Traffic-Related Air Pollution, Climate, and Prevalence of Eczema in Taiwanese School Children

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The prevalence of childhood eczema is increasing in many countries. Epidemiological studies, however, say little of its association to outdoor air pollution and climate factors. We conducted a nationwide survey of middle-school students in Taiwan from 1995 to 1996. The 12-month prevalence of eczema was compared with air monitoring station data of temperature, relative humidity, and criteria air pollutants. A total of 317,926 children attended schools located within 2 km of 55 stations. Prevalence rates of recurrent eczema were 2.4 and 2.3% in boys and girls, respectively, with prevalence rates of flexural eczema 1.7% in both sexes. After adjustment for possible confounders, flexural eczema was found to be associated with traffic-related air pollutants, including nitrogen oxides and carbon monoxide. Recurrent eczema was associated with traffic-related air pollution only in girls. There were no associations for the highest monthly means of temperature, whereas the annual means and the lowest monthly means of temperature were negatively related to flexural eczema, but only in girls. The lowest monthly mean relative humidity was positively related to eczema. The results suggest that air pollution and climatic factors, which showed stronger associations in girls than boys, may affect the prevalence of childhood eczema.

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INTRODUCTION

Eczema, a chronically relapsing skin disease characterized by pruritus, is the most common inflammatory skin disease in children (Williams, 1995). Recently, prevalence of childhood eczema has increased substantially in many countries (Selnes *et al.*, 2002; Wang *et al.*, 2004; Galassi *et al.*, 2006; Grize *et al.*, 2006; Lee *et al.*, 2007a). This increase has been too rapid to be accounted for by changes in gene frequencies. It is also unlikely to be totally accounted for by changes in either clinical diagnostic patterns or increased recognition of associated symptoms by the general population (Hopkin, 1995). It may, however, suggest a role for environmental factors in the etiology of this evolving epidemic (McNally *et al.*, 2000, 2001; Harris *et al.*, 2001).

Many factors are proven to be associated with childhood eczema, including personal factors (smoking habits, genetics, age, gender, nutritional status, number of siblings, lifestyle, allergy status, and family history) and indoor environmental stimuli (house dust, animal danders, moulds, cockroach infestation, occupational exposure, environmental tobacco smoke, heating systems, and aeroallergens) (Heinrich *et al.*, 1998; Diepgen, 2001; Annesi-Maesano *et al.*, 2004; Zutavern *et al.*, 2005; Langan *et al.*, 2006). Few studies have scientifically evaluated the relationship between outdoor environmental factors and symptoms of eczema (Weiland *et al.*, 2004). The relative importance of air pollution exposure and climatic condition to the incidence and prevalence of eczema is not well understood.

This study was designed to compare the prevalence of childhood eczema from a nationwide survey with air pollutant and climatic data from 55 monitoring stations of the Taiwan Environmental Protection Administration (EPA; Taipei, Taiwan) (Figure 1). The effects of traffic-related air pollutants and climatic factors on eczema prevalence in middle-school students was assessed and compared for boys and girls.

RESULTS

Table 1 shows the characteristics of study subjects by sex and prevalence of childhood eczema according to the covariates. Prevalence rates of recurrent eczema were 2.4 and 2.3% in boys and girls, respectively, with prevalence rates of flexural eczema 1.7% in both sexes. The prevalence of childhood eczema was positively related to high level of parental education, asthma and rhinoconjunctivitis histories, and active smoking habits (Table 1).

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Abbreviations: CO, carbon monoxide; NOx, nitrogen oxides; O_3, ozone; PM_{10}, particulate matter with an aerodynamic diameter of less than 10 μm; RR, relative risk; SO_2, sulfur dioxide

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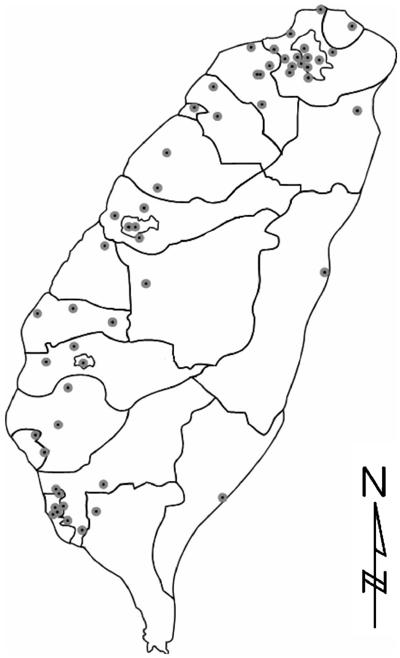

Figure 1. The 55 air-monitoring stations in this study and their 2-km catchment areas in Taiwan, 1994.

Table 2 summarizes the community-specific air pollution and meteorological annual means at these communities in year 1994. Two community-specific factors, traffic-related air pollution and fossil fuel combustion-related air pollution, were identified from the principal component factor analysis (Table 3). The first factor was positively associated with carbon monoxide (CO) and nitrogen oxides (NOx) and negatively associated with ozone (O_3), suggesting traffic-related motor vehicle emissions; the second was highly associated with sulfur dioxide (SO_2) and particles with an aerodynamic diameter of 10 μm or less (PM_{10}), indicating emissions from power plants, industry, and domestic fossil fuel combustion, as previously reviewed in Taiwan (Ko, 1996).

After adjustment for possible confounders, traffic-related air pollution showed positive and statistically significant associations for flexural eczema in both sexes (RR = 1.09, 95% confidence interval 1.00–1.19 in boys; RR = 1.12, 95% confidence interval 1.04–1.22 in girls). However, recurrent eczema was associated with traffic-related air pollution only in girls (Table 4). The effects of each air pollutant on childhood eczema were also assessed separately. The risks of eczema were positively related to CO and NOx, but only in girls (Table 4). In contrast, negative or weak associations were found for O_3, SO_2, and PM_{10}. Adjusted community-specific eczema prevalences were plotted against the traffic-related air pollution factor scores (Figure 2). There were no obvious outliers seen. Quadratic and cubic terms were used in the regression models and these terms were also not statistical significant (data not shown), which indicated the regression lines were compatible with linearity.

Table 5 presents the association between climatic factors and the prevalence of eczema. No associations were seen with the highest monthly means of temperature, while the annual means and the lowest monthly means of temperature were negatively related to flexural eczema, but only in girls. However, the lowest monthly mean relative humidity was positively related to eczema (Table 5).

DISCUSSION

This study was based on a large dataset and investigated the chronic effects of ambient air pollutants and climatic factors on childhood eczema in a cross-sectional design. Our analysis showed that the prevalence of eczema in middle-school students from 55 communities in Taiwan were associated with traffic-related air pollutants, especially NOx and CO. Annual means and the lowest monthly means of temperature were negatively related to eczema; however, lowest monthly mean relative humidity was positively related to eczema. In general, air pollution and climatic factors showed stronger associations in girls rather than boys. Compared with recurrent eczema, we could also find the effect estimates were larger on flexural eczema in both sexes.

Questionnaires have been widely used to assess the prevalence of chronic illness such as eczema. Our definition of recurrent eczema is relatively broad and may include many inflammatory skin diseases, such as contact dermatitis. However, by using ISAAC questions, researchers have well predicted eczema validated by dermatologists' examination in United Kingdom (Williams *et al.*, 1996), Germany (Kramer *et al.*, 1998), and Ethiopia (Haileamlak *et al.*, 2005), although it was suggested that the translated questionnaire is less effective than the English version in assessing the prevalence of eczema (Chan *et al.*, 2001). We used typical symptoms of childhood eczema during the past 12 months as the main outcome measurement in determining risk factors. The overall prevalence in our study were 2.4% for recurrent eczema and 1.7% for flexural eczema, lower than that reported in other countries, such as Australia (16.3%) (Marks *et al.*, 1999), Singapore (20.8%) (Tay *et al.*, 2002), and Germany (10.5%) (Werner *et al.*, 2002). The cause of these substantial differences is beyond the scope of this report, but some researchers hypothesize a Western lifestyle to be responsible: the higher the level of Westernization, the higher the prevalence of eczema (Diepgen, 2001; Dotterud *et al.*, 2001).

We found higher parental education level to be associated with childhood eczema (Table 1). The phenomenon could be partly explained that better educated parents might be more capable to notice health problems of their children, and hence more likely to report these children as having eczema (Heinrich *et al.*, 1998; Zutavern *et al.*, 2005). Moreover, eczema was significantly associated with asthma and rhinoconjunctivitis. This could probably be explained by the fact that these diseases are related to an atopic background (Bjorksten *et al.*, 1998). Active smoking in adolescence would have significant effects on occurrence of eczema (Annesi-Maesano *et al.*, 2004). We adjusted these covariates in following analytical models because they might interfere the relationship between eczema and outdoor air condition. Environmental tobacco smoke and incense burning at home showed relatively weak effects on the

Table 1. Number and prevalence rate of eczema by characteristics of the study population

	Boys							Girls						
	Subjects	Recurrent eczema			Flexural eczema			Subjects	Recurrent eczema			Flexural eczema		
	n (%)	*n* (%)	OR	95% CI	*n* (%)	OR	95% CI	*n* (%)	*n* (%)	OR	95% CI	*n* (%)	OR	95% CI
Age (years)														
<13	38,188 (24.1)	959 (2.5)	1.00		686 (1.8)	1.00		38,056 (23.9)	883 (2.3)	1.00		628 (1.7)	1.00	
13	54,002 (34.0)	1,336 (2.5)	1.01	0.93–1.10	939 (1.7)	1.00	0.91–1.11	54,189 (34.0)	1,215 (2.2)	0.98	0.89–1.07	869 (1.6)	0.98	0.89–1.09
14	54,112 (34.1)	1,290 (2.4)	0.99	0.91–1.08	909 (1.7)	0.99	0.89–1.09	54,294 (34.1)	1,251 (2.3)	1.03	0.94–1.12	923 (1.7)	1.08	0.97–1.19
15	12,430 (7.8)	260 (2.1)	0.91	0.79–1.05	190 (1.5)	0.97	0.82–1.14	12,655 (8.0)	312 (2.5)	1.10	0.97–1.26	222 (1.8)	1.13	0.96–1.32
Parental education level (years)														
<9	70,379 (44.3)	1,245 (2.0)	1.00		920 (1.3)	1.00		70,046 (44.0)	1,384 (2.0)	1.00		938 (1.3)	1.00	
9–11	58,190 (36.7)	1,355 (2.3)	1.07	0.99–1.16	972 (1.7)	1.17*	1.07–1.28	58,479 (36.7)	1,310 (2.2)	1.06	0.98–1.15	959 (1.6)	1.13*	1.03–1.23
>12	30,163 (19.0)	1,065 (3.5)	1.49**	1.37–1.63	832 (2.8)	1.73**	1.56–1.92	30,669 (19.3)	967 (3.2)	1.39**	1.27–1.52	745 (2.4)	1.52**	1.37–1.69
Asthma														
No	148,768 (93.7)	3,226 (2.2)	1.00		2,224 (1.5)	1.00		152,754 (96.0)	3,204 (2.1)	1.00		2,263 (1.5)	1.00	
Yes	9,964 (6.3)	619 (6.2)	2.18**	1.99–2.40	500 (5.0)	2.42**	2.18–2.68	6,440 (4.1)	457 (7.1)	2.39**	2.15–2.66	379 (5.9)	2.71**	2.40–3.05
Rhinoconjunctivitis														
No	113,692 (71.6)	2,045 (1.8)	1.00		1,360 (1.2)	1.00		127,997 (80.4)	2,237 (1.8)	1.00		1,557 (1.2)	1.00	
Yes	45,040 (28.4)	1,800 (4.0)	1.93**	1.80–2.06	1,364 (3.0)	2.10**	1.94–2.27	31,197 (19.6)	1,424 (4.6)	2.30**	2.14–2.47	1,085 (3.5)	2.40**	2.21–2.61
Active smoking habit[1]														
No	153,200 (96.5)	3,702 (2.4)	1.00		2,623 (1.7)	1.00		158,020 (99.3)	3,608 (2.3)	1.00		2,605 (1.7)	1.00	
Yes	5,532 (3.5)	143 (2.6)	1.28**	1.08–1.53	101 (1.8)	1.35**	1.10–1.65	1,174 (0.7)	53 (4.5)	2.08**	1.56–2.76	37 (3.2)	2.07**	1.48–2.89
ETS at home[2]														
No	70,370 (44.6)	1,798 (2.6)	1.00		1,328 (1.9)	1.00		70,958 (44.8)	1,652 (2.3)	1.00		1,235 (1.7)	1.00	
Yes	87,562 (55.4)	2,030 (2.3)	1.01	0.95–1.08	1,386 (1.6)	0.96	0.89–1.04	87,541 (55.2)	1,995 (2.3)	1.07	1.00–1.15	1,398 (1.6)	1.02	0.94–1.11
Incense burning at home[2]														
No	73,137 (46.8)	1,868 (2.6)	1.00		1,363 (1.9)	1.00		74,696 (47.4)	1,809 (2.4)	1.00		1,324 (1.8)	1.00	
Yes	83,317 (53.3)	1,940 (2.3)	1.01	0.95–1.08	1,336 (1.6)	0.99	0.92–1.07	82,930 (52.6)	1,817 (2.2)	0.98	0.92–1.05	1,292 (1.6)	0.98	0.91–1.06
Total	158,732 (100.0)	3,845 (2.4)			2,724 (1.7)			159,194 (100.0)	3,661 (2.3)			2,642 (1.7)		

CI, confidence interval; ETS, environmental tobacco smoke; OR, odds ratio.
ORs are mutually adjusted by listed factors.
*$P<0.05$, **$P<0.01$.
[1]Responded to by the children themselves.
[2]Numbers of subjects do not add up to total *n* because of missing data.
Some percentages do not total 100 because of rounding.

occurrence of eczema (Table 1). One possible explanation could be that environmental tobacco smoke and incense use might be reduced by families with children of eczema. Exposure to tobacco or incense might also provide protective effects for atopic diseases through selection mechanisms, especially in cross-sectional study (Hjern *et al.*, 2001).

Because of the close correlation among the air pollutants, it is impossible to separate the effects of individual pollutants. All the measured pollutants have several sources: NOx and CO are predominantly from vehicle emissions, while SO_2 and PM_{10} are mainly from stationary fossil combustion processes (Guo *et al.*, 1999; Lee *et al.*, 2003). Therefore, we used factor analysis to group the patterns of pollutants into two classes of pollutants: traffic-related and fossil fuel combustion-related. We found a significantly positive correlation between traffic-related pollutants and prevalence of

Table 2. Mean and distribution of 1994 annual air pollution and meteorology from 55 monitoring stations in Taiwan

	Mean	Standard deviation	Minimum	25 percentile	Median	75 percentile	Maximum
SO_2 (ppb)	7.57	4.15	0.88	5.01	7.22	8.77	21.2
CO (ppb)	853	277	381	675	843	1,001	1,610
O_3 (ppb)	36.8	8.3	21.7	29.8	37.7	42.4	54.2
PM_{10} ($\mu g\,m^{-3}$)	69.2	17.8	40.1	54.0	65.9	81.7	116.2
NOx (ppb)	35.1	13.4	10.2	25.6	34.0	42.9	72.4
Temperature (°C)							
Annual mean	22.9	1.1	19.6	22.3	22.8	23.6	25.1
The lowest monthly mean	15.2	1.9	11.3	14.0	14.7	16.2	19.0
The highest monthly mean	28.5	0.8	25.3	28.1	28.5	29.0	29.7
Relative humidity (%)							
Annual mean	76.2	3.7	64.8	74.8	76.6	78.6	86.2
The lowest monthly mean	64.8	6.5	50.8	59.8	65.3	70.2	77.8
The highest monthly mean	83.5	3.8	73.3	80.8	84.0	85.9	91.6

PM_{10}, particulate matter with aerodynamic diameter less than 10 μm; SD, standard deviation.

Table 3. Factor loading of the annual average levels of criteria air pollutants in Taiwan, 1994. Two factors represent traffic-related air pollution and fossil fuel combustion-related air pollution

	Factor 1(traffic-related air pollution)	Factor 2 (fossil fuel combustion-related air pollution)
Eigenvalues (% variance explained)	**2.53 (50.6%)**	**1.67 (33.4%)**
SO_2	0.345	**0.766**
CO	**0.913**	0.198
O_3	**−0.813**	0.435
PM_{10}	−0.093	**0.937**
NOx	**0.874**	0.349

PM_{10}, particulate matter with aerodynamic diameter less than 10 μm. Two factors have eigenvalues >1 and account for 84.0% of variance. Values in boldface are those rotated factor scores with absolute value >0.5.

eczema in both sexes. When the effect of each pollutant on eczema prevalence was examined, significantly positive association was found for NOx and CO, but only among girls. Previous questionnaire studies from Sweden and Germany showed increased risks for self-reported living close to heavy traffic and eczema symptoms (Schafer and Ring, 1997; Montnemery *et al*., 2003). In a recent human study, exposure to road traffic enhanced skin wheal responses and induced plasma inflammatory markers in patients with eczema, while it had no effect in normal controls (Kimata, 2004). Except for ''asthma'' or ''wheezing'', the association between traffic-related exposure and allergy-related symptoms, such as eczema, was inconclusive (Dotterud *et al*., 2000, 2001). In another study from our group, parentally perceived ambient air pollution was found to be associated with the occurrence of childhood eczema (Lee *et al*., 2007b). To our knowledge, this study was the first report directly comparing the eczema prevalence with outdoor air pollutant data. All these results suggested that exposure to heavy traffic might provoke symptoms of eczema. For this reason, NOx and CO might serve as indicators of motor vehicle emission levels rather than as direct measurements of the causal agent. Our findings were compatible with the hypothesis that exposure to traffic-related pollutants might have caused changes in the susceptibility of children to allergens, and therefore might have contributed to the development of eczema.

In our analyses, fossil fuel combustion-related air pollution, mainly PM_{10}, showed negative effects on childhood eczema (Table 4). This finding is unexpected and we do not have a good explanation for it. Taiwan is of subtropical area with hot and humid climate. Air conditioning and mechanical filtration are commonly used types of filtration in Taiwanese classrooms and homes. Since indoor particulates could be interfered by mechanical filtration or air condition (Partti-Pellinen *et al*., 2000; Cyrys *et al*., 2004), any known or unknown factors such as air change, penetration, deposition, as well as emission strengths for particulates, could be responsible for the observed association between eczema and outdoor particulate exposure. This is a common problem in all the previous studies assessing the effects of outdoor particulate matters on human health.

Table 4. RRs with 95% CIs for the relationship between eczema and air pollution factors in Taiwanese school children

	Boys				Girls			
	Recurrent eczema		Flexural eczema		Recurrent eczema		Flexural eczema	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Air pollution factor								
Traffic-related	1.06	0.99–1.15	1.09*	1.00–1.19	1.08*	1.00–1.16	1.12*	1.04–1.22
Fossil fuel combustion-related	0.98	0.90–1.06	0.93	0.85–1.02	0.89*	0.82–0.97	0.84*	0.76–0.91
Air pollutant								
SO_2	1.00	0.94–1.07	0.98	0.92–1.06	0.97	0.91–1.05	0.93	0.86–1.00
CO	1.06	0.98–1.15	1.08	0.98–1.18	1.06	0.97–1.16	1.10*	1.00–1.22
O_3	0.95	0.88–1.02	0.92	0.85–1.01	0.94	0.87–1.02	0.90	0.82–0.99
PM_{10}	0.97	0.87–1.08	0.91	0.81–1.02	0.87*	0.78–0.97	0.79**	0.70–0.89
NOx	1.06	0.97–1.15	1.07	0.97–1.18	1.06	0.96–1.17	1.11*	1.02–1.21

CI, confidence interval; PM_{10}, particulate matter with aerodynamic diameter less than 10 μm; RR, relative risk.
*$P<0.05$, **$P<0.01$.
Models are adjusted for age, parental education level, asthma, rhinoconjunctivitis, and active smoking habit.
RRs are expressed for a change in each factor by interquartile range.

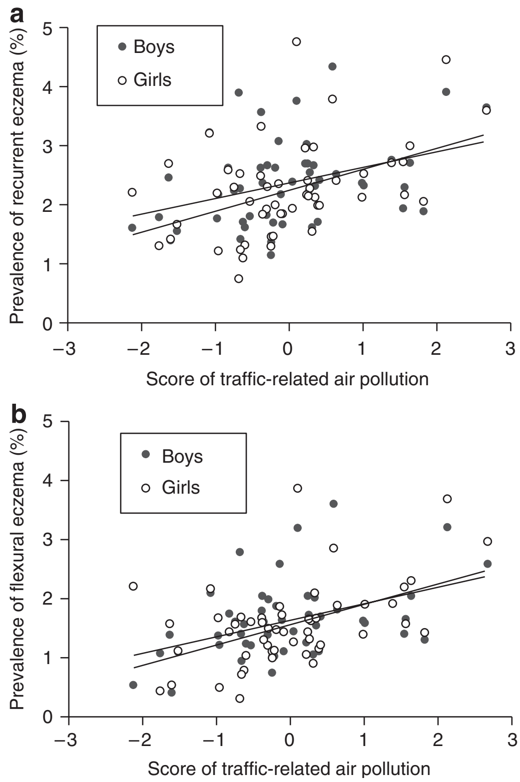

Figure 2. Association of traffic-related air pollution with prevalence rates of eczema. (**a**) Recurrent and (**b**) flexural eczema. Scores are normalized to mean 0 and variance 1 after factor analysis.

Previous studies have revealed that cold weather and abrupt falls in temperature can exacerbate eczema symptoms (Vocks *et al.*, 2001). Although cooling environments may mitigate itching symptoms (Fruhstorfer *et al.*, 1986), it was suggested that low temperatures could enhance skin irritability (Uter *et al.*, 1998). With increasing temperature, the water vapor content of the air increases the water content of the stratum corneum (Agner and Serup, 1989), which, in turn, would reduce itching symptoms (Werner and Lindberg, 1985; Hagermark, 1991). Weiland *et al.* (2004) used worldwide data from ISAAC centers and also found eczema prevalence to be negatively associated with annual mean temperature. This is consistent with our study, in which the annual means and the lowest monthly means of temperature showed a negative correlation with flexural eczema (Table 5).

From a prospective study in United Kingdom, outdoor relative humidity was proved to significantly influence the occurrence of eczema symptoms (Langan *et al.*, 2006). In Germany, Vocks *et al.* (2001) observed patients with eczema and found that more intense itching symptoms increased on foggy days with a maximal relative humidity. Outdoor relative humidity is high in Taiwan (monthly average, 64.8–86.2%). Trans-epidermal water loss, which cools the skin through evaporation, would therefore be lower and therefore provoke or exacerbate itching symptoms (Pinnagoda *et al.*, 1990). In our analysis, the lowest monthly mean relative humidity significantly increased the prevalence of eczema in both sexes, which was consistent with our previous finding that asthma was more prevalent in communities with higher winter humidity (Guo *et al.*, 1999).

We found in our previous report that sex might play an important role on eczema (Lee *et al.*, 2007b). Therefore, we stratified our analyses by sex in this study. Although boys and girls had similar prevalence rates of eczema, when we estimated the effect of outdoor climatic factors and air pollution on childhood eczema, a stronger relationship was noted in girls than in boys (Tables 4 and 5). These results were in accordance with our findings concerning the effects of indoor environmental factors on childhood eczema (Lee *et al.*, 2007b). Although some risk factors, such as active

Table 5. RRs with 95% CIs for the relationship between eczema and climatic factors in Taiwanese school children

	Boys				Girls			
	Recurrent eczema		Flexural eczema		Recurrent eczema		Flexural eczema	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Temperature								
Annual mean	0.99	0.90–1.09	0.94	0.84–1.04	0.92	0.83–1.02	0.86*	0.76–0.96
The lowest monthly mean	1.00	0.92–1.09	0.95	0.87–1.04	0.97	0.89–1.06	0.91*	0.83–1.00
The highest monthly mean	1.05	0.97–1.15	1.07	0.97–1.18	1.04	0.95–1.15	1.09	0.98–1.21
Relative humidity								
Annual mean	1.03	0.93–1.13	1.03	0.91–1.15	1.07	0.97–1.19	1.08	0.96–1.22
The lowest monthly mean	1.08	0.97–1.19	1.15*	1.04–1.27	1.14*	1.03–1.28	1.22*	1.08–1.38
The highest monthly mean	0.95	0.87–1.04	0.94	0.84–1.04	0.95	0.87–1.05	0.94	0.84–1.06

CI, confidence interval; RR, relative risk.
*$P<0.05$.
Models are adjusted for age, parental education level, asthma, rhinoconjunctivitis, and active smoking habit.
Relative risks are expressed for a change in each factor across interquartile range.

smoking habits, were indeed different in prevalence between girls and boys, the mechanism of such female-led susceptibility was not well understood. Sex differences in the pathogenesis of eczema might be partly due to difference in lifestyle, or differences in skin morphology and physiology.

Routine air pollution monitoring data were used as the basis for exposure assessment. These data represented reasonably well exposures both in the school and in the home for two reasons. The schools were chosen to be in the vicinity of the monitoring stations. Almost all the children attended schools within one kilometer of their homes because the density of middle schools in Taiwan is very high. Additionally, the two-stage hierarchical modeling took into account the fact that community-level exposure information was used. Although we did not collect information about the vicinity of the busy road, the present study and previous studies from German (Kramer *et al.*, 2000) and Mexican cities (Ramirez-Aguilar *et al.*, 2002) provide consistent evidence that the outdoor NO_2 level is a better predictor of traffic exposure than exposure to NO_2 at the personal level. We also proved outdoor data of traffic-related air pollutants from air monitoring stations as predictors of the prevalence of childhood eczema.

In cross-sectional studies, selection bias is a potential threat to validity. A plausible mechanism of selection is that parents of children with eczema move to residential areas with lower levels of air pollution, which will lead to underestimation of the relation between exposure and outcome. Any random migration is likely to result in underestimation of the air pollution effects but would not introduce a positive bias in the associations. The exposure information obtained from air monitoring stations was limited to the criteria air pollutants in 1994 and later years. Using air pollution and meteorology data from 1994 in exposure assessment was rational in considering the latency period of eczema. Our definitions of diseases were ascertained by parental-reported questionnaire rather than medical records, so misclassification may have arisen from imperfect parental recall of events. Parental reports may also not exactly reflect the health conditions of children. However, in the presence of a true association, misclassification of eczema that was random with respect to other study variables would weaken the observed association rather than lead to false-positive results.

Ecologic confounders like urbanization and socialization actually could exist in the data analysis, and incomplete adjustment between community differences and residual confounding is possible. However, more complete personal risk factors are very difficult to obtain in such a large-scale survey. Investigators decided not to try to obtain more personal information, because it would have resulted in a lower participation rate and would have introduced greater bias in the study.

CONCLUSION

After adjustment for possible confounders, eczema in both boys and girls were highly correlated with traffic-related air pollutants, NOx and CO. Annual means and the lowest monthly means of temperature were negatively related to eczema; however, the lowest monthly mean relative humidity was positively related to eczema. We also found that girls were more susceptible to outdoor air pollution and climatic factors. Public health policies to reduce certain traffic-related air pollutants may help reduce the morbidity of childhood eczema.

MATERIALS AND METHODS

Design and study methods

Between October 1995 and May 1996, we conducted a nationwide cross-sectional study among middle-school students in Taiwan. A total of 800 middle schools in 24 counties were investigated. The study protocol was approved by the Taiwan EPA and the Institutional Review Board at National Cheng Kung University Medical College, and it complied with the Declaration of Helsinki Principles (41st World Medical Assembly, 1990). The standard ''International Study of Asthma and Allergies in Childhood''-Chinese version (ISAAC-C) questionnaire was taken home by students and answered by parents with informed consent (Guo *et al*., 1999; Lee *et al*., 2003). Only some personal data, for example, active smoking habits, were reported confidentially by children themselves.

There were 1,139,452 students enrolled in 800 middle schools in 24 counties in Taiwan. A total of 1,018,031 (89.3%) students and their parents responded to the questionnaire satisfactorily (individual school range, 87–93%). Of that number, 334,966 (32.9%; 168,092 boys, 166,874 girls) were enrolled in a school within the 2-km catchment areas of each air-monitoring station. After excluding questionnaires with unanswered questions, data from 317,926 (31.2%; 158,732 boys, 159,194 girls) were left for further analysis. Subjects were mostly between the ages of 12–14.

Definition of health outcomes

Two indicators of eczema were considered. Recurrent eczema was defined by positive parental responses to the following two questions, ''Have your child ever had an itchy rash which was coming and going for at least six months?'' and ''Has your child had this itchy rash at any time in the past 12 months?'' If both of the answers were ''yes'', the parent would be further asked, ''Has this itchy rash at any time affected any of the following places: the folds of the elbows, behind the knees, in front of the ankles, under the buttocks, or around the neck, ears, or eyes?'' In our study, children who were reported to suffer from a skin rash in the previous year occurring at specific locations were defined as flexural eczema. Because of the large sample size in this study, it was not possible for us to perform medical record review. The definition of physician diagnosis of asthma and rhinoconjunctivitis were based on parental reports of the subject's lifetime history in questionnaire.

Air pollution and meteorology data

Complete monitoring data for the air pollutants SO_2, NOx, O_3, CO, and PM_{10}, as well as daily temperature and relative humidity, were available from 66 EPA monitoring stations beginning in 1994. Concentrations of each pollutant were measured continuously and reported hourly—CO by non-dispersive infrared absorption, NOx by chemiluminescence, O_3 by ultraviolet absorption, SO_2 by ultraviolet fluorescence, and PM_{10} by beta-gauge. The study population was limited to children attending schools located within 2 km of 55 of these monitoring stations. Eleven stations were discarded because there were no schools in 2-km catchment areas.

Community-specific annual averages were computed of the 24-hour SO_2, NOx, CO, PM_{10}, temperature, and relative humidity, and of the 1000–1800 hour (the 8-hours daytime) averages of O_3 in 1994. Principal component factor analysis with varimax rotation (Kaiser, 1958) was used to produce independent indicators of the source-specific indicators of exposure to air pollution. For the outdoor temperature and relative humidity values of each community we calculated the annual mean and the mean of the month with the highest and the lowest values.

Statistical analysis

All analyses were stratified by sex and conducted using SAS software version 9.1 (SAS Institute, Cary, NC). The RRs were estimated in two-stage hierarchical models to assess the relation between outdoor exposure and the risk of childhood eczema. The models assume two sources of variation: the variation among subjects in the first stage, part of which could be explained by the individual characteristics, and the variation among communities in the second stage, part of which could be explained by variables measured at community level. In the analyses we assumed that (1) the outcome variable follows Bernoulli distribution; (2) intercept terms are random at the community level; and (3) all the explanatory variables are fixed effects. A logistic regression model was fitted in the first stage for the risk of childhood eczema as a function of site-specific intercepts, j, where $\alpha j = 1,\ldots, 55$, and personal covariates. The adjusted site-specific intercepts and prevalence rates are related by $P_j = e^{\alpha j}/(1+e^{\alpha j})$. In the second stage, these intercept terms representing the logit of the site-specific prevalence rates (P_j; $j = 1,\ldots, 55$), adjusted for personal covariates, were regressed on each site-specific ambient pollutant level by using a linear ''ecologic'' regression, that is, logit $\alpha j = \alpha + U_j + \beta Z_j$, where U_j denotes random departure from the general prevalence αj on the logit scale for site j; Z_j denotes the ambient climatic and pollution level for site j. The results from the models are presented as RRs, along with their 95% confidence intervals.

The goodness of fit was assessed with likelihood ratio tests to determine whether a variable contributed significantly to the model. First, we fitted a full model with a complete set of covariates. To elaborate sources of confounding, we fitted models with different combinations of covariates and compared the effect from models with and without the covariate of interest. If the adjusted RR differed from the crude RR by more than 10%, that covariate will be included in the final model. The effect of each air pollutant and climatic factor on the risk of childhood eczema was expressed for a change by interquartile range, along with their 95% confidence intervals. The two-stage hierarchical model was used not only to derive more precise estimates of site-specific parameters and site-level effects, but also to adjust for multiple comparisons (Witte *et al*., 2000). The sex-specific adjusted prevalences of eczema were plotted against the scores of rotated components of traffic-related air pollutants, using weights proportional to the inverse variance of the prevalence. Statistical significance was set at $P < 0.05$ based on a two-sided calculation.

CONFLICT OF INTEREST

The authors state no conflict of interest.

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