Research Report

Respiratory symptoms associated with transient exposure to sulfur dioxide (SO_2) from Mt. Oyama volcano on Miyake Island south of Tokyo

Hideyuki Uno* MD[1,2], Hyogo Horiguchi MD PhD[1] and Fujio Kayama MD PhD[1]

Abstract

The onset of volcanic activity of the Mt. Oyama volcano on Miyake Island in June 2000 prompted authorities to evacuate all of the inhabitants of the island. Despite the relative cessation of activity since the last eruption in 2002, it is thought that the emission of volcanic gas (principally SO_2) will continue for some time. We undertook a three-day rehabilitation project in April 2003 that included a survey of the inhabitants who participated this project during October and December 2003. This questionnaire included respiratory symptoms (cough, phlegm, wheeze and breathless) and pre-existing symptoms. In addition, we also measured ambient SO_2 concentrations in six regions of the island and divided the inhabitants into High and Low exposure groups after assaying atmospheric SO_2 concentration levels. We examined the relationship between SO_2 air pollution and respiratory symptoms. We also regarded respiratory symptoms as dependent variables in order to exclude confounding factors such as gender, age, and respective pre-existing symptoms.

In conclusion, we found that high ambient sulfur concentrations have the effect of causing breathlessness the elderly (age>70) when ambient concentrations are high. However, except for breathlessness, SO_2 air pollution was not observed to aggravate respiratory symptoms.

(Keywords : respiratory symptoms, volcanic gas, SO_2, self-administrated questionnaire)

Introduction

Miyake Island is a small isolated volcanic island in the Pacific Ocean located approximately 185km south of Tokyo (Figure 1). At its center is the 775m high Mt. Oyama (34°04'43" N, 139° 31'46" E), a volcano that began exhibiting volcanic activity in June 2000. In August 2000, the largest recorded eruption of Mt. Oyama occurred ; considerable quantities of volcanic gas, mainly SO_2, was released into the atmosphere, volcanic ash covered most of the island, and pyroclastic flow reached the shore. All of the inhabitants were subsequently evacuated from the island and have not been allowed to return home. Remarkably, Mt. Oyama currently emits as much as 3,000 to 10,000 tons of SO_2 per day, which is approximately 10 to 30% of all the SO_2

1 Center for Community Medicine, Division of Environmental Medicine, Jichi Medical School, Yakushiji 3311-1, Minami-Kawachi, Kawachi-Gun, Tochigi 329-0498, Japan
2 Tokyo Metropolitan Government, Welfare and Health Office, Department of Medical Policy
* Corresponding author : Tel. : +81-285-58-7336 ; Fax : +81-285-44-8465.
E-mail address : h-uno@jichi.ac.jp (H. Uno)

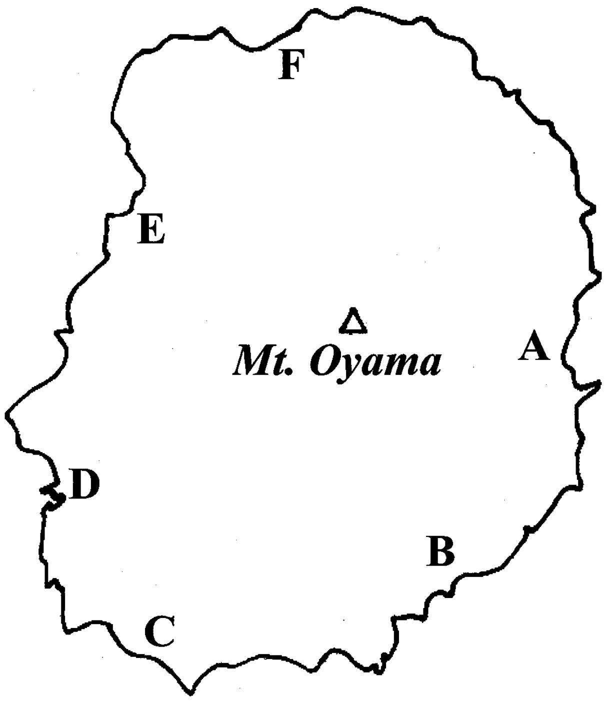

Figure 1 Miyake Island is part of the Izu island chain south of Tokyo. Six locations at which meteorological observations, such as sulfur dioxide, hydrogen sulfide, wind velocity, wind direction were measured. The locations were taken as being representitive of atmospheric conditions in each area. The locations of samples sites are : A. Miike, B. Tsubota, C. Usuki, D. Ako, E. Izu and Igaya, F. Kamitsuki.

emitted by volcanoes around the world. Placed in context, Kilauea Volcano on Hawaii is famous for emitting SO_2, yet it only effuses approximately 1,000 tons per day[1]. This means that the Mt. Oyama eruption was one of the biggest episodes of net SO_2 air pollution derived from a disaster and has presented us with a unique opportunity for studying transient exposure of a population to SO_2 without having to control for co-exposure to nitrogen oxides, ozone, volatile chemicals and other chemicals normally associated with most major metropolitan areas around the world.

According to the poll conducted by Miyake-mura in May and June 2004, approximately 70% of the former inhabitants expressed a desire to return to the island despite the risks associated with SO_2 exposure. In order to assess the relative risks associated with rehabitation we conducted a three-day trial on the island in April 2003. The trial was necessary given the risks associated with exposure to SO_2, particularly since even brief exposure can precipitate an asthma attack[2–7]. There are also several reports of increased airway flow resistance in healthy subjects[2] exposed to 5 ppm SO_2 and in asthmatics[3–5] exposed to 0.40 to 1.0 ppm SO_2 for several minutes. Furthermore, SO_2-sensitive asthmatics exhibit significant bronchoconstriction at exposure to 1 ppm[6,7] and 0.5 ppm SO_2[6] for a few minutes ; well below currently accepted standards[8]. Consequently, inhabitants with respiratory diseases were excluded from the study for reasons of safety.

A recent study[9] on the effect of volcanic fog on emergency department visits suggested that the rate of emergency visits for Asthma/Chronic obstructive pulmonary disease diagnosis was independent of incidence of volcanic fog, including SO_2. However, average daily SO_2 concentrations measured in this study were between single- and mid-double-digit ppb, considerably higher than that observed in a previous study[9]. To date, no studies have reported the incidence of adverse health effects in response to volcanic SO_2 emissions. We therefore investigated the relationship between SO_2 air pollution and the incidence of respiratory symptoms in response to exposure.

Materials and methods

Study population

As part of a project supported by the National-, Tokyo Metropolitan- and Miyake-mura Governments, we organized a three-day rehabilitation project involving a trial stay on Miyake Island during October and December 2003. The participants were not allowed on the island without informed consent regarding the adverse effects associated with SO_2 air pollution. Former inhabitants with respiratory illnesses were excluded from the rehabitation project. Furthermore, participants were obliged to reside in newly-built accommodations fitted with sulfur-scrubbing systems between the hours of 4 p.m. and 8 a.m. and commuting on the island was only permitted by bus for reasons of safety. When SO_2 levels exceeded 2 ppm for 5-minutes, subjects were required to wear masks fitted with a sulfur-scrubbing cartridge (Chemical Cartridge Respirator, GM76, SHIGEMATSU, Tokyo, Japan). We explained the rationale underlying the experiment to 1,260 participants.

Measurement of atmospheric SO2

Atmospheric SO_2 concentrations were measured at six locations (A-F) on Miyake Island by the National-, Tokyo Metropolitan- and Miyake-mura Governments (Figure 1). We employed a 5-minute frequency for SO_2 sampling, measured continuously for 5 minutes using automatic atmospheric samplers (Ambient SO_2 Monitor APSA-360, HORIBA, Kyoto, Japan in region A-E, and 100-AH, RIKEN KEIKI, Tokyo, Japan in region F) ; ambient SO_2 concentrations were measured and recorded in real time by UV fluorescence We used these values as indicators of short-term exposure. Hourly, weekly and monthly averages of the 5-minute values were taken as indicators of long-term exposure. Ambient SO_2 concentrations were measured and recorded in real time by UV fluorescence (Ambient SO_2 Monitor APSA-360, HORIBA, Kyoto, Japan in region A-E, and 100-AH, RIKEN KEIKI, Tokyo, Japan in region F). We used cut-off values of 2 ppm ,0.1 ppm and 0.04 ppm for the 5-minute period value, hourly and monthly average value according to Threshold Limit Value-Time Weighted Average (TLV-TWA) determined by American Conference of Government Industrial Hygienists (ACGIH 1998), Short-Term Exposure Limit (STEL) determined by National Institute of Occupational Safety and Health (NIOSH 1997) and the environmental safety levels determined by the Japanese Government, respectively.

Self-administrated questionnaire

We explained the purpose of this study to the participants and checked their medical history information for the incidence of current and pre-existing respiratory symptoms (cough, phlegm, wheeze and breathlessness) as well as the region in which they resided on the island using self-administrated questionnaires. We selected major respiratory-symptom complaints received from outpatients (most of whom were local migrant contractors engaged in reconstruction efforts on the island, not inhabitants) consulting doctors at the Miyake-mura National Health Insurance Central Clinic between July 2002 and September 2003. The questionnaires were distributed to each of the participants and completed responses were collected from subjects residing in the newly-constructed accommodations during the period of the study.

Statistical analysis

The average age divided by SO_2 concentration levels was analyzed by t-test and the prevalence of respiratory symptoms was analyzed using Fisher's exact test. In multiple logistic regression models, we used ``Age`` as a continuous variable and judged a factor as significant when the standard partial regression coefficient (SPRC) was relative high with $p<0.05$, evaluating Odd's ratio (OR). Statistical analyses were performed using Stat View (Version 5.0, Abacus Concepts, Inc., USA).

Results

Classification of subjects relative to ambient SO2 concentrations in the different regions

Atmospheric SO_2 concentrations were remarkably high in regions A and C and exceeded environmental safety levels as defined by the TLV-TWA, the STEL and the Japanese environmental safety levels. (Figure 2-1, 2-2). Concentrations of SO_2 in these regions exceeded 2 ppm for a 5-minute period for more than 1.2 hours per day in (Figure 2-1), an hourly average of 0.1 ppm for more than 10% of the day and a monthly average of 0.04 ppm (Figure 2-2).

Given the variation in SO_2 exposure, we divided inhabitants into two groups based on ambient SO_2 concentration : High exposure group (regions A and C) and a Low exposure group (regions B, D, E and F). There was no significant difference in the average between both groups (Table 1).

Appearance of respiratory symptoms in the subgroups relative to SO_2 exposure or pre-existing symptoms

Seven-hundred and thirty eight of the 1260 subjects initially approached consented to, and

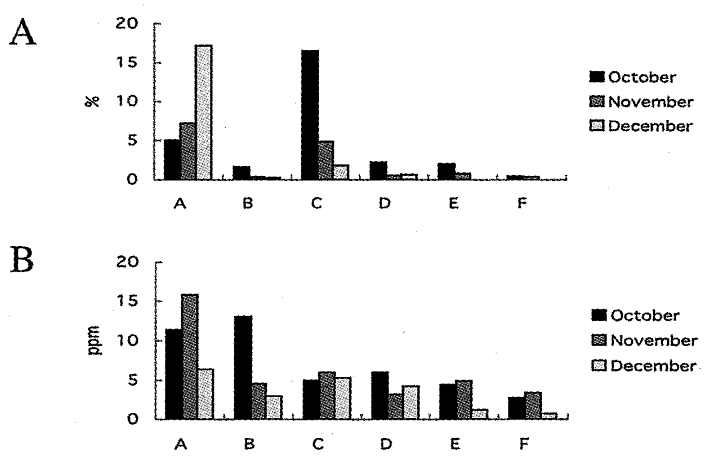

Figure 2-1 Five-minute intervals for SO_2 between October and December 2003
A : The frequency of 5-minute period value exceeding 2 ppm
B : The maximum SO_2 concentration recorded for 5-minute period value

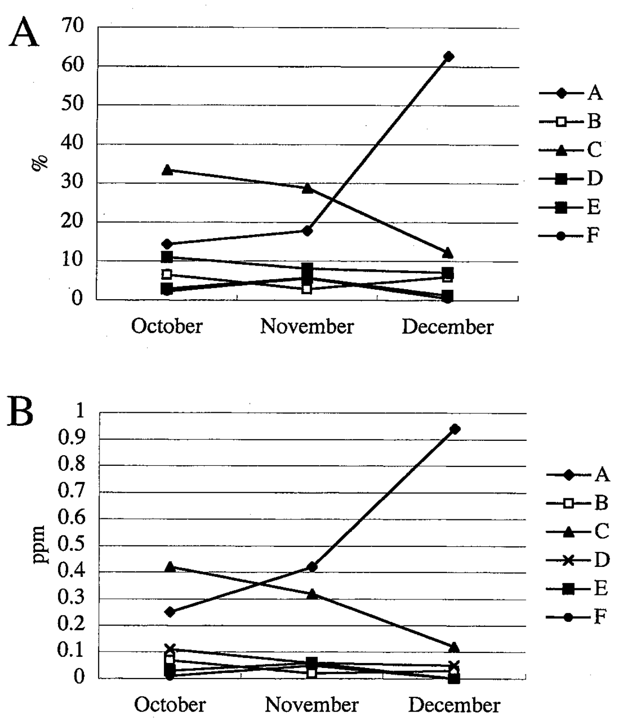

Figure 2-2 Monthly average SO_2 concentration between October and December 2003
A : The frequency of hourly average value exceeding 0.1 ppm
B : Average monthly value

Table 1 The numbers and ages in the groups divided by SO_2 concentration levels

Total (n=601)	L	H	*P* value
n	564	37	
Mean±SD	63.1±12.5y.o.	62.0±12.8y.o.	0.612
(range)	(15-88y.o.)	(32-82y.o.)	
Male (n=281)	**L**	**H**	***P* value**
n	267	14	
Mean±SD	63.0±13.1y.o.	62.1±12.0y.o.	0.158
(range)	(15-85y.o.)	(39-82y.o.)	
Female (n=320)	**L**	**H**	***P* value**
n	297	23	
Mean±SD	63.2±12.0y.o.	58.3±12.2y.o.	0.061
(range)	(16-88y.o.)	(32-77y.o.)	

H : High exposure group, A+C, L : Low exposure group, B+D+E+F
Significant difference between L and H was judged by t-test.

successfully completed, questionnaires for the study. After exclusion of 137 responses due to redundant or incomplete responses, 601 complete questionnaires (response rate : 47.7%) were analyzed (male : 281 ; female : 320 ; average age : 63 ; Figure 3).

We first compared the rates of appearance of the four different respiratory symptoms in subgroups divided by gender and age classes (Table 2-1), and in the two SO_2 exposure groups relative to gender and age (Table 2-2). No significant difference in the appearance rates of phlegm, wheeze and breathlessness were observed, considering gender and age. However, the

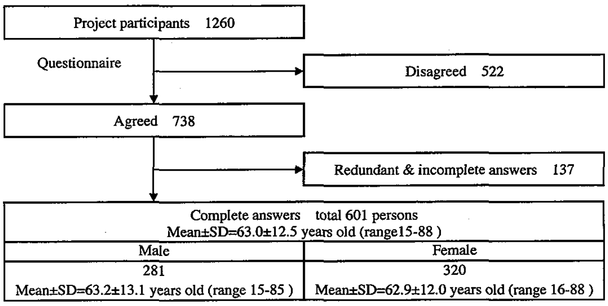

Figure 3 Selection process for inhabitants that participated in this project

Table 2-1 Appearance of respiratory symptoms in subgroups divided by gender and age classes

	Age (y.o.)	Total (%)	Male (%)	Female (%)	P value
Cough	Total	51/601 (8.5)	16/281 (5.7)	35/320 (10.9)	0.027*
	>70	14/179 (7.8)	5/88 (5.7)	9/91 (9.9)	0.406
	60-70	17/236 (7.2)	4/108 (3.7)	13/128 (10.2)	0.076
	<60	20/186 (10.8)	7/85 (8.2)	13/101 (12.9)	0.35
Phlegm	Total	37/601 (6.2)	17/281 (6.0)	20/320 (6.3)	>0.999
	>70	13/179 (7.3)	5/88 (5.7)	8/91 (8.8)	0.567
	60-70	15/236 (6.4)	7/108 (6.5)	8/128 (6.3)	>0.999
	<60	9/186 (4.8)	5/85 (5.9)	4/101 (4.0)	0.734
Wheeze	Total	22/601 (3.7)	10/281 (3.6)	12/320 (3.8)	>0.999
	>70	10/179 (5.6)	7/88 (8.0)	3/91 (3.3)	0.207
	60-70	6/236 (2.5)	1/108 (0.9)	5/128 (3.9)	0.223
	<60	6/186 (3.2)	2/85 (2.4)	4/101 (4.0)	0.690
Breathlessness	Total	24/601 (4.0)	12/281 (4.3)	12/320 (3.8)	0.836
	>70	15/179 (8.4)	9/88 (10.2)	6/91 (6.6)	0.428
	60-70	4/236 (1.7)	2/108 (1.9)	2/128 (1.6)	>0.999
	<60	5/186 (2.7)	1/85 (1.2)	4/101 (4.0)	0.378

* Significantly different from gender by Fisher's exact test ($P<0.05$).

Table 2-2 Appearance of respiratory symptoms in subgroups divided by SO_2 concentration levels, gender and age classes

	Age	Total (n=601)			Male (n=281)			Female (n=320)		
	(y.o)	H (%)	L (%)	P value	H (%)	L (%)	P value	H (%)	L (%)	P value
Cough	Total	3/37 (8.1)	48/564 (8.5)	>0.999	0/14 (0.0)	16/267 (6.0)	>0.999	3/23 (13.0)	32/297 (10.8)	0.727
	>70	0/10 (0.0)	14/169 (8.3)	>0.999	0/6 (0.0)	5/82 (6.1)	>0.999	0/4 (0.0)	9/87 (10.3)	>0.999
	60-70	0/14 (0.0)	17/222 (7.7)	0.607	0/6 (0.0)	4/102 (3.9)	>0.999	0/8 (0.0)	13/120 (10.8)	>0.999
	<60	3/13 (23.1)	17/173 (9.8)	0.151	0/2 (0.0)	7/83 (8.4)	>0.999	3/11 (27.3)	10/90 (11.1)	0.149
Phlegm	Total	2/37 (5.4)	35/564 (6.2)	>0.999	1/14 (7.1)	16/267 (6.0)	0.592	1/23 (4.3)	19/297 (6.4)	>0.999
	>70	1/10 (10.0)	12/169 (7.1)	0.539	1/6 (16.7)	4/82 (4.9)	0.304	0/4 (0.0)	8/87 (9.2)	>0.999
	60-70	1/14 (7.1)	14/222 (6.3)	>0.999	0/6 (0.0)	7/102 (6.9)	>0.999	1/8 (12.5)	7/120 (5.8)	0.412
	<60	0/13 (0.0)	9/173 (5.2)	>0.999	0/2 (0.0)	5/83 (6.0)	>0.999	0/11 (0.0)	4/90 (4.4)	>0.999
Wheeze	Total	0/37 (0.0)	22/574 (3.9)	0.388	0/14 (0.0)	10/267 (3.7)	>0.999	0/23 (0.0)	12/297 (4.0)	>0.999
	>70	0/10 (0.0)	10/169 (5.9)	>0.999	0/6 (0.0)	7/82 (8.5)	>0.999	0/4 (0.0)	3/87 (3.4)	>0.999
	60-70	0/14 (0.0)	6/222 (2.7)	>0.999	0/6 (0.0)	1/102 (1.0)	>0.999	0/8 (0.0)	5/120 (4.2)	>0.999
	<60	0/13 (0.0)	6/173 (3.5)	>0.999	0/2 (0.0)	2/83 (2.4)	>0.999	0/11 (0.0)	4/90 (4.4)	>0.999
Breathlessness	Total	4/37 (10.8)	20/564 (3.5)	0.053	2/14 (14.3)	10/267 (3.7)	0.114	2/23 (8.7)	10/297 (3.4)	0.210
	>70	3/10 (30.0)	12/169 (7.1)	0.040*	2/6 (33.3)	7/82 (8.5)	0.113	1/4 (25.0)	5/87 (5.7)	0.242
	60-70	0/14 (0.0)	4/222 (1.8)	>0.999	0/6 (0.0)	2/102 (2.0)	>0.999	0/8 (0.0)	2/120 (1.7)	>0.999
	<60	1/13 (7.7)	4/173 (2.3)	0.307	0/2 (0.0)	1/83 (1.2)	>0.999	1/11 (9.1)	3/90 (3.3)	0.374

H : High exposure group, A+C, L : Low exposure group, B+D+E+F

* Significantly different from SO_2 concentration by Fisher's exact test ($P<0.05$).

Table 3 Appearance of respiratory symptoms in subgroups divided by pre-existing symptoms or not, gender and age classes

	Age	Total (n=601)			Male (n=281)			Female (n=320)		
	(y.o.)	pre-existing symptom (%)	no pre-existing symptom (%)	*P* value	pre-existing symptom (%)	no pre-existing symptom (%)	*P* value	pre-existing symptom (%)	no pre-existing symptom (%)	*P* value
Cough	Total	6/36(16.7)	45/565(8.0)	0.111	3/16(18.8)	13/265(4.9)	0.054	3/20(15.0)	32/300(10.7)	0.469
	>70	2/11(18.2)	12/168(7.1)	0.208	1/5(20.0)	4/83(4.8)	0.259	1/6(16.7)	8/85(9.4)	0.475
	60-70	1/12(8.3)	16/224(7.1)	0.601	0/5(0.0)	4/103(3.9)	>0.999	1/7(14.3)	12/121(9.9)	0.537
	<60	3/13(23.1)	17/173(9.8)	0.151	2/6(33.3)	5/79(6.3)	0.075	1/7(14.3)	12/94(12.8)	>0.999
Phlegm	Total	7/48(14.6)	30/553(5.4)	0.021*	4/23(17.4)	13/258(5.0)	0.040*	3/25(12.0)	17/295(5.8)	0.198
	>70	3/16(18.8)	10/163(6.1)	0.096	1/9(11.1)	4/79(5.1)	0.425	2/7(28.6)	6/84(7.1)	0.114
	60-70	2/19(10.5)	13/217(6.0)	0.345	1/7(14.3)	6/101(5.9)	0.383	1/12(8.3)	7/116(6.0)	0.556
	<60	2/13(15.4)	7/173(4.0)	0.123	2/7(28.6)	3/78(3.8)	0.052	0/6(0.0)	4/95(4.2)	>0.999
Wheeze	Total	6/25(24.0)	16/576(2.8)	<0.001*	4/13(30.8)	6/268(2.2)	<0.001*	2/12(16.7)	10/308(3.2)	0.069
	>70	4/12(33.3)	6/167(3.6)	0.002*	4/8(50.0)	3/80(3.8)	<0.001*	0/4(0.0)	3/87(3.4)	>0.999
	60-70	1/8(12.5)	5/228(2.2)	0.189	0/3(0.0)	1/105(1.0)	>0.999	1/5(20.0)	4/123(3.3)	0.183
	<60	1/5(20.0)	5/181(2.8)	0.153	0/2(0.0)	2/83(2.4)	>0.999	1/3(33.3)	3/98(3.1)	0.115
Breathlessness	Total	3/27(11.1)	21/574(3.7)	0.087	1/13(7.7)	11/268(4.1)	0.440	2/14(14.3)	10/306(3.3)	0.091
	>70	2/14(14.3)	13/165(7.9)	0.332	1/8(12.5)	8/80(10.0)	0.594	1/6(16.7)	5/85(5.9)	0.344
	60-70	1/9(11.1)	3/227(1.3)	0.145	0/4(0.0)	2/104(1.9)	>0.999	1/5(20.0)	1/123(0.8)	0.077
	<60	0/4(0.0)	5/182(2.7)	>0.999	0/1(0.0)	1/84(1.2)	>0.999	0/3(0.0)	4/98(4.1)	>0.999

H : High exposure group, A+C   L : Low exposure group, B+D+E+F

* Significantly different from SO_2 concentrations judged by Fisher's exact test ($P<0.05$).

rate of cough in total Female cohort was significantly higher than total Male cohort (M/F : 5.7%/10.9% ; $p=0.040$) (Table 2-1). No significant difference in the appearance rates of cough, phlegm and wheeze were observed between High and Low exposure groups, even after considering gender and age. However, the rate of breathlessness in the High exposure group for the>70year-old cohort was significantly higher than the Low exposure group (H/L : 30.0%/ 7.1% ; $p=0.040$) (Table 2-2).

We then divided the population according to pre-existing respiratory symptoms, gender and age (Table 3). Statistically significant differences were observed in the total phlegm group (14.6%/5.4% ; $p=0.021$), in the male phlegm group (17.4%/5.0% ; $p=0.040$), in the total wheeze group(24.0%/2.8% ; $p<0.001$) in the male wheeze group (30.8%/2.2% ; $p<0.001$). In the phlegm subgroups, the appearance rate in males below 60 years old (28.6%) and females over 70 years old (28.6%) was higher, but there were no statistical significances when these subgroups were divided by age. Borderline significance was observed in males below 60 years old (28.6%/3.8% ; $p=0.052$). In the wheeze subgroups, statistical significance was observed in the total group (33.3%/3.6% ; $p=0.002$) and in males over 70 years old (50.0%/3.8% ; $p<0.001$), even after division by age. Borderline significance was also observed in male cough group (18.8%/4.9% ; $p=0.075$).

Multivariate logistic regression analysis

Results of the multiple logistic regression analyses are shown in Table 4. In the cough group, gender (OR : 2.052 ; 95% CI : 1.104-3.812) was a significant factor. For the phlegm (OR : 2.930 ; 95% CI : 1.211-7.089) and wheeze (OR : 11.277 ; 95% CI : 3.885-32.736) groups, pre-existing symptoms conferred the strongest statistical contributions. In the breathlessness group, extant SO_2 levels had more of an influence than pre-existing symptoms (OR : 3.595 ; 95% CI : 1.132-11.412).

Discussion

Several previous studies of artificial work-related respiratory symptoms[10] in response to SO_2

Table 4 Multiple logistic regression analysis on the subjects with respective symptoms (n=601)

Dependent variable	Independent variable	SPRC	*P* value	OR (95% CI)
Cough	Male	2.273	0.023	2.052(1.104-3.812)
	Age (Older)	1.976	0.048	1.022(1.000-1.044)
	High exposure group	−0.253	0.800	0.853(0.249-2.924)
	pre-existing cough	1.680	0.093	2.237(0.875-5.722)
Dependent variable	**Independent variable**	**SPRC**	***P* value**	**OR (95% CI)**
Phlegm	Male	0.137	0.891	1.048(0.535-2.052)
	Age (Older)	−0.775	0.438	0.989(0.961-1.018)
	High exposure group	−0.189	0.850	0.868(0.199-3.791)
	pre-existing cough	2.385	0.017	2.930(1.211-7.089)
Dependent variable	**Independent variable**	**SPRC**	***P* value**	**OR (95% CI)**
Wheeze	Male	0.330	0.741	1.161(0.479-2.815)
	Age (Older)	−0.467	0.641	0.991(0.953-1.030)
	High exposure group	−0.004	0.997	<0.001(0.000-)
	pre-existing cough	4.456	<0.001	11.277(3.885-32.736)
Dependent variable	**Independent variable**	**SPRC**	***P* value**	**OR (95% CI)**
Breathlessness	Male	−0.214	0.831	0.913(0.397-2.100)
	Age (Older)	−2.471	0.014	0.944(0.902-0.988)
	High exposure group	2.171	0.030	3.595(1.132-11.412)
	pre-existing cough	1.558	0.119	2.809(0.766-10.296)

SPRC : standard partial regression coefficient OR : Odd's ratio CI : confidence interval.

exposure have been published. These include activities associated with smelting[11], silicon carbide production[12], pulp milling[13,14] and other similar activities. However, respiratory symptoms caused by a natural disasters have not yet been reported. As present, the current Japanese environmental safety levels do not include provisions for natural disasters.

In our previous study[15], we did not identify any respiratory diseases directly connected with the amount of ambient SO_2 air pollution, and in this study there were no participants with respiratory diseases. In addition, there was also no patient with asthma attack to consult a doctor in the island clinic after this volcanic eruption, although migrant local workers, public officials underwent only daytime-stay until July 2002. We therefore needed to determine whether SO_2 air pollution triggered respiratory symptoms in the participants without respiratory diseases.

In some studies[12,16], positive dose dependent relationships have been found between exposure to SO_2 and the appearance of respiratory symptoms. However, in this study, cough, phlegm and wheeze were not observed to be dependent on SO_2 levels. This result may be due to several factors. First, an observation period of only three days may have been too short to detect the appearance of symptoms. This is important given that development of bronchial asthma in response to SO_2 takes a few days[17,18], Second, we used atmospheric SO_2 concentration data and did not consider the mitigating effect of the mask with fitted with a sulfur-scrubbing cartridge. Third, we did not consider the effect of decreased frequency of smoking associated with the changes subjects had made in their lifestyles and because there were no smoking-places in Miyake Island. It is known that lung functioning in current oriental smokers are not statistically related with that of oriental never-smokers[19]. Future research will address the impact of these issues, which we could not examine due to the limitatons in this study.

An additional important finding is that breathlessness was found to be dose-dependent with SO_2 exposure levels. This finding is difficult to interpret due to the small numbers sampled and may be related to neurological conditions[20]. But no positive relationships between SO_2 concentrations and subjects presenting with asthma have been reported to date[11]. Similarly, with the exception of breathlessness, there was no evidence of any positive relationship between SO_2 exposure and respiratory symptoms in this study.

In conclusion, attention needs to be focused on the exacerbation of breathlessness in elderly (age$>$70) under conditions of elevated ambient SO_2 concentrations. Except for breathlessness, SO_2 air pollution does not appear to aggravate respiratory symptoms. In this study, however, we could not show the satisfied conclusion, as we could not evaluate the response bias due to the limitation of the unordinary field study. Further investigations are currently being undertaken to better assess the effect of SO_2 pollution on the incidence of respiratory functioning, with particular focus on the duration of exposure, evaluating the efficacy of mitigation measures, and establishing controls for smoking.

Acknowledgements

The authors thank Dr. Maruyama K, Director of the Tokyo Islands Health Center for his support for making this project possible. We would like to extend our most sincere gratitude to the Tokyo Metropolitan Government's Field Provision Headquarters, Miyake-mura officials, and the staff of Miyake-mura National Health Insurance Center Clinic for their cooperation.

References

1) Elias T., Sutton A. J., Stokes J. B. et al : Sulfur dioxide emission rates of Kilauea Volcano, Hawai'i 1979-1997. US Geological Survey Open-File Report 98-462, 1998.

2) Frank N. R., Amdur M. O., Worcester J. et al. : Effects of acute controlled exposure to sulfur dioxide on respiratory mechanics in healthy male adults. J Appl Physiol 17 : 252-258, 1962.

3) Linn W. S., Shamoo D. A., Spier C. E. et al. : Respiratory effects of 0.75 ppm sulfur dioxide in exercising asthmatics : Influence of upper respiratory defenses. Environ Res 30 : 340-348, 1983.

4) Schachter E. N, Witek T. J., Beck G. J. et al. : Airway effects of low concentrations of sulfur dioxide : Dose-response characteristics. Arch Environ Health 39 : 34-42, 1984.

5) Bethel R. A., Sheppard D., Geffroy B. et al. : Effects of 0.25 ppm sulfur dioxide on airway resistance in freely breathing, heavily exercising, asthmatic subjects. Am Rev Respir Dis 131 : 659-661, 1985.

6) Balmes J. R., Fine J. M. and Sceppard D. : Symptomatic bronchoconstriction after short-term inhalation of sulfur dioxide. Am Rev Respir Dis 136 : 1117-21, 1987.

7) Horstman D. H., Seal E. Jr, Folinsbee L. J. et al. : The relationship between exposure

duration and sulfur dioxide-induced bronchoconstriction in asthmatics subjects. Am Ind Hyg Assoc J 49 : 38-47, 1988.

8) Sheppard D., Wong W. S., Uehara C. F. et al. : Lower threshold and greater bronchomotor responsiveness of asthmatic subjects to sulfur dioxide. Am Rev Respir Dis 122 : 873-8, 1980.

9) Jon P. M., John S. G. and Dmitry K. : Emergency department visits and "vog"-related air quality in Hilo, Hawai'i. Environ Res 95 : 11-19, 2004.

10) Kremer A. M., Pal T. M., Boleij J. S. et al. : Airway hyper-responsiveness and the prevalence of work-related symptoms in workers exposed to irritants. Am J Ind Med 26 : 655-69, 1994.

11) Donoghue A. M. and Thomas M. : Point source sulfur dioxide peaks and hospital presentations for asthma. Occup Environ Med 56 : 232-6, 1999.

12) Osterman J. W., Greaves I. A., Smith T. J. et al. : Respiratory symptoms associated with low level sulfur dioxide exposure in silicon carbide production workers. Br J Ind Med 46 : 629-35, 1989.

13) Jaakkola J. J., Vikka V., Marttila O. et al. : The South Karelia Air Pollution Study. The effects of malodorous sulfur compounds from pulp mills on respiratory and other symptoms. Am Rev Respir Dis 142 : 1344-50, 1990.

14) Partti-Pelline K., Marttila O., Vilkka V. et al. : The South Karelia Air Pollution Study : effects of low-level exposure to malodorous sulfur compounds on symptoms. Arch Environ Health 51 : 315-20, 1996.

15) Uno H., Horiguchi H., Omae K. et al. : Effects of volcanic sulfur dioxide on reconstruction workers and residents returning to Miyake Island. San Ei Shi 47 : 142-148, 2005 (in Japanese with English abstract)

16) Witek T. J. Jr., Schachter E. N., Beck G. J. et al. : Respiratory symptoms associated with sulfur dioxide exposure. Int Arch Occup Environ Health 55 : 179-83, 1985.

17) Braga A. L., Zanobetti A. and Schwartz, J. : The lag structure between particulate air pollution and respiratory and cardiovascular deaths in 10 US cities. J Occup Environ Med 43 : 927-933, 2001.

18) Desqueyroux H., Pujet J. C., Proster M. et al. : Short-term effects of low-level air pollution on respiratory health of adults suffering from moderate to severe asthma. Environ Res 89 : 29-37, 2002.

19) Seltzer C. C., Siegelaub A. B., Friedman G. D. et al. : Differences in pulmonary function related to smoking habits and race. Am Rev Respir Dis 110 : 598-608, 1974.

20) Barnes PJ ; Neural mechanisms in asthma. Br Med Bull 48 : 149-168, 1992.

三宅島雄山噴火 SO_2 排出ガス短期曝露による呼吸器症状の検討

宇野　秀之　　堀口　兵剛　　香山不二雄

要　約

三宅島にある雄山が2000年6月から噴火が始まり，それ以来全住民が避難となった。2002年には噴火は消退しているが，火山ガス（ほとんど SO_2）排出は当分続くであろう。2003年4月から3日間滞在型帰島プロジェクトが始まり，我々は2003年10～12月にこのプロジェクトに参加した住民にアンケートを行った。アンケートには呼吸器症状（咳嗽，喀痰，喘鳴，息切れ）出現とそれらの症状を元々持っていたかどうかを含めた。さらに我々は島内6箇所の大気中 SO_2 濃度を知り，濃度により2つのグループに分けた。我々は SO_2 大気汚染と呼吸器症状との関係を調査した。我々はまた最終的に性別，年齢，元々存在した呼吸器症状のような交絡因子を排除するため，それぞれの呼吸器症状を独立変数として類推評価した。

結論として，大気中 SO_2 濃度がより高いときは70歳以上の高齢者では息切れの悪化に注意を払った方がよいのだろう。しかし，SO_2 大気汚染は息切れ以外の呼吸器症状悪化に影響を与えていないのかも知れない。

＊　自治医科大学　地域医療学センター　環境医学部門