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Original Article

Survey on Negative Impact of Chironomid Midges (Diptera) on Bronchial Asthmatic Patients in a Hyper-eutrophic Lake Area in Japan

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Abstract

Chironomid midges have been revealed to be a hazardous inhalant antigen of bronchial asthma. To determine the awareness of the negative impact of chironomid midges (*Chironomus plumosus* and *Propsilocerus akamusi*) among patients, a questionnaire survey of 118 patients in the Lake Suwa area and in the Matsumoto area was conducted from early September to mid-November of 1993. The life style was almost the same among the asthmatic patients in the Lake Suwa area and in the Matsumoto area, but the reactions to the nuisance differed significantly from each other. Although "Flight density" was higher in the Lake Suwa area ($p < 0.01$) than that in the Matsumoto area, 25.5% of the patients in the Lake Suwa area and 9.1% of those in the Matsumoto area answered "Endurable" ($p < 0.01$). Further follow-up studies including prick tests, intradermal tests and provocation tests should be conducted for patients who complained a strong allergic reaction.

Key words: Bronchial asthmatic patients, Chironomid midges, Lake Suwa, Nuisance, Questionnaire

Introduction

Chironomid midges (Diptera: Chironomidae) are aquatic insects with important roles in the food web. Their abundant larvae being primary consumers and a source of food for higher trophic levels[1]. However, recent research has revealed some negative impacts of chironomid midges on human activities. Ali[2,3] and Tabaru *et al.*[4] reported that adult chironomids emerging from eutrophic lakes or polluted bodies of water have become an intolerable nuisance and a cause of economic problems. Moreover, Cranston[5] revealed that many researchers have found chironomid particles to be a strong allergen, and one of the hazardous inhalant antigens of asthma. Kimura *et al.*[6], using the ELISA inhibition test to detect antigens of chironomids in house dust, found that the level of antigen was nearly half that of the house dust mite, Dermatophagoides. They also reported that they could detect the chironomid antigen in the soil and air.

In the area around Lake Suwa, massive flights of the adult midges *Propsilocerus akamusi* (Tokunaga) and *Chironomus plumosus* (L.) have been recurring, and have caused problems in the daily life of local residents[7,8]. Furthermore, as Hirabayashi *et al.*[9] proved by measuring the positive IgE antibodies to chironomid midges that bronchial asthma has been induced by chironomid midges in this district.

The huge number poses a threat to the health of bronchial asthmatic patients residing in the vicinity of hyper-eutrophic natural lakes, such as Lake Suwa. In this questionnaire survey, an attempt is made to measure quantitatively the impact of the chironomid midges on these patients, and a comparison is made with the Matsumoto area as a control. By clarifying the impact of this nuisance, proposals might later be made as means to prevent further impact.

Study Site

Lake Suwa (surface area: 13.3 km^2, maximum depth: 6.5 m) is located in the central highlands of Honshu (at the latitude and

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Table 1 Questionnaire.

Q1. Area: 1. Matsumoto area 2. Lake Suwa area
Q2. Sex: 1. Male 2. Female
Q3. Age: 1. A < 30 2. 30 ≦A < 40 3. 40 ≦A < 50 4. 50 ≦A < 60 5. 60 ≦A < 70 6. 70 ≦A

Q4. Does your family (parents or siblings or grandparents) have an allergic predisposition (bronchial asthma, a nettle rash, atopic dermatitis, allergic rhinitis) ? If so, who are they ? (Circle any number that applies.)
1. parents 2. siblings 3. grandparents

Q5. Are you prone to eczema?
1. Yes 2. No

Q6. Do you have allergic rhinitis (sneezing, mucus, stuffy nose)?
1. Yes 2. No
↓
Which months do your symptoms usually seem worse? (Circle any number that applies.)
1. January 2. February 3. March 4. April 5. May 6. June
7. July 8. August 9. September 10. October 11. November 12. December

Q7. Do you have allergic conjunctivitis (eyes congest, itching)?
1. Yes 2. No
↓
Which months are the symptoms most apparent? (Circle any number that applies.)
1. January 2. February 3. March 4. April 5. May 6. June
7. July 8. August 9. September 10. October 11. November 12. December

Q8. What kind of allergens does your doctor say your bronchial asthma is caused by ? (Circle any number that applies.)
1. House dust 2. Animals (hair and/or dander of dog and cat, bird, etc.) 3. Mites
4. Food (milk, eggs, soybean, etc.) 5. Eumycetes (Candida, etc.) 6. Pollen (Japanese cedar, orchard grass)
7. Others (Please state:) 8. Not identified

Q9. Is there heavy traffic around your area of residence?
1. Yes 2. No

Q10. Do you have pets at home?
1. Yes 2. No
↓
What kind of pets? (Circle any number that applies.)
1. Dog 2. Cat 3. Bird 4. Others (Please state:)

Q11. Does someone smoke in your residence?
1. Yes 2. No

Q12. How do you clean your futons? Please choose one category from the following:
1. Sometimes air in the sun
2. Sometimes vacuum clean
3. Both 1 and 2
4. I do nothing about it

Q13. Are you familiar with chironomid midges?
1. Yes 2. No
↓
Which months do you see chironomid midges the most? (Circle any number that applies.)
1. January 2. February 3. March 4. April 5. May 6. June
7. July 8. August 9. September 10. October 11. November 12. December

Q14. Do you know that the particles of chironomid midges cause bronchial asthma?
1. Yes 2. No
↓
How do you know ? (Circle any number that applies.)
1. Doctor 2. Friends 3. Books, magazines, etc. 4. TV and/or Radio
5. Others (Please state:)

Q15. Did you observe many chironomid midges on your screens or windows?
If so, please choose one category from the following:
1. Very dense. I could not open the window or screen door at all.
2. Dense. Dozens of midges were on the window.
3. Not so dense. No more than ten midges on the window.
4. A few. I saw them occasionally.
5. None. I could not find any midges on the window.

Q16. How do you feel about the present fly problem of chironomid midges around you?
Please choose one category from among the following.
1. No trouble
2. Endurable
3. Cannot stand any more

Thank you very much for taking the time fill out this questionnaire.

longitude of 36°03' N and 138°05' E, respectively) at an altitude of 759 m above the sea level. This lake is a well-known hyper-eutrophic lake in Japan and is surrounded by several municipalities, i.e., Okaya City, Shimo-suwa Town and Suwa City, with a total population of 200,000. Many resort hotels and business establishments in this area are severely affected by the dense swarms of chironomid midges that emerge from the lake. There are large populations of larval chironomids, *C. plumosus* and *P. akamusi*[10]. In recent years, Hirabayashi and Hirabayashi and other researchers have attempted to take rid of these nuisance chironomid midges by artificial light[11-15].

The Matsumoto area was the control area, located at a distance of ca. 50 km from the Lake Suwa. Situated at the foot of the Japanese Northern Alps, Matsumoto has developed as a highland city, with a total population of 220,000. There are no big lakes and the City is surrounded completely by mountains. Until now, complaints on chironomid midges have not been recorded among people living in the Matsumoto area.

Materials and Methods

A questionnaire survey was conducted of 123 bronchial asthmatic patients (62 from 4 hospitals in the Lake Suwa area and 61 from one hospital in the Matsumoto area) from early September to mid-November of 1993 when adult midges of *C. plumosus* and *P. akamusi* emerged from the Lake. The locations of residence of the patients spread throughout both areas. The questionnaire used included background information of respondents, complaint severity, present nuisance, environmental factors and so on is shown in Table 1.

We defined the criteria for asthma as follows: chronic chest illness associated with recurrent episodes of wheezing, breathlessness, chest tightness, and coughing. These symptoms are usually associated with widespread, but variable, airflow limitation that is at least partly reversible either spontaneously or with treatment (cardiac disease excluded).

Results

From the total survey of 123 bronchial asthmatic patients, 118 questionnaires were collected (the rate of response was 95.9%) from the Lake Suwa area (62 patients) and the Matsumoto area (56 patients). Table 2 shows the background of

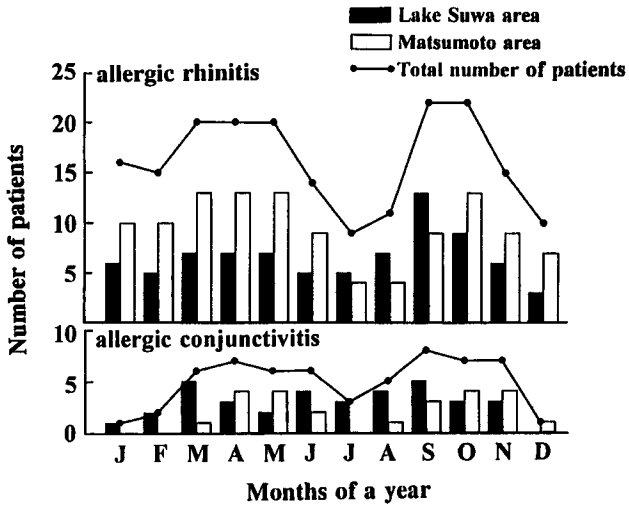

Fig.1 Seasonal changes in number of patients with complaints of allergic rhinitis (upper) and allergic conjunctivitis (lower).

Table 2 Background information of respondents from the Lake Suwa area and the Matsumoto area.

Items		Number of respondents in Lake Suwa area	Number of respondents in Matsumoto area	Total number of respondents (%)	df	χ^2 test χ^2
		62 (52.5)	56 (47.5)	118 (100)		
Sex	Male	32 (51.6)	20 (35.7)	52 (44.4)	1	3.017
(Q2)	Female	30 (48.4)	36 (64.3)	66 (55.9)		N.S.
Age	A < 30	10 (16.0)	4 (7.1)	14 (11.8)	5	7.174
(Q3)	30 ≦A < 40	5 (8.1)	3 (5.4)	8 (6.8)		N.S.
	40 ≦A < 50	5 (8.1)	7 (12.5)	12 (10.2)		
	50 ≦A < 60	12 (19.4)	21 (37.5)	33 (28.0)		
	60 ≦A < 70	24 (38.7)	17 (30.4)	41 (34.7)		
	70 ≦A	6 (9.7)	4 (7.1)	10 (8.5)		
Family	Parents	13 (65.0)	14 (60.9)	27 (62.8)	2	0.726
(Q4)	Siblings	7 (35.0)	7 (30.4)	14 (32.6)		N.S.
	Grandparents	3 (15.0)	6 (26.1)	9 (20.9)		
Eczema	Yes	17 (38.6)	17 (41.5)	34 (40.0)	1	0.071
(Q5)	No	27 (61.4)	24 (58.5)	51 (60.0)		N.S.
Rhinitis	Yes	22 (46.8)	27 (64.3)	49 (55.1)	1	2.738
(Q6)	No	25 (53.2)	15 (35.7)	40 (44.9)		N.S.
Conjunctivitis	Yes	11 (25.6)	9 (22.2)	20 (23.8)	1	0.152
(Q7)	No	32 (74.4)	32 (78.0)	64 (76.2)		N.S.

N.S.: not significant.

the respondents, i.e., sex (Q2), age (Q3), allergic predisposition in family (Q4), eczema (Q5), allergic rhinitis (Q6) and allergic conjunctivitis (Q7). There were 52 males (44.4%) and 66 females (55.9%). The age distribution was as follows: A < 30, 14 individuals (11.8%); 30 ≦A < 40, 8 individuals (6.8%); 40 ≦A < 50, 12 individuals (10.2%); 50 ≦A<60, 33 individuals (28.0%); 60 ≦ A<70, 41 individuals (34.7%); and 70 ≦A, 10 individuals (8.5%). Also, 27 respondents (62.8%) answered that their parents had an allergic predisposition. Moreover, 34 (40.0%) respondents were prone to eczema, while 49 (55.1%) and 20 (23.8%) indicated that they had allergic rhinitis or allergic conjunctivitis, respectively. The differences in characteristics were insignificant between the Lake Suwa area patient group and the Matsumoto area patient group (χ^2 test).

Figure 1 shows the seasonal changes in patient numbers complaining of allergic rhinitis (upper) and allergic conjunctivitis

Table 3 Environmental factors affection of respondents from the Lake Suwa area and the Matsumoto area.

Items		Number of respondents in Lake Suwa area	Number of respondents in Matsumoto area	Total number of respondents (%)	χ^2 test df	χ^2 test χ^2
		62 (52.5)	56 (47.5)	118 (100)		
Traffic (Q9)	Yes	17 (37.0)	10 (23.8)	27 (30.7)	1	0.378
	No	29 (63.0)	32 (76.2)	61 (69.3)		N.S.
Pets (Q10)	Yes	7 (14.9)	8 (17.8)	15 (16.3)	1	0.140
	No	40 (85.1)	37 (82.2)	77 (83.7)		N.S.
	Dog	0 (0.0)	3 (42.9)	3 (21.4)		
	Cat	5 (71.4)	5 (71.4)	10 (71.4)		
	Bird	1 (14.3)	0 (0.0)	1 (7.1)		
	Others	1 (14.3)	0 (0.0)	1 (7.1)		
Smoker (Q11)	Yes	24 (51.1)	24 (54.5)	48 (52.7)	1	0.111
	No	23 (48.9)	20 (45.5)	43 (47.3)		N.S.
Futons (Q12)	Aired	35 (76.1)	31 (70.5)	66 (73.3)	3	1.550
	Vacuum cleaned	0 (0.0)	1 (2.3)	1 (1.1)		N.S.
	Aired & vacuum cleaned	8 (17.4)	10 (22.7)	18 (20.0)		
	Non-treated	3 (6.5)	2 (4.5)	5 (5.6)		

N.S.: not significant.

Table 4 Knowledge, flight density and severity impression of chironomid midges among respondents from the Lake Suwa area and the Matsumoto area.

Items		Number of respondents in Lake Suwa area	Number of respondents in Matsumoto area	Total number of respondents (%)	χ^2 test df	χ^2 test χ^2
		62 (52.5)	56 (47.5)	118 (100)		
Knowledge of chironomid (Q13)	Yes	37 (78.7)	17 (37.8)	54 (58.7)	1	15.898
	No	10 (21.3)	28 (62.2)	38 (41.3)		**
Knowledge of chironomid as an allergen (Q14)	Yes	6 (12.5)	7 (17.5)	13 (14.8)	1	0.433
	No	42 (87.5)	33 (82.5)	75 (85.2)		N.S.
	Doctor	3 (50.0)	6 (54.5)	9 (52.9)		
	Friends	0 (0.0)	1 (9.1)	1 (5.9)		
	Book etc.	1 (16.7)	2 (18.2)	3 (17.6)		
	TV. etc.	2 (33.3)	2 (18.2)	4 (23.6)		
Flight density[a] (Q15)	1	2 (4.9)	0 (0.0)	2 (3.4)	4	22.849
	2	7 (17.1)	0 (0.0)	7 (11.9)		**
	3	12 (29.3)	2 (11.1)	14 (23.7)		
	4	14 (34.1)	2 (11.1)	16 (27.1)		
	5	6 (14.6)	14 (77.8)	20 (33.9)		
Severity impression[b] (Q16)	1	16 (40.0)	15 (68.2)	31 (50.0)	2	12.015
	2	21 (52.5)	2 (9.1)	23 (37.1)		**
	3	3 (7.5)	5 (22.7)	8 (12.9)		

[a] Flight density: 1. Very dense, 2. Dense, 3. Not so dense, 4. A few, 5. None
[b] Severity impression: 1. No trouble, 2. Endurable, 3. Cannot stand any more
** $p<0.01$, N.S.: not significant.

(lower). The numbers of patients having rhinitis or conjunctivitis tended to be highest in spring and fall in both areas.

Table 3 shows the environmental factors of respondents, i.e., heavy traffic (Q9), pets (Q10), smokers (Q11), and cleaning futons (Q12), in each of the two areas. Twenty seven (30.7%) respondents answered that there is heavy traffic around their area of residence. Fifteen (16.3%) respondents mentioned some pets inside the house, and about 70% of them (10 individuals, 71.4%) had cats. More than 50% of respondents answered that someone smokes in their residence; 73.3% of them answered "futons are sometimes aired in the sun". Comparison of the two areas for each of the items (heavy traffic, pets, smokers, and cleaning futons), showed that the number was statistically insignificant (χ^2 test).

Table 4 shows knowledge (Q13 and 14), flight density (Q15) and severity impression (Q16) of chironomid midges by respondents in both areas. Nearly 60% of respondents knew about chironomid midges, although only 13 (14.8%) knew that the particles of chironomid midges can cause bronchial asthma. Furthermore, about half of them (52.9%) heard about it from their doctors. Concerning the massive flights of chironomid midges, 12.9% of respondents answered that they "could not stand it any more". On the other hand, "no trouble" and "endurable" were given by 31 individuals (50.0%) and 23 individuals (37.1%), respectively. Moreover, in the case of flight density in the Lake Suwa area, 22.0% of respondents answered that they saw "very dense (4.9%)" or "dense (17.1%)" swarms of chironomid midges on their windows or screens, whereas 77.8% of respondents in Matsumoto did not witness such a phenomenon. Comparing both areas for each item (knowledge, flight density and severity impression), "the knowledge of allergen (Q14)" was statistically insignificant. However, the other items (knowledge of chironomid: Q13, flight density: Q15 and severity impression: Q16) were statistically significant between the two areas (χ^2 test, $p < 0.01$).

Table 5 shows the allergens which were identified by doctors as causing bronchial asthma. There were 48 (40.7%) patients whose allergens were identified by their doctors. House dust was the most frequently identified allergen (18 individuals, 37.5%), followed by pollen (15 individuals, 31.3%). On the other hand, around 60% of the patients (64.5% in the Lake Suwa area; 53.6% in the Matsumoto area) were unaware what allergens were causing problems.

Table 5 Allergens identified by doctors as the cause of bronchial asthma among respondents from the Lake Suwa area and the Matsumoto area.

Allergens	Number of respondents in Lake Suwa area	Number of respondents in Matsumoto area	Total number of respondents (%)
Identified	22 (35.5)	26 (46.4)	48 (40.7)
House dust	7 (31.8)	11 (42.3)	18 (37.5)
Animals	2 (9.1)	3 (11.5)	5 (10.4)
Mites	3 (13.6)	8 (30.8)	11 (22.9)
Foods	3 (13.6)	3 (11.5)	6 (12.5)
Eumycetes	3 (13.6)	1 (3.8)	4 (8.3)
Pollen	6 (27.3)	9 (34.6)	15 (31.3)
Others	7 (31.8)	13 (50.0)	20 (41.7)
Not identified	40 (64.5)	30 (53.6)	70 (59.3)
Total	62 (100)	56 (100)	118 (100)

Discussion

Chironomids have impacted human activities in many ways, because they are one of the most ubiquitous and abundant groups of aquatic insects in fresh water[16]. Robinson[17] reported that chironomid midges emerge in extremely large numbers from aquatic environments. Although these adult midges are non biting, they are a nuisance and present economic, and in some cases, medical problems to humans living within their dispersal range[18]. According to Ali[19], in central Florida, *Chironomus crassicaudatus* was one of the major nuisance midges and an economically damaging species of chironomid. Industry and tourism-related business in that part of the State suffer annual loss of more than $4 million in cost for pest control and the frequent washing and maintenance of properties and other areas affected by adult midges.

On the other hand, chironomids induce environmental allergies in exposed populations in Egypt, Italy, Sweden, UK, USA and Japan (reviewed by Cranston[5]). According to Kagen *et al.*[20], 45% of atopic individuals in Wisconsin heavily exposed to *C. plumosus* had immunological reactions to the midge. In Japan, according to Ito *et al.*[21], RAST with extracts of larvae and adult midges, *P. akamusi*, was performed on 105 randomly selected asthmatic patients in metropolitan Tokyo, and 32.4% of them were tested positive to one or the other extract. This positive rate among the asthmatic patients was second to the positive rate of RAST using mite antigen. The authors suggested that antigens from midges were the second most prevalent allergens in the metropolitan area of Tokyo. Igarashi *et al.*[22] reported that 119 asthmatic children (aged 1-15 years, mean 8.3) in Toyama were tested with extracts of selected species of nuisance chironomids (*Polypedilum kyotoense*, *C. yoshimatsui* and *P. akamusi*; adult and larvae), and with house dust-mite extracts. Positive skin-test rates ranging between 7.6% and 23.4% were produced by different midge extracts while 94.1% were positive for *D. farinae*, suggesting some cross-reactivity.

In the Lake Suwa area, Hirabayashi and other researchers[7,8] reported that residences, resort hotels and business establishments were severely affected by dense swarms of adult chironomids, especially *C. plumosus* and *P. akamusi*, which emerge from the lake. Massive accumulations of living and dead chironomids, on

Table 6 Severity impression categorized by residents, tourists and bronchial asthmatic patients from the Lake Suwa area and the Matsumoto area.

Severity impression category*		Number of respondents (male, female)	1	2	3
			Number (%)		
Residents[7]	: Lake Suwa area	249 (220, 29)	126 (50.6)	91 (36.5)	32 (12.9)
Tourists[8]	: Lake Suwa area	159 (95, 63)	27 (17.0)	55 (34.6)	49 (30.8)
Patients	: Lake Suwa area	62 (32, 30)	16 (40.0)	21 (52.5)	3 (7.5)
	: Matsumoto area	56 (20, 36)	15 (68.2)	2 (9.1)	5 (22.7)
	: Overall	118 (52, 66)	31 (50.0)	23 (37.1)	8 (12.9)

*Severity impression category: 1. No trouble, 2. Endurable, 3. Cannot stand any more.

the streets and on structures, are not uncommon. Moreover, the activity of the flies is a nuisance, and the accumulations of dead adults is a respiratory health hazard for many people. According to Hirabayashi *et al.*[9], among 65 adult patients having bronchial asthma with an external cause who produced positive allergy tests, 11 (16.9%) were positive to *C. yoshimatsui*, 8 (12.3%) to *C. plumosus*, and 3 (4.6%) to *P. akamusi*, in this area.

In this study, the numbers of patients' complaints about allergic rhinitis and conjunctivitis tended to be highest in spring and fall in both areas (Fig. 1). In these seasons, many chironomid midges emerge from the water and take flight. According to Kimura *et al.*[6], particles from the dead bodies of midges are detected in air, soil and house dust with large seasonal (especially, spring and fall) and local variations. These particles are considered to be an important source of allergens, and usually become airborne after disturbance in rooms. However, in these seasons, many other allergens such as pollen and particles from the dead bodies of other insects, are also detected in the air[23]. Therefore, it is impossible to determine which allergens cause these symptoms by solely work of our study data.

The analysis of replies to the questionnaires also showed that the difference in patient attributes (Q2-Q7) and environmental factors for sensitization (Q9-12) was statistically insignificant between patient groups of the two areas (Table 2 and 3). This means that both patient groups have nearly equal population characteristics. However, the awareness of chironomid midges, i.e., knowledge (Q13), flight density (Q15) and severity impression (Q16) were statistically significant between the patient groups of the two areas (Table 4). In the Lake Suwa area, nearly 80% of respondents were familiar with the chironomid midges; 7.5% answered that they "could not stand it any more" to the massive flights of midges but 52.5% found the situation "endurable." In addition, in the case of the flight density impression provided by Lake Suwa patients, 22.0% saw "very dense" or "dense" swarms of chironomid midges on their screens or windows, whereas 77.8% of respondents in the Matsumoto area noticed no such phenomenon (Table 4). This difference reflects the local variation in the numbers of chironomid midges in flight, i.e., greater numbers of adult midges are attracted by light to houses in the Lake Suwa area than in the Matsumoto area.

We compared the present results to those of Hirabayashi and other researchers[7,8] in an attempt to further clarify the severity impression given by bronchial asthmatic patients. Table 6 shows the severity impression category among residents, tourists and bronchial asthmatic patients, based on the data reported by Hirabayashi[7] and Hirabayashi and Okino[8] (the same question was asked around the Lake Suwa area, but the ratio of respondents' sex and age distribution was different). In the Hirabayashi[7] report, 32 (12.9%) residents, about half of those living within 500 m from the lake shore, answered that they "could not stand any more" to the massive flights of chironomid midges. According to Hirabayashi and Okino[8], 49 (30.8%) tourists who visited and stayed in the area felt such flights were a nuisance. In the Lake Suwa area, 3 (7.5%) of our respondents answered that they "could not stand it any more". On the other hand, there were 16 (40.0%) answers of "no trouble" and 21 (52.5%) of "endurable." According to Hirabayashi[24], the distance from the lake shore to the respondents' place of residence was the major factor contributing to the impression of chironomids as nuisance. Thus, the number of chironomid flights depended on the distance from the lake shore. The percentage of severity impression of tourists was high, as almost all tourist facilities are built along the shore of the lake. On the other hand, as the locations of residence of patients were more spread out throughout the Lake Suwa area, the percentage of nuisance responses from patients was lower than that from the tourists.

In addition, only 13 (14.8%) patients knew that the particles of chironomid midges cause bronchial asthma. However, about half of them (52.9%) heard about it from their doctor. Thus, we concluded that information from the doctor played an important role in the patients' awareness (Table 4).

In the future, more of the patients in these areas need to be surveyed. Further follow-up studies including prick tests, intradermal tests and provocation tests should be conducted to patients who complained a strong allergic reaction.

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