

# The Effects of Volcanic Disaster on the Prevalence and Severity of Bronchial Asthma

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**Objectives:** To evaluate the impact of volcanic disaster on bronchial asthma, the prevalence and the extent of deterioration of asthma were studied among primary school children aged 6 to 11 years who experienced the volcanic eruption of Mt. Unzen Fugen, Nagasaki, Japan.

**Methods:** Questionnaire data were collected from the parents or guardians of primary school children. Asthma was classified into four categories: diagnosed asthma, current asthma, remitted asthma, and deteriorated asthma, and the prevalence of each category was compared according to sex and grade. We also analyzed the relation between asthma and past illness and family history including experience of volcanic disaster.

**Results:** Multiple logistic regression analysis showed that past illnesses of allergic diseases, such as allergic rhinitis, dermatitis and conjunctivitis were associated with either current asthma or deteriorated asthma. On the effects of volcanic disaster, a change of family member after volcanic disaster was significantly associated with deteriorated asthma (odds ratio=3.20, 95% confidence interval=1.79-5.70). Location of school seemed to somewhat influence the prevalence of deteriorated asthma, which might relate to the distance from the volcanic crater.

**Conclusion:** Our findings suggest that not only gases and ash but also changes in psychosocial conditions by refuge or related anxiety may influence the prevalence of asthma among primary school children.

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**Key Words:** Mt. Unzen-Fugen, volcanic eruption, primary school-children, bronchial asthma, refugee, logistic analysis

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## Introduction

The prevalence of bronchial asthma has been increasing with great variability among local populations and communities (1-5). The differences among populations suggest that the prevalence and severity of asthma are influenced by human-environment system that has been established in each local community (6-9). Although the etiology of increased prevalence of asthma is not fully understood, exposure to air pollutants, such as dust, pollen, gases and chemicals according to urbanization and industrialization has been considered to affect the prevalence and development of asthma (1,10). In addition, susceptibility to asthma is reported to be influenced by the psychosomatic condition of children as well as family situation (11-15). Previous studies have suggested that family factors can be important predictors of asthma (16-18). Further, Boyce *et al.* (19) reported a strong relationship between childhood respiratory illness and the degree of chronic family stress. Another study related to depression or hopelessness and cholinergic activation suggests that sad emotion states can evoke patterns of autonomic reactivity that predispose to cholinergically-mediated airway construction in asthma (11, 12). In this regard, pathological family settings are known to cause more emotional and behavioral problem in children, and influence the attitude and/or personality of asthmatic children (16).

Several studies have focused on the effects of volcanic eruptions on prevalence of asthma and/or respiratory function, but the results are inconsistent among studies on volcanic eruptions in Mt. St. Vincent (20), Mt. St. Helens (21, 22), Mt. Runapehu (23), and Mt. Sakurajima (24-30). In a series of human ecological studies, we previously examined the environmental effects of volcanic eruption of Mt. Unzen Fugen on health. Particular points related to the eruption included both environment pollution by volcanic

emissions, such as gases, and related psychosomatic stress of refugees seeking safer places and living at unfamiliar places (31-34). The impact of psychological changes on asthma has already been reported (11-19). However, previous studies only examined the effects of volcanic ash or gases on asthma (20-30), and did not consider the changes in human and environment system *per se* on the prevalence of asthma. The aim of the present study was to elucidate the impact on childhood asthma of volcanic eruption, based on the disaster at Mt. Unzen Fugen volcanic eruption, Nagasaki, Japan. We conducted a comprehensive study of the effects of both psychosomatic factors as well as volcanic gases and dust on asthma in school children.

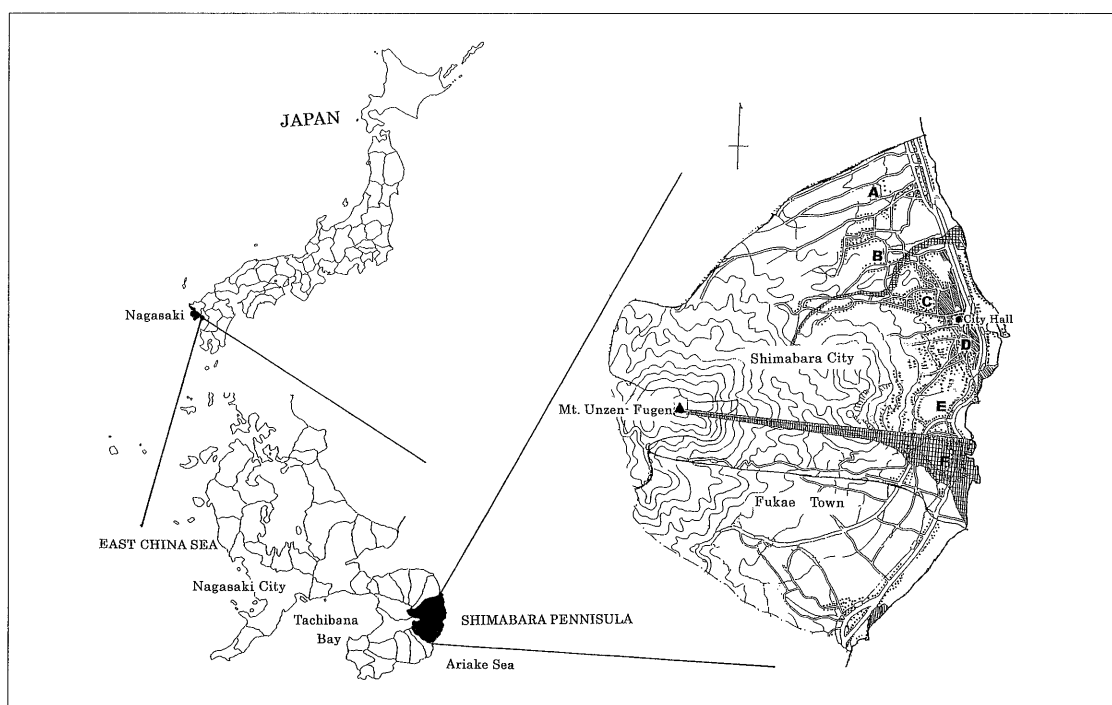
## Background

Volcanic eruption of Mt. Unzen Fugen (elevation, 1,500 m) in Unzen mountains in the Shimabara Peninsula, east of Nagasaki City, Southwestern Japan (Figure 1) started its activity in November 1990. The biggest pyroclastic flow occurred on June 29th 1991, in which 44 people died. The volcanic debris (lahars) have endangered several thousand people and destroyed more than 2,000 buildings and farmland. The government committee in charge officially declared

the end of eruption and the restoration of safety on May 25<sup>th</sup>, 1995.

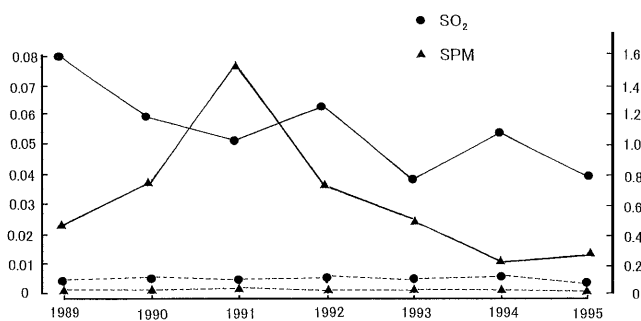
One of the characteristics of that volcanic activity was that densely populated areas (e.g., Shimabara City with 44,800 residents and Fukae Town with 8,422 residents according to 1990 census) were located only 6 km away from the crater of Mt. Unzen Fugen. To avoid the damage caused by flows, over three thousands households took temporary refuge in community houses and gymnastic halls of schools (35, 36). Following continued volcanic activity, the local government built temporary houses for refugees. In addition to dormitories, schools also moved to safer places (37).

The average concentrations of sulfur dioxide (SO<sub>2</sub>) and suspended particle matter (SPM) were continuously measured at the roof of Shimabara City Council located 7 km northeast from the volcanic crater. The concentration of SO<sub>2</sub> never exceeded the Japanese standard for air pollution control (0.04 ppm of daily average and 0.1 ppm of an hour average), but those of SPM measured at the station exceeded the standard (0.1 mg/m<sup>3</sup> of daily average and 0.2 mg/m<sup>3</sup> of an hour average) (38), and reached up to 1.56 mg/m<sup>3</sup> in July of 1991. Following a decrease in the frequency of eruptions, the concentrations of both SO<sub>2</sub> and SPM progressively decreased but the annual average of SPM in 1995, 0.37 mg/m<sup>3</sup>, was the highest among 48 stations in Nagasaki prefecture.



**Figure 1.** Sketch map of Shimabara Peninsula and Shimabara city.

Striped lesions show pyroclastic and volcanic debris flows which occurred from 1990 to 1995. School A and B in northern part and School C-F in southern part are respectively located in less and severe hazardous districts.



**Figure 2.** Annual changes of concentration of sulfur dioxides (SO<sub>2</sub>) and suspended particulate matter (SPM) at the monitoring station on roof Shimabara city council located at 7 km east distance from the crater. Solid and dotted line show the highest and annual average of concentrations for an hour measurement, respectively.

## Materials and Methods

The target population consisted of the total number of 3,029 pupils aged 6 to 11 years old in all six primary schools in the Shimabara City. Two types of questionnaires were given to the parents or guardians and were related to the asthma conditions of the pupils. The first survey was carried out in September 1994. A total of 2,958 questionnaires (97.7%) were collected. The questionnaire on asthma consisted of the following eight questions, representing the Japanese version of ATS-DLD (American Thoracic Society-Division of Lung Diseases) questionnaire (39-41). 1) Has the child ever had an attack of wheezing or whistling that caused him/her to be short of breath? 2) Has he/she had 2 or more such episodes? 3) Has a doctor ever said that the child had asthma or asthmatic bronchitis? 4) Since the child was diagnosed with asthma or asthmatic bronchitis, had he/she an attack of wheezing? 5) Since the child was diagnosed with asthma or asthmatic bronchitis, had he/she an attack of whistling? 6) Has he/she had such episode or medical treatment for bronchial asthma or asthmatic bronchitis in the past two years? 7) Does he/she have such sound only when he/she has a cold? 8) Has he/she had such sound twice or more times in the past two years?

Those who answered "yes" to questions 1) to 6) were classified as the diagnosed asthma group. The diagnosed group was classified into two subgroups based on the response to question 6): those who responded "yes" were classified as current asthma group, and those who answered "no" as the remitted asthma group. In addition to the above eight questions, we used one question related to the effect of the volcanic

eruption: 9) Did his/her asthma become more frequent or were more severe symptoms noted after the eruption of Mt. Unzen-Fugen? Those who answered "yes" were classified as the deteriorated asthma group.

The second survey was carried out in December of 1994, and the recovery rate was 93.8%. The aim of the second survey was to evaluate the extent of risks as listed by ATS-DLD (39). The survey contained questions regarding 1) feeding patterns and type of food during babyhood, 2) past illnesses, such as respiratory diseases, eczema until 2 years of age, pertussis, atopic dermatitis, allergic rhinitis and allergic conjunctivitis, 3) family history of allergic diseases including asthma among parents, grandparents and uncle/aunt, 4) indoor environment and living factors, i.e., whether he/she is living with smoker(s), construction of houses, especially material of floor (wood/tatami), whether the heating system is ventilated or not, and whether a dog or cat was kept indoor, and 5) impact of volcanic disaster, including whether he/she lived in a refuge or dormitory, and whether the family member(s) has changed after the eruption.

For 3,029 children, 2,304 pair of questionnaires (76.1%) were completed by parents or guardians for both first and second questionnaire (Table 1). Statistical analyses were performed by the SAS statistical package.

**Table 1.** The grade-distribution of school children in six primary schools in Shimabara city

Grade	South area (n=4)			North area (n=2)			All the city (n=6)			%
	Boy	Girl	Both sexes	Boy	Girl	Both sexes	Boy	Girl	Both sexes	
1st	131	134	265	59	60	119	190	194	384	(16.7)
2nd	137	143	280	66	64	130	203	207	410	(17.8)
3rd	135	131	266	49	63	112	184	194	378	(16.4)
4th	151	158	309	64	52	116	215	210	425	(18.4)
5th	128	158	286	52	53	105	180	211	391	(17.0)
6th	114	121	235	39	42	81	153	163	316	(13.7)
Total	796	845	1641	329	334	663	1125	1179	2304	(100.0)

\* : Numerals in parenthesis are number of primary school

## Results

### 1. Prevalence of bronchial asthma

The prevalence of diagnosed asthma was 15.4% for boys and 10.6% for girls. In both sexes, the rates tended to decrease with advancing grade; the prevalence in boys decreased significantly between 1st/2nd grade (6 and 7 years old) and 3rd/4th grade (8 and 9 years old), but the decline of prevalence in girls was found between 3rd/4th grade and 5th/6th grade (10 and 11 years old) (Table 2). Among those of diagnosed asthma group, 28.5% of reported asthma in boys (49/172) and 34.7% in girls (43/124) remitted asthma

**Table 2.** Prevalence of bronchial asthma

		1st & 2nd grade		3rd & 4th grade		5th & 6th grade		Total	
		No.	%	No.	%	No.	%	No.	%
Boy	Diagnosed BA	66 / 392	16.8	57 / 393	14.5	49 / 330	14.8	172 / 1115	15.4
	Current BA	49 / 393	12.5	36 / 398	9.0	38 / 333	11.4	123 / 1124	10.9
	Remitted BA	17 / 393	4.3	21 / 398	5.3	11 / 333	3.3	49 / 1124	4.4
	Deteriorated BA	31 / 386	8.0	18 / 386	4.7	18 / 328	5.5	67 / 1100	6.1
Girl	Diagnosed BA	46 / 399	11.5	46 / 402	11.4	32 / 371	8.6	124 / 1172	10.6
	Current BA	26 / 401	6.5	34 / 403	8.4	21 / 374	5.6	81 / 1178	6.9
	Remitted BA	20 / 401	5.0	12 / 403	3.0	11 / 374	2.9	43 / 1178	3.7
	Deteriorated BA	15 / 395	3.8	18 / 401	4.5	16 / 365	4.4	49 / 1161	4.2
Both Sexes	Diagnosed BA	112 / 791	14.2	103 / 795	13.0	81 / 701	11.6	296 / 2287	12.9
	Current BA	75 / 794	9.4	70 / 801	8.7	59 / 707	8.3	204 / 2302	8.9
	Remitted BA	37 / 794	4.7	33 / 801	4.1	22 / 707	3.1	92 / 2302	4.0
	Deteriorated BA	46 / 781	5.9	36 / 787	4.6	34 / 693	4.9	116 / 2261	5.1

attack during primary school age. The prevalence of current asthma was significantly higher in boys than in girls at every grade (overall prevalence, boys: 10.9%, girls: 6.9%), and was still high at the 5th/6th grades of primary school. Moreover, 68.9% of current asthma was reported to be worse after volcanic eruption.

## 2. Relationship between past illness, family history, indoor environment and volcanic disaster and asthma

The extents of contribution of factors in past illness, family history, indoor environment and volcanic disaster to bronchial asthma was estimated by crude odds ratio (OR). The highest crude OR for current asthma was found in past illness of allergic rhinitis (OR=7.12, 95% confidence interval [CI]=5.19-9.78) (Table 3). The next highest one was family history of asthma (OR=3.65, 95%CI=2.61-5.10). All the factors in either past illness or family history showed highly significant associations for current asthma. Among indoor

**Table 3.** Prevalence and crude odds ratio of bronchial asthma

General attribute	Current BA			Deteriorated BA		
	Prevalence	Odds ratio	95% CI	Prevalence	Odds ratio	95% CI
Grade (3rd&4th/1st&2nd)	8.7/9.4	0.92	0.64 - 1.31	4.6/5.9	0.77	0.48 - 1.23
(5th&6th/1st&2nd)	8.3/9.4	0.87	0.60 - 1.27	4.9/5.9	0.82	0.51 - 1.33
Sex (girl/boy)	6.9/10.9	0.60***	0.44 - 0.81	4.2/6.1	0.68*	0.46 - 1.01
Lactation (not only breast milk / breast milk only)	8.3/9.9	0.82	0.61 - 1.12	4.9/5.6	0.88	0.59 - 1.31
<b>Past illness</b>						
Respiratory diseases < 2 years (yes/no)	21.4/7.1	3.57***	2.51 - 5.06	13.6/4.0	3.79***	2.44 - 5.90
Eruption diseases <2 years (yes/no)	16.6/7.0	2.66***	1.93 - 3.66	11.9/3.5	3.69***	2.47 - 5.52
Pertussis (yes/no)	20.6/8.5	2.79**	1.45 - 5.29	11.9/4.9	2.63*	1.13 - 5.89
Atopic dermatitis (yes/no)	14.3/6.0	2.62***	1.94 - 3.54	9.0/3.1	3.06***	2.05 - 4.56
Allergic rhinitis (yes/no)	28.0/5.2	7.12***	5.19 - 9.78	15.7/3.1	5.81***	3.87 - 8.71
Allergic conjunctivitis (yes/no)	22.0/7.2	3.64***	2.53 - 5.23	15.4/3.9	4.45***	2.86 - 6.91
<b>Family history</b>						
Bronchial asthma (yes/no)	21.2/6.9	3.65***	2.61 - 5.10	13.6/3.6	4.17***	2.72 - 6.39
Allergic rhinitis (yes/no)	16.0/6.6	2.72***	1.98 - 3.72	8.8/4.0	2.32***	1.54 - 3.50
atopic dermatitis (yes/no)	13.9/7.5	2.00***	1.43 - 2.78	9.5/3.9	2.57***	1.69 - 3.90
Allergic conjunctivitis (yes/no)	18.1/8.4	2.42***	1.51 - 3.86	14.3/4.5	3.50***	2.03 - 5.99
<b>Indoor environment</b>						
Indirect smoking (yes/no)	8.3/10.2	0.79	0.58 - 1.08	5.1/5.2	0.97	0.64 - 1.47
Unventilated heating apparatus (yes/no)	9.7/7.4	1.34#	0.95 - 1.89	5.8/3.8	1.56#	0.98 - 2.51
Keeping a dog or cat indoor (yes/no)	9.7/8.8	1.12	0.65 - 1.90	5.0/5.1	0.97	0.45 - 2.02
<b>Effect of volcanic eruption</b>						
Area (south/north)	9.2/8.1	1.14	0.81 - 1.59	5.7/3.8	1.51#	0.94 - 2.44
Experience of refuge (yes/no)	9.6/8.4	1.16	0.86 - 1.56	5.6/4.9	1.16	0.79 - 1.72
Change of family member (yes/no)	13.1/8.3	1.67*	1.08 - 2.58	10.6/4.5	2.49***	1.51 - 4.09

Statistical significant level : # : p<0.1, \* : p<0.05, \*\* : p<0.01, \*\*\* : p<0.001  
CI = Confidence interval

environment, only the use of unventilated heating system was a contributing factor although its significance was weak. Among the factors related to volcanic disaster, a change of family member living with showed significance for current asthma (OR=1.67, 95%CI=1.08-2.58). The results for deterioration of asthma were substantially similar to those for current asthma. However, the odds ratio of change of family member was higher (OR=2.49, 95%CI=1.51-4.09).

## 3. Associations with asthma in multiple variable adjusted model

Multiple variable adjusted odds ratios showed almost similar pattern with respect to statistical signifi-

**Table 4.** Adjusted odds ratio of bronchial asthma

General Attribute	Current BA		Deteriorated BA	
	Odds ratio	95% CI	Odds ratio	95% CI
grade (5th&6th/3rd&4th/1st&2nd)	0.93	0.75 - 1.17	0.95	0.71 - 1.27
sex (girl/boy)	0.68*	0.47 - 0.99	0.86	0.53 - 1.37
feeding (milk + mixed / breast)	0.77	0.54 - 1.11	0.82	0.51 - 1.32
<b>Past illness</b>				
respiratory disease < 2 years (yes/no)	2.68***	1.73 - 4.15	3.41***	1.99 - 5.86
eruption disease <2 years (yes/no)	1.35	0.88 - 2.09	1.75*	1.03 - 2.98
pertussis (yes/no)	2.12#	0.94 - 4.79	1.55	0.55 - 4.39
atopic dermatitis (yes/no)	1.56*	1.05 - 2.32	1.89	1.12 - 3.22
allergic rhinitis (yes/no)	4.32***	2.92 - 6.39	3.33***	1.98 - 5.58
allergic conjunctivitis (yes/no)	2.47***	1.58 - 3.88	3.13***	1.82 - 5.39
<b>Family history</b>				
bronchial asthma (yes/no)	3.23***	2.16 - 4.85	3.57***	2.17 - 5.87
allergic rhinitis (yes/no)	1.36	0.91 - 2.05	0.82	0.48 - 1.41
atopic dermatitis (yes/no)	1.16	0.76 - 1.78	1.30	0.76 - 2.23
allergic conjunctivitis (yes/no)	0.85	0.46 - 1.57	0.97	0.47 - 2.02
<b>Indoor environment</b>				
indirect smoking (yes/no)	0.68*	0.47 - 0.99	0.75	0.46 - 1.22
unventilated heating apparatus (yes/no)	1.30	0.87 - 1.96	1.45	0.84 - 2.51
keeping a dog or cat indoor (yes/no)	1.81#	0.98 - 3.33	1.17	0.49 - 2.80
<b>Effect of volcanic eruption</b>				
area (south/north)	1.12	0.74 - 1.68	1.63#	0.92 - 2.89
experience of taking refuge (yes/no)	0.89	0.61 - 1.28	0.72	0.44 - 1.17
change of family member (yes/no)	1.54	0.91 - 2.59	3.20***	1.79 - 5.70

Statistical significant level : #<0.1, \* : p<0.05, \*\* : p<0.01, \*\*\* : p<0.001  
CI = confidence interval

cance between current asthma and deteriorated asthma (Table 4). However, only asthma in family history remained significant, and the other factors in family history diminished in significance. Past illness, such as allergic rhinitis, allergic conjunctivitis and respiratory diseases before 2 years of age still showed significant associations. The volcanic eruption was associated with deteriorated asthma; a change of family member living with during the disaster showed significant association. Children who lived in the southern part of the city where the disaster was more serious showed borderline association with deteriorated asthma. Cohabitation with a smoker and keeping a dog or cat indoor was slightly related to only current asthma.

## Discussion

In the present study, the overall prevalence of asthma was 12.9%, which seems to be higher than that reported in previous studies on Japanese children in western Japan (4). With regard to the survey of prevalence in asthma, it is considered that the definition of asthma is the most problematic point in such surveys (43). We used the standardized method developed in USA (39). Although our school nurse and school doctor provided sufficient instructions on how to answer the questionnaire, misunderstanding of parents or guardians might increase or decrease the prevalence. Admittedly, however, under hazardous situation such as volcanic disaster, people, especially parents would pay too much attention for their children's health.

In our previous study using self-reported questionnaire on school children who took refuge in Shimabara City in 1993, the prevalence of diagnosed asthma was 6.2% among primary school children (34), which was slightly different from the present result. This difference may be influenced by differences in timing of exposure to the volcanic disaster and definitions of asthma used in the two studies.

Studies on the natural history of asthma during childhood indicate that the frequency of asthma decreases with age (1, 4, 42). However, the prevalence of current asthma in the present study was still high at the 5th/6th grades of primary school. Moreover, 68.9% of current asthmatics were reported to be worse after volcanic eruption. The volcanic disaster may in part contribute to the higher prevalence of current asthma and deterioration of asthma.

We showed the associations of both current and deteriorated asthma with past illness of allergic diseases, which is in agreement with the established theory

that most cases of asthma are related to allergic reaction (1). The extraordinary high prevalence of asthma throughout grades indicates that environmental factors may act on vulnerability for allergic reaction. With respect to the effect of volcanic disaster on asthma, previous studies described direct effects by volcanic ash (20). As one of etiological factors, exposure to indoor pollutants, such as dust mites, cockroaches, mammal dander, and molds may result in the development of allergic symptoms (1, 43).

Our crude analysis showed that unventilated heating apparatus was slightly responsible for both current and deteriorated asthma. In the multiple adjusted model, cohabitation with a smoker and keeping a dog or cat indoor slightly contributed to current asthma. It is not clear at present why cohabitation with a smoker showed a negative association. The main agricultural product in the study area is tobacco leaves and the percentage of smokers is rather higher than in other areas of Nagasaki prefecture. It is conceivable that such close relation with tobacco might influence the response to smoking-related question.

On the effect of volcanic ash and gases to asthma, increased frequency of asthma and deterioration of asthma have already been reported (23,26,29,30). On the other hand, several other studies concluded that asthma is not negatively influenced by volcanic eruption. While we do not have any direct parameter to evaluate individual exposure level among children, significant association of living in the southern part of the city, where both exposure to volcanic ash and largest number of refugee were found, and deterioration of asthma may indicate that volcanic ash contributes to the development of asthma.

Interestingly, the change of family member was significantly associated with asthma. Previous studies have noted that psychosocial factor and stress or post traumatic factor could modify the occurrence of asthma among children (33). In our previous study, 60% of children experienced a change of family member through the refuge (34). Family type in this area is in general a traditional expanded family. In addition to refuge in small public houses, parents had to change their jobs from farming to part-time work in retail shops or buildings, which might influence the life style of their children. In our previous study, one third of primary school children reported stress-related symptoms, such as anxiety about surrounding (22.7%), frequent experience of nightmare (31.0%) and getting angry about issues of little significance (36%) (34). Psychological factors such as change of family members may be a risk factor for development of asthma.

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