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ORIGINAL RESEARCH

Increased Risk of Hospital Admission for Asthma from Short-Term Exposure to Low Air Pressure

Jia Fu[1], Yanbo Liu[2], Yakun Zhao[1], Yuxiong Chen[1], Zhenge Chang[1], Kai-Feng Xu[3], Zhongjie Fan[1]

[1]Department of Cardiology; Chinese Academy of Medical Sciences and Peking Union Medical College, Peking Union Medical College Hospital, Beijing, People's Republic of China; [2]Department of International Medical Services; Chinese Academy of Medical Sciences and Peking Union Medical College, Peking Union Medical College Hospital, Beijing, People's Republic of China; [3]Department of Respiratory Medicine; Chinese Academy of Medical Sciences and Peking Union Medical College, Peking Union Medical College Hospital, Beijing, People's Republic of China

Correspondence: Zhongjie Fan, Department of Cardiology, Chinese Academy of Medical Sciences and Peking Union Medical College, Peking Union Medical College Hospital, No. 1, Shuaifuyuan Wangfujing, Dongcheng District, Beijing, 100730, People's Republic of China, Tel/Fax +86 010 6915 6114, Email Fanzhongjie@pumch.cn

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Purpose: Asthma has a major impact on patients' quality of life, mortality, and healthcare burden. Some evidence suggests that environmental factors may trigger asthma. However, there has been limited research on the relationship between air pressure and asthma hospital admissions, especially in China. Thus, we aimed to study the influence of air pressure and identify potentially susceptible populations.

Methods: The study data were gathered from hospitalization records with a primary diagnosis of asthma from all secondary and tertiary hospitals in Beijing from January 1, 2013, to December 31, 2016. The study examined the association between the risk of asthma and air pressure using a distributed lag non-linear model (DLNM). We also performed a stratified analysis to identify the susceptible populations.

Results: A total of 23,697 asthma hospital admissions were included in the study. We found that the relative risk (RR) and the 7-day cumulative relative risk (CRR) of asthma had an approximate negative correlation with air pressure. At the same time, we found that the association was most apparent on the day of exposure (lag = 0).

Conclusion: Ambient air pressure had an approximately negative correlation with daily asthma hospital admissions in Beijing, China. That means the risk of hospital admission for asthma would be increased by low air pressure. Furthermore, air pressure has a significant effect on asthma only on the day of exposure. It is possibly significant to protect the vulnerable on days with low air pressure, especially those younger than 65 years.

Keywords: asthma, air pressure, distributed lag non-linear model, DLNM

Introduction

Asthma is a common, non-communicable disease of the airway affecting both children and adults. It presents with wheezing, dyspnea, chest tightness, cough, and even death in severe cases.[1] Globally, asthma has a tremendous impact on patients' quality of life and mortality and is a big burden to the healthcare system. Approximately 262 million individuals have asthma worldwide, according to the World Health Organization (WHO) in 2019.[2] What is more, there were 22.8 million disability-adjusted life years (DALYs) attributable to asthma in 2017 as the Global Burden of Disease Study reported.[3] It has been one of the main contributors to the global burden of disease.

The natural history of asthma is variable and complex.[4,5] Although the etiology of asthma is not fully elucidated and there is no cure, asthma can be controlled by medications and by avoiding exposure to relative risk factors. With the development of the global economy in recent years, some evidence suggests that environmental risk factors may trigger asthma. Previous studies have indicated that ambient air pollution increases the risk of asthma hospital visits for children.[6] Besides, the ambient temperature was also associated with childhood or adult asthma.[7–9] However, there has been limited research on the relationship between air pressure and asthma hospital admissions, especially in China.[10,11] Thus, it is meaningful for us to

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study the influence of air pressure and identify the susceptible populations. This study was designed to explore the effects of air pressure on asthma hospital admissions using the Distributed Lag Non-linear Model (DLNM).

Materials and Methods

Data Collection

Hospital admissions for asthma were defined as outcome events from January 1, 2013, to December 31, 2016. We obtained daily asthma hospital admission data from the Beijing Municipal Health Commission Information Center. The data contained hospital name, hospital level, patient's anonymous identification number, gender, age, birthplace, present address, permanent residence address, work unit address, date of admission, discharge diagnosis and so on. We filtered all asthma patients with the code J45-J46 as primary diagnosis according to the International Classification of Diseases 10th revision (ICD-10). The data were divided into several subgroups by gender (male, female) and age (<65, ≥65 years).

The daily Meteorological data from January 1, 2013, to December 31, 2016, were obtained from the China Meteorological Administration (CMA). It included Daily mean temperature (Tmean), Daily maximum temperature (Tmax), Daily minimum temperature (Tmin), Air Pressure (AP), Relative Humidity (RH) and Wind Speed (WS). The air pressure was defined as the daily mean atmospheric pressure in Beijing, China and hectopascal (hPa) was used as the units of measure. As for the daily minimum/mean/maximum temperature, Celsius (°C) was used as the units of measure. As for the wind speed, meter per second (m/s) was used as the units of measure. Air pollutants may affect respiratory diseases,[12] so the pollutant concentration level was adjusted as a confounding factor in the study. We adjusted the Air Quality Index (AQI), which integrated the effects of all air pollutants as various pollutants fluctuate differently throughout the day. The AQI data were obtained from the Beijing Environmental Protection Bureau.

Influenza viruses are frequently associated with asthma hospitalization,[13,14] so the influenza epidemic (IF) was also adjusted as a confounding factor in the study. The influenza epidemic was defined as when the positive rate of influenza isolation in any given week exceeded 20% of the maximum weekly positive rate of influenza isolation in the whole surveillance season (from the 27th week of the previous year to the 26th week of the following year) in northern China.[15] The influenza surveillance data were obtained from the Chinese National Influenza Center.[16]

Data Preprocessing

All the data were pre-processed in IBM SPSS 26 and Microsoft Excel 2019. For the daily asthma hospital admission data, we selected residents in Beijing ordinarily according to their Present Address, permanent residence address and work unit address.

Statistical Analysis

We conducted a descriptive analysis of demographic data and environmental measurement data. Sum, maximum, minimum, average number, and standard deviation were used to represent these numerical variables. Statistical analysis was conducted using R software (R x64 v3.4.2) with "mgcv" and "dlnm" package. Since hospital admissions for respiratory diseases were small probability events and the events were independent of each other, the number of daily asthma hospital admissions was regarded as a Poisson distribution to allow for over-dispersion in daily counts of hospitalizations.[17] What is more, previous studies have shown that the association between meteorological factors and respiratory diseases was not linear.[10] So, the Poisson distribution was applied to establish the Distributed Lag Non-linear Model (DLNM), which was first used by Armstrong in 2006.[18] The DLNM was used to describe the exposure–response relationship and lag–response relationship and estimate the health effect of meteorological factors. In this model, we adjusted Day Of the Week (DOW), Public Holiday (PH), Air Quality Index (AQI), Secular Time Trend, Air Pressure (AP), Relative Humidity (RH), Wind Speed (WS) and influenza epidemic (IF) to explore the relationship between exposure and asthma hospital admission. For instance, a natural cubic spline of time (seven degrees of freedom per year) was adjusted to exclude long-term and seasonal trends in hospital admission. A natural cubic spline of AQI, RH, WS and AP (three degrees of freedom) was incorporated to adjust the influence of atmospheric pollutants and other meteorological factors.[19–23] PH, DOW and IF were also included to control the effect of different days in one week, the special holiday, and the influence of influenza.[14,24,25] The public holiday included the New Year's Day, Spring Festival, Tomb-sweeping Day, Labor Day, Dragon Boat Festival, Mid-Autumn Festival and National Day. And the data of the public holiday were obtained from the website of the Central People's Government of the People's Republic of China.[26]

In the model, we calculated the cumulative relative risk (CRR, obtained by accumulating the relative risk of each lag day) of asthma hospital admission within seven days to fully capture the overall temperature difference effects and the possible harvesting effects. Then, we constructed their exposure–response curves.

What is more, we conducted a stratification analysis based on gender and age to verify the reliability of the overall effect and compare susceptibility. We also regarded the most moderate air pressure (MMAP) of the total population as a reference for different subgroups.

Patient and Public Involvement

Our study only used the patients' anonymous data, and no patient and public privacy was involved. No human body was involved in our study.

Results

Descriptive Analysis

There were a total of 23,697 asthma hospital admissions between January 2013 and December 2016 in Beijing. While 9856 of them were male and 15,077 were younger than 65 years old. Table 1 shows the number and percentage of the asthma hospital admissions in the total population and different groups in Beijing.

Descriptive statistics for meteorological and air pollution data are shown in Table 2. The average daily mean temperature was 12.880°C, average air pressure was 1016.555hPa, average relative humidity was 53.426% and average wind speed was 9.287 m/s during the period of study.

Seven Days Cumulated Relative Risk

Although a statistically significant association was not noted between most of the AP and the seven-day CRR of asthma among the total population in Beijing (Figure 1), we could still see the changing trend of CRR. We found that the MMAP of AP was 1034.5 hPa, and when AP was less than MMAP, the seven-day CRR had an approximate negative correlation with

Table 1 Baseline Information of Asthma Hospital Admissions of the Total Population and Subgroups in Beijing

	N	Min	Max	Sum	Average	SD
Total	1461	0	65	23,697	16.22	7.861
Male	1461	0	31	9856	6.75	3.813
Female	1461	0	34	13,841	9.47	5.09
< 65	1461	0	52	15,077	10.32	5.397
≥65	1461	0	19	8620	5.9	3.612
PH	1461	0	1	–	–	–
IF	1461	0	1	–	–	–

Table 2 Baseline Information of Meteorological and Air Pollution Data in Beijing

	N	Min	Max	Average	SD
AQI	1459	23	485	123.65	75.173
RH(%)	1461	8	97	53.43	19.858
WS(m/s)	1461	3	34	9.29	4.754
AP(hPa)	1461	994	1044	1016.56	10.166
Tmean(°C)	1461	−16	32	12.88	11.169

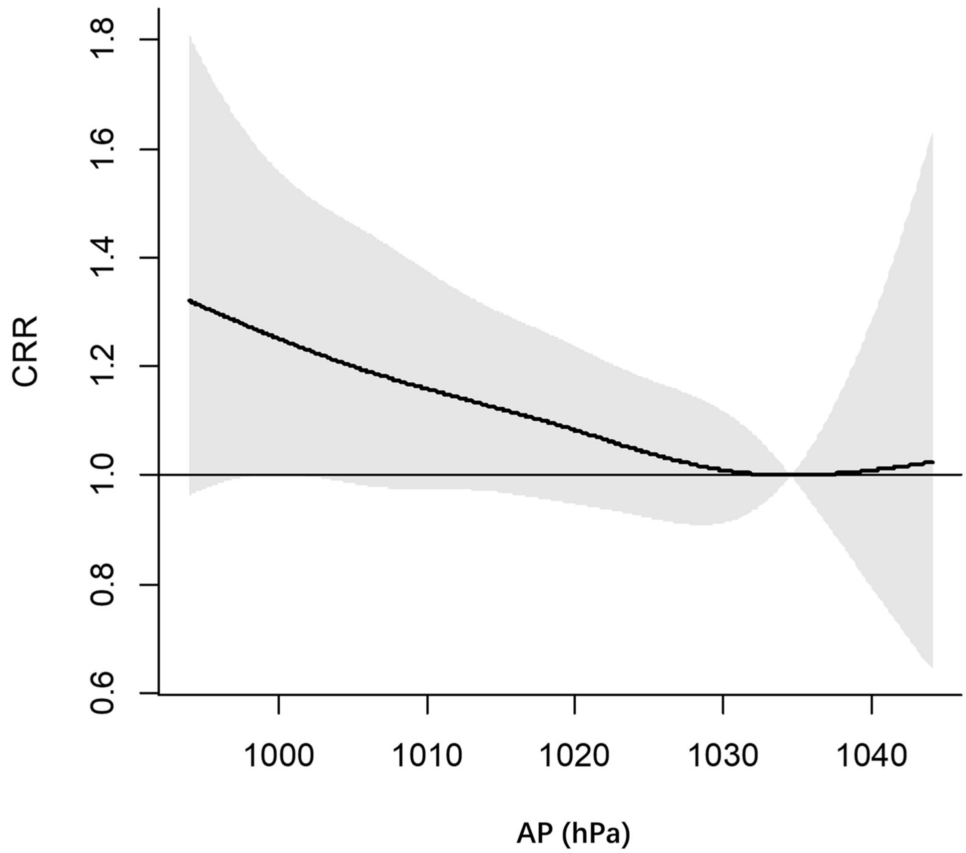

Figure 1 The seven-day CRR (include 95% C.I.) of asthma among the total population in Beijing.

AP. Table 3 shows the values of seven-day CRR in the different AP percentiles. The seven-day CRR (include 95% C.I.) were 1.27 (1.00–1.62), 1.24 (1.00–1.54), 1.22 (0.99–1.50) and 1.17 (0.98–1.41), when the air pressure were 998 hPa (first percentile), 1001 hPa (fifth percentile), 1003 hPa (tenth percentile) and 1008 hPa (twenty-fifth percentile), respectively.

Single-Day Lag Effect

Figure 2 shows the overall trend of the association between the relative risk of asthma and the AP on the same day (lag = 0). We found that the RR of asthma had an approximate negative correlation with the air pressure (lag = 0). Figure 3 shows the overall trend of the association between the relative risk of asthma and the AP on different lag days. We found that there was no statistically significant association between the RR of asthma and the AP one day ago (lag = 1). Noticeably, among all lag days, the association was statistically significant only in lag 0 day.

Table 3 The Seven-Day CRR (Include 95% C.I.) of Asthma Among the Total Population in Beijing in the Different AP Percentiles

Percentiles	CRR	95% C.I. (Lower Bound)	95% C.I. (Upper Bound)
P1(998hPa)	1.27	1.00	1.62
P5(1001hPa)	1.24	1.00	1.54
P10(1003hPa)	1.22	0.99	1.50
P25(1008hPa)	1.17	0.98	1.41

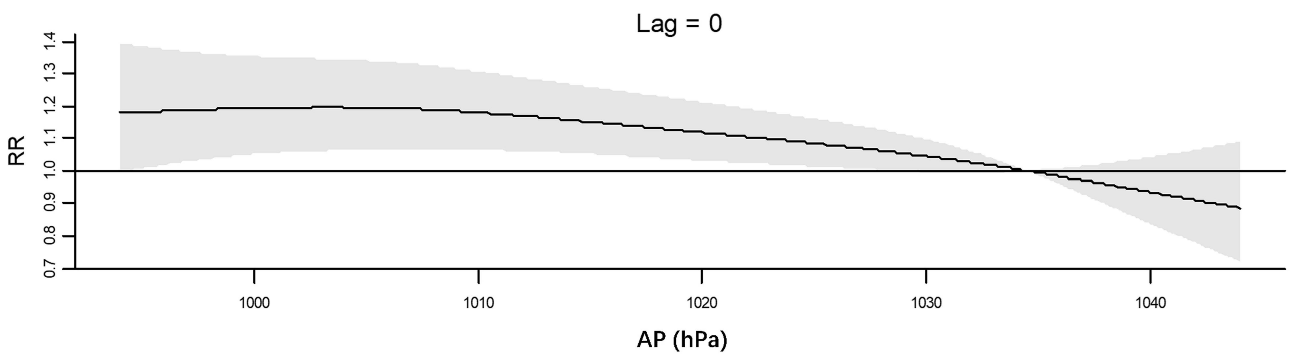

Figure 2 The association between the AP and the relative risk of asthma in lag 0 day among the total population in Beijing.

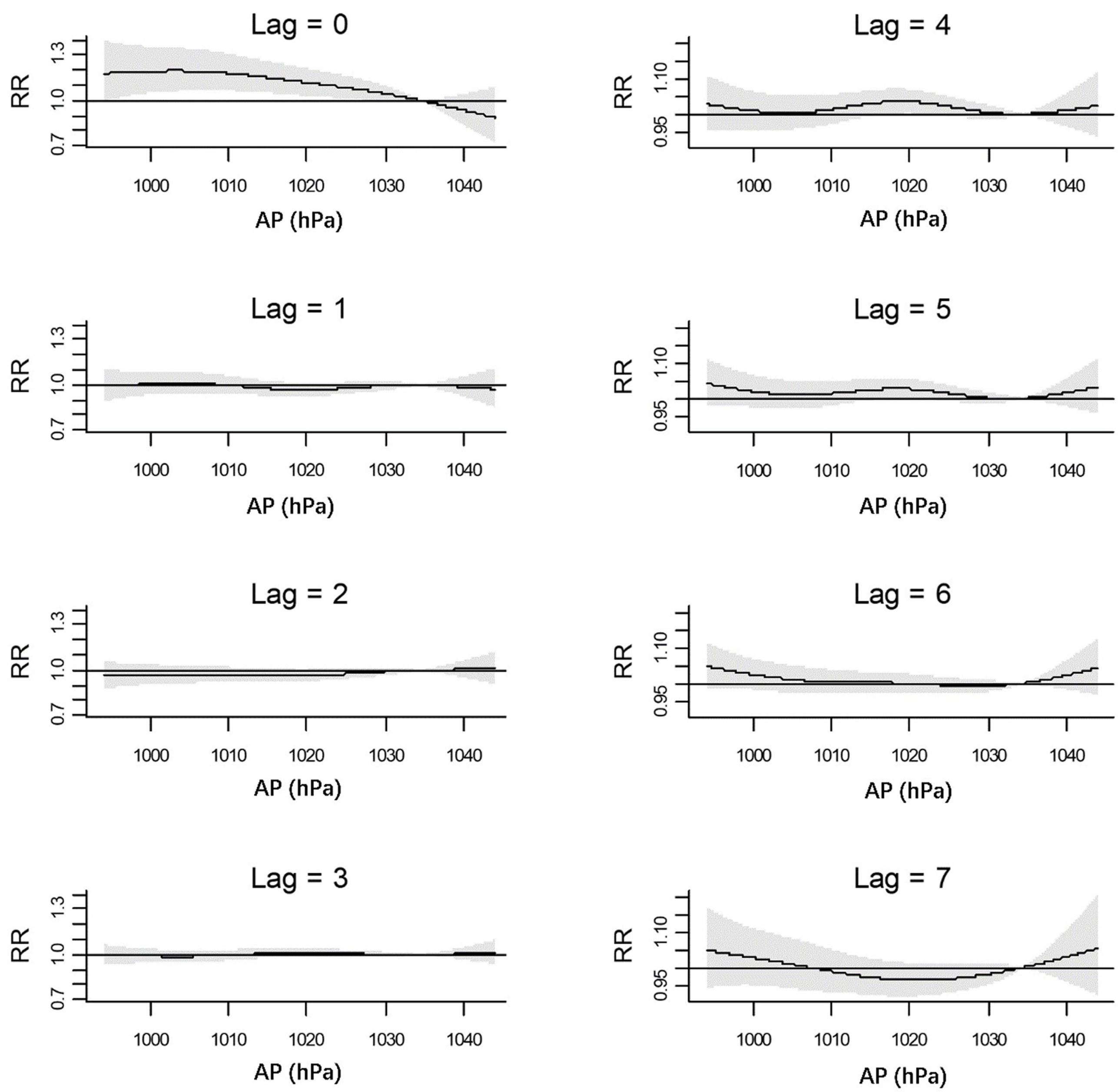

Figure 3 The association between the AP and the relative risk of asthma in different single lag day among the total population in Beijing.

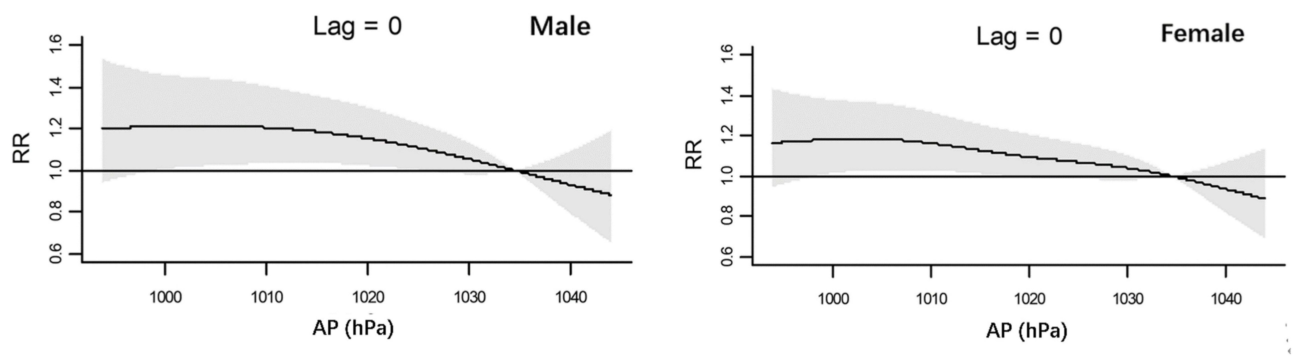

Figure 4 The association between the AP and the relative risk of asthma on the day of exposure (lag 0) in different gender subgroups in Beijing.

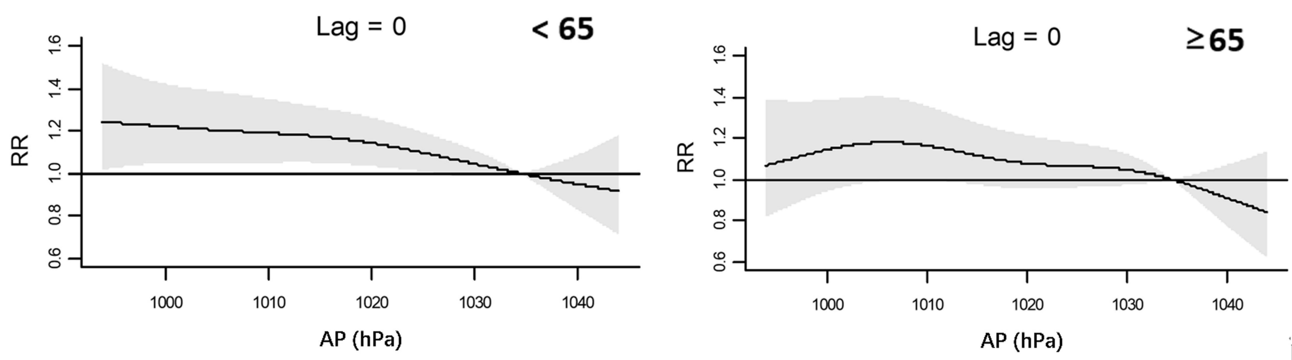

Figure 5 The association between the AP and the relative risk of asthma in lag 0 day in different age subgroups in Beijing.

Stratification Effect

Figures 4 and 5 depict the association between the AP (lag = 0) and the RR of asthma among different groups in Beijing. We found that the overall trends of the association between AP and RR of asthma among different gender or age subgroups were in line with the overall trend in the total population. At the same time, the effect of AP (lag = 0) was similar in the male and the female population. While the effect of AP (lag = 0) was significant in the age group younger than 65 but not in the older population in a statistical sense.

Discussion

Beijing is a typical northern temperate semi-humid continental climate. The four seasons are distinct, and the precipitation is mainly in the summer. Our study found significant associations between the hospital admissions of asthma and the air pressure using a Distributed Lag Non-linear Model in this region. The results indicate that the lower air pressure could increase the relative risk of asthma.

The association between air pressure and asthma has been studied extensively before, but the existing results are inconsistent. Some studies made conclusions in line with ours. A study that determined the influence of meteorological variables on airway disorders reported that the air pressure was negatively correlated with the daily visits at general practitioners (−27% per 10 hPa change).[27] A study from Okinawa island found that the decrease in temperature and barometric pressure were related to induced asthma attacks.[28] There have been different voices. A study in Shenyang, China, found that higher air pressure was associated with increased asthma admissions.[10] Another study in Japan found that the hospital visits for childhood asthma were positively associated with air pressure (odds ratio [OR] = 1.016 with 1-hPa increase).[29] Moreover, a study in Shanghai found allergic disease admissions increased with higher air pressure.[30] A study reported no significant association between changes in barometric pressure and pediatric asthma exacerbations.[31]

A study from Oulu University Central Hospital found that only temperature among the meteorological factors (temperature, humidity, barometric pressure, rainfall) had a small association with asthma.[32]

Although the specific physiological mechanisms of the air pressure effect on asthma have still not been fully elucidated, several speculations can be made with caution. First, allergy is a primary cause of asthma symptoms[33,34] and some studies have suggested that air pollution may induce or aggravate asthma.[6,35,36] Allergens and air pollutants would be concentrated in low pressure and not quickly diffused. Also, the lower air pressure led to thinner air, which decreases the partial pressure of oxygen in both the air and lungs. This, on the other hand, increases the breathing rate and exposes the population to more allergens and air pollutants. What is more, lower air pressure tends to occur during extreme weather, such as thunderstorms, which has been linked to asthma exacerbations, known as "thunderstorm asthma."[37–39] Studies of weather events have found that thunderstorm would increase the levels of respiratory allergens present in the air, particularly pollen and mold spores.[37,40] Conditions at the beginning of a thunderstorm can cause pollen grains to rupture, increasing the concentration of pollen debris. The debris can be inhaled into the lower airways, triggering asthma exacerbations.[41,42]

The lag effect was not apparent for air pressure. We speculated that the air pressure imposes more of a rapid process, with acute physiological changes. Also, the effect of AP was significant in a population younger than 65, which is consistent with a higher chance of outdoor exposure in this age group. More outdoor activity means more allergen exposure.

Our study holds particular apparent strengths. First, the data of asthma hospital admissions cover all secondary and tertiary hospitals in Beijing from January 1, 2013, to December 31, 2016. What is more, to our knowledge, this is the first report to study the association between air pressure and asthma hospital admissions in Beijing. Then, the meteorological data are both authoritative and accurate. Last but not least, multiple confounding factors are adjusted in our study, such as the influence of influenza, air quality index, and the special holiday. This study has certain limitations: individual exposure analysis was not carried out. Furthermore, we only studied data from China's mainland, so our findings may not apply to other regions with different climates or healthcare systems.

Conclusion

Ambient air pressure had an approximately negative correlation with the daily asthma hospital admissions in Beijing, China. Our findings suggest that the risk of hospital admission for asthma would be increased by low air pressure. The effect of air pressure is most apparent on the day of exposure with no lagging effect. Thus, it is potentially significant to protect the vulnerable on days with low air pressure, especially those younger than 65 years old.

Abbreviations

AP, Air Pressure; AQI, Air Quality Index Pressure; Air Quality Index; °C, Celsius; CAMS, Chinese Academy of Medical Sciences; CMA, China Meteorological Administration; CRR, Cumulative Relative Risk; DALYs, Disability-Adjusted Life Years; DLNM, Distributed Lag Non-linear Model; DOW, Day Of the Week; hPa, hectopascal; ICD-10, International Classification of Diseases 10th revision; IF, Influenza epidemic; MMAP, Most Moderate Air Pressure; m/s, meter per second; PH, Public Holiday; PUMCH, Peking Union Medical College Hospital; RH, Relative Humidity; RR, Relative Risk; Tmax, Daily maximum temperature; Tmean, Daily mean temperature; Tmin, Daily minimum temperature; WHO, World Health Organization; WS, Wind Speed.

Data Sharing Statement

Data are available if you get the permission from Professor Zhongjie Fan (Fanzhongjie@pumch.cn).

Ethics Statement

The studies involving human participants were reviewed and approved by Peking Union Medical College Hospital (PUMCH) Institutional Review Board. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

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Disclosure

The authors declare that there are no financial or non-financial conflicts of interest in this work.

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