2% in Kimmen to 13.0% in the Taipei metropolitan area (Table 1). The prevalence of asthma was higher among boys than girls (10.0% *vs* 7.1%).

Table 2 shows that higher rates of asthma were found in the highly urbanized areas than in the moderately and less urbanized areas. More urbanized areas also had a higher density of population, automobiles, and motorcycles.

Associations

In the univariate analyses, the prevalence of asthma varied with age (between 12 and 15 years), passive

Table 1. Prevalence of asthma among 7th to 9th graders in 25 cities and counties in Taiwan by gender from the 1995–96 mass screening survey

Area	Total		Male		Female	
	n	Rate (%)	n	Rate (%)	n	Rate(%)
Taipei Metropolitan	15,328	13.0	9,195	15.2	6,133	10.6
Tainan City	4,593	11.4	2,689	13.3	1,904	9.4
Kaohsiung Metropolitan	8,157	11.1	4,772	13.0	3,385	9.3
Taichung City	4,440	9.3	2,663	11.2	1,777	7.4
Hualien City	1,478	9.1	825	9.9	653	8.2
Keelung City	1,523	9.1	920	10.9	603	7.3
Taipei County	13,739	8.8	7,918	10.1	5,821	7.5
Chiayi City	1,456	8.7	870	10.4	586	7.1
Hsinchu City	1,370	8.2	802	9.4	568	6.9
Kaohsiung County	4,161	8.2	2,409	9.6	1,752	6.9
Taoyuan County	6,476	8.0	3,807	9.2	2,669	6.7
Tainan County	3,237	7.3	1,926	8.6	1,311	5.9
Taitung County	796	7.1	407	7.2	389	6.9
Chiayi County	1,266	6.7	747	7.9	519	5.4
Pintung County	2,716	6.7	1,562	7.8	1,154	5.6
Hsinchu County	1,268	6.7	751	7.8	517	5.5
Taichung County	4,800	6.6	2,842	7.7	1,958	5.4
Ilan County	1,391	6.3	820	7.3	571	5.3
Nantow County	1,470	6.1	920	7.6	550	4.6
Penghu County	246	5.8	150	7.0	96	4.6
Changhua County	3,583	5.6	2,167	6.7	1,416	4.5
Yunlin County	2,038	5.6	1,289	6.9	749	4.2
Miaoli County	1,161	5.3	687	6.2	474	4.3
Lienchiang County	14	5.1	9	6.6	5	3.6
Kimmen County	122	4.2	78	5.1	44	3.2
All	86,829	8.5	51,225	10.0	35,604	7.0

Table 2. Average population density, automobile density, motorcycle density, and prevalence of asthma by urbanization level in Taiwan

Urbanization	Population density (/km²)	Automobile density (/km²)	Motorcycle density (/km²)	Asthma prevalence (%)
Highly urbanized	6,208	1,488	2,427	11.2
Moderately urbanized	961	560	390	7.4
Less urbanized/rural	210	46	95	6.9

smoking, family use of incense, student exercise, and parental education level. Seventh-graders had the highest prevalence (9.4%), followed by eighth-graders (8.6%) and ninth-graders (7.6%). Children whose parents were college educated were more likely to suffer from asthma than children whose parents were less educated (12.9% *vs* 7.7%).

After controlling for all variables and comparison with regions with low EPA-monitored air pollution, the multivariate logistic regression model predicted that the estimated risk of asthma would increase 10% (95% CI of OR: 1.03, 1.16) in regions with middle air pollution levels, and 30% (95% CI of OR: 1.18, 1.42) in regions with higher air pollution levels (Table 3).

Similar multivariate analysis, based on parental ranking of the air pollution level, also demonstrated an apparent dose response in asthmatic risk (Table 4). For children living in areas with heavy air pollution, the estimated risk of asthma increased by 101%. Table 5 shows the joint association of parental education and parental ranking of air pollution with asthma prevalence. Across each parental educational level, a consistent increase in asthmatic risk for children in heavily polluted areas, ranging from 83% to 102%, was estimated using the rate ratio.

Table 3. Crude and adjusted odds ratios of asthma by Environmental Protection Administration-reported local air pollution level

	Asthma prevalence	Odds ratio		
	% (n)*	Crude	Adjusted†	95% CI
Air pollution, CO‡				
< 0.75 ppm	7.2 (36,016)	1.0	1.0	
0.75–0.99 ppm	8.0 (13,589)	1.24	1.10	1.03, 1.16
≥ 1.0 ppm	10.7 (37,244)	1.56	1.30	1.18, 1.42

*Missing values not included; †adjusted for sex, grade, family, passive smoking and incense burning, student exercise, and parental education level; ‡carbon monoxide (CO): local annual average level in parts per million (ppm). CI = confidence interval.

Table 4. Crude and adjusted odds ratios of asthma by parent-reported residential air pollution level

	Asthma prevalence	Odds Ratio		
	% (n)*	Crude	Adjusted†	95% CI
Air pollution level				
None	6.5 (15,545)	1.0	1.0	
Light	8.5 (49,413)	1.32	1.30	1.27, 1.32
Moderate	11.3 (16,465)	1.81	1.71	1.62, 1.76
Heavy	13.6 (4,120)	2.25	2.01	1.94, 2.09

*Missing values not included; †adjusted for sex, grade, family, passive smoking and incense burning, student exercise, and parental education level. CI = confidence interval.

Discussion

There is a lack of consensus as to the best definition to use for determining the prevalence of asthma. In order to facilitate comparison of our results with published international prevalence rates for childhood asthma derived from questionnaire surveys, the Steering Committee of this study adapted Chinese versions of the ISAAC video questionnaires that have been used internationally [15–17] and the parental questionnaires developed by Hsieh and Shen [14]. Hsieh and Shen demonstrated the acceptability of the parental questionnaire for asthma screening. The prevalence of asthma measured in this study was intended to be a conservative estimate, with symptoms other than asthmatic wheezing or physician-diagnosed cases categorized only as suspected asthma.

Many Western countries have experienced an increased mortality, morbidity, and prevalence of childhood asthma [2–10, 17–29]. Rising trends of childhood asthma have also been reported for some Asian populations, including in Taipei and Hong Kong [14, 21]. The European Community Respiratory Health Survey (ECRHS) found prevalence rates of wheezing ranging from 4% to 32% for 463,801 children aged 13 to 14 years in 155 collaborating centers in 56 countries [30]. The results of this island-wide survey indicate that 8.5% of

Table 5. Number and percentage of asthma cases among all middle school students by parental education level and parent-reported residential air pollution level

Education	Pollution				All	*p*-value of
	None	Light	Moderate	Heavy		trend
≤ 9 yr,	n (%) 7,029 (5.3)	18,887 (6.8)	5,678 (8.9)	1,245 (10.7)	32,834 (6.8)	0.001
10–12 yr	n (%) 5,168 (6.9)	17,331 (8.7)	5,897 (11.6)	1,425 (13.5)	29,821 (8.9)	0.001
≥ 13 yr	n (%) 3,071 (10.1)	12,452 (12.5)	4,669 (15.7)	1,393 (18.5)	21,591 (12.9)	0.001

middle school students in Taiwan have childhood asthma. The prevalence of asthma in this population was lower than that in most ECRHS countries. However, the prevalence was similar to that found in previous studies involving 12-year-old children in Hong Kong (8.9%) [21], in La Serena and Chile (both 8.0%) [22], in 6- to 12-year-old children in the Netherlands (8.9%) [23], and in 9- to 11-year-old children in East Germany (7.2%) and West Germany (9.2%) [4]. Higher asthma prevalence was found in children in England (13.1%) [5], and in Melbourne, Australia (23.2%) [22]. Asthma had been diagnosed in 4.6% of students island wide and 6.5% of students in the Taipei metropolitan area. These results are different from some reported data, such as 5.9% among 12-year-olds in Switzerland [24], 4.4% among 7 to 12-year-olds in eastern Finland [25], 4.8% among 7 to 14-year-old white children in the USA [26], and 6.2% among 7- to 11-year-old Asian children in Southampton [27]. However, the prevalence among white children (12.1%) was about twice as high as that among Asian children in Southampton.

Hsieh and Shen reported that the prevalence of asthma among 7- to 15-year-olds in Taipei in 1985 was 5.1% [14]. The prevalence estimated in this study was 13.0% for 13- to 15-year-olds, a remarkable increase within a 10-year period in Taipei. The 8.5% overall prevalence of asthma found in this mass screening survey might have been slightly underestimated as non-respondents might have included asthmatic children who were absent from schools due to illness (most of the survey questionnaires were delivered and collected during the peak asthma season: November, December, and January). Data from this study show that asthmatic attacks occur most frequently in these 3 months. During this period, about 34% of asthmatic children had one attack with wheezing. Because of the large sample size in this study and the high response rate, it is unlikely that our estimations were significantly biased due to non-respondents. Data from large population-based mass surveys have better statistical power in analyzing effects of risk factors than data from surveys with a small sample size, and allow greater precision in estimating risk without generalization of issues.

This study has confirmed the widespread impression that asthma is becoming increasingly common in younger children. Boys were more likely to be affected than girls across all three grades (10.0% *vs* 7.0%). The gender difference in asthma prevalence was very significant ($p = 0.007$), but could not be explained by geographic variation or socioeconomic factors, because parental education levels for boys and girls were similar.

Our results indicate that the prevalence of asthma was higher in more urbanized areas where there were a greater number of motor vehicles and factories.

Childhood asthma was about twice as common in cities as in rural areas. The prevalence of childhood asthma was also higher in areas with both EPA-reported and parent-reported heavy air pollution than in less polluted areas. These results indicate that air pollution may be a significant factor in the development of asthma. The risk of childhood asthma has been related to parental education level. It is possible that parents who are well educated are more likely to perceive childhood asthmatic episodes. They are also more likely to be of a higher socioeconomic status, and therefore have increased access to health care, which increases the likelihood that children's asthmatic symptoms will be diagnosed.

Air pollution is a very prevalent public issue in Taiwan, but there is lack of public awareness regarding asthma. Several studies have offered some insight as to a possible link between air pollution and asthma [10–12, 28, 29]. Our results provide additional evidence of such an association. This study found a significant association between the prevalence of asthma among students and the CO level in their school district. To our knowledge, no previous study has reported this association. Environmental CO level is indirectly linked to urban air pollution, particularly from automobiles, because CO is the most abundant pollutant in automobile exhaust.

Several studies have reported a significant effect of indoor air pollution, particularly maternal smoking, on the development of asthma [10, 23]. Although few women (4%) in Taiwan are smokers,

many men (55–60%) are smokers. This study failed to demonstrate a significant family smoking association with asthmatic risk for adolescents unless there were five or more smokers in the family (OR = 1.26, 95%CI, 1.17–1.45).

In summary, evidence from this survey and previous studies in Taiwan suggests that the prevalence of asthma in the middle school student population in Taiwan is still increasing, comparable with most studies reported for other young populations in the world. We also found that urbanization and local air pollution levels were related to asthma risk regardless of parental education level. Boys and younger students were more susceptible to asthma than girls or older students. A smoking effect was found if five or more family members smoked. Further investigation of other indoor risk factors, including dust mites, is required.

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