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Association between climatic elements and acute appendicitis in Japan

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ABSTRACT

Background: In Japan, it has been reported that an increase in atmospheric pressure is associated with a higher incidence of acute appendicitis. The aim of this epidemiologic study was to investigate the association between climatic elements and the incidence of acute appendicitis.

Materials and methods: A case-crossover design was used in the present study. Two wk before diagnosis was used for the target period. The same 2-wk period, but 1, 2, and 3 y before diagnosis, was used for the control period. The study participants were patients with acute appendicitis (10-29 y) from 14 facilities in the Greater Tokyo Area. Mean of the observed values for atmospheric pressure, temperature, relative humidity, and hours of sunshine calculated for each target and control period were used as climatic elements to investigate trends 1 and 2 wk before diagnosis.

Results: The year of diagnosis, a statistically significant moderate upward trend in atmospheric pressure was observed during the 2-wk period before diagnosis of acute appendicitis (tau = 0.47; $P = 0.0213$), whereas a weak nonsignificant downward trend was observed 1 y before diagnosis (tau = −0.29; $P = 0.1596$), and weak nonsignificant upward trends were observed 2 (tau = 0.24; $P = 0.2505$) and 3 y (tau = 0.28; $P = 0.1634$) before diagnosis.

Conclusions: An association was found between atmospheric pressure and the incidence of acute appendicitis. However, no significant differences were found in relation to sex or age. These findings suggest that changes in atmospheric pressure are associated with the likelihood of patients visiting the hospital.

Introduction

Although acute appendicitis is a well-known disease with a long history, its cause remains unclear.[1] In recent years, research has been conducted around the world on the association between climatic elements and the incidence of acute appendicitis,[2] with studies from Western countries such as the United States,[3-6] Canada,[7] Italy,[8] and Finland[9] and from Asian countries such as South Korea[10] and Taiwan[11] reporting that acute appendicitis occurs more frequently during the summer. Since acute appendicitis has been reported to be more likely to occur during the summer, direct associations with factors such as relative humidity, gastrointestinal infections, changes in diet, and travel are suspected in these

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studies. In Japan, some studies have reported finding an association between the incidence of acute appendicitis and increases in atmospheric pressure.[12-14] However, no such association was found in another study[15]; therefore, a definitive conclusion has yet to be reached.

Japan is located in the mid-latitudes and has a temperate climate. In Tokyo, the mean temperature is lowest in January (5.2°C) and highest in August (26.4°C). The weather in this area is quite seasonal. The Greater Tokyo Area experiences migratory anticyclone activity in the spring (March to May) and autumn (September to November). The first half of the summer (June to mid-July) is the rainy season, whereas the second half (mid-July to August) is hot and humid with clear skies. The winter (December to February) is marked by cold and sunny days with relatively low precipitation and low humidity. In addition, several typhoons pass through the Greater Tokyo Area each year in the summer and autumn months.[16]

If the incidence of acute appendicitis is affected by climatic elements, this association should be apparent in areas with high seasonal variability and changing weather patterns. Therefore, the aim of this epidemiologic study was to investigate the association between climatic elements and the incidence of acute appendicitis.

Methods

A case-crossover design was used in the present study. Two wk before diagnosis was used for the target period. The same 2-wk period, but 1, 2, and 3 y before diagnosis, was used for the control period.

For data regarding the incidence of acute appendicitis, we used information from a control group of patients with acute appendicitis who participated in a different case-control study in Japan.[17] These patients (age range, 10-29 y) were being treated for acute appendicitis at 14 facilities in the Greater Tokyo Area. Ethical review of the protocol of the study was conducted at each facility. All patients were recruited at the time of diagnosis in each facility and asked to take part in interviews and complete a questionnaire survey. Informed consent was received from all patients. For patients who were minors, informed consent was also received from the patient's guardian.

Of the 546 diagnosed cases, 416 (76.2%) agreed to participate. Of these, 357 patients with a confirmed date of diagnosis of acute appendicitis who were living in the Greater Tokyo Area (Tokyo's 23 wards, suburban Tokyo, Kanagawa, Saitama, and Chiba) were included for analysis in the present study. In the analysis, we investigated the incidence of acute appendicitis according to sex, age group (10- to 19-y or 20- to 29-y old), and date of diagnosis.

In previous studies in East Asia, atmospheric pressure, temperature, relative humidity, hours of sunshine, and precipitation were considered in the analyses.[10,11] Therefore, in the present study, we also considered these weather elements. For climatic elements, we obtained data from the Japan Meteorological Agency website.[18] The observation point was Otemachi, a district in central Tokyo. We used daily mean values for atmospheric pressure, temperature, and relative humidity and measured values for hours of sunshine and precipitation.

Means of the observed values were calculated for each target and control period and then assessed for trends in the 1- and 2-wk period before diagnosis. First, we investigated changes in atmospheric pressure, temperature, relative humidity, and hours of sunshine in the year of diagnosis. Second, we observed changes in atmospheric pressure 1, 2, and 3 y before diagnosis. Next, we investigated changes in atmospheric pressure in the year of diagnosis by sex, age, and season (spring: March-May; summer: June-August; autumn: September-November; and winter: December-February). The Mann-Kendall test was used to identify trends in the 1- and 2-wk periods before diagnosis. The significance level was set at 5%. Statistical analysis was performed using R statistical software (R Foundation for Statistical Computing, Vienna, Austria).

Results

The background characteristics of the participants are shown in Table 1. There were more male ($n = 198$, 55.5%) than female participants ($n = 159$, 44.5%), and more patients aged 10-19 y ($n = 185$, 51.8%) than 20-29 y ($n = 172$, 48.2%). Tokyo's 23 wards are located in the center of the Greater Tokyo Area, whereas Saitama is located to the north, Kanagawa to the south, Chiba

Table 1 – Participant background characteristics.

Background characteristics	n	%
Sex		
Male	198	55.5
Female	159	44.5
Age (y)		
10-19	185	51.8
20-29	172	48.2
Residential area		
Tokyo's 23 wards (central)	289	81.0
Suburban Tokyo (west side)	33	9.2
Kanagawa (south side)	14	3.9
Saitama (north side)	17	4.8
Chiba (east side)	4	1.1
Year of diagnosis		
2011	39	10.9
2012	75	21.0
2013	145	40.6
2014	94	26.3
2015	4	1.1
Month of diagnosis		
March-May (spring)	71	19.9
June-August (summer)	96	26.9
September-November (autumn)	113	31.7
December-February (winter)	77	21.6
Total	357	100.0

to the east, and suburban Tokyo to the west. Regarding residential area, most patients lived in Tokyo's 23 wards ($n = 289$, 81.0%), followed by suburban Tokyo ($n = 33$, 9.2%) and Saitama ($n = 17$, 4.8%). Regarding the date of diagnosis of acute appendicitis, most patients were diagnosed in 2013 ($n = 145$, 40.6%), followed by 2014 ($n = 94$, 26.3%) and 2012 ($n = 75$, 21.0%). Regarding the month of diagnosis, most patients were diagnosed from September to November (autumn; $n = 113$, 31.7%), followed by June to August (summer; $n = 96$, 26.9%) and December to February (winter; $n = 77$, 21.6%).

The results of trend analysis are shown in Table 2. In the year of diagnosis, a statistically significant moderate upward trend in atmospheric pressure was observed during the 2-wk period before diagnosis (tau = 0.47; $P = 0.0213$). A moderate upward trend was also observed during the 1-wk period before diagnosis (tau = 0.47), but this difference was not significant ($P = 0.1346$). Regarding temperature, a statistically significant moderate downward trend was observed during the 2-wk period before diagnosis (tau = −0.41; $P = 0.0479$); however, no trends were observed in the 1-wk period (tau = −0.04). Regarding relative humidity, no trends were observed during the 2-wk period before diagnosis (tau = 0.06). A moderate downward trend was observed during the 1-wk period before diagnosis (tau = −0.59); however, this difference was not significant ($P = 0.0595$). Regarding hours of sunshine, no trends were observed during either the 1-wk (tau = 0.04) or 2-wk periods (tau = −0.01) before diagnosis.

Next, we investigated changes in atmospheric pressure 1, 2, and 3 y before diagnosis as the control periods. One year before diagnosis, weak nonsignificant downward trends were observed during both the 1-wk (tau = −0.27; $P = 0.4473$) and 2-wk (tau = −0.29; $P = 0.1596$) period before diagnosis of acute appendicitis. Two years before diagnosis, a weak nonsignificant upward trend was observed in the 2-wk period (tau = 0.24; $P = 0.2505$), but no trends were observed in the 1-wk period (tau = 0.11). Three years before diagnosis, a weak nonsignificant upward trend was observed in the 2-wk period (tau = 0.28; $P = 0.1634$), whereas a statistically significant moderate downward trend was observed in the 1-wk observation (tau = −0.69; $P = 0.0248$).

We then investigated changes in atmospheric pressure during the year of diagnosis according to season. In both the summer and autumn, a statistically significant moderate upward trend was observed in the 2-wk period before diagnosis of acute appendicitis (tau = 0.52; $P = 0.0104$ and tau = 0.57; $P = 0.0044$, respectively). In the spring, a weak nonsignificant upward trend was observed in the 2-wk period before diagnosis (tau = 0.31; $P = 0.1245$), whereas in the winter, a moderate nonsignificant upward trend was observed in the 1-wk period before diagnosis (tau = 0.57; $P = 0.0635$).

Next, we investigated changes in atmospheric pressure during the year of diagnosis according to sex. In females, a statistically significant moderate upward trend was observed in the 2-wk period (tau = 0.44; $P = 0.0281$), whereas in males, a moderate nonsignificant upward trend was observed in the 1-wk period (tau = 0.57; $P = 0.0746$).

Finally, we investigated changes in atmospheric pressure during the year of diagnosis according age group. In patients aged 20-29 y, a statistically significant moderate upward trend was observed in the 2-wk period before diagnosis of acute appendicitis (tau = 0.53; $P = 0.0080$), whereas in those aged 10-19 y, no trends were observed in either the 1-wk (tau = 0.00) or 2-wk periods (tau = −0.06).

Discussion

This study was conducted to investigate whether climatic elements affect the incidence of acute appendicitis. As a result, we found an upward trend in atmospheric pressure during the

Table 2 – Results of the Mann-Kendall trend test for climatic elements.

Climatic element	Period	Target population	*n*	2 wk before diagnosis		1 wk before diagnosis	
				Kendall's tau	*P* value	Kendall's tau	*P* value
Atmospheric pressure	Year of diagnosis	All	357	0.47	0.0213*	0.47	0.1346
Temperature				−0.41	0.0479*	−0.04	1.0000
Relative humidity				0.06	0.8005	−0.59	0.0595
Hours of sunshine				−0.01	1.0000	0.04	1.0000
Atmospheric pressure	1 y before diagnosis	All	357	−0.29	0.1596	−0.27	0.4473
	2 y before diagnosis			0.24	0.2505	0.11	0.8000
	3 y before diagnosis			0.28	0.1634	−0.69	0.0248*
Atmospheric pressure	Year of diagnosis	Spring	71	0.31	0.1245	0.14	0.7105
		Summer	96	0.52	0.0104*	0.29	0.4213
		Autumn	113	0.57	0.0044*	0.45	0.1669
		Winter	77	−0.23	0.2545	0.57	0.0635
Atmospheric pressure	Year of diagnosis	Males	198	0.08	0.7221	0.57	0.0746
		Females	159	0.44	0.0281*	0.07	0.9000
Atmospheric pressure	Year of diagnosis	10- to 19-y old	185	−0.06	0.8003	0.00	1.0000
		20- to 29-y old	172	0.53	0.0080*	0.33	0.3186

* Significantly different at alpha = 0.05.

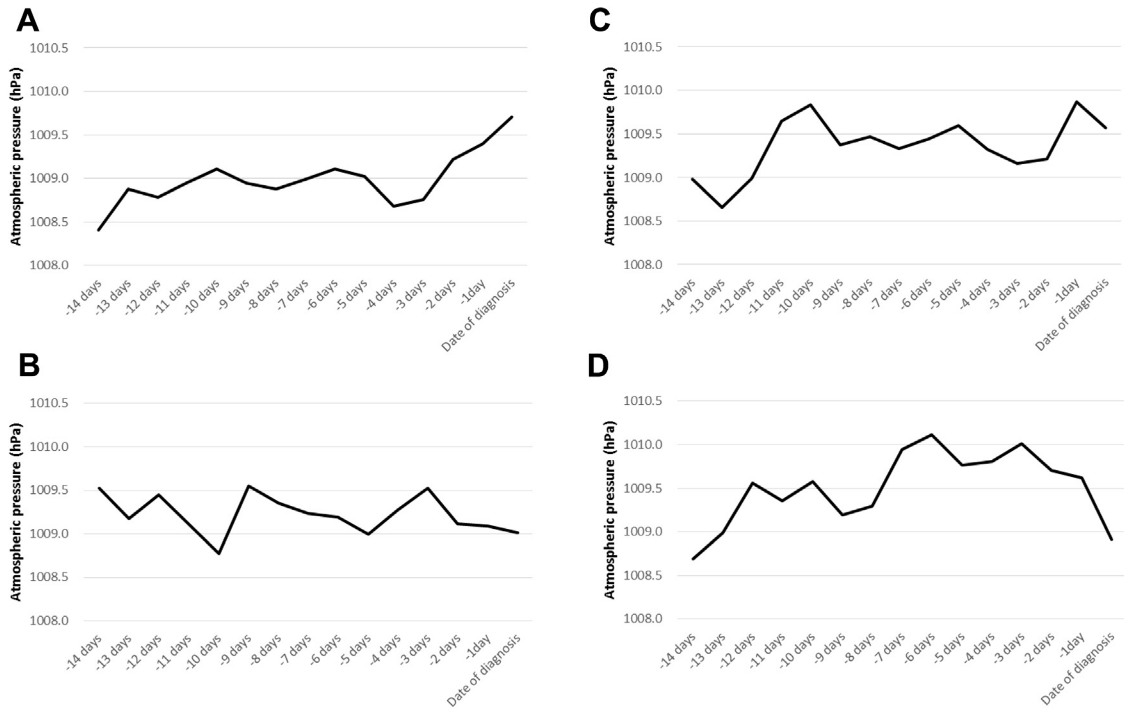

Fig. 1 — Annual changes in mean atmospheric pressure during the 2-wk period before diagnosis. (A) Year of diagnosis; (B) 1 y before diagnosis; (C) 2 y before diagnosis; and (D) 3 y before diagnosis.

2-wk period before diagnosis (Fig. 1). In addition, no trends were observed in the control period (1, 2, and 3 y before diagnosis). These results suggest the presence of an association between changes in atmospheric pressure and the incidence of acute appendicitis.

In the seasonal analysis, we found a statistically significant upward trend in atmospheric pressure during the summer and the autumn. On the other hand, in the spring, although an upward trend was observed, it was not statistically significant. In the winter, an upward trend was observed in the 1-wk period before diagnosis, but this was also not statistically significant. These results suggest that the association between changes in atmospheric pressure and the incidence of acute appendicitis is influenced by seasonal variability.

Fukuda *et al.* reported that changes in atmospheric pressure affect the immune system through the autonomic nervous system[12,13]; therefore, changes in atmospheric pressure can be expected to affect the incidence of acute appendicitis regardless of sex or age. In the present study, although a statistically significant upward trend was observed in the 2-wk period before diagnosis among females and patients aged 20-29 y, but not among males and patients aged 10-19 y, it remains difficult to imagine how the pathogenesis of acute appendicitis could differ by sex and age.

Based on the results of the present study, it can be inferred that changes in atmospheric pressure may be associated with the patient behavior of visiting the hospital. Some patients with acute appendicitis experience stomach pain a few days before diagnosis.[19] High atmospheric pressure leads to clear weather, and patients are more likely to leave their homes when the weather is clear. Therefore, the effects of high atmospheric pressure may lead to higher rates of medical consultation and diagnosis.

In the present study, an analysis of temperature, relative humidity, and hours of sunshine revealed no consistent trends in the 1- or 2-wk periods before diagnosis of acute appendicitis. An association between mean monthly temperatures and the incidence of acute appendicitis has been reported in previous studies.[9,11,20] The incidence of acute appendicitis is high in the summer months; however, in the present study, since we focused on changes in temperature during the relatively short period of 2 wk before diagnosis, no association was found between temperature and the incidence of acute appendicitis. In addition to atmospheric pressure, temperature, relative humidity, and hours of sunshine, the association between the incidence of acute appendicitis and precipitation levels has also been examined.[11] In the present study, precipitation was excluded from the analysis due to the relatively short 1- and 2-wk period, during which heavy rains occurred in some years and led to highly variable data.

Since the present study used a case-crossover design, background factors such as sex, age, and familial and medical histories were considered to be comparable. A number of previous studies have analyzed mean monthly values for various climatic elements in relation to the incidence of acute appendicitis.[9,11,20] The unique feature of the present study was that we included control groups in our investigation of the association between changes in climatic elements and the incidence of acute appendicitis. Suspected risk factors for acute appendicitis such as stress or gastrointestinal tract infections are also likely to be affected by changes in atmospheric pressure in the 2-wk period before diagnosis. The association between such risk factors and changes in climatic elements should be examined in future research.

In this study, we used data from a control group of patients with acute appendicitis who participated in a different case-control study. During recruitment, we obtained consent from those patients after explaining the purpose of our study. Among the 546 diagnosed cases, we could not obtain consent to participate in the survey from 130 cases. Among these 130 cases, 53.4% were male, 46.6% were female, 33.9% were aged 10-19 y, and 66.1% were aged 20-29 y. Although the percentages of males and females did not differ compared to the participants, the percentage of those aged 20-29 y was greater than the percentage of those aged 10-19 y. Despite this bias in the age, our results were not thought to have been affected by a selection bias associated with climatic elements.

The patient data used in the present study were sex, age, residential area, and date of diagnosis. Since patients were recruited at the time of diagnosis, the possibility of an information bias was also considered minimal. Although we recruited patients from 14 separate facilities from February 2011 to June 2015, the start and end dates regarding cooperation with this study differed at each facility. Therefore, the size of the study population differed according to the date. For this reason, we could not directly compare the incidence of acute appendicitis by year or month.

Conclusion

In the present study, we observed an association between the incidence of acute appendicitis and changes in atmospheric pressure using a case-crossover design. Since no consistent results were seen in terms of analysis by sex and age, it can be inferred that changes in atmospheric pressure affect the likelihood of patients visiting the hospital. A more detailed analysis of the association between changes in atmospheric pressure and the incidence of acute appendicitis is warranted.

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Authors' contributions: Y.S. and N.K. contributed to the conception and design of the study. N.K. acquired the data. Y.S. analyzed the data and drafted the manuscript. M.E. and K.K. interpreted the data. N.K. and N.Y. critically revised the manuscript and gave final approval of the manuscript.

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Disclosure

Authors have no conflicts of interest, including relevant financial interests, activities, relationships, and affiliations.

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