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황사 및 관련예보 정확도가 천식질환 발생빈도에 미치는 상관관계 분석

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Correlation Analysis About the Effect of Asian Dust Storm and Related Forecasts on Asthma Disease

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황사(Asian dust storm, ADS)란 중국이나 몽골 등 중앙아시아 지역의 사막 지대의 작은 모래나 황토 또는 먼지가 하늘에 떠다니다가 상층풍을 타고 멀리까지 날아가 떨어지는 현상을 말하며, 주로 봄철에 우리나라를 비롯한 동아시아 지역에 영향을 준다. 이와 같은 황사에 영향을 받는 지역에서는 거주민들의 건강에 부정적인 영향을 미치는 것으로 알려져 있다. 본 연구는 2005년도에서 2008년도까지 4년간 서울지역 거주민들 사이에서 황사현상이 천식질환에 미치는 영향을 분석하고자 한다. 이를 위해 황사발생일(기준일 또는 index day)과 기준일 대비 7일 전후(비교일 또는 comparison day) 황사가 발생하지 않은 날에 병의원에서 진료를 받은 천식환자 수를 황사예보의 정확도에 따라 비교 분석하였다. 그 결과 24시간 전 제공된 황사예보가 황사발생을 정확히 예측한 경우라 하더라도 비교일 대비 기준일의 천식환자 수가 여전히 더 많다는 사실을 알 수 있었다. 다만, 증가 정도는 통계적으로 유의한 수준은 아니었다는 점에서 정확한 황사예보가 최소한 어느 정도는 천식질환 발생을 저감시키는 효과는 분명히 가지고 있다고 판단할 수 있다. 반면에 24시간 전 황사예보가 황사발생을 정확하게 예측하지 못한 경우에는 비교일 대비 기준일에서 5~6일 후에 진료 받은 천식환자 수가 통계적으로 유의할 수준까지 높게 나타났다. 하지만, 기준일 및 기준일 다음 날의 경우에는 오히려 천식환자 수가 감소하는 경향을 보였다. 본 연구를 통해 황사예보 및 황사발생의 다양한 경우에 따라 천식환자 수의 일정한 변화패턴이 발견되었으며, 이와 같은 연구결과는 황사 관련 의료서비스 체계를 보다 효율적으로 설계하는데 활용될 수 있을 것으로 기대된다.

Keywords : Asian Dust Storm(ADS), Asthma Disease, Paired t-test, ADS Forecast

1. Introduction

East Asia, including Korea, has often been under the influence of windblown dust storms from the deserts of Mongolia and China mainly in spring, and this is referred to as Asian dust storm (ADS) events. ADS events are often accompanied by ambient dust particles of less than $10\mu m$ in size, and this is known to cause adverse effects on the health of the general public. Such large-scale movement of clouds of sand primarily influences the eastern Asia regions, but can travel

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as far as to the western regions of the U.S. and Canada [13]. The Asian dust phenomenon has been recorded in a number of historical records of Korea since the 2nd century [3], and ADS lasting over 10 days have occurred every year since the year 2000, except in 2003 and 2004 [8].

With increasing concerns regarding the influence of Asian dust on human health, there have recently been a large number of studies performed on this issue. According to [4], the effects of particulate matters on health are mainly related to the size and chemical composition (chemistry) of the particle. According to the findings of several studies, there is a dramatic increase in the concentration of coarse particles (between $2.5\mu m$ and $10\mu m$ in diameter) compared to fine particles (aero-dynamic diameters equal to or less than 2.5 μm) on the days of ADS events. This is associated with high wind speed, which plays a role in decreasing the concentration of fine particles and other combustion-related pollutants. Thus, the PM^{10} levels, i.e., the concentration of particulate matter less than $10\mu m$, increase greatly above the normal levels caused by the local conditions [6]. Studies considering the nature of Asian dust have investigated the effects of ADS on mortality [2, 9, 11], respiratory symptoms [5, 7, 12, 15], cardiovascular diseases [14] and stroke [16].

Studies performed to date have analyzed the frequencies of diseases and deaths arising from the occurrence of ADS, but there have not been any studies analyzing the frequency of diseases caused by the accuracy of Asian dust forecasts. Thus, the purpose of this study is to analyze the effects of the accuracy of the ADS event forecast on the asthma attacks, a respiratory disease, in Seoul region from 2005 to 2008. For this purpose, the average numbers of medical treatments provided to asthma patients on the index days and the comparison days were compared. The comparative analysis was performed separately on the hit and miss cases, which were determined by whether the ADS forecast provided 24 hours in advance was correct (hit) or incorrect (miss).

2. Material and Methods

2.1 Data

We obtained two sets of data, which are the number of medical services provided to asthma patients at all hospitals and the information associated with the forecasts and occurrence of ADS in the Seoul region from 2005 to 2008. The data were acquired from 'Health Insurance Review and Assessment Service' and 'Korea Meteorological Administration.' <Table 1> shows the dates of ADS occurrence observed in the Seoul region for a total of 40 days from 2005 to 2008.

<Table 1> Asian Dust Days in Seoul, Korea, 2005~2008

Year	Date
2005	29 March, 7 April, 10 April, 14~15 April, 20~22 April, 28~29 April, 6~7 November
2006	11 March, 13 March, 28 March, 7~9 April, 18 April, 23~24 April, 30 April, 1 May
2007	14 February, 6 March, 27~28 March, 31 March, 1~2 April, 8~9 May, 25~26 May, 29 December
2008	12 February, 2~3 March, 16 March, 3~4 April, 30~31 May

2.2 Analysis

This study employs the concept of index days and comparison days used by [2, 16]. Index days are defined as the corresponding days on which windblown ADS events are actually occurred. However, only the last day of 2 or more consecutive days of ADS was considered as the index day unless there was a significant difference (i.e., $110\mu g/m^3$) between the PM^{10} concentrations of each day, so as to cope with the harvesting effect. which is individuals who are vulnerable to asthma caused by ADS will visit the hospital on only one of the consecutive ADS days and thus, the number of visits to the clinics may be unexpectedly decreased on the following days. This phenomenon may deteriorate the correlation analysis between ADS and the related asthma diseases [16]. However, if the ADS forecasts were different for the consecutive ADS event days, all the days were considered as the index days.

Comparison days correspond to the symmetrical days without any windblown dust storms, which are 7 days before and after the corresponding index day. The symmetrical comparison days are adopted to control confounding by the day of the week and seasonal trends [1, 2, 16]. We performed paired t-tests on the numbers of asthma patients on the index days and comparison days. If ADS occurred on one of the two comparison days, only the number of medical services provided on the other comparison day was used as data for the paired t-test. If ADS occurred on both comparison days of an index day, they were excluded from the analysis data. Thus, three days from April 20th to 22nd in 2005 satisfying this criterion were excluded from the data. The index days

and comparison days selected by the constraint conditions are shown on <Table 2>.

<Table 2> ADS Days Selected for the Analysis

Year	Date
2005	29 March, 7 April, 10 April, 15 April, 29 April, 7 November
2006	11 March, 13 March, 28 March, 9 April, 18 April, 24 April, 1 May
2007	14 February, 6 March, 28 March, 1~2 April, 8~9 May, 26 May, 29 December
2008	12 February, 3 March, 16 March, 4 April, 30~31 May

The effects of ADS on human health tend to appear days later and asthma is not a type of disease that must be treated immediately upon onset like that of stroke or heart diseases. Thus, a patient's visit to the hospital itself may take place a few days after the ADS event. In order to reflect so-called the lag effect, this study adopted a moving average of the number of daily medical services for asthma patients from the ADS event day to the corresponding lag day in the paired t-test. For example, in order to observe the lag effect between the day of ADS occurrence and three days after the occurrence, a 4-day moving average of the number of visits to clinics on the index day, and the next three days as well as a 4-day moving average of the number of medical services on the comparison day and the next three days were used in the paired t-test for analysis.

In addition, the index days were categorized into two groups depending on whether the ADS forecast issued 24 hours in advance was correct (hit) or incorrect (miss) and a paired t-test was performed on each group to investigate the effects of the ADS forecasts on the frequency of asthma attacks. Also, in order to analyze the patterns of the number of medical services on the hit group and miss group in detail, each group was further divided into two groups according to the 24-hour average PM^{10} concentrations and t-tests were carried out on each of the four groups.

3. Results

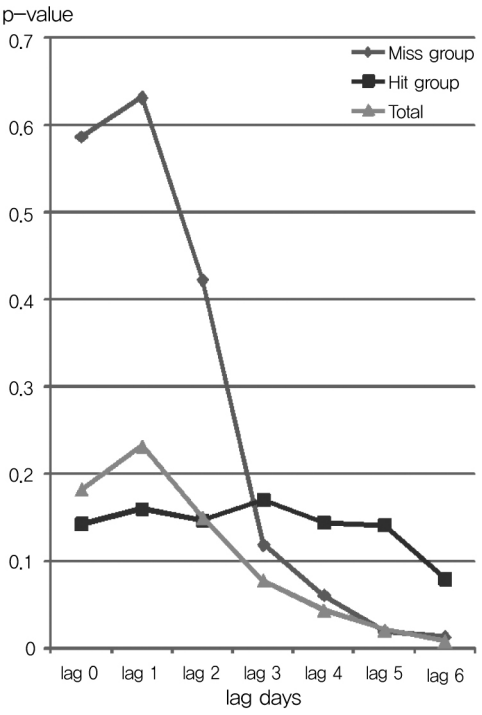
The index days were divided into a group for which the ADS forecast issued 24 hours prior to the ADS event was correct (hit) and a group for which the forecast was incorrect (miss). <Table 3> shows the percentage increase in the number of patients on the index days compared to the comparison days as well as the mean value of the moving average of asthma care according to the day lags of the index days and the comparison days for each group. The p-value of <Table 3> shows the results of one-sided paired t-test on the alternative hypothesis (H_1), where the average number of medical services was found to be higher on the index days than the comparison days. The p-values of the paired t-test conducted on the corresponding day lags of each forecast group were represented in a graph form as shown in <Figure 1>.

In terms of the entire group, the increase in the number of asthma patients on the index days became statistically significant after the 4-day lag, and there was a pronounced pattern of increase at 5-day lag and 6-day lag. In the hit group, there was an increase in the number of medical services provided for asthma for all day lags of the index days compared to the comparison days, but it was not statistically significant.

<Table 3> Number of Asthma Patients on ADS Days and Comparison Days in Hit and Miss Groups by Various Lags

Group	Description	ADS day	1-day lag	2-day lag	3-day lag	4-day lag	5-day lag	6-day lag
Miss	Index days	5122.09	5227.86	5685.58	6093.98	6167.15	6497.42	6666.09
	Comparison days	5405.68	5619.59	5492.29	5061.32	4959.35	4875.14	5140.29
	% increase	-5.25%	-6.97%	3.52%	20.40%	24.35%	33.28%	29.68%
	p-value	0.5868	0.6317	0.4227	0.1192	0.0614*	0.0204**	0.0132**
Hit	Index days	8281.48	7537.00	7491.12	7256.59	6810.64	6733.22	6676.09
	Comparison days	6728.28	6481.16	6537.35	6503.74	6101.53	6101.66	5909.07
	% increase	23.08%	16.29%	14.59%	11.58%	11.62%	10.35%	12.98%
	p-value	0.1430	0.1609	0.1469	0.1702	0.1445	0.1418	0.0805*
Total	Index days	7259.32	6789.93	6906.97	6880.45	6602.45	6656.93	6672.85
	Comparison days	6300.38	6202.42	6199.24	6037.07	5732.00	5704.85	5660.35
	% increase	15.22%	9.47%	11.42%	13.97%	15.19%	16.69%	17.89%
	p-value	0.1823	0.2320	0.1495	0.0776*	0.0437**	0.0209**	0.0087**

*p-value < 0.1, **p-value < 0.05.



<Figure 1> p-values of Paired t-test for Miss and Hit Groups by Various Lags

On the other hand, in the miss group, the number of medical services provided on the index days at 5-day lag and 6-day lag increased to the extent that they were statistically significant. Thus, the pattern of the p-values at each day lag of each group shows that there is a difference in the pattern of increase in the number of asthma patients depending on the accuracy of the ADS forecasts. However, there was no significant difference between the number of asthma patients on the ADS event days compared to no ADS days in case of 2-4 day lag and there was actually a decrease in the number of asthma patients on the ADS occurrence day and the following day as their p-values were over 0.5.

In order to identify the different patterns of increase in the asthma cases between the miss group and the hit group, the groups was divided into sub-groups according to the concentration of Asian dust, i.e., the PM^{10} concentration, for analysis. Thus, the hit and miss groups were further divided into groups with PM^{10} concentration of less than $110\mu g/m^3$ and groups with PM^{10} concentration of over $110\mu g/m^3$, and the average percentage increase in the number of medical services provided for asthma at each day lag of the index days compared to the comparison days was calculated for each group as shown in <Table 4>.

The (-) sign indicates that there were more medical services on the comparison days than the index days, whereas the p-values were obtained from the t-test conducted to see whether there were any differences in mean values of the percentage increase between the sub-groups divided according to the PM^{10} concentrations for the miss and hit groups. In the hit group with PM^{10} concentration of less than 110 $\mu g/m^3$, the rate of incidence of asthma on the index days was lower than on the comparison days from 2-day lag to 6-day lag, whereas in the case of PM^{10} concentration of over $110\mu g/m^3$, ADS events caused approximately 20~27% increase in the incidence of asthma at all day lags. In the miss group with PM^{10} concentration of less than $110\mu g/m^3$, there was an approximately 11~33% increase in the incidence of asthma at all day lags of the index days, whereas in the case of PM^{10} concentration of over $110\mu g/m^3$, there was a decrease in the incidence of asthma between 0-day lag and 4-day lag from the ADS events. However, ADS events led to dramatic increases of 21% and 34% at 5-day lag and 6-day, respectively. Five days out of the total 11 days for the miss group showed a decrease in the number of asthma on the index days compared to the comparison days. The 24 hr average PM^{10} concentration of the five days was 133.5 $\mu g/m^3$, whereas the average PM^{10} concentration of the other 6 days was $51.3\mu g/m^3$. In other words, even though the forecast did not accurately predict the occurrence of ADS, if the concentration of the ADS was so high that people could

<Table 4> % Increase on Asthma Patients on ADS Days Compared to Comparison Days According to PM^{10} Concentration Groups by Various Lags

Group	Description	ADS day	1-day lag	2-day lag	3-day lag	4-day lag	5-day lag	6-day lag
Miss	PM^{10} < 110	23.87%	11.05%	19.09%	30.65%	27.53%	33.36%	24.53%
	PM^{10} > 110	-47.36%	-52.83%	-53.99%	-46.44%	-3.04%	21.49%	34.11%
	p-value	0.0180**	0.0090**	0.0020**	0.0007**	0.3020	0.4063	0.4131
Hit	PM^{10} < 110	5.90%	5.77%	-4.77%	-5.03%	-4.42%	-9.79%	-9.93%
	PM^{10} > 110	26.27%	20.01%	24.31%	20.71%	19.44%	21.03%	27.46%
	p-value	0.2327	0.2709	0.0728*	0.0740*	0.0703*	0.0228**	0.0069**

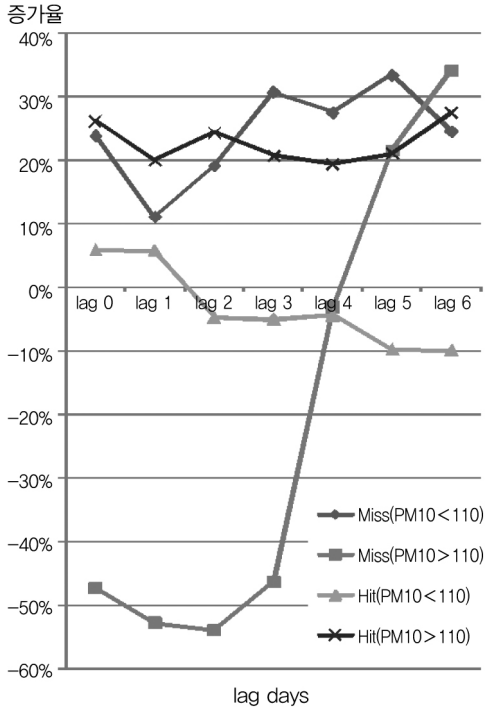
*p-value < 0.1, **p-value < 0.05.

perceive the dust with the naked eye, they would have refrained from going outdoors on the day of ADS and for shortly afterwards. Also, asthma patients with minor symptoms would have postponed their regular visits to the hospital. This could explain the reason for the decrease in the number of asthma patients on the ADS event days and the following days and for the significant increase in the hospital visits of asthma patients on 6 days after the occurrence of ADS.

The percentage increases in the number of medical treatments for all the hit/miss groups and PM^{10} concentration groups shown in <Table 4> are demonstrated in the form of a graph in <Figure 2> for a comparative analysis. In the hit group, the percentage increase in the number of asthma patients was higher at all day lags when the 24 hr average PM^{10} concentration was above $110\mu g/m^3$ compared to when it was below $110\mu g/m^3$. On the other hand, in the miss group, the patterns of increase were different according to the day lag; a pattern that was similar to that of the hit group was seen at 6-day lag, but from the ADS event day up to the 5-day lag, the percentage increase in the incidence of asthma was higher when the 24 hr average PM^{10} concentration was below $110\mu g/m^3$ compared to when it was above $110\mu g/m^3$. Such results of the analysis are thought to have been caused by a combinatorial effect of behavior and psychological factors as well as the nature of the ADS forecast and residential environment. When the ADS forecast released 24 hours in advance was accurate, the 24 hr average PM^{10} concentration was found to be $174.6\mu g/m^3$ on the day of the ADS occurrence. On the other hand, when the ADS forecast failed to predict the incoming of ADS event, the concentration was $103.5\mu g/m^3$ on the day of the ADS event. This showed that there were relatively higher frequencies of severe ADS in the hit group compared to the miss group. In particular, in cases of severe ADS events with a 24 hr average PM^{10} concentration of over 200, the ADS forecasts were all accurate except for only one day of ADS event. Thus, in case of severe ADS events, even if people decided to refrain from going outside, pollution of the air inside buildings was unavoidable [10] and this is the reason for the relatively higher percentage increase in the number of asthma patients at higher PM^{10} concentrations of the hit group compared to the lower PM^{10} concentration group. Also, accurate forecast for ADS events with lower PM^{10} concentrations was found to significantly reduce the asthma attacks in patients. For the miss group, the pattern of increase in the number of asthma treatments for PM^{10} concentration of below and above $110\mu g/m^3$ showed the opposite pattern from the hit group, except at 6-day lag.

4. Conclusions

The findings from the analysis of the total days of ADS occurrence from <Table 3> and <Figure 1> showed that there was a higher number of asthma patients on the index days than the comparison days and this number was statistically significant between the 4-day lag and 6-day lag, which indicates that the lag effect on the incidence of asthma occurs from 4-day lag and onwards. The effects of ADS on asthma were categorized for analysis depending on the accuracy of the ADS forecast provided 24 hours prior to the actual ADS event day in order to identify the impact of the ADS forecast. For this purpose, the patterns of the p-values were obtained from the paired t-tests for the hit group and miss group according to the day lags shown in <Figure 1>, and a comparison showed in the case of hit group, the numbers of asthma patients on the index days was higher than those on the comparison days but it was not statistically significant for all day lags.



<Figure 2> Increased Percentage of Asthma Patients for 4 Groups Combined with PM^{10} Concentration and Accuracy of Forecast

These analysis results present several implications for the future provision of ADS forecasts and their utilization methods. Accurate ADS forecasts significantly reduce the number of asthma patients visiting hospitals in cases of ADS with low PM^{10} concentration and can reduce the percentage increase in the number of asthma patients to a certain extent even in cases of severe ADS. Thus, enhancing the accuracy of ADS forecast will significantly contribute to the improvement of public health. Also, even though the ADS forecast issued 24 hours in advance fails to predict ADS event, if efforts are made to inform the public by media that provides real-time information, such as TV, Radio, DMB and smart phone, it will also effectively reduce the incidence of asthma. The real-time information service by various media will produce a greater positive effect especially in the cases of minor ADS events.

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