

Original article

Epidemiology of pediatric allergic diseases in the Ogasawara Islands

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BA, bronchial asthma; AD, atopic dermatitis;

AR, allergic rhinitis; FA, food allergy;

ISAAC, International Study of Asthma and

Allergies in Childhood; ppb, parts per billion

ABSTRACT

Background: The Ogasawara Islands, away from mainland Japan, belong to a subtropical area. Although the daily eating habits and food are relatively similar to that on the mainland, the living environment is quite different. The prevalence of allergic diseases in the Ogasawara Islands is unknown. This study aimed to identify the prevalence of allergic diseases in the Ogasawara Islands.

Methods: A survey was conducted among all children belonging to preschool, elementary school, and junior high school in the Ogasawara Islands. A questionnaire was prepared in accordance with the International Study of Asthma and Allergies in Childhood (ISAAC) core written questionnaire in bronchial asthma (BA) and the West Japan Study of Asthma and Allergies in Childhood core written questionnaire for atopic dermatitis (AD), allergic rhinitis (AR), and food allergy (FA). At the same time, height, weight, duration of dwelling on the island, home environment, lifestyle, and exercise habits were also asked.

Results: The target population comprised 352 children, of whom 284 (80.6%) completed the questionnaires. The current prevalence was 9.3% for BA, 4.3% for AD, 17.8% for AR, and 3.0% for FA. Significantly lower rates of current BA and AD were observed compared to previous reports from Japan. The percentage of children belonging to sports clubs, and exercising more than 3 times per week at the Ogasawara Islands is higher compared with the national average.

Conclusions: The lower prevalence of BA and AD in the Ogasawara Islands implies the influence of differences in the living environment and exercise habits.

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Introduction

The Ogasawara Islands, consisting of many uninhabited islands and two manned islands named Chichijima and Hahajima, are located 1000 km south of mainland Japan (Fig. 1). The total area of the Ogasawara Islands is approximately 100 km², with an annual mean temperature of 23.2 °C, an annual mean humidity of 77%, and an annual amount of precipitation of approximately 1292 mm. Approximately 2500 people live in the Ogasawara Islands and the percentage of the population younger than 15 years is 18.8%. The major industries are tourism, agriculture, and fishery, and there are hardly any secondary industries in the Ogasawara village. The Ogasawara Islands, in contrast to mainland Japan, belong to a

subtropical area and the living environment is significantly different. Various natives live in Ogasawara Islands, and it's called "the Oriental Galapagos Islands." The means of transportation to the Ogasawara Islands is solely by a weekly ship. Because of the subtropical climate, cedars do not exist in the Ogasawara Islands. However, the daily eating habits and foods are relatively similar to that of the mainland because essential food items are transported from the mainland to the island by ship. The first author of this article worked as a physician in the Ogasawara Islands from 2010 to 2012. Although an increasing prevalence of allergic diseases among Japanese children has been recently reported,¹ this author was under the impression that the number of patients with allergic disorders was small in the islands at that time. The prevalence of allergic disease in the Ogasawara Islands is unknown. Moreover, the author believed that these islands might be suitable for the identification of environmental or lifestyle factors contributing to the development of allergic diseases as they comprise the same races with relatively similar eating habits as people on the mainland. This study aimed to identify the prevalence and highly

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Fig. 1. Location of the Ogasawara Islands. The Ogasawara Islands are located at a distance 1000 km south of mainland Japan. They extend from latitude 20° 25 min north to 27° 40 min north and from longitude 136° 04 min east to 153° 59 min east. The star marks the Chichijima, the biggest island in Ogasawara.

correlated factors of pediatric allergic diseases in the Ogasawara Islands, with a specific focus on the environment and lifestyles.

Methods

Subjects

The survey was conducted among all children in preschool, elementary school, and junior high school in the Chichijima and Hahajima islands. The distribution, response, and collection of survey questionnaires were done in December 2012 through the schools.

Questionnaire

The questionnaire was prepared in accordance with the International Study of Asthma and Allergies in Childhood (ISAAC)² core written questionnaire Japanese version in bronchial asthma (BA) and West Japan Study of Asthma and Allergies in Childhood (WJSAAC)³ core written questionnaire in atopic dermatitis (AD), allergic rhinitis (AR), and food allergy (FA) (Fig. 2). Height, weight, duration on the island, home environment, smoking habits in the family, lifestyle, and exercise habits were also asked at the same time. The obesity rate was calculated with the method of the Ministry of Education, Culture, Sports, Science and Technology in Japan,¹ and the obesity trend was defined as $\geq 20\%$.

Ethical considerations

A study plan was created in accordance with the guidelines of ethics of an epidemiology investigation made by Ministry of Health, Labour and Welfare, and Ministry of Education, Culture, Sports, Science and Technology. The ethics committee of Ogasawara village, Tokyo approved the study protocol. The questionnaire was carried out using an unsigned method to maintain anonymity of the participants. Prior to filling out the questionnaire, all participants in the study provided informed consent. The children in the

older age group completed the questionnaire on their own, while the children in the younger age group completed it by taking help from their parents.

Statistical analysis

The background and each item in the questionnaire were analyzed using frequency distribution and percentages for categorical variables, and the mean and standard deviation for the continuous variables. Chi-square tests were used for associations between categorical variables. A two-sided significance level was set at 0.05. All statistical analyses were performed with the IBM SPSS version 22.0.0 (IBM Corp. Armonk, NY).

Results

Of the two preschools, two elementary schools, and two junior high schools on the Chichijima and Hahajima islands approached for study participation, all institutions decided to participate. Target population comprised 352 children, and 284 children (80.6%) completed questionnaires. Of the 284 children that we were able to analyze, 152 (53.5%) were boys, and 130 (45.8%) were girls. The gender could not be determined in two children. Of the 284 children, 99 children (35%) were in preschool, 142 children (54%) were in elementary school, and 43 children (15%) were in junior high school. Of the 284 children, 212 children (75%) lived on the Chichijima island, and 72 children (25%) lived on the Hahajima island (Table 1).

Bronchial asthma

The estimated lifetime BA prevalence was 20.0% and the current BA prevalence was 9.3%, of which 12.2% of patients were in preschool, 7.8% were in elementary school, and 7.0% were in junior high school (Fig. 3A). Of 26 current BA children, 16 (61%) were boys. The prevalence tended to be lower in older children. The percentage of severe asthma, frequent wheezing, and sleep disturbance showed a

Age ____ Grade ____ Sex: male/female Height ____cm Weight ____kg
 Have you lived on the island for less than 12 months? Yes/No

Eating habit
 Q1 How often do you eat breakfast?
Eat every day/ Mostly eating/Often do not eat/Eat rarely
 Q2 Do you usually eat with your family? Every day/Mostly/Do not often/Rarely
 Q3 How many times do you eat snacks in one week?
Every day/Mostly/Do not often/ Rarely

Exercise habits
 Q4 Do you like exercise or sports? Yes/Somewhat like/Somewhat do not like/No
 Q5 Do you belong to athletic or sports club? Yes/No
 Q6 How many times a week do you exercising? (Excluding physical education hours)
Every day/About half the week/1–2 times/Nothing
 Q7 When exercising, how many hours a day is it done?
<30 minutes/30 to <60 minutes/60–120 minutes/>120 minutes

Lifestyle habits
 Q8 What time do you usually sleep? _____
 Q9 What time do you usually wake up? _____
 Q10 What are you doing until you sleep after you have a meal? (Multiple selection is possible) Study/Use mobile phone/Indoor play (Such as reading)/Outdoor exercise/Play TV game or use PC/Talk to your family/Exercise/Sleeping/Other
 Q11 How many hours do you watch television, play a video game, or use a PC in a day?
<1 hour/1 to <3 hours/>3 hours

Living environment
 Q12 What is the structure of the living room of your house? Wooden/Rebar/Others
 Q13 What types is the floor of the bedroom of your home?
Tatami/Wooden/Carpet/Other(_____)
 Q14 Do you keep an animal that has fur? Yes/No
 Q15 Is there a person who smokes in the family? Yes/No

Allergic diseases

Q16 Have you ever had wheezing or whistling in the chest at any time in the past?
Yes/No

Q17 Have you ever been diagnosed with bronchial asthma or asthmatic bronchitis?
Yes/No

Q18 Have you had wheezing or whistling in the chest in the past 12 months? Yes/No
 IF YOU ANSWERED “NO” PLEASE SKIP TO QUESTION 24.

Q19 How many attacks of wheezing have you had in the last 12 months? _____times

Q20 In the last 12 months, how often, on average, has your sleep been disturbed due to wheezing?
Never woken with wheezing/Less than one night per week/One or more nights per week

Q21 In the last 12 months, has wheezing ever been severe enough to limit your speech to only one or two words at a time between breaths?
Yes/No

Q22 In the last 12 months, have you seen a doctor for asthma?
Yes/No

Q23 In the last 12 months, have you hospitalized for asthma?
Yes/No

Q24 Have you ever been diagnosed with atopic dermatitis from a doctor?
Yes/No
 IF YOU ANSWERED “NO” PLEASE SKIP TO QUESTION 26.

Q25 In the last 12 months, how often, on average, have you been kept awake at night by this itchy rash?
Never in the last 12 months/Less than one night per week/One or more nights per week

Q26 Have you ever been diagnosed with allergic rhinitis or hay fever from a doctor?
Yes/No

IF YOU ANSWERED “NO” PLEASE SKIP TO QUESTION 28

Q27 Does the symptom still continue?
Yes/No

Q28 Have you ever been diagnosed with food allergies from a doctor?
Yes/No
 IF YOU ANSWERED “NO” PLEASE SKIP TO QUESTION 31

Q29 Does the symptom still continue?
Yes/No

Q30 Have you had anaphylaxis?
Yes/No

Q31 Is there a person with an allergic disease with your family?
Yes/No
 IF YOU ANSWERED “YES” PLEASE MARK THE APPLICABLE PLACE BELOW.

	Bronchitis asthma	Allergic rhinitis	Atopic dermatitis	Food allergy
Father				
Mother				
Brother and Sister				

Fig. 2. Survey questionnaire. The questionnaire was made in accordance with the International Study of Asthma and Allergies in Childhood (ISAAC) core written questionnaire in bronchial asthma (BA) and West Japan Study of Asthma and Allergies in Childhood core written questionnaire in atopic dermatitis (AD), allergic rhinitis (AR), and food allergy (FA). Height, weight, duration on the island, home environment, lifestyle, and exercise habits were also researched at the same time.

prevalence of 3.9%. The group with pets had a higher prevalence of BA (pet+ 17.2%, pet– 8.4%. $p = 0.16$), and this was especially significant in the preschool group ($p = 0.048$). There was no significant relationship between BA and the structure of the house (wooden 13.0%, rebar 7.8%, $p = 0.23$), or the kind of floor in the bedroom [tatami (Japanese straw mat), 12.0%; flooring, 6.6%; $p = 0.15$] although the incidence tended to be higher with wooden and tatami flooring. There was no significant relationship between BA and obesity (BA + obesity+ 10.0%; BA + obesity– 8.1%). There was no significant difference between BA and current family history of smoking (family smoking+ 9.8%, family smoking– 9.1%, $p = 0.82$). The group with a

family history of BA had a significantly higher prevalence of BA (family history +18.3%, family history– 7.0%, $p = 0.012$).

Atopic dermatitis

The estimated lifetime AD prevalence was 9.9% and the current AD prevalence was 4.3%, of which 7.1% of patients were in preschool, 2.8% in elementary school, and 2.3% in junior high school (Fig. 3B). Of 12 current AD children, 8 (67%) were boys. The prevalence tended to be lower in older children. The prevalence of severe symptoms of AD was 1.7%. There was a strong relationship with AR ($p = 0.009$), FA ($p = 0.003$), and family history of allergies ($p = 0.031$). Although there was no significant difference, the group with pets tended to have a lower prevalence of AD (pet+ 0.0%, pet– 4.8%, $p = 0.65$).

Allergic rhinitis

The estimated lifetime AR prevalence was 24.3% and the current AR prevalence was 17.8%, of which 9.8% of patients were in preschool, 22.1% were in elementary school, and 22.0% were in junior high school (Fig. 3C). Of 46 current AR children, 29 (63%) were boys.

Food allergy

The estimated lifetime FA prevalence was 8.9% and the current FA prevalence was 3.0%, of which 2.1% of patients were in preschool,

Table 1
Background of the subjects.

Sex	Number			
Male	152			
Female	130			
	Preschool	Elementary school	Junior high school	Total
Chichijima	70	112	30	212
Hahajima	29	30	13	72
Total	99	142	43	284
Parameter	Preschool school	Elementary school	Junior high school	Total
Quantity of responses	126	169	57	352
Response rate	99	142	43	284
	78%	84%	75%	80%

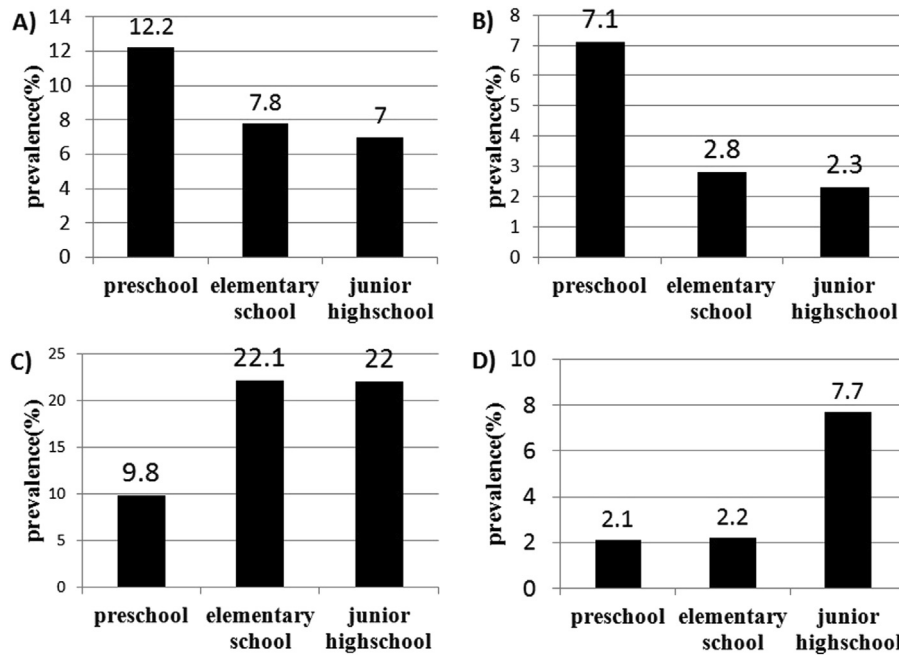


Fig. 3. Prevalence of allergic diseases in this survey. (A) Prevalence of bronchial asthma. (B) Prevalence of atopic dermatitis. (C) Prevalence of allergic rhinitis. (D) Prevalence of food allergy. The prevalence of BA and AD tend to be lower in older children. On the other hand, the prevalence of AR and FA tend to be higher in older children.

2.2% were in elementary school, and 7.7% were in junior high school (Fig. 3D). Of 7 current FA children, 4 (57%) were boys.

Obesity, TV watching, and exercise

The children in Ogasawara children tended to be less obese. (Fig. 4A). The general obesity trend of the Ogasawara children was lower than the national average (Fig. 4B). In particular, there were no children with a tendency towards obesity in preschool. The average prevalence of obesity in the elementary and junior high school in Ogasawara Islands was 6.6%. On the other hand, the result of the national average in 2013 was 8.3% in boys and 7.0% in girls.¹ In the association of the durations of television watching, use of personal computers, and playing video games, the group reporting <1 h was 36% in the Ogasawara Islands and 14% on the national average; the group with 1–3 h was 57% in Ogasawara Islands and 55% in the national average; and the group with more than 3 h was 7% in the Ogasawara Islands and 31% in the national average.⁴ The proportion of the children whom answered “I like exercise” was 93.7%. Eighty-four percent of children belonged to sports clubs in the Ogasawara Islands compared to the 61% in the national average. The group that exercised more than 3 times per week constituted 58% of the study population in the Ogasawara Islands, whereas it was 48% in the national average.

Comparison with previous reports

Many BA research studies have used ISSAC in Japan, such as Fukuoka⁵ in 2002, Tochigi⁶ in 1995, and Setagaya⁷ in 2005. In this research study, the prevalence of current BA was lower than that reported in these studies (Fig. 5A). For example, the prevalence of this study was significantly lower than all the age groups of 6–14 years in the Setagaya study ($p = 0.026$). With respect to AD, the Health, Labor and Welfare Ministry conducted a research study between 2000 and 2002^{8,9}, and the Allergy Research Association in the western districts of Japan reported on AD in 2012.³ Compared to

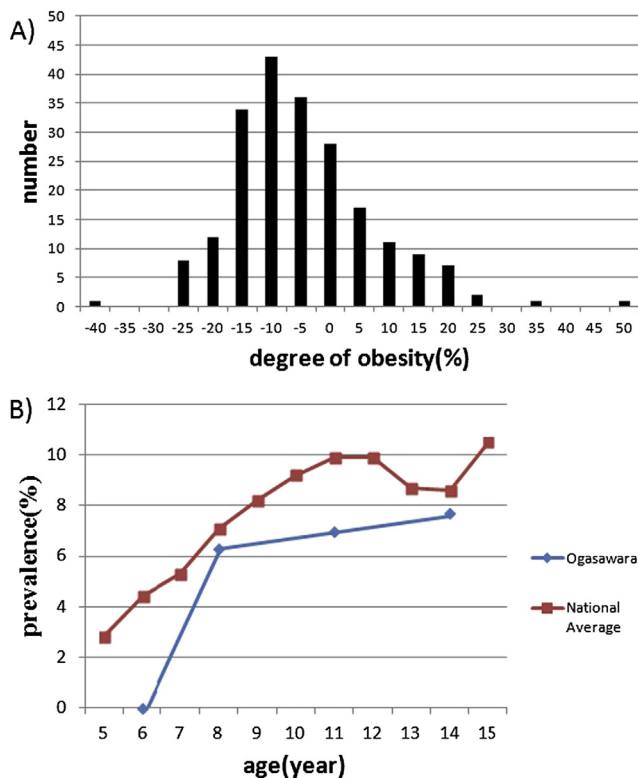


Fig. 4. Degree of obesity in the Ogasawara Islands and comparison with the national average. (A) Degree of obesity in Ogasawara children. (B) Comparison of obesity rates between the national average and that in the Ogasawara Islands. The general obesity trend in Ogasawara children was lower than the national average.

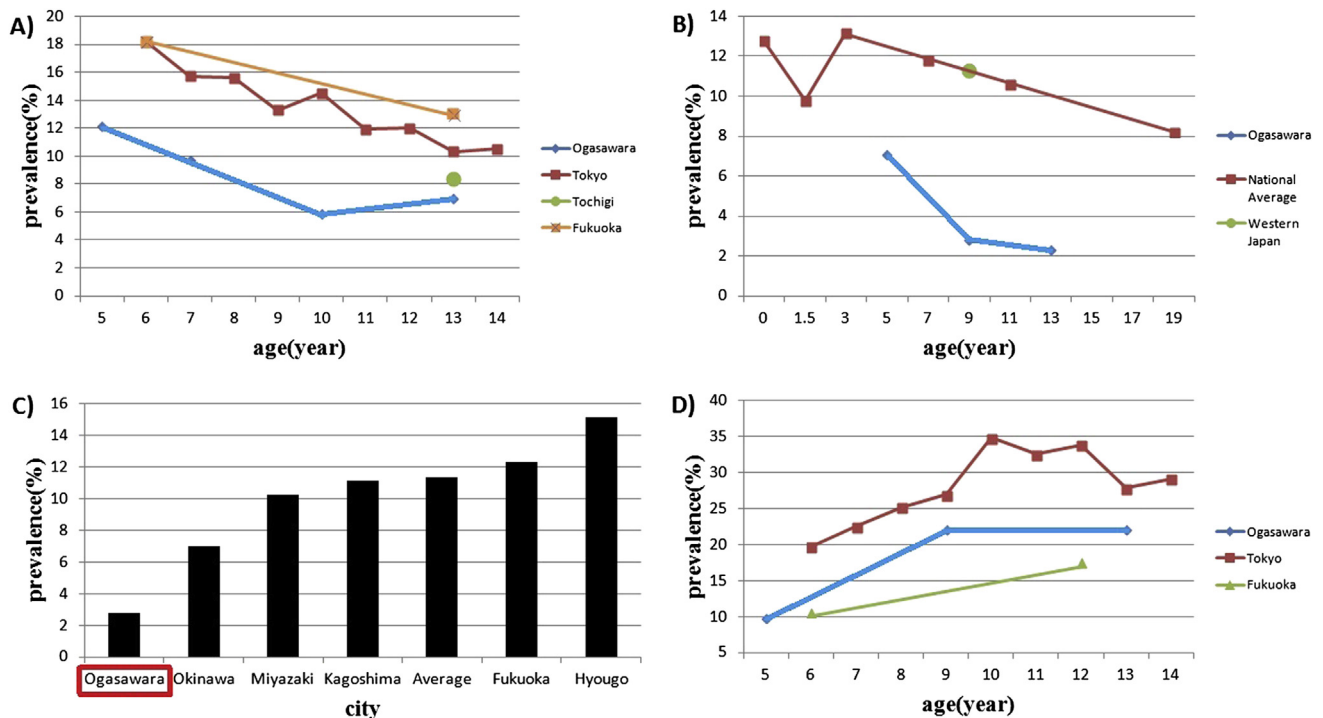


Fig. 5. Comparison with previous reports. (A) Comparison of BA prevalence. (B) Comparison of AD prevalence. A and B show that BA and AD prevalence is significantly low. (C) Comparison of AD prevalence between Ogasawara Islands and each city in Japan, with a lower prevalence of AD in the Ogasawara Islands. (D) Comparison of AR prevalence between Ogasawara and previous reports, with no significant differences in the prevalence of AR at the Ogasawara Islands compared to previous reports.

these reports, the prevalence of AD was significantly low in this survey ($p < 0.001$) (Fig. 5B). Compared to different cities in Japan, the prevalence of AD in the Ogasawara Islands was significantly lower ($p = 0.001$) (Fig. 5C). The prevalence of AR did not show a significant difference compared with that on mainland Japan ($p = 0.085$) (Fig. 5D).

Discussion

In this investigation, the prevalence of BA and AD was significantly lower than that reported in previous research studies conducted in Japan. We attribute this result to two main factors. The first factor could be the difference in the environment. With respect to BA, there was no air pollution in the Ogasawara Islands.¹⁰ The Ogasawara Islands are designated as a world natural heritage site. There are no factories and only a few cars. According to the National Institute for Environmental Studies and Ministry of the Environment in Japan, the annual average concentration of sulfur dioxide is <0.1 parts per billion (ppb) in the Ogasawara Islands¹⁰ compared to the 1–2 ppb on the mainland¹¹ (Setagaya, Tokyo). The concentration of nitrogen oxides is also lower than the specified sensitivity at the Ogasawara Islands¹⁰ versus 25–28 ppb on the mainland¹¹ (Setagaya, Tokyo). Thus, air pollution in Ogasawara Islands was significantly low as compared to other areas in Japan. On the other hand, amount of the house dust mite antigen in Ogasawara Islands might be large because of its warmth and humidity. Although there was no quantitative data of mites in this study, it is known that mites propagate between 23 and 30 °C and 60%–80% humidity,^{12,13} which is applicable for Ogasawara Islands. In general, sensitization to the house dust mite appears to have an important association with asthma. The distribution of mites on the basis of housing pattern indicates that reinforced concrete construction type of buildings supports maximum dust mite population, and the lowest count was observed in wooden houses.¹⁴ The percentage of

wooden houses was 27% at Ogasawara Islands in this study, which is lower than the mean percentage of Japanese housing (58%).¹⁵ Moreover, a number of fungi and cockroaches lived in the Ogasawara Islands because of its warmth and high humidity. Sensitization to fungus and cockroach allergens has been shown to be a significant risk factor in the development of asthma.^{16,17} Thus, it is notable that the prevalence of BA was lower in Ogasawara Islands, despite the hot and humid condition with low percentage of wooden houses. We speculate that strong factors other than the house dust mites, fungi, and cockroaches contribute to the low prevalence of BA. Further investigation is needed to clarify this inconsistency. With respect to AD, the warmth of temperature and the high humidity might be attributed to lower prevalence. Silverberg et al. reported that residence in the United States with the highest quartile mean temperatures and highest quartile mean annual relative humidity were significantly associated with lower AD prevalence than the lowest quartile.¹⁸ It is also notable that there was a lot of time spent playing in the sea and exposure to strong ultraviolet rays in the study population. Previous reports indicate that swimming in the sea and sunbathing can improve the patient's skin condition and quality of life.¹⁹ Many children in Ogasawara Islands play in the sea through most of the year because of the warmth and the proximity to the sea²⁰ (Fig. 6). The ultraviolet intensity is stronger than that on the mainland throughout the year²¹ (Fig. 7). The difference of such an environment may have improved the prevention, and ameliorated the symptoms, of AD.

We consider that, not only environmental factors but also lifestyles may be associated with the lower prevalence of the disease. One factor could be that television viewing time is shorter and exercise is more common in Ogasawara children, as shown by our data. These lifestyle factors might lead to a lower obesity trend in Ogasawara children than that of the Japanese national average. Generally, obesity rate decreases with exercise, and the production of vitamin D is promoted by outdoor exercise. Although a direct causal

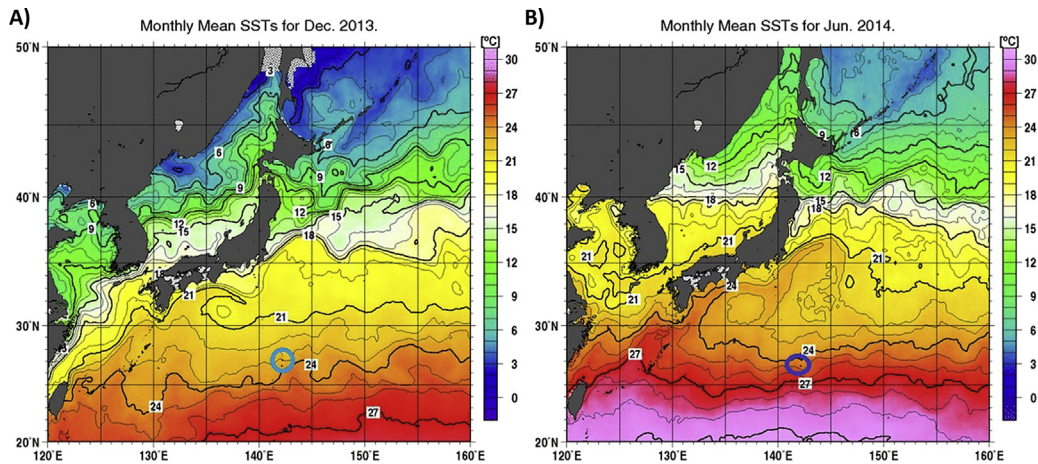


Fig. 6. Environmental differences in the Ogasawara Islands. The chart indicating the distribution of the sea water temperature around Japan. (A) In winter (December 2013) (B) In summer (June 2014). O marks the location of the Ogasawara Islands. It can be seen that the temperature of seawater is higher than that on the mainland both in summer and winter.

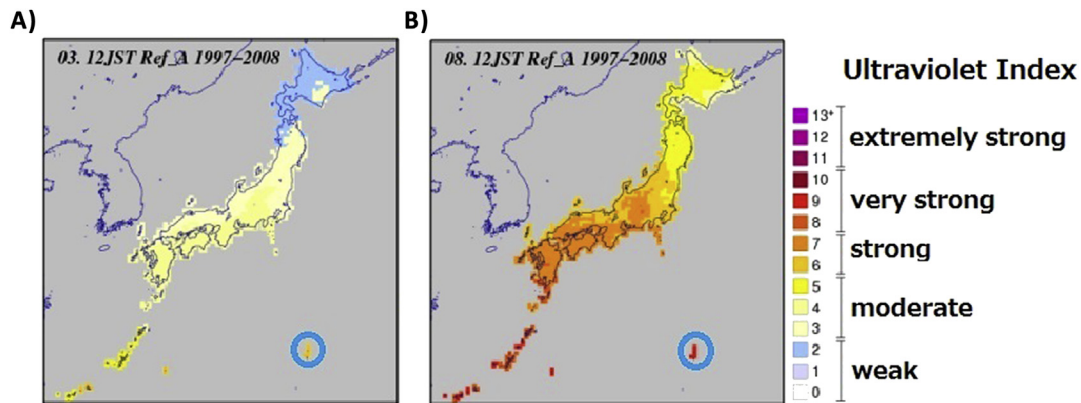


Fig. 7. Distribution map of ultraviolet index. The distribution of ultraviolet indices around Japan. (A) Average ultraviolet index in March from 1997 to 2008. (B) Indicates the average ultraviolet index in August from 1997 to 2008. O marks the location of the Ogasawara Islands. The ultraviolet intensity is stronger than on the mainland throughout the year.

relationship was not proven, there were many reports of a correlation between BA and obesity^{22,23}. The relationship between vitamin D and allergic diseases has also attracted attention in recent years^{24,25}. With respect to the AD, Wang et al. reported that vitamin D deficiency is associated with childhood AD²⁶. Exercise might possibly have decreased the prevalence of BA and AD in our investigation. Further investigation in this regard is required, including the measurement of serum vitamin D in the population at the Ogasawara Islands.

There is no significant difference in the prevalence of AR in this survey. Although cedar pollen is one of the mundane causes of hay fever on mainland Japan, there are no cedars in the Ogasawara Islands. Thus, it is somewhat surprising that the prevalence of AR in Ogasawara Islands was not significantly lower compared with that on the mainland. On account of space limitations, we could not obtain details of whether the AR was seasonal or perennial. A plant that could potentially trigger AR, such as casuarina,²⁷ which is a wind-pollinated flower with a wide distribution in the tropic region and its pollen flies from April to June, does grow in the Ogasawara Islands. Chinen reported 5 pollinosis patients at Okinawa, almost at the same latitude to the Ogasawara Islands in Japan, due to casuarina by demonstrating the positive intracutaneous test.²⁸ There is a possibility that the prevalence of AR did not change because patients who originally reacted to cedar pollen allergy were sensitized to those of the plant instead. If the sensitization to these plants would be demonstrated in future blood tests, a hypothesis could be generated that modern people are easily sensitized not only to the

cedar pollen but to other pollen. Further investigations in all islanders, including adults, such as a medical interview or allergy blood test will be necessary for the elucidation of AR mechanisms in patients.

The results of our survey revealed that the prevalence of BA was higher and AD was lower in pet-keeping group, and these were compatible with previous reports^{29,30}. However, small sample size and lack of evaluation of the kind of animal kept as a pet were limitations of this study.

With respect to FA, the prevalence was highest in junior high school students in this study. The prevalence of FA usually decreases with aging; however, it is interestingly not the case. We listed two reasons for this. First, although this is a census survey, the sample size of junior high school students was too small to discuss (n = 43). Second, this survey was conducted only via questionnaire. Therefore, it could be higher than the actual prevalence. These two factors were the limitations of this study.

The prevalence in boys was higher than that in girls in each allergic disease of the present study. This supports the findings of the result of a previous study^{5,7}.

In conclusion, the present study demonstrated that the prevalence of pediatric BA and AD is lower in the Ogasawara Islands than indicated by previous reports of these conditions in Japan. The reasons for the lower prevalence of BA and AD could be the influence of differences in the living environment and exercise habits. Comparisons in similar future investigations conducted in the

Ogasawara Islands may elucidate the factors associated with the increasing prevalence of allergic diseases.

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Conflict of interest

The authors have no conflict of interest to declare.

Authors' contributions

YO is the first author of this manuscript. AA designed the study and revised the manuscript. YM performed the statistical analysis and interpretation of the results. HK wrote and critically revised the manuscript. All authors have read and approved the final manuscript.

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