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Original Article

Effect of Climatic Conditions on Epidemic Patterns of Influenza in Okinawa, Japan, during the Pandemic of 2009: Surveillance of Rapid Antigen Test Results

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SUMMARY: Climatic conditions may have affected the incidence of influenza during the pandemic of 2009 as well as at other times. This study evaluated the effects of climatic conditions on influenza incidence in Okinawa, a subtropical region in Japan, during the 2009 pandemic using surveillance data from rapid antigen test (RAT) results. Weekly RAT results performed in four acute care hospitals in the Naha region of the Okinawa Islands from January 2007 to July 2011 were anonymously collected for surveillance of regional influenza prevalence. Intense epidemic peaks were noted in August 2009 and December 2009–January 2010 during the influenza pandemic of 2009. RAT positivity rates were lower during the pandemic period than during the pre- and post-pandemic periods. Lower ambient temperature was associated with higher influenza incidence during pre- and post-pandemic periods but not during the pandemic of 2009. Lower relative humidity was associated with higher influenza incidence during the pandemic as well as during the other two periods. The association of climatic conditions and influenza incidence was less prominent during the pandemic of 2009 than during pre- and post-pandemic periods.

INTRODUCTION

The seasonality of influenza epidemics is well-established. Winter is a known influenza epidemic season in temperate and cold climates. Possible underlying causes of seasonality of influenza epidemics include biological, social, and environmental factors (1). Inverse relationships of temperature and humidity with influenza epidemics have been previously described (2–5). However, recent reports have documented influenza outbreaks during the summer in Southeast Asia (6), where the climate is tropical or subtropical. The reasons for the different seasonality of influenza epidemics in Southeast Asia are not yet understood (6).

The influenza pandemic caused worldwide distress in 2009. In March 2009, a novel influenza A(H1N1) virus from swine origin emerged in Mexico and spread worldwide. On June 11, 2009, the World Health Organization (WHO) raised the global pandemic alert level to phase 6 (7). In Japan, the first infection of the pandemic A(H1N1)2009 virus (A(H1N1)pdm09) was identified on May 16, 2009 (8). In Okinawa, the first case of A(H1N1)pdm09 infection was identified on June 29, 2009 (9). By August 2010, the WHO stated that the influenza pandemic had ceased.

The Okinawa Islands are located in the southernmost part of Japan (latitude 26°N), where the climate is subtropical. The epidemic patterns of seasonal influenza in the Okinawa Islands appear to be different from those observed on the mainland Japan, which has a temperate climate (10,11). In accordance with observations of seasonal influenza, the epidemic patterns during the influenza pandemic of 2009 differed between subtropical Okinawa and temperate mainland Japan. During the 2009 pandemic, the first epidemic occurred earlier in Okinawa than in mainland Japan (12).

This report describes the results of a 4-year surveillance of influenza incidence in the Naha region of Okinawa Island conducted from January 2007 to July 2011. We previously published surveillance data from 2007–2008 for this region (11), and this study extended the investigation period to include the influenza pandemic of 2009. The present study examined effects of climatic conditions on epidemic patterns of influenza during the pandemic of 2009.

METHODS

Geographic and climatic background: Naha City is the capital of Okinawa Prefecture and is located on the Okinawa main island in the southernmost region of Japan. The climate in this region is humid with temperate and subtropical regions. Temperatures average 18°C

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in winter and 28°C in summer. Daily climate data, including data on ambient temperature, relative humidity, total rainfall, and total hours of sunshine, were retrieved from the Japanese Meteorological Agency website (13). Weekly climatic variables were calculated on the retrieved data.

Data collection and rapid antigen test for influenza virus: Clinical practice of influenza management in Japan includes performing rapid antigen tests (RATs) for influenza virus using nasal or throat swab samples. The number of RATs conducted in the clinical laboratories of the 4 general hospitals in the Naha region in Okinawa from January 2007 to July 2011 was counted every week. The test result data were anonymously collected from the hospitals by the Clinical Laboratory Center of the Medical Association in Naha City, Okinawa. The collected data included the total number of tests conducted and the number of positive cases of influenza A and B. The data were accumulated and provided to the hospitals for clinical epidemiological purposes. This study used only the accumulated test data; no clinical data of individuals were used.

The influenza pandemic of 2009: The first case of A(H1N1)pdm09 infection in the Okinawa Islands was identified in June 2009 (9). WHO declared that the pandemic of 2009 ended in August 2010. Therefore, in this study, the period of the pandemic influenza of 2009 is defined as the period from June 2009 to August 2010. We defined the pre-pandemic term as the period from January 2007 to June 2009 and the post-pandemic term as the period from August 2010 to July 2011. Reverse transcriptase-polymerase chain reaction (RT-PCR) and hemagglutinin inhibition test analyses revealed that almost all influenza A cases during the June 2009–August 2010 period were due to A(H1N1)pdm09 (9,14).

Statistical analyses: The associations between positive RAT cases and climatic variables were evaluated by Spearman's correlation coefficient test using the Statistical Package for the Social Sciences (15.0J) (IBM SPSS, Tokyo, Japan).

RESULTS

From January 2007 to July 2011, RATs were performed for 106,880 patients in the Naha region of Okinawa. Of these, 25,973 cases (24.3%) were positive for influenza A virus antigen, and 4,630 cases (4.3%) were positive for influenza B virus antigen. The number of patients positive for both A and B antigens was 32 (0.03%). During the pre-pandemic period (January 2007–June 2009), an average of 356.6 tests were performed per week. Of all the tested individuals, 13,375 (29.5%) were positive for influenza virus antigen (Table 1); most of the individuals were diagnosed with influenza A (11,227 cases, 24.3%), and a few were diagnosed with influenza B (2,148 cases, 4.7%) infection. During the influenza pandemic of 2009 (June 2009–August 2010), 38,842 influenza virus antigen detection tests were performed (626.5 tests per week). Most tested individuals were diagnosed with influenza A (10,703 cases, 27.6%), while a few individuals were diagnosed with influenza B (554 cases, 1.4%). The average number of RATs performed per week during the influenza pandemic of 2009 period was higher than that performed during the pre- and post-pandemic influenza periods (626.5 versus 356.6 and 483.9, respectively) (Table 1).

The numbers of positive cases of influenza A and influenza B detected by RAT each week from January 2007 to July 2011 are shown in Fig. 1. Intense epidemics of influenza A were observed in February–April 2007, January–February 2009, August 2009–January 2010 (the pandemic of 2009), and January 2011. Outbreaks of influenza B occurred from May to July 2009 and from March to June 2011. Two epidemic peaks were noted during the influenza pandemic of 2009. The epidemic curve during the pandemic period was different from those during the pre- and post-pandemic periods. No epidemic was noted during the summer of 2010, whereas an influenza B epidemic occurred from March to June 2011. Influenza A and B were detected throughout the year in 2007–2008. Separate epidemic curves for the 4 hospitals showed similar patterns (data not shown).

Table 1. Performance of influenza antigen tests

Period		Tests performed	Influenza A positive (%)	Influenza B positive (%)
Pre-pandemic	2007	19,229	5,149 (26.8)	629 (3.3)
	2008	13,089	1,881 (14.4)	829 (6.3)
	2009 Jan.–June	12,975	4,197 (32.3)	690 (5.3)
	Total (127 weeks)	45,293	11,227 (24.3)	2,148 (4.7)
	Average per week	356.6	88.4	16.9
Pandemic of 2009	2009 June–Dec.	28,987	8,562 (29.5)	481 (1.7)
	2010 Jan.–Aug.	9,855	2,141 (21.7)	73 (0.7)
	Total (62 weeks)	38,842	10,703 (27.6)	554 (1.4)
	Average per week	626.5	172.6	8.9
Post-pandemic	2010 Aug.–Dec.	3,970	369 (9.3)	36 (0.9)
	2011 Jan.–July	18,775	3,674 (19.6)	1,892 (10.1)
	Total (47 weeks)	22,745	4,043 (17.8)	1,928 (8.5)
	Average per week	483.9	86.0	41.0
Total		106,880	25,973 (24.3)	4,630 (4.3)

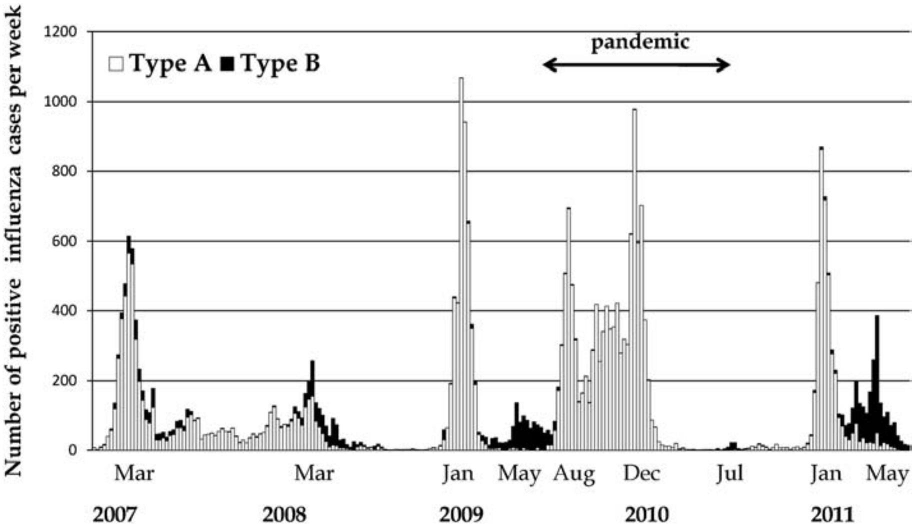

Fig. 1. Incidence of influenza A and B in Okinawa, Japan, from 2007 to 2011 determined using the number of positive results for rapid antigen tests (RAT) for influenza from 4 representative hospitals in the Naha region.

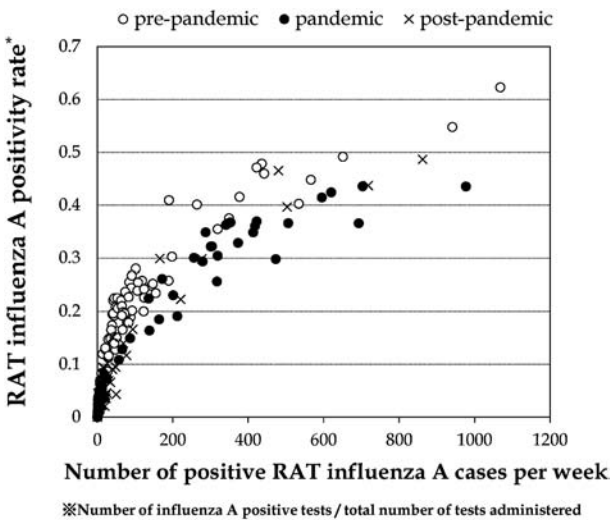

Fig. 2. Association of the RAT influenza A positivity rate and the number of positive test results per week. Closed circles represent the period of the influenza pandemic of 2009, open circles represent the pre-pandemic period, and X-marks represent the post-pandemic period.

As the number of cases with positive RAT results for influenza A per week increased, the RAT influenza A positivity rate (number of positive tests/total number of tests) also increased (Fig. 2). The maximum RAT influenza A positivity rate was 62.3% and 48.6% during the pre- and post-pandemic influenza epidemics, respectively. The maximum RAT influenza A positivity rate during the influenza pandemic of 2009 (43.7%) was lower than either of these rates (pre- and post-pandemic).

We evaluated the relation between climate-related variables (mean ambient temperature, mean relative humidity, total rainfall, and total hours of sunshine) in the Naha region and the incidence of influenza in the region (Fig. 3). Lower mean ambient temperature was associated with a higher incidence of influenza during the pre- and post-pandemic periods, while no significant association of ambient temperature and influenza incidence was observed for during the pandemic period. Lower mean relative humidity was associated with a higher incidence of influenza during all periods evaluated. In addition, shorter sunshine time was associated with a higher incidence of influenza during pre- and post-pandemic periods, whereas lower weekly rainfall was associated with a higher incidence of influenza during the pandemic of 2009 (Table 2).

DISCUSSION

Several limitations of using RAT data for influenza surveillance should be noted. First, RAT cannot determine subtypes of influenza A virus. Second, the RAT is not as sensitive as other influenza detection methods (15). However, the present data obtained using RAT results were very similar to the influenza cases reported per sentinel weekly in Okinawa (12). This finding supports the utility of RATs during the influenza pandemic of 2009 (16).

This study clearly showed that RATs were conducted more frequently during the influenza pandemic of 2009 than during the pre- and post-pandemic periods. Several factors might be involved. First, residents of Okinawa may simply have been susceptible to A(H1N1)pdm09 during the pandemic, as has been observed in other countries (17). Second, both patients and physicians in Okinawa might have altered their attitudes towards testing during the influenza pandemic of 2009, resulting in more tests being conducted.

Comparison of RAT positivity rates during the different periods were not straight forward because the rates depended on the number of positive influenza A cases (Fig. 2). When the relationship between influenza A positivity rates and number of positive RAT influenza A cases per week was considered, positivity rates were found to be lower during the influenza pandemic of 2009 than during the pre- and post-pandemic periods (Fig. 2). Several factors may have affected the RAT positivity rates during the 2009 influenza pandemic. Sensitivity of RATs for influenza A is lower for

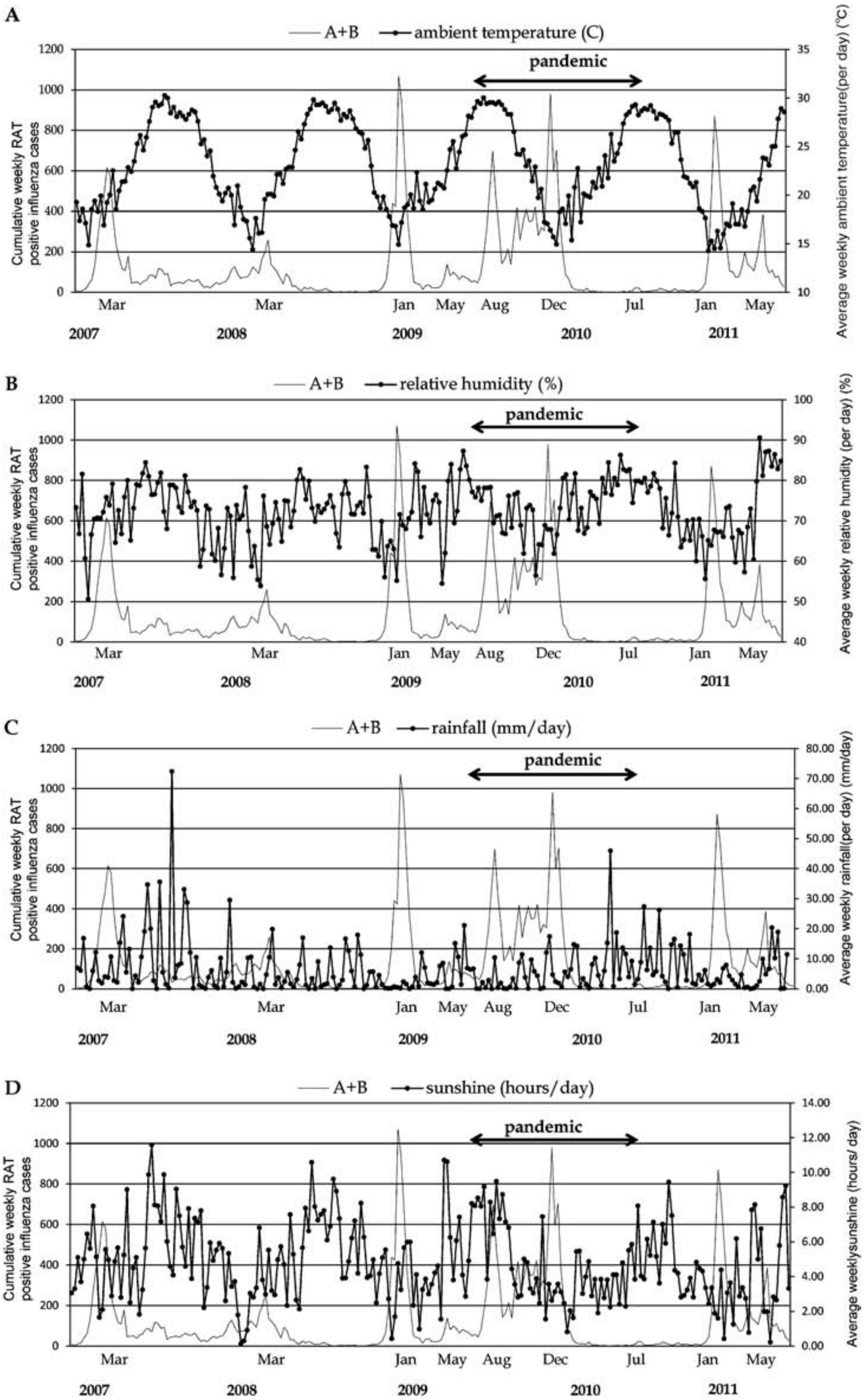

Fig. 3. Relationships between average climatic conditions and influenza cases per week. The climatic conditions consist of temperature (A), mean relative humidity (B), total rainfall (C), and hours of sunlight (D). The left side Y-axes represent the incidence of weekly RAT positive cases. Right side Y- axes represent average weekly temperature (°C), relative humidity (%), rainfall (mm), and sunshine (hours) in (A), (B), (C), and (D), respectively.

A(H1N1)pdm09 than for conventional influenza A strains (18–20). In addition, lower viral load at the time of conducting RAT may be associated with lower RAT positivity rates for the pandemic period (21).

It is interesting to compare the patterns of the 2009 influenza pandemic in tropical and subtropical regions to those in temperate regions. The course of the influenza pandemic of 2009 in Southeast Asia has been described elsewhere (22–26), but the information was limited. The present study showed that in Okinawa, the influenza pandemic of 2009 was associated with 2 intense epidemic peaks, 1 in August 2009 and 1 in late December 2009. According to the influenza cases reported per sentinel weekly, the epidemic peak of the 2009 influenza pan-

Table 2. Correlations between climatic conditions and influenza cases each week

	Correlation coefficient							
	Pre-pandemic		Pandemic		Post-pandemic		Total	
Antigen test	A+	A+ or B+	A+	A+ or B+	A+	A+ or B+	A+	A+ or B+
Ambient temperature	−0.435**	−0.439**	−0.180	−0.076	−0.790**	−0.615**	−0.379**	−0.352**
Relative humidity	−0.218*	−0.166	−0.613**	−0.513**	−0.354*	−0.147	−0.354**	−0.248**
Rainfall	−0.037	−0.064	−0.327**	−0.294*	−0.253	−0.243	−0.173**	−0.180**
Sunshine	−0.192*	−0.165	0.024	0.063	−0.430**	−0.384**	−0.151*	−0.129*

Speaman's correlation coefficient was calculated.
** represents $P < 0.01$.
* represents $P < 0.05$.
Definition of pandemic: From week 24 (June 11) of 2009 to week 32 (Aug. 10) of 2010.

demic occurred in the mainland Japan at the beginning of December (27). The first epidemic peak in Okinawa occurred earlier than the peak observed in the mainland Japan.

Taiwan also had 2 intense epidemics during the 2009 pandemic in August–September and in December (26). The epidemic curves for Okinawa were more similar to those for Taiwan than to those for mainland Japan. Since the Okinawa Islands are located close to Taiwan, influenza epidemics in the 2 regions may share certain influencing factors.

This study demonstrated that lower relative humidity and lower ambient temperature were associated with a higher incidence of influenza A during the pre- and post-pandemic periods, whereas only lower relative humidity was associated with a higher incidence of influenza during the pandemic of 2009. These findings suggest that the influence of weather conditions on influenza incidence during the pandemic was lesser than that during conventional influenza A outbreaks. Moreover, factors other than climatic conditions may affect influenza incidence. These include biological factors such as viral evolution, the immune status of hosts, and seasonal host health. In addition, the social behavior of humans may affect the incidence of influenza (1).

In our previous report (11), monthly climate data were used to analyze the relationship between climatic conditions and influenza incidence, and the only significant association detected was between influenza incidence and mean ambient temperature. In contrast, the present study analyzed weekly data of climatic parameters and found that lower relative humidity, shorter sunshine time, and lower ambient temperature were associated with a higher incidence of influenza during the pre-pandemic period. The disagreement between these 2 studies might be because of the number of items for analysis. Drawing conclusions will require further intensive analysis over longer periods and across wider study areas.

In conclusion, surveillance of RAT results is a useful tool for evaluating regional influenza prevalence, although the sensitivity of the tests differed during the influenza pandemic of 2009 and the pre- and post-pandemic periods. The incidence of influenza in Okinawa, Japan, during the pandemic of 2009 was different from that in the temperate area of mainland Japan. This study showed that the association between climatic conditions and influenza incidence was less prominent during the pandemic of 2009 than during pre- and post-pandemic periods.

Conflict of interest None to declare.

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